

Interactive comment on “A self-adapting and altitude-dependent regularization method for atmospheric profile retrievals” by M. Ridolfi and L. Sgheri

M. Ridolfi and L. Sgheri

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General. We thank the reviewer for the deep analysis of our paper.

We agree that our paper contains also some important technical aspects, however the subject of the paper is strictly connected with other relevant scientific papers related to MIPAS and already published in ACPD / ACP: see e.g. the referenced papers of Raspollini et al. (2006), Payan et al. (2007), Fischer et al. (2008) and generally all the papers published in the ACP 2006 Special Issue dedicated to MIPAS. For this reason the authors would prefer and hope that also the current paper will be published as a regular scientific ACP paper.

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Regarding the specific comments

- *p.18009, l.19*: We agree that vertical oversampling is not the only cause of profile oscillations. These can be triggered also by specific systematic errors. In the revised manuscript we will mention also this possible cause of oscillations.
- *p.18010, l.10*: The plot in panel (a) of figure 1 shows that oscillations beyond the random error bars are possible also in absence of systematic errors (figure 1 refers to a retrieval from synthetic measurements). In fact, even if *globally* the LS profile is statistically consistent with the reference profile, *locally* the oscillations can exceed the error bars. In severely ill-conditioned problems numerical rounding errors can easily produce oscillations beyond the random error bars. We agree that regularization can also smooth out oscillations due to systematic errors, however in the VS approach this smoothing is limited by the random error bars (in S_x) via the w_e setting parameter. In the revised paper we will clarify these concepts.
- *p.18010, l.23*: OK, we agree on this point. We will correct this sentence in the revised version of the paper.
- *p.18012, l.13*: The inversion of $\mathbf{K}^T \mathbf{S}_y^{-1} \mathbf{K}$ is not problematic in our case because the retrieval grid (tangent altitudes) is not over-ambitious, therefore the inversion is neither ill-posed nor severely ill-conditioned. However we agree that the inversion might be problematic in cases such as e.g. retrievals at a fine altitude grid from nadir observations. In this case, before applying the VS regularization, the inversion must be made possible using (even very soft) constraints such as a-priori information with the OE method. In the ACPD paper we intentionally dedicated only a single statement (see p.18012, ll.13-15) to this problem, in order to make more simple the equations presented. However, considering the reviewer comment, we now feel that this problem may discourage potential users of our method. Therefore in the revised version of the paper we will extend the equations presented in order to include the treatment of singular $\mathbf{K}^T \mathbf{S}_y^{-1} \mathbf{K}$ matrices.

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- *p.18018, l.7:* We are sorry for the misunderstanding, in our tests we always used $x_a = 0$ because we are convinced that in practical cases it is very difficult to find reliable estimates for x_a . We will specify this choice in the revised version of the paper. Since we use the L_2 operator, the choice $x_a = 0$ corresponds to a penalization of profiles that deviate significantly from a straight line.
- *p.18018, l.20:* Yes, we will add a comment. The VS method makes an attempt to stretch the LS profile compatibly with the error bars of the LS profile. As shown in Fig. 1, panel (a), this objective is successfully achieved also in the region around 70 km. The large difference between retrieved VS and Reference is necessary to make the VS profile more similar to a straight line; this operation is allowed due to the large error bars of the LS profile at this altitude (i.e. due to the large noise the actual observations are not sensitive to this difference).
- *p.18018, l.20:* We agree that studying the UTLS region in detail is of great importance for climate change issues. However, in order to study this region with greater details, measurements with precision and vertical resolution better than those assumed for this test are required. We remind that, according to pre-launch laboratory measurements, the vertical MIPAS field-of-view (FOV) is presently modeled as a trapezium with smaller base = 2.8 km and greater base = 4 km (see Ridolfi et al. 2000). Furthermore, for this test we artificially increased by a factor of 20 the nominal measurement noise of MIPAS above 40 km, so that the global performance of the retrieval illustrated in Fig.1 is worse than that achieved in the case of real MIPAS observations (see e.g. Fig.7 for an O_3 retrieval from real data). More specifically: we repeated the test of Fig. 1 with the nominal MIPAS noise in the whole altitude range and the residual oscillation that you noticed around 15 km disappeared from the VS profile. This implies that most likely in the test currently reported in Fig. 1 the VS method is not able to apply strong regularization around 15 km due to the already large χ^2 penalty (second term of the TF in Eq.(7)) paid to strongly regularize the LS profile above 40 km with very large oscillations (sometimes larger than error bars).

- *p.18019, l.10...*: As stated in the paper (p.18013, l.4,5), we calculate the vertical resolution using a modified version of Eq.(6) in which the elements of the AK are replaced with their absolute value. In case of AKs peaking at the diagonal elements, Eq.(6) estimates the FWHM of the AKs. In case of AKs not peaking at the diagonal elements, Eq.(6) provides an overestimate of the FWHM, hence penalizing (through the TF of Eq.(7)) this type of AKs. In the revised version of the paper we will include a comment to clarify this issue.
- *p.18021-18022, chapter 4.2 and 4.3*: In real data analysis the true atmospheric profile is never known, for this reason we did not base our definition of “optimal” regularization scheme on the knowledge of the true profile. As implicitly stated at l.18-19 p.18013 and l.1-4 p.18014, we aim at an “optimal” regularization scheme that finds the smoothest profile compatible (within a given error margin established by w_e) with the available observations, provided that the vertical resolution is not degraded beyond a pre-defined margin w_r . This definition is implemented in the VS method. The strength of the regularization is driven by the parameters w_e and w_r and their choice depends on the specific application in which we are using the retrieved profiles.

We do not know whether the structures at 25-30 km in the CH_4 profile and 15-20 km in the H_2O profile are real, however the point is: can we *believe* an oscillation or feature of the LS retrieved profile if its amplitude is comparable with the error bars ? The answer to this question depends on the specific application in which we are using the profile itself. If we decide that we can trust this type of structures then we may switch off the regularization or use a very weak strength (see e.g. Fig.4, $(w_e; w_r) = (0.2; 2)$ or $(w_e; w_r) = (0.6; 3)$). On the other hand, if we do not want to trust profile structures with amplitude comparable to the error bar of the LS solution, then we may go for a stronger regularization, such as $(w_e; w_r) = (1; 5)$. Our choice for a rather strong regularization is supported by the large oscillations that were detected in the MIPAS profiles during the validation phase (see p.18009, l.11,12).

After this comment we noticed that both an explicit definition of the desirable features

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for a regularization scheme and the guidelines for the choice of the regularization strength (depending on the specific application) are presently not clear in the paper. In revised version of the paper we will fix this problem.

- *p.18022, 1.5-10*: Regarding Fig. 8, please note that the LS and VS profiles are fully compatible within the error bars of the LS profile in the 15-20 km range. We understand that a given user may not like the degradation of vertical resolution achieved with the VS method in this altitude range. In this case one should use a smaller w_r parameter. The structure appearing in the LS profile was smoothed out by the VS method because its amplitude was smaller than one error bar of the LS profile (we used $w_e = 1$ and allowed the method to degrade the vertical resolution up to a factor of 5 with $w_r = 5$). We believe that ultimately, in order to resolve the possible structure in the water profile in this altitude range we would need a thinner FOV and / or better signal to noise ratio in the measurements.
- *p.18022-18024, chapter 5*: As mentioned above (see reply to comment on p.18018, 1.7) we always used $x_a = 0$.

The revised version of the paper will include the results from an entire simulated orbit (see also reply to Susan Kulawik).

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 18007, 2008.

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