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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Technical Note: Four-dimensional variational data assimilation for inverse modelling of atmospheric methane emissions: method and comparison with synthesis inversion" *by* J. F. Meirink et al.

J. F. Meirink et al.

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We thank the reviewer for his/her comments. Here is our point-by-point reply.

1. We agree with the reviewer and have removed 'Technical note' from the title.
2. The OH field has been produced by a relatively old full-chemistry simulation with the TM3 model. The calibration involved determination of a (single) scaling factor yielding optimal agreement with MCF measurements from the period 1978 to 1993. Most importantly, the OH distribution leads to a tropospheric CH_4 lifetime

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of 9.4 years, very close to the IPCC recommended value of 9.6 years (see also Bergamaschi et al. ACP, 2005). This information has been added to the text.

3. We feel that adding much technical detail in the paper on the construction of the adjoint is not useful for the reader. Instead, we have added supplementary material to the paper with additional technical information, including a practical example of adjoint construction.

4. The vector **p** is actually not used at all in this paper, but it is mentioned because it is used in the follow-up paper Meirink et al. (2008). Therefore, we do not want to expand on it. However, we have modified the text as follows: 'and **p** contains any additional parameters, for example model parameters in parameterizations of physical processes. In the present paper, **p** is not used, but in Meirink et al. (2008) it contains parameters that model a bias in the satellite observations that are assimilated.'

5. This is a good suggestion. We have added after Eq. (5) the sentence: 'This equation illustrates that the assimilation of observations leads to posterior errors that are smaller than the prior errors. In other words: the inversion yields an error reduction (also termed uncertainty reduction in this paper).'

6. We assume that the reviewer would like to have an idea of the representativeness error. Therefore, we have added the following: 'This yields values smaller than 1 ppb for the Antarctic stations, and typical values of 10 to 15 ppb for most other stations, with occasional increases to several tens of ppb's at stations near large CH_4 gradients. '

7. This approach is followed to get rid of the possible detrimental impact of observations that cannot be reproduced by the model simulation even after modifying the surface emissions. The reason for this could indeed be an error in modelled transport, but the measurement might also be corrupt or influenced by local sources.

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In any case, it is better to withdraw the observation from the inversion procedure. We have added an additional sentence to the text containing this explanation.

8. It is not the only difference, but all elements mentioned by the reviewer are indeed the same (i.e. observations and their errors, TM5 model version including OH field). This is mentioned in the first paragraph of Section 2.3. There are some minor differences between the inversions, such as the time window of the assimilation, as is also mentioned in Section 2.3. We have replaced 'major' by 'only important' in the text.

9. The actual value of this mean uncertainty reduction is really not very relevant. In Section 3.1 we are mainly interested in the convergence *behaviour*. Useful and understandable information on uncertainty reductions is presented in Table 1 for large regions, and in Figure 5 on the grid-scale level.

10. Fig. 2 is first referenced on page 12032, line 16, while Fig. 3 is first referenced on page 12034, L3. Hence, the figures appear in the right order.

11. Our discussion of the differences between these plots with emission increments from both inversions is qualitative. We are not interested in quantitative comparisons of the grid-scale emission increments, since we don't expect those to be the same. Instead, we are more interested in aggregations over large regions. Therefore, those numbers are presented in great detail in Table 1.

12. We indeed performed additional inversions with larger correlation lengths (set to 10,000 km for all categories), and the results (incl. Asia) were very similar.

13. The synoptic-scale events may indeed be hard to discern when Figure 4 is printed on a single page. But when the reader is really interested, he/she can zoom into the time series and really confirm that most synoptic-scale events are well-captured. For example, one can see this very nicely at the Assekrem station.

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14. We argue that the overall chi-squared values reported here are mainly useful for (i) showing the close agreement between 4D-Var scenario A and the synthesis inversion and (ii) illustrating the effect of reduced error correlation lengths in 4D-Var scenario B, which leads to increased flexibility in modifying emission patterns and thus to a closer match to the observations. The overall chi-squared values for both scenarios seem to be close enough to 1 and do not justify a conclusion that too much weight has been put on the observations. Therefore, the word 'satisfying' has been added in line 1 of page 12039. However, for certain stations the chi-squared goes up to 2, really pointing to a potential underestimation of the observation errors. This is mentioned specifically at the end of Section 4.2.

15. It is 1.8. We have added this number to the text.

16. This is a good point. A similar issue is present with error correlations between high-resolution observations, as noted by the other reviewer. We have added the following sentence in line 7: 'It has to be noted that these advantages weaken considerably if the prior error correlations of emissions and observations cannot be properly determined, which is unfortunately often the case.' Subsequently, the last sentence of Section 4.3 is modified to: 'In any case, the 4D-Var offers a flexible and computationally efficient means to perform inversions with both large control vectors and many assimilated observations.'

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 12023, 2008.