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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Averaging kernels for DOAS total-column satellite retrievals" *by* H. J. Eskes and K. F. Boersma

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We thank the referee for a careful reading of our manuscript. The referee acknowledges that DOAS averaging kernels are of great interest for the scientific community. However, the referee asks for additional clarification of the derivation of the DOAS kernels. We will quote the remarks of the referee and provide our reply below.

"... any definition of weak absorption is missing. Authors just state it is the case for NO_2. "

Indeed we can be more precise on this point, and we have added a paragraph to the manuscript to discuss this. A typical optical thickness is provided for NO_2. Typical values are of the order of 0.005. This implies that the radiation field is not substantially influenced by the amount of tracer, that the absorption features are far from saturation, and that the radiation level is approximately linear in the amount of tracer.

" $\partial\mathcal{S}/\partial\mathbf{y}\ \partial\mathbf{Y}/\partial S \approx 1$ and $S = \sum_l C_l x_l$. Any comments concerning validity of these assumptions are missing. "

We agree with the referee that these points may not be obvious to the reader, and we have included explicit discussions of these two points in the text.

On $\partial\mathcal{S}/\partial\mathbf{y}\ \partial\mathbf{Y}/\partial S \approx 1$:
Normally one will assume that the DOAS fit of the retrieval method accurately reproduces the slant column in the forward model, then $\partial\mathcal{S}/\partial\mathbf{y}\ \partial\mathbf{Y}/\partial S \approx 1$. In this case the averaging kernel can be directly expressed in terms of the air-mass factor. For an ideal DOAS retrieval this equation will hold. In reality there will be many reasons which will cause this relation to hold only approximately. Sources of errors are inaccuracies in the modelled reflectivities, inaccurate instrument slit function, non-orthogonality of the cross section with other trace gas cross sections and the polynomial, Ring effect, assumptions about the mean temperature of the trace gas and others. If for some reason this relation does not hold, one may want to improve the DOAS approach, instead of introducing a correction factor in the averaging kernel.

On $S = \sum_l C_l x_l$:
This follows simply from the linearity of the intensity in the small optical thickness limit. The text has been rewritten: first a constant C is introduced, which is then identified as the air-mass factor.

" This means that no solution for strong absorbers is proposed."

The small absorption optical thickness case is really the one of interest for the UV-Visible range. The trace gases mentioned in the introduction (NO2, HCHO, BrO, OClO, SO2) are in this category. Also ozone has an optical absorption thickness less than 1 for wavelengths larger than about 320 nm. This is now also discussed in the revised manuscript.

"The authors fail to demonstrate that one of the concluding statements, namely, 'The

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use of the AK together with the retrieved column removes the (often large) dependence on a-priori assumptions about the profile shape', is true.Actually, the averaging kernels do not remove this dependence they just introduce the same dependence into reference data allowing the vertical columns obtained from different methods to be comparable."

We agree that statements about the a-priori dependence should be made carefully and precisely to avoid confusion. Also referee 1 made this point. We can agree with both referees that the way this point is discussed in our paper may easily cause such a confusion. We have gone through the manuscript and have replaced several lines by more precise statements.

We have also added a paragraph on contributions to the error which addresses this point.

The issue is subtle: the vertical column retrieval product is always depending on the a-priori profile shape, and kernels do not change this. The comparison with independent data through the kernels, however, is a fair one, and this comparison does not suffer from an a-priori dependence. We think that the reason for this has in fact been explained adequately in the first paragraph of the section on the use of the averaging kernel information. Mathematically it is related to the total air-mass factor which appears in both the retrieved column and in the kernel. As the referee states: the kernel allows the vertical columns obtained from different methods to be comparable.

Specific comments:

- The first two specific comments have been discussed already. The validity of the assumptions is discussed in more detail in the new manuscript.

- " The right hand side shows that this is computed in the same way as the total airmass factor, ...: Right hand side of Eq. (12) shows nothing, the left hand side, however, have nothing in common with the standard expression for airmass factor.

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The latter statement is not true. The air mass factor is defined as the ratio between the slant column and the vertical column. When all the absorber is located in layer l, then the air-mass factor becomes S/x_l, which, for optically thin absorbers is equal to $\partial S/\partial x_l$. For small optical depths the radiation intensity is a linear function of the absorber density, and the slant column can be written as $S = \sum_l \mathcal{M}_l x_l$ (with $\mathcal{M}_l$ not yet identified). Because of this, the coefficients $\mathcal{M}_l$ are identified as the air mass factor in case all of the absorber is concentrated in the layer l.

We agree that the discussion on Eq 12 may cause confusion. The text has been rewritten and we hope that the new line of reasoning is clearer.

Interactive comment on Atmos. Chem. Phys. Discuss., 3, 895, 2003.