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Atmospheric Measurement Techniques Discussions

Interactive comment on "A non-iterative linear retrieval for infrared high resolution limb sounders" *by* L. Millán and A. Dudhia

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Response to anonymous referee # 1:

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We sincerely thank the referee #1 for his/her thoughtful comments on the previous draft, we hope this new version is more suitable for publication.

We added two figures to this new draft, one showing the averaging kernels of the Mipas implementation of the linear retrieval and one showing the linear - linearisation points.

Below are our responses in red.

1 Reviewer 1

This paper describes a study on the application of a pure linear retrieval approach for the analysis of infrared limb-sounding observations. It is logically structured and all methods are clearly explained. Besides the obvious run-time aspect, it has been stated that one advantage of the method would be the strongly reduced noise

error due to the large spectral region useable in contrast to conventional retrievals based on microwindows. It would be good to demonstrate this advantage e.g. by showing the noise errors in case of the MIPAS examples. Also, the trade-off between noise-error and other systematic errors should be mentioned, i.e. that increasing the spectral range may not lead to a significant improvement of the total error. Further, the agreement between the error estimation for the linear retrieval and the differences compared to the MORSE and/or MLS retrievals should be demonstrated. Specific comments are listed below.

P722: The abstract is very general. It would be nice if any quantitative numbers could already be stated therein.
The abstract was changed to include: We determine that pressure and temperature retrievals can be treated linearly up to a 20% difference between the atmospheric state and the linearisation point for a 3% error margin and up to 10 K 'difference' for a 3 K error margin near the stratopause and less than 0.5 K elsewhere. Assuming perfect pT knowledge, CH_4 retrievals can be be treated linearly up to a 20% CH_4 concentration 'difference' for a 2% error margin.

P724Eq1: The equation seems incomplete. Instead of $K_i^T S_y^{-1}(y - F(x_i))$ I would expect: $[K_i^T S_y^{-1}(y - F(x_i)) - \gamma^{-1} R(x_i - x_a)]$ Could you clarify?
The equation was change to:

$$\mathbf{x}_{i+1} = \mathbf{x}_i + \left(\mathbf{K}_i^T \mathbf{S}_y^{-1} \mathbf{K}_i + \gamma^{-1}\mathbf{R}\right)^{-1} \left[\mathbf{K}_i^T \mathbf{S}_y^{-1} \left(\mathbf{y} - \mathbf{F}(\mathbf{x}_i)\right) - \gamma^{-1}\mathbf{R}(\mathbf{x}_i - \mathbf{x}_0)\right] \quad (1)$$

And the reference for von Clarmann et al. (2003) was used instead of Rodgers(2000).

P724Eq2: In case of optimal estimation (i.e. $\gamma^{-1}R = S_a^{-1}$) this would be the formulation for the total retrieval error, i.e. the smoothing error plus the retrieval noise

error. However, in case of Twomey Tikhonov this error makes no real sense since one has not a good estimate of the smoothing error part, which would need a realistic assumption on the atmospheric state covariance matrix. So one should rely on the retrieval noise error which is: $(K^T S_y^{-1} K + \gamma^{-1} R)^{-1} K^T S_y^{-1} K (K^T S_y^{-1} K + \gamma^{-1} R)^{-1}$
corrected and Figure 13 was updated.

P725L15: Could you show the resulting vertical resolution from the averaging kernel matrix to get a feeling of how strong the retrieval is constrained by the regularization?
I did not add the averaging kernels figure in this section because the noise is not the same as in the implementation section which may confuse the reader, instead I added the sentence: 'The resulting simulated retrieved values have a vertical resolution of 3 km in the stratosphere and lower mesosphere and around 4.5 km in the upper mesosphere.'
Furthermore, I added a figure (plus accompanied text) describing the vertical resolution of the linear pt retrieval in the 'Multiple linearisation points' section and added the following sentence in the 'Further VMR practical considerations' section: The vertical resolution of these retrievals is 3 km throughout the entire vertical retrieval range.

P726L10: The discussion of Fig. 4 is a bit weak. One should at least try to explain why the profiles oscillate much more than in Fig. 3. (Is there an issue with the regularization?)
An error was found in the implementation of the Jacobian units change which resulted in the oscillations, the figure was updated.

P728L19 practically at all altitudes : But 20% are exceeded at some altitudes. Could you be more specific here.
The text was changed to say: As shown, for a 10 K perturbation the errors induced are less than $\sim$20% except around 45 km where the deviation is almost 70%.

