Atmos. Chem. Phys. Discuss.,
doi:10.5194/acp-2016-322-RC1, 2016

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Direct Inversion of Circulation and Mixing from Tracer Measurements: I. Method" *by* Thomas von Clarmann and Udo Grabowski

Anonymous Referee #2

Received and published: 20 July 2016

General comment:

The paper presents a method for deducing atmospheric circulation (wind field) and mixing parameters from trace gas measurements by inversion of the continuity equation. In a first step, the mathematical framework is defined and explained. Second, the method is applied to idealized tracer fields and to MIPAS satellite measurements (in the "proof of concept" section 5), to show that the inversion indeed results in reliable velocities and diffusivities.

Deducing information about the circulation from measurements, without involving information from models, is a great challenge in atmospheric sciences. This paper seems to contain an important contribution to reach that goal, what renders it definitely pub-

lishable and of great interest to a large readership of ACP. However, I have two major points which the authors need to assess before publication. First, the paper is not easy-to-read and the presentation quality needs improvement - otherwise I feel that the paper will fail in addressing a large readership. Second, I have some concerns about the so-called "proof of concept".

Major comments:

1) Presentation and Notation:

Overall, the paper is overloaded with detailed formulae, but lacking motivating and explanatory paragraphs. In their own words (P2, L33), the authors aim to avoid "that the reader does not see the forest for the trees" but, in my opinion, there are still too many trees around. For instance in section 3, there should be a clear motivation at the beginning, why the derivatives (which are calculated in the following) are needed and what the matrix notation means. After that the equations (15-26) could be nicely combined into one single equation-array (similarly in section 4, starting with equation (37)). Concerning all formulae, writing $X, \chi, \mu, ...$ for mixing ratio instead of vmr would help to increase readability.

Moreover, while many steps in the calculation are written in detail (like taking derivatives), at some points I was not able to understand the derivations in detail. One such example is the matrix notation in equation (27). First, a clear motivation should be given why this matrix notation is advatageous and what it means (this is the heart of the paper). Second, I did not succeed in understanding the dimensionalities of the quantities involved. As the authors state, the D-matrix is build from three submatrices of dimensions $K_0 \times K_0$ (I_K), $K_0 \times 2K_0$ (W_i), and $J_0 \times L_0$ ($\mathrm{D}_{\rho,nom}$). Therefore, the D-matrix has dimensions $(2K_0 + J_0) \times (3K_0 + L_0)$, which is, as far as I can see, not consistent with the vector it is acting on. Please check the dimensionalities again and explain clearly what equation (27) means. Equation (35) caused me similar problems with understanding. Please explain clearly where it comes from.

The appendix is, in my opinion, not necessary. It just presents a recalculation of the existing literature. I would recommend to reduce such recalculations, but to add explanations at the critical and new steps of this paper (e.g., around Eqns. 27/35). If the authors want to keep that part, it could be moved to the supplementary material.

2) “Proof of concept”:

In my opinion, section 5.3 does not really present a “proof of concept”, as promised by the title of section 5. The method is used to deduce velocities and diffusivities from tracer measurements, but the true underlying circulation is not known. Therefore, this case is no proof that the inversion method yields the correct result. I think, for a true “proof of concept” the circulation and diffusivities must be known before and need to be reproduced by the method. Section 5.2 points into this direction, but is exclusively descriptive. The optimal “proof of concept” would be to have a 2D-model based on equations (3-4) with idealized velocities and diffusivities, and to invert the resulting trace gas distributions. At least, the cases described in section 5.2 should be explained in more detail and related results should be shown in the paper.

Specific comments:

P2, L1ff: Another source of uncertainty when deducing mean age from SF_6 is related to the fact that the tropospheric increase is not strictly linear (see Garcia et al., 2011, JAS).

P2, L7: To my knowledge, in models usually the surface layer is used as a reference, not the upper edge of the TTL. Please clarify.

P18, L11: How robust are the deduced velocities and diffusivities with respect to the choice of initial value for the iteration. Please give some quantitative estimate.

P20, L7: How can the residual be small for SF_6 if no chemical sink is included in the calculation? Is the sink effect absorbed in the transport terms, or is a significant sink only existing above the upper boundary for the calculation?

P20, L13: “Velocities are roughly consistent with mean ages...”. Some misinterpretations in the past arose from relating mean age simply to the stratospheric circulation. However, mean age is known to be controlled by circulation and mixing (e.g., Neu and Plumb, 1999; Garny et al., 2014; Ploeger et al., 2015). So please discuss carefully what you mean here with “consistent”.

Technical corrections:

Equation (11): I think there should be no minus here (in the supplement there is also no minus: Eq. (34)).

Equation (13): Brackets missing around the argument of volume mixing ratio.

Equation (18): Missing point behind equation.

Equation (27): Are the dimensions correct - see my major comment 1.

P12, L15: Point behind “numerical artefacts.”

P13, L6: K’s should have an index j, like v and w.

P13, L15: vmr in italics - or better: use some symbol instead (e.g., X, see also my major commet 1).

P18, L27: “set to zero.”

P19, L13: Replace “In order to fight...” by “Due to...”

P19, L27: “...macro timestep”

P20, L21: I guess you mean Figure 2.

P20, L23: Figure 3 has no middle column.

Figure 1: The figure, and particularly the descriptions need to be enlarged.

Figure 2: Give a color bar for the velocities in the upper/left panel. Caption: “...(upper right panel). Bottom panels show...”. And write K_ϕ instead of K_{phi}.

Figure 3: The lower/right panel is the same as the upper/right - it should show K_z. Caption: Use v, w instead of $v_\phi, ...$ and K_ϕ, to be consistent with the rest of the paper.

References:

Garcia et al. (2011), J. Atmos. Sci., 68.

Garny et al. (2014), J. Geophys. Res., 119.

Neu and Plumb (1999), J. Geophys. Res., 104.

Ploeger et al. (2015), J. Geophys. Res., 120.

Interactive comment on Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2016-322, 2016.