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Atmospheric Measurement Techniques Discussions

# *Interactive comment on* "Microwave radiometer to retrieve temperature profiles from the surface to the stratopause" *by* O. Stähli et al.

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Dear Referee

Thanks a lot for the helpful and constructive comments.

Abstract: The abstract contains information which is not really important, e.g. sentence 2: " The instrument operates thermally stabilized inside a lab." The authors should remember, that the abstract and the conclusion are the parts which are read first in order to make a decision if the publication is worth reading. Therefore I would suggest to rewrite the abstract to contain only the information of what has is done and what has been achieved.



===Answer: We agree.

Introduction: Generally the introduction should be reordered to make reading it more easy. The authors tend to jump, e.g. at page 3 line 23ff the authors describe what is contained in the publication, carry on with describing their own group activities and go back to the detailed content in the last paragraph of the introduction. The authors should keep in mind that from 2014 no satellite will be able to measure stratospheric profiles of gases and temperatures will be available anymore, at least not on high altitude resolution. In my view, this is the most important justification of doing measurements of ground-based profiles using ground-based millimeter wave radiometry. Do the authors think otherwise, because they do not mention this?

===Answer: We agree. We will reorder the introduction. Yes, it is important to mention that there might be a lack of satellites to measure temperatures profiles in the stratosphere in the future and therefore ground-based microwave instruments might be a valuable contribution. We will mention this in the paper.

Page 2 Line 20 Please include some of the most important citations.

===Answer: Done.

Page 3 line 6 Citations!

===Answer: Done.

Page 3 line 13 There is a bracket missing.

===Answer: No, the bracket is starting at line 10!

Page 3 line 15-16 This sentence is not really connected to the text before.

===Answer: We will change the sentence.

Page 3 line 21 I think a few sentences should be written about the instrument described by Svetsov et. al. (2010) in comparison to the instrument described here, line

measured, alitude range and such.

===Answer: We think it does not make sense to describe this instrument here, because this is not the topic of our paper. It is important to cite it. Furthermore it is a quite short paper and gives not many details. Nevertheless we can answer some question about it. They measure the same oxygen lines as we measure (52.5424 and 53.0669 GHz) with the same type of fft spectrometer (Acqiris) but with only 16384 channels. We have 32768 channels due to the I/Q Mixer. They have written that they can retrieve temperature profiles from 10-55 km (depending on azimuth viewing direction (Zeeman effect)). For us it is not clear how they get good results below 15 km, because in our case the measurement response is at this altitude range less than 0.3. In their paper there are missing some data like averaging kernels, retrieval errors and measurement response.

Chapter 2 Page 4 line 19 ff and equation 1 The introduction of the Rayleigh Jeans limit is too early here. The formula 1 is still general, the Rayleigh-Jeans approximation is used in equation 4.

===Answer: We agree. We will change the sentence.

Page 5 line 18 This sentence is a repetition of line 10 on page 4.

===Answer: Heterodyne receiver is mentioned the first time and the frequency is a important repetition.

Page 5 line 18 and 19 The specification are noted in table 1 not figures 1 or 2.

===Answer: We agree. We will change the sentence.

Page 6 line 18-20 This is confusing and the important information, that the FFT measures always the same frequency range is submerged in less important detail information.

===Answer: We think these sentences are important and should be understandable.



Page 6 line 17 I doubt that the technique of using an IQ-mixer is common knowledge. Please add either a citation or describe it in more detail.

===Answer: We add a citation.

Page 6 line 25 Please be a bit more specific which details are listed in table 2.

===Answer: Done.

Page 8 line 6 ff At which temperature is the hot load?

===Answer: The hot load temperature is the room temperature of the temperature stabilized laboratory (around 293 K). This is now mentioned in the beginning of the section ”Instrumental description”. It is measured by 8 Sensors distributed over the load.

Page 8 line 21 In consider the calibration of the spectra quite crucial. Therefor add a few more details: What do you mean by "normally stable"? What is abnormal? Has this been measured? How many weeks are several weeks?

===Answer: We will change the text. The noise diode temperature is stable (deltaTnd < 0.3 K) more than 4 weeks. Yes, we did some tests. These tests showed, that it makes sense to calibrate every month.

Page 9 line 10,11 The problem is ill-posed because the noise has an excessively large influence.

===Answer: Yes, we expressed this not clear enough. The text is changed to "This is an ill-posed problem and to obtain an "optimal" solution a statistical constrain is introduced. The solution can be defined as the zero of the gradient ..."

Page 9 line 17 The solution is actually the probability distribution "a posteriory". The optimal estimation method restricts all distributions to be Gauss distributions, therefor the mean "a posteriory" is equal to the mode of the "a posteriory distribution".

===Answer: We agree and is similar to what we tried to expres in a very compact manner. The part is extended to "This principle is based on Bayes' probability theorem. It is assumed that measurement uncertainties (Se) and a priori knowledge (Sa) both follow Gaussian statistics. On the condition that the forward model is not strongly non-linear, the posterior distribution is then also Gaussian. The solution, xhat, is taken as the state with highest probability, that for Gaussian statistics is also the expected value of the distribution."

Page 10 line 19 – 25 This paragraph does not belong here.

===Answer: We do not agree. We think this paragraph does belong here because before the Averaging kernels are introduced.

