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Interactive comment on "Smoothing error pitfalls" *by* T. von Clarmann

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Clive,

I would like to reply here to the three major points mentioned in your review.

1. Error in Eq. 16: I agree that the analytically correct evaluation of the smoothing error requires the averaging kernel which represents the response of the retrieval to the variation of the true atmosphere on the fine grid. I have used the averaging kernel which represents the response of the retrieval to the variation of the true atmosphere on the coarse grid and have then interpolated this coarse-grid averaging kernel to the fine grid. Thanks a lot for pointing out! In the following I will discuss the implications of this error for the paper.

Implication for the main result of the paper: The main result of the paper is that

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Gaussian error propagation is not compatible with the smoothing error concept. This conclusion is even more supported when the fine-grid averaging kernel is used in Eq. 16. The conclusion holds a fortiori.

Implication for the calculated smoothing error: I do not quite see that the use of the interpolated averaging kernel leads to a loss of the fine-scale information of S_e. This would happen if one applied the interpolation to the difference $(I_{coarse} - A_{coarse})$; with this, Eq. 16 would finally be identical with Eq. 15. I do not, however, see that the use of $(I_{fine} - WA_{coarse}V)$ systematically removes the fine-scale information of S_e. It rather distorts somewhat the altitude structure of the smoothing error. More about interpolability of the averaging kernel (and Jacobian) is discussed below.

Implication for Sect. 3.2, theory part: Here the incorrect Eq. 16 can easily be replaced by the correct one.

Implications for Sect 3.2, case study: For the particular idealized Jacobian chosen here it happens that $A_{fine} = WAV$ holds. Thus the case study is still valid.

Implication for Sect. 5: It is suggested that instead of the smoothing error, the averaging kernel should be distributed to the data users. I thought this to be advantageous because the user then could evaluate the smoothing error on his preferred grid using (old) Eq 16 and an S_e matrix on this grid. The advantage would have been that the data user would have needed no further instrument-specific information to evaluate the smoothing error relative to his favourite grid (I consider A, S_x, K, G instrument-specific but not S_e). Accepting that the old version of Eq 16 is incorrect, we must admit that the data user is not much helped with having access to A on the retrieval grid. However, I am confident that the situation is not that bad: I think that $WA_{coarse}V$ is in many cases an appropriate approximation to A_{fine}. This is, because (a) the calculation of K involves an integration along an atmospheric path. Thus, it is fair to hope that fine-scale variation along this path averages out to a large degree. (b) (valid particularly for limb sounders): Instruments have a finite field of view. The calculation of K involves integra-

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tion of the so-called pencil beams over the field of view. Also here I think that fine-scale atmospheric structure averages out. (c) Nadir averaging kernels are quite smooth and wide anyway, and do not reflect the fine structure of the atmosphere. These three arguments suggest that it might be not that bad to interpolate K (and thus A). In turn, if the correct averaging kernels indeed strongly reflected atmospheric fine-scale structure, it would not be very plausible why the inverse problems are as ill-posed as they often are. Couldn't then a major part of the ill-posedness just be fought by evaluating the Jacobians on a finer grid? Further, there is still a more formal argument: We work in the framework of linear theory, and apply this to (in the worst case) moderately non-linear inverse problems. This implies that the diagnostic quantities are assumed not to depend on the atmospheric state when the latter varies around the solution of the inverse problem. Doesn't this mean that the averaging kernel should be fairly insensitive to fine-scale variations of the atmosphere? With all this in mind, I tend to still recommend distribution of the averaging kernel matrix to the user, and to suggest to use (old) Eq 16 as an approximation (conditionally, only for cases when interpolation of A can be justified). I have not provided a formal proof but it seems that much less harm is done by the use of WAV than by $S_{e,coarse}$.

2. Possibility of arbitrarily large variation in the state vector at fine scales: Here I feel a little misunderstood. I do not claim that this variation is large. I just claim that it does not disappear, even at fine scales. What I intend to say is that, if one has evaluated the smoothing error on a fine grid, there always is a finer grid with its own small-scale variability, and Gaussian error propagation will fail when the smoothing error is propagated to this finer grid. There is no limit beyond which there is no more additional variability and where Gaussian error propagation would be fully applicable to the smoothing error.

3. Difficulty to evaluate S_e on a fine grid: I agree that an 'educated guess' (as you call it on p 163 of your book) is often possible. In my original manuscript I did not at all mention difficulties to evaluate S_e on a fine grid. The discussions during the access

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review phase and during the first part of the official discussion phase have pushed me somewhat towards this issue although my main interest is the conflict between the smoothing error and Gaussian error propagation. My concern is that the data user who has no access to instrument-specific data cannot transform the smoothing error to a finer grid than that used for the calculation of the original smoothing error. In other words: I do agree with you that the smoothing error can be calculated (directly, from $S_{e,fine}$) on the fine grid. We also agree that the smoothing error on the fine grid cannot be estimated from a smoothing error on a coarse grid via Gaussian error propagation. We might not agree that the term “error” is misleading and might be inadequate in a context of a quantity which is in conflict with the established error propagation laws. My personal choice would be to focus on the error propagation problem and just to assume that the data provider did calculate the smoothing error on the given grid correctly. However, to satisfy all involved people with respect to this looks a bit like an ‘overdetermined problem’.

Thomas

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