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Atmospheric Chemistry and Physics Discussions

Interactive comment on "An improved Kalman Smoother for atmospheric inversions" *by* L. M. P. Bruhwiler et al.

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General comments

The estimation of CO2 sources and sinks from atmospheric data by Bayesian inversion, if done in traditional ways, involves transport model runs and matrix operations that are computationally very expensive and require a lot of computer memory. The present paper describes an improved Kalman smoother technique that can reduce this cost considerably. Although this involves approximations with respect to the original problem, the authors demonstrate by example that the agreement with the full solution is excellent. As an essential innovation, an improved way to propagate the flux

covariance matrix between the Kalman smoother time steps is developed, which both improves the approximation of the a-posteriori covariance matrix and even the flux estimates themselves.

This is a very interesting, original, and relevant contribution to the field of atmospheric CO2 inversions, clearly also applicable to other trace gases. Increasing computational efficiency is not only a technical issue, as it allows to explore a wider range of configurations which might otherwise be infeasible. The paper is written in a concise way. My only specific comment below just refers to a side issue; apart from this, I'd mainly like to recommend some revisions to increase accessibility of the manuscript. I therefore clearly recommend this work for publication in ACP.

Specific comment

Page 1911, lines 2-13:

Many inversion studies show that a-priori assumptions, though necessary for mathematical stability, have large influence on the results. I fully agree with the authors that it would be very desirable to reduce this influence as much as possible. The paragraph claims that the Kalman might be a way towards this aim. In the presented form, however, this is unequivocally not the case, as it is, by construction, a close approximation to the usual Bayesian estimator. The paragraph then alludes to a different way of using the Kalman smoother, that would be able to reduce the influence of prior flux estimates and uncertainties. The description of that method is not very detailed and I might have misunderstood it, but it seems to me very unlikely that it is correct. Rather, it appears that measurements would be used more than once.

If the Kalman smoother is indeed able to reduce the influence of a-priori assumptions, I'd like to encourage the authors to describe and discuss this in detail, as it is an important issue. Otherwise, I'd suggest to drop this paragraph.

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Suggestions concerning accessibility

Page 1897, line 3-5: As the time periods overlap, it is unclear which fields have been used. A jump between data sources seems an unlikely choice for interannual runs. Could you clarify?

Page 1898, line 1: I'd expect errors in the long-range transport to be equally important.

Page 1899, line 13: Explain symbol p''

Page 1900, line 11: Explain 'pseudo-inverse'

Page 1901, lines 3-4: The effective dimension of Q is only small if there are no assumed correlations in time.

Page 1901, line 5: Mention explicitly that this example referres to an inversion with monthly time step in data and fluxes.

Page 1901, Eqs. (14) and (15): The choice of symbols makes these equations a bit confusing to read. I'd suggest to mention explicitly the sizes of the involved vectors, as they are different from the previous uses of the symbols **z** and **s**. Further, it seems that **z** and **s** in Eq. (15) are now scalars, and elements of just one example line of Eq. (14); they should therefore not be set in bold face, and their being example should be made clear.

Page 1902, lines 7-18, Fig 1: Well-mixed situation at Mace Head seems to be reached only after much more than 4-6 months, even for close-by source regions as North Atlantic.

Page 1902, Eq. (16): Again, it should be made more clear that Eq. (16) represents one example line of Eq. (14), not the full matrix structure.

Page 1902, lines 21ff: The exact way how the smoother steps though time is not explained well. The reader needs to infer this rather indirectly. As this is a methods' paper,

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I'd consider it essential that all operations are described explicitly and algorithmically.

Page 1905, line 22: Replace 'are often much less uncertain' e.g. by 'falsely appear to be much less uncertain'.

Page 1907, Eqs. (22) and (23): What is Q_{11} etc.?

Page 1908, lines 19-22: Sentence not clear.

Page 1909, lines 1-7: The fact that the improved propagation of uncertainties also improves the flux estimates themselves, is mentioned here just as a side remark. However, I would rate this as one of the most important contributions of the paper, and would consider the use of improved intermediate covariance matrices as a core part of the algorithm without which it would be incomplete. Therefore, I'd like to encourage the authors to give this much more weight.

Page 1909, lines 15ff: It cannot be fully inferred from this text how the algorithm is exactly performed in the two variants. For example, in the on-line variant, is the transport model run over the entire time span, or only over the Kalman lag? Is it run as often as there are Kalman steps, and with how many tracers per run? All this should be said explicitly, and moved to the Methods section (see comment to Page 1902, lines 21ff).

Figure legends: The legends of figures 3-8 are very repetitive, which makes it unnecessarily difficult to notice the differences between these figures. Moreover, as there is only one example inversion set-up used for all the figures, details of this set-up should not be explained in the legends at all, but in the Methods section.

Figures 4 and 5: As they show exactly the same, just for different regions, I'd suggest to join them.

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Technical corrections

Page 1894, line 20: Delete ‘from’

Page 1898, line 5: Typo ‘%.05’

Interactive comment on Atmos. Chem. Phys. Discuss., 5, 1891, 2005.