Page 11 line 26 Is another ARTS (instead of ARTS2) package used here?

===Answer: We used always ARTS2 and QPack2.

Page 12 line 10 Which user guide?

===Answer: http://www.sat.ltu.se/arts/misc/arts-doc-stable/uguide/arts_user.pdf: can be found on the webpage www.sat.ltu.se/arts/docs/.

Page 12 line 11 What does this mean? The weighting functions are the partial derivative, so there is only one state variable perturbed per partial derivative.

===Answer: We will change the text.

Generally I think section 3.3. has too much weight for this publication and it does not contain anything important in the context of temperature measurements. I would propose to just state a few facts on what is used.

===Answer: We agree. We will change the text.

Chapter 3.4. The smoothing error is defined differently in Rodgers(2000). Please correct.



===Answer: Eq. 15 matches the first term of Eq. 3.16 of Rodgers (2000). Rodgers later discusses the requirements for an exact evaluation of the smoothing error, ending up with Eq. 3.17, where "Sa" is replaced with "Se". Eq. 3.17 can not be used in practice as the exact true mean state is not known. To repeat this discussion in the paper seems "overkill". Anyhow, we, as basically everybody else, define the smoothing error following Eq. 3.16, implying that xa is our best knowledge of the true mean state.

Is the error eq. 15 really random?

===Answer: Not necessarily, and yes the word "random" shall be removed (page 13, line 1).

What is about systematic errors, spectroscopic error, calibration error and such. How much influence has the missing modeling of the Zeeman effect?

===Answer: We will incorporate also the systematic errors. For the Zeeman part: We avoid the Zeeman affected part of the spectrum and the impact of the effect should be small compared to other errors. It is mentioned several times that we avoid spectra ranges and altitudes as Zeeman is not included in the radiative transfer, and Zeeman is left for future work (Conclusions).

Chapter 3.5. Again, what is normal?

===Answer: We will change the text and do not use "Normally".

Page 14 line 15 The forward model grid is coarser than the retrieval grid? Please justify.

===Answer: The retrieval grid has the same resolution as the forward model grid. We will change the text.

Page 15 line 3 Is the information about the ILW taken from the TROWARA? This information should come before it is referenced. What is meant by "the retrieval works fine"?

===Answer: We deleted the line 4-5 on Page 15, because the topics about cloudy sky,

retrieval and cloud information from TROWARA are explained in the next section 4.1. With ”the retrieval works fine” we mean, that the retrieval converged and we get good results compared with satellite data.

Page 16 line 15 ff That means there are 3 independent layers under 1000 m and 5 underneath 10 km? Looking at figure 7 I would guess there are only three independent layers in the region up to 10 km.

===Answer: The height resolution is shown in figure 8: A resolution of about 300 m below 1 km, 2 km at 2km, 4 km at 5 km and 5 km at 10 km is seen. That means for example that we are able to detect three independent layers in the first kilometer and only 2 independent layers from 5-10 km.

Page 17 line 7 What do you mean be "reasonable"? Please quantify, also justify the threshold.

===Answer: With reasonable we mean, that the results agree not so good with the radiosonde data as for clear sky conditions. Further information about the comparison between TEMPERA and the Radiosondes can be found in Section 4.2.3.

Chapter 4.2.3 How are they compared? Using the AVK's, directly? Are the radiosonde data binned and averaged over the bins?

===Answer: The radiosonde data (e.g. figure 11) are regridded to TEMPERA grid and not averaged. Further the figures with the correlation coefficient and the differences T(TEMPERA)-T(Radiosondes or Satellite) (e.g. figure 12 and 13) are additionally convolved data (using equation (13)).

Page 18 lines 5 and 17 You use the expressions "fairly well" and "reasonably well" for the same comparison. I would recommend using numbers or a graph showing the results rather than use descriptions which are not objective and even seem to contradict each other.

===Answer: We agree. We will write the text in a more quantitative way and we will not



use the words ”fairly well” and ”reasonably well”.

Page 18 line 3ff How significant is a CC > 0.97? Why is a CC > 0.86 good? Please justify.

===Answer: All correlation coefficients displayed in this publication have a confidence level above 95%. We will mention this in the paper. We think a CC>0.85 is a reasonable well agreement. We will change the text.

Page 18 lines 16-21 This seems to be a repetition of what is said earlier.

===Answer: We agree. This will be considered in the revised manuscript.

Page 18 lines 22-27 Why is this interesting? This seems completely unconnected to the rest of the manuscript.

===Answer: This is interesting because these were special events in the year 2012. Furthermore we can see that TEMPERA is able to measure such interesting weather situations.

Page 19 line 11 This is only the error due to measurement noise and the smoothing error, not the retrieval error. This error has also been called observation error in chapter 3.4. I would recommend to stick to one term.

===Answer: We agree. We will change the text.

Chapter 4.3.1 and 4.3.2 Please put the text into a stringent order and remove double information.

===Answer: We agree. This will be done.

Figure 14 In the text page 19 it is said, that the calculated spectra agree well to the measured except in the line center. This cannot be seen in this figure, please append a residuum for clarification of what you mean.

===Answer: We agree. We incorporated a plot of a residuum in the paper.

Technical comments: I believe the term altitude is commonly used instead of height (above sea level). Please check this.

===Answer: We agree. We will change this.

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