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Comment

***Interactive comment on “Regularisation model study for the least squares retrieval of aerosol extinction time series from UV/VIS MAX-DOAS observations for a ground layer profile parametrisation and westward viewing direction” by A. Hartl and M. O. Wenig***

**Anonymous Referee #2**

Received and published: 16 May 2013

General comments

This manuscript presents a comprehensive model study on the retrieval of tropospheric aerosol information from multi-axis DOAS observations. Various general and specific aspects of the aerosol retrieval are presented (I'm avoiding listing them again here). The paper is in my opinion suited for publication in Atmospheric Measurement Techniques. The paper is generally well written, but some parts contain a lot of details that

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disturb the flow and make it difficult to read. Still, I have no really major objections to the publication of this paper. I'd ask the authors to consider and address the specific comments listed below.

### Specific comments

- Page 2588, line 22: 'Through this choice, the stratospheric contributions in Eq. (2) cancel and one is left with the desired tropospheric part to the differential absorption optical depth.'

Is this really exactly true, and not just an approximation? In a general sense, the stratospheric slant column density will also depend on the elevation angle, won't it?

- Page 2589, line 14: '\$\lambda\_{fm}\$'

What does 'fm' stand for? Presumably 'forward model'. Section 2.3 does not explain this, either.

- Page 2591, equation (11): The main closing parenthesis should appear after the constraint term, and not after the first term.

- Page 2592, line 17: 'It uses the fact,'

It's not clear, what 'It' refers to; to the 'ad hoc choice' or the simple L-curve scheme?

- Page 2592, equation (12): Sorry, I missed why 'e' can be replaced by the square root of 'm' here.

- Page 2592, line 24: 'with  $x_{RMS}$  being the RMS of  $\mathbf{x}_{RMS}$ .'

This sounds somewhat tautological, particularly, because the latter term ( $\mathbf{x}_{RMS}$ ) has not been defined, as far as I can tell.

- Page 2593, line 6: suggest to write: 'The first expression on the right hand side OF EQUATION (13) ..'

- Same line: 'contribution from' -> 'contribution of'

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- Page 2593, line 9: 'For least squares solutions  $\gamma \rightarrow 0$ '

This suggests that the solution for non-zero regularization parameter is not a least-squares solution, but it generally is, too.

- Page 2595, line 13: Spell out 'fm' in ' $\lambda_{fm}$ '

- Page 2595, line 13: '.. WHICH .. have to be specified as part of the forward model parameters b.'

I'm not entirely sure, what 'WHICH' refers to. Is it perhaps the reference wavelength? (That's what I assume). If yes, then the sentence should read '.. which .. HAS to be specified as part ..'. The sentence - as it is - is confusing.

- Page 2596, line 5: Please mention explicitly that subscript 'k' occurring several terms in this line refers to the iteration number (that's at least, what I think it is).

- Page 2596, line 7: 'starting throughout with  $\mathbf{x}_0 = \mathbf{x}_{a,k}$ '

Sorry, I think I'm missing a point here. How is  $\mathbf{x}_{a,k}$  defined? It should be explained here, not only 10 lines below.

- Page 2601, line 3: '(top panel in Fig. 3)'

I think this should read '(bottom panel in Fig. 3)'

- Page 2601, line 6: '(bottom panel in Fig. 3)'

and this should probably read '(top panel in Fig. 3)'

- Page 2602, line 10: 'on the layer extinctions at the minimum  $\hat{x}$ '

The part 'at the minimum  $\hat{x}$ ' confuses me. Why should  $\hat{x}$  be at a minimum here? Chi-square is near the minimum for the parameter range shown.

- Page 2604, line 15: 'Consequently  $d_s$  is considerably smaller for the profile with larger AOD  $\tau \sim 1$ '

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Please explicitly mention the specific reason why the case with larger AOD is associated with a smaller number of degrees of freedom.

- Page 2604, line 18: I think this is the first time 'DOF' appears. Most readers will know what it means, but please spell it out once.

- Page 2604, line 20: I think it would be appropriate to remind the reader, what 'condition number' refers to.

- Caption Fig. 9: What's explained under 'Top' actually refers to the two panels (top and bottom) on the left AND the top right panel. Your 'bottom' only refers to the bottom right panel, right?

- Page 2606, line 19: 'between 20–30% are not fixed by the measurement'

Not entirely clear, what you mean by '20-30% are not fixed by the measurement'. Can you rephrase this?

- Page 2608, line 2: 'With  $\varphi_{rel}$  getting LARGER'

This should read 'SMALLER', not 'LARGER', right?

- Page 2608, line 5: 'are underestimated for  $\varphi_{rel} < \sim 90$  deg, whereas they become overestimated for  $\varphi_{rel} > \sim 90$  deg'

Perhaps I'm missing a point here, but it seems to me that it's the other way around, looking at the bottom left panel of Fig. 14 ( $\tau_L$ ) and the dotted line (azimuth angle)??

- Fig. 15: Please mention in Fig. caption that the thin colored lines correspond to the percentage of valid retrievals, and the thicker (they could be even thicker) lines to the residuals

- Page 2608, line 27: 'of adding relative intensities to the fit vector is that the LATTER are'

The 'latter' in this sentence refers to 'the fit vector', which is - I assume - not the intended

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meaning ?

- Page 2608, last line: 'Instead of regarding the addition of intensities as an augmentation of the data vector, one might look at it as an additional contribution to the a priori or regularisation term ...'

I don't quite understand this statement (and it's relation to the previous sentence). The relative intensities contain information on the aerosol AODs, OK, but this is exactly what you want, right? That's the reason, why the AOD retrieval works better if the intensities are included (bottom right panel of Fig. 14). I don't quite understand why the relative intensities can be considered making a contribution to the a priori rather than the measurement.

- Caption Fig. 16, line 4: 'Lines show averages of random errors'

The lines do certainly not show averaged random errors, do they? They show averages over the (up to) 100 representations of the retrievals with random errors applied, right?

- Page 2611, line 4: 'While for all profile series so far starting point and sequence of the retrieval process co-incided with the chronological order of the time series'

I read this sentence several times, but I'm still not sure what the intended meaning is. How can the starting point coincide with the 'chronological order'? Can you phrase it differently?

Typos etc.

- Page 2594, line 23: 'in Hendrick et al. (2006); Wagner et al. (2007)' -> 'in Hendrick et al. (2006) and Wagner et al. (2007)'

- Page 2595, line 16: 'The optimisation problem Eq. (11)' -> 'The optimisation problem presented in Eq. (11)' or 'The optimisation problem (Eq. (11))'

- Same sentence: suggest rearranging sentence to read: 'The optimisation problem ... is solved using an implementation of the Levenberg-Marquard (LM) algorithm, which is

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well suited for this kind of nonlinear least squares problem (..), and which is provided by the MINPACK library ..'

- Page 2607, line 19: 'The graphs are result' -> 'The graphs are results' or 'The graphs are the result'

- Page 2609, line 8: '.. the time series .. start' -> '.. the time series .. starts'

- Page 2616, line 9: 'in Laepple et al. (2004); Hartl et al. (2006)' -> 'in Laepple et al. (2004) and Hartl et al. (2006)'

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Interactive comment on Atmos. Meas. Tech. Discuss., 6, 2583, 2013.

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