**Atmospheric
Chemistry
and Physics
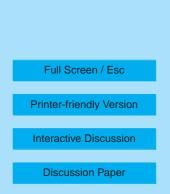Discussions**

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

Anonymous Referee #2

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The authors present a self-adapting altitude-dependent regularization method applicable to iterative Gauss-Newton algorithms from the retrieval of vertical distribution profiles from atmospheric remote sounding measurements.This method aims at smoothing out artificial oscillations while preserving real small-scale structures in the retrieved profile whenever related information is detected in the observations. By applying it to the retrieval of O3 from simulated radiance spectra as recorded by MIPAS on Envisat, the authors demonstrate its good performance. The proposed regularization scheme is further tested by application to real MIPAS observations.

The paper is well written and the proposed method is sound. However, I have three

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general comments with respect to the overall applicability of the regularization schemes and possible limitations which should be considered by the authors in their final version. Other specific comments are minor.

General comments:

1. I understand that the purpose of the regularization scheme is to avoid instabilities related to the oversampled retrieval grid and to smooth out artificial oscillations produced by the mapping of systematic errors (related to spectral calibration or accuracy limitations of the forward modeling). While there is no issue about the first, it is not clear to me how the latter purpose can be achieved with the proposed method in the case of systematic spectral errors which exceed the noise level. Wouldn't these systematic errors then be "identified" as real spectral information and, in consequence, be vertically resolved by the proposed method rather than being smoothed out? The authors should comment on the performance of their method in the presence of systematic errors and should identify its limitations in this sense.

2. The proposed method requires an unregularized solution of the inversion problem to be calculated first. While this appears to be no problem in the case of a slightly oversampled retrieval grid (as for the ORM processing of MIPAS spectra discussed here), the unregularized retrieval equation might not be invertable in the case of strong oversampling or profile retrievals from nadir observations, even when including Levenberg-Marquardt terms. The authors point out that optimal estimation (OE) terms can then easily be included in order to avoid severe ill-conditioning (i.e., p18012, l14). However, the proper selection of these OE terms, which should introduce an "as-weak-as-possible" regularization effect while ensuring an invertable retieval problem, is not straight forward and might depend on the atmospheric conditions of the actual scan. The authors should give some recommendations how to address this problem and/or comment on the limitations of their method with respect to specific retrieval problems, particularly when stating in the abstract " the proposed method is generally applicable to iterative Gauss-Newton algorithms for the retrieval of vertical distribution profiles

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from atmospheric remote sensing measurements".

3. It appears that the proposed method tends to strongly smooth retrieved profiles in the absence of "real" profile structures, hence resulting in a heavily degraded vertical resolution (values of 10-20 km (!) above 35 km in the case of the H2O retrieval shown in Figure 8) with respect to the unregularized solution or, in other words, in a significant reduction of degrees of freedom. This is not a serious problem when analyzing the retrieved profiles themselves (as the authors demonstrate, the application of their scheme results even in a better agreement of the inverted and the true O3 profile, i.e., Figure 1), but complicates the comparison to independent observations or model results. To illustrate this with an example: The retrieved H2O profile of Figure 8 shall be compared to a modeled H2O profile which, in contrast to the retrieved one, shows a localized "bump" at 50 km. In order to allow for a meaningful comparison, averaging kernels of the retrieved profiles are applied to the modeled profile. Due to the strong regularization applied to this profile region, the bump in the modeled profile would be smoothed out, resulting in an unrealistic good agreement between model and data, despite of the existing model deficiencies. In principle, the described problem could be avoided with a different selection of the tunable parameters (i.e., a lower value of w_r). In this sense, the authors should revise their recommendations for selection of the (w_e,w_r) couple (Sections 4.1 and 5) which are only based on the minimization of Chi2 and maximization of the profile smoothness achieved. Instead, they should also consider requirements for a meaningful scientific interpretation of the retrieved profiles, particularly with respect to vertical resolution and precision.

Specific comments:

18013 Eq 7: The normalization of the first term with the mean value of the actual profile might lead to a strong weight of particular profile regions in the case of species with a pronounced vertical variability (i.e. H2O, CO). What is the reason for normalizing outside the sum over S_{jj} (instead of performing the sum over S_{jj}/x_j)?

18014, l16: Isn't x_k (instead of x_LS) substituted in Eq. 10 by plugging in Eq. 3?

18016 l9: what is i?

18017 Sec 3: It would be interesting to extend the simulated retrievals also to other target species. The performance of the regularization scheme could be particularly well demonstrated when applying it to "difficult" but realistic situations, i.e.: polar winter CH4 retrieval in the case of vortex air masses sounded in a limited vertical region, H2O retrieval in the case of a shifted hygropause location, polar winter NO2 retrieval in the presence of descended NOx produced by particle precipitation.

18018 l8-10: What kind of a priori has been used? If not zero, it would be unresting to see the retrieval performance for the case of an a priori which is shifted in altitude with respect to the truth.

18020 l27: What do you mean with a NO2 profile with physically unacceptable shape?

18023, Sec 5: The evaluation of different regularization schemes in their application to a MIPAS/Envisat orbit should not be based on profile smoothness (Omega_2) and Chi2 increase alone. I recommend to include also degrees of freedom (trace of AK) and/or minimum/maximum/mean vertical resolution.

Technical corrections:

18023 l7: "...if the profile is a STRAIGHT line"

18025, l20: extension

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