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Atmospheric Measurement Techniques Discussions



# *Interactive comment on* "Time series inversion of spectra from ground-based radiometers" *by* O. M. Christensen and P. Eriksson

**Anonymous Referee #1**

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This paper correctly identifies the problem that retieved abundances often have to be smoothed before being used for any scientific purposes to reduce the noise and that this smoothing in the time domain might interfere with timeseries analyses. The authors suggest to solve this problem by adding time as an additional dimension to the MAP retrieval and thus get the optimal smoothing in a Bayesian sense. I consider this method as original and useful and thus recommend publication of this manuscript in AMT. I suggest the following comments to be considered. Although these arenumerous and lengthy, I like the paper very much.

Title: I am not quite sure about the grammar of the term 'inversion', i.e., what is inverted and what is the result of the inversion. It might be worthewhile to verify with

the help of a native English speaker that the term ‘time series inversion of spectra’ is unambiguous.

Introduction: The paper is primarily about a retrieval strategy, and I understand that it is not very relevant that the case study chosen is based on microwave measurements. Thus, I find it misleading that the introduction strarts with a paragraph on ground-based microwave spectrometers. I suggest to move the first paragraph of the intro after l4 on page 1558, and to reword the intro such that it does not depend on the microwave technique. This will, of course, imply some wording adjustments but the reader is led more directly to the focus of the paper.

Eq 1: No Bayesian nor MAP context has been introduced so far, so the use of the term ‘a priori’ is somewhat out of context. I suggest to repace $x_a$ by $x_0$. For the moment, this can be any starting value, since no concept involving the term ‘a priori’ has been introduced yet. Just say somwhere near Eq 2 that you replace $x_0$ by $x_a$.

p1559 bottom: I am not sure if ‘measurement response’ is the commonly used term. I have also read ‘measurement sensitivity’ in this contex. It is suggested to check with the literature and verify that you use the establisshed term here (The contents is correct, this comment ia only about the wording).

p1562 top: Here you present a method to construct the covariances of the a priori state vector, which contains at least some ad hoc elements. Thus the method is no longer a maximum a posteriori method as stated in the paper. I know that I am somewhat pedantic here, but the problem can be avoided by stating "We use the formalism of the MAP method" rather than "We use the MAP method" throughout the paper.



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p1563 last par: It is not intuitive that the a priori variance is necessarily smaller for a larger time interval. The last two paragraphs in Rodgers 10.3.1.1. seem to me to refer to a condition where all variation around the mean is random. For a larger interval, the sample mean will of course be closer to the population mean. But what if you have, e.g., periodic (e.g. diurnal) changes: A 'morning' climatology will have smaller variability than an 'all day' climatology. I see that in your case study you don't look down into the troposphere, so diurnal variation of $H_2O$ plays no role here, but since the concept presented in this paper has more general applicability, I suggest to add a caveat on this issue somewhere. Some people might wish apply the method to $NO_2$ or $N_2O_5$...

p1565: Have the simulated spectra been superimposed with artificial noise, or are these noise-free test retrievals? Is the noise only in the $S_\epsilon$ matrix or is $S_\epsilon$ chosen consistent with the noise-superimposed synthetic spectra? The authors are encouraged to be more specific here.

p1565: "The single spectrum inversions have no error": Is this because no noise has beed added to the synthetic spectra, or is it because the results are constrained so heavily towards the a priori that noise cannot push the results away from the prior?

p1565 l21 Not sure what "unit change" is.

p1566 l12/13: This is confusing? How is the time domain included in the AVK for single spectra retrievals. I thought that single speacta retrievals are $n \times n$, not $nN \times nN$? I agree that there should be no information crosstalk in time in single spectra retrievals but I doubt that the AVK is the right diagnostic to show this? Or aren't these real single spectra inversions but formal time series inversions but with no constraint in the time domain, thus behaving like single spectra retrievals. Please be more specific here.



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p1568: Have you thought about the Purser and Huang (gridwidthe divided by diagonal of averaging kernel, c.f. Rodgers Sect.3.4.4) criterion for the resolution? It seems more meaningful to me particular in cases when the 'measurement' response is low but the FWHM still small. Let A be a diagonal values with 0.5 along the diagional, for illustration what my point is.

p1569 l6/7 Is it easy to understand that the FWHMs of retrieval error and AVK can be different? Normally, they are different because K is 'non-diagonal' (I know that this is sloppy wording because K is not usualy quadratic; I mean there is cross-talk over altitudes). This makes the retrieval error correlated in the altitude domain even if there is no constraint, i.e. even if the AVK is diagonal. But here the situation is different: In K there is no cross-talk between times, i.e. the only mechanism which can lead to retrieval error correlations in time is the smoothing constraint. Both describe how a variation of the measurement at one time affects the result at another time. It is not obvious to me where the differences come from. Some discussion of this issue would be appreciated. Is it because this is coupled to mutual error propagation in the altitude domain as discussed above?

p1569 bottom: is there any systematic (even if indirect) dependence of noise with time? If so, noise-weighted averaging might lead to a sampling bias within the 3 hrs intervals. This could be helped by weighting the measurement times accordingly and by assigning the measurement to the weighted mean of the time.

p1570 l3/4 the term 'retrieval matrices' souds like a technical term but it is not, which is confusing. I guess you need a generic term including covariance matrices and Jacobians etc. Further, the term 'large' is not very precise. I suggest 'the dimensions



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of the matrices involved in Eqs. 3-4 become quite large.'

p1570 l 14/15: Same issue as above: If noise varies between the 3 hrs intervals, how do you know that it does not vary within the 3 hrs intervals? And if it varies within the 3 hrs intervals, the weighting will cause a temporal sampling bias.

p1571 l6:... but N is smaller than in the theoretical case (for the same overall time period), since there were no data gaps. So the N+N' corresponds to the N of the synthetic case, doesn't it. I find this somewhat confusing because one might think that the new N+N' is necessarily larger than the old N. Some clarification of this will be appreciated.

p1570 middle: I appreciate that the most important parameter settings for the real data retrieval are summarized here but I consider it helpful to additionally refer to a publication where the retrieval details are explained in more depth if available.

p1576 middle: again please add a cavead about periodic a priori correlations (diurnal variation etc).

p1576 l20 and 27 Wouldn't it be better to replace 'practical' by 'based on real data'?

p1576 l21 'normal desktop computer': journal articles are written for eternity, not for the moment. What do you think a reader in 10 years from now understands is a normal desktop computer? Please be more specific. Further, non-microwave remote sensing scientists do not know how many spectral gridpoints you use (I suspect you do not calculate radiative transfer on the final output channels but on a finer monochromatic



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grid), on which altitude grid the retrievals are represented etc, if you do explicite line-by-line calculations or if you use pre-tabulated absorption cross-sections etc. All these choices affect the calculation time. Either mention all these key data, or consider to remove the statement on calculation time.

Discussion: please add a caveat that there can be artefacts if the time averaging kernels are not considered by the data user: Imagine something like the tropical tape recorder. Naively analyzing the tropical $H_2O$ tape recorder in your inverted time series, the decrease of its amplitude with altitude would be overestimated etc. I appreciate the benefits of this method, but as every method involving priori information, there are also traps for the data user, which should be honestly discussed.

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Interactive comment on Atmos. Meas. Tech. Discuss., 6, 1555, 2013.