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Improving retrieval quality for airborne limb-sounders by horizontal regularisation

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1   General

This manuscript continues a series of papers on various aspects of tomographical limb retrievals [Ungermann et al., 2010a,b, 2011] published by the author along with co-authors from the Jülich (and Karlsruhe) group and applies the 2D/3D inversion methodology to recent measurements of an airborne limb sounder that have already been discussed — in a "conventional" 1D approach — in another AMT paper [Ungermann et al., 2012]. Prospects, challenges (essentially from a computational point of view), and potential benefits of the 2D/3D approach vs. the 1D approach have already been discussed in several papers published (mostly) in the last decade [e.g. Livesey and Read, 2000; Carlotti et al., 2001; Steck et al., 2005]. In view of the large heritage of past and existing limb sounders providing Terabytes of high-quality data, and the promising potential of future instruments (e.g., PREMIER) further developments and exploitation of this "new" approach is clearly justified.

The author presents in detail the mathematical apparatus, provides an extensive exposition of horizontal / vertical regularization, and examines the trade-off, pros/cons of the tomographic approach using regularization by comparisons with horizontally smoothed 1D retrievals. In summary, the paper is well written with a clear, reasonable structure and detailed analysis of results, and can be recommended for publication after revision.

2   Major Remarks

2.1   Detailed presentation of mathematical methodology — duplication with previous work

There is quite some redundancy / repetition in the presentation of the retrieval approach — Gauss-Newton iteration, setup of regularization matrix, averaging kernel and gain matrix diagnostics, etc. ... — when comparing this manuscript with the previous papers mentioned above, nb. the two GLORIA papers. For the reader

of this manuscript (including the reviewers) it is therefore cumbersome to identify the advances presented in the current manuscript. A detailed presentation of the methodology has been clearly useful in former times, when papers were difficult (or sometimes almost impossible) to obtain. However, nowadays literature is mostly accessible by just a "few mouse clicks". In particular, all previous Ungermann et al. papers have been published in an Open Access journal (AMT(D)) and therefore are readily available.

As a consequence I suggest to rewrite the methodology section 2 in a significantly more compact manner, clearly indicating the differences to the previous presentation.

2.2 "Noise" in retrieved state vector

The term "noise" used frequently in this manuscript to describe some properties of the retrieved profile(s) is not appropriate. Clearly the measurement (vector) is contaminated by noise, however, the retrieved profile(s) (or their discretized representation, the state vector) can have instabilities, oscillations, ... in case of insufficient regularization.

3 Minor Remarks

Duplications in abstract The last sentence of the first paragraph (line 6) and the third sentence of the second paragraph (line 12) are somehow similar.

Acronyms Please explain "RECONCILE"
(Possible already in abstract, along with "CRISTA")

6580.02 Livesey and Read [2000] is historically older.

6580.14 "This is *typically* accomplished by adding constraints ..."
Are there other ways of regularization?

6581.04 The second sentence is incorrect, not only limb sounding inversion is ill-posed, nadir sounding is even worse (as correctly stated in the final section).

6581.06 "... representation of the atmospheric state x is modified ... until the fit ... is deemed good enough ..."
This sounds like an iterative procedure, which is clearly required for nonlinear problems. However, linear (small-scale) problems can be solved in just one step without iteration.

6581.10 "... forward model capable of simulating the physics of radiative transport and *measurement* ..."
The forward model "simulates" the entire measurement process comprising radiative transfer in atmosphere and instrument ($\implies$ replace "measurement" by "instrument").

6583.19 "... insert the minimum of the cost function x_f ..."
Rephrase! x_f is not the minimum of the cost function, rather it is the x minimizing the cost function.

6590.18 "...get reduced in lockstep ..." — Please explain

6591.11 "This data set is rather unique ..." — Does this refer to the entire campaign data set or just the second flight on 2. March??? If necessary move this sentence down or the very last sentence up.

6591.23 "...from the flight altitude down to 15 km below ..." — This is quite confusing. According to Ungermann et al. [2012] the scan goes down to 5 km.

6592.24 Retrieval setup: it would be helpful to indicate the (total) length of the measurement vector and of the state vector.

6593.04 "All targets are derived between 0 km and 25 km ..."
Probably the lower limit is essentially the lowest tangent height!?!
According to Ungermann et al. [2012] the retrieval grid above $30\,$km has a spacing of $2\,$km?

6596.18 HITRAN11: the HITRAN 2008 database [Rothman et al., 2009] including recent updates?

6600.25 "...*being* the retrieval *being* nonlinear)." — Isn't the retrieval nonlinear anyway???

4   Technical Remarks (typos etc.)

Sub/Superscripts for variables such as x indicating an abbreviation etc. should be given in upright font, not math italic. Accordingly correct the fonts used for, e.g., x_f or x_T (the a-priori x_a is already displayed correctly).

6578.18 "limb-sounders measurements" $\longrightarrow$ "limb-sounder measurements"

6579.02 "2-D cross-Sects. ." $\longrightarrow$ "2-D cross-sections."

6579.17 "an limb-sounder" $\longrightarrow$ "a limb-sounder"

6583.12 "...during the solving of equation systems ..." — Rephrase!

6584.13 Move opening parenthesis to front of citation

6586.16 134 pp $\longrightarrow$ p. 134 ?

6587.15 "...next Section." $\longrightarrow$ "dots next subsection"

6588.11 "...can the be analysed ..." $\longrightarrow$ "...can then be analysed ..."

6592.04 "Obtaining a single spectra ..." $\longrightarrow$ "Obtaining a single spectrum ..."

6592.15 "...derived from *the* emissivity growth approximation ..."

6593.22 "The case study necessarily derives ..."
In this case study ???
Why *necessarily*???

6595.10 "...farther away than suggest*ed* ..."

6597.25 "The impact of *the* naturally dimensioned factor-200 ..."

6597.27 Sentence???

6599.20 "...in the *later* part of the flight ..."

6599.24 "...ran together ..." — coincide, overlap, ...???

6599.25 "...there may to be ..." ⟶ "...there may be ..."

6601.04 For better readability it might help to move Eq. (10) upwards to the second paragraph of subsection 3.8 introducing this approach.

6603.13 "A different questions is ..." ⟶ "A different question is ..."

6605.17 "...the more simple ..." ⟶ "the simpler ..."

6605.20 "Both approache*s* ..."

Figs. 2, 3, 4, 5, 11 Title of the plots "retrieval results" ???

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