P728L19 'less than 2% error margin at most of the altitudes': Also here at 10% and 20% pressure increments, the error is larger 2% at many altitudes. Could your statement be made more exact.
The text was changed to say: As portrayed, the adjustment works up to a 20% perturbation with less than 2% error margin except around 20 and 50 km.

P734L10 'from band A where most of the CO2 lines occur': Perhaps add a sentence why not band D, where also many CO2-lines are.
The text was changed to: Here we use the spectra taken in the MA mode from band A where most of the CO_2 lines occur and because these CO_2 lines (as opposed to the CO_2 lines in band D) are close to LTE up to at least 100 km (López-Puertas and Taylor, 2001), and from band B where most of the CH_4 lines occur.

P734L11 'This viewing mode was selected to apply the algorithm here described because it is in this mode where this algorithm has the more potential.': Could you explain why?
the text was changed to: The MA viewing mode was selected to apply the algorithm here described because in this mode more microwindows are needed to compensate the small signal to noise ratio encountered at higher altitudes, and hence, in this mode this algorithm has the most potential.

P735 Section7.2.1: Does the selection depend on height?
the text was changed to: The spectral profiles assumed to be due to "pure" CO_2 emissions were selected, tangent height at a time, using ...

Could you estimate the resulting errors due to the assumed limits of 0.9 and 1.1?

This paragraph was added to the section: The 10% range (i.e. the assumed limits of 0.9 and 1.1) is a compromise between the spectral points available and the influence of the overlapping species and nonLTE emissions. Simulated retrievals showed that this 10% range removes within 0.3 K the influence of overlapping species and reduces by around 70% the impact of nonLTE emissions. To properly take into account the nonLTE emissions either vibrational temperatures need to be retrieved as part of the retrieval scheme (too computationally expensive) or a vibrational temperature climatology needs to be developed.

P737 Section7.3: Is the selection made for MIPAS band A or B?
the text was updated to: Figure 15 shows the linearisation points selected for the pT retrieval (from MIPAS spectra band A) the 7th June 2007 using equation (20).

Can you explain why the equatorial profile has been selected so rarely at low latitudes?
Not really, thats just what the retrieval chose. The following was added to the second to last paragraph in section 7.3: Although it is not selecting as much the equatorial profile as expected, this will not affect the retrieval results as shown in section 7.4.

P738L21-24: The description of Fig. 16 does not fit well to the differences shown in Fig. 16.
the text was changed to: However, as seen in the absolute difference subplot, compared to MORSE and MLS the linear retrieval seems to underestimate the temperatures for pressures between 0.1 and 0.01 hPa at all latitudes and underestimate the temperature for pressures between 1 and 0.1 hPa. For pressures greater than 1 hPa in general there seems to be no significant difference (less than 3 K) between the linear, MORSE and the MLS results.

P739L13 'lower than 0.01 hPa': Should this read 'lower than 0.1 hPa'?
Corrected

P740L17: 'its results should improve once a more reasonable linearisation point climatology is used.' It would be good to demonstrate that this is the reason for the larger errors, e.g. by showing in Fig. 18 the difference between MORSE and the linearization points (or, better, results of the error estimation from chapter 6 applied to the actual case).
A figure showing the linear retrieval - linearisation points was added. The text was updated to include:
"Figure 21 shows VMR, pressure and Temperature zonal means $\mathbf{x} - \mathbf{x}_0$ 'distances', or in other words the separation between the retrieved atmospheric state and the linearisation points used. For most altitudes and latitudes, these 'distances' are greater that the requirements to fall within the linear regime (see section 7.4) suggesting that the linear retrieval results should improve once a more reasonable linearisation point climatology is used."
Also, the error estimation using section 6 equations is shown.

Technical:

P723L7: A more recent overview than 'Fischer, 2000' (instead of 'Fisher' as in the text) is 'H. Fischer et al., Atmos. Chem. Phys., Vol. 8, 2151-2188, 2008.'
We added the reference to Fischer, 2008 and corrected the spelling.

P732Eq15 first term on right side:'$\nu - \nu_0'$ should read '$v - v_0'$ since this would imply 'wavenumber'. Also I doubt that the indices in the equation and below in the text should contain ν since this would imply 'wavenumber'.

Changed all the ν to v.

P734L11 'This viewing mode was selected to apply the algorithm here described because it is in this mode where this algorithm has the more potential.': 'most' instead of 'more'
Corrected

P740L21 'consider': Should read 'considered'
Corrected