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Atmospheric Measurement Techniques Discussions

Interactive comment on "Retrieval of tropospheric water vapour by using spectra of a 22 GHz radiometer" *by* R. Bleisch et al.

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1 Replies to general comments:

Our paper deals about a new, unconventional approach to retrieve water vapour profiles using spectra of 1 GHz around the 22 GHz line. These spectra usually are used to retrieve stratospherical and mesospherical water vapour. In this paper, we want to show the potential of our approach, which allows a gain of information compared to just using the opacity and the surface value (section 5 of the paper). Therefore the validation/comparison is not our central issue, but to get informations about the accuracy of our retrieval setup it is indispensable to make comparisons with other instruments. To clarify this, in a revised version chapters 4 and 5 are merged and rearranged in a way

that the discussion about information content is placed before the comparisons (the order of sections will be: 4.1, 5.1, 5.2, 4.2, 5.3). Consequently, also the order of figures is changed. According the recommendation of the referee we decided to change the term “validation“ to ”comparison“.

We agree, with the referee, that a comparison with an accurate and validated instrument at the same location would be the optimal solution. But as there is no such instrument at hand, we have to use what is available, even if the data is not really collocated. Due to the nature of a balloon sounding, the comparison/validation of any instrument with balloon soundings would not be possible, if the main focus is set on a large collocation between the probed airmasses. At 5 km, the altitude range with the highest sensitivity of our retrieval approach, the sensor often is closer to Zimmerwald than 40 km (see e.g. Fig.11 showing the large spread of sounding positions when passing an altitude of 5 resp. 10 km). Also at this altitude, the natural variability is much smaller. Further, statistical calculations of mean differences have already been done, among others showing that the standard deviation of MIA-snd decreases significantly when applying a distance filter (see Fig.9).

An alternative comparison with satellites or reanalysis data (as NCEP or ECMWF) suffers of a lack of horizontal resolution, which is not sufficient to resolve the complex terrain of the Swiss prealpine and alpine region leading to a substancial uncertainty in such data (This is a well known problem for any model/reanalysis application for this region). We made comparisons of MIAWARA and sounding profiles with profiles from ECMWF-reanalysis (see Fig.13 in the manuscript as an example), which clearly revealed this uncertainty.

As we are interested in the water vapour profile the integrated water vapour amount is not in the focus of this study. To clarify this aspect, in the introduction p1429 l15-17, “retrievals of tropospheric water vapour“ will be precised to “retrievals of tropospheric water vapour profiles“.

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In our opinion the IWV cannot serve as major criterium for the relevancy of our profile retrieval algorithm, because the low vertical resolution makes it impossible to resolve large water vapour gradients in lower troposphere, which can have a significant influence on IWV. To consider IWV, we are rather thinking of including the IWV as additional constraint in the retrieval setup.

The RPG-HATPRO instrument is a radiometer developped by RPG and is operationally used at many different sites delivering reliable data. Its specifications are given in Tab.1. of the paper. Further MeteoSwiss did some comparison studies with balloon soundings revealing a good correlation. Thus a detailed discussion of the quality of the HATPRO data would in our opinion go beyond the scope of our paper.

2 Point-to-point replies to specific comments:

1. P1428 L9-12: This listing of results is somewhat poor for a paper abstract. A retrieval is sensitive up to 7 km (which is only about 6 km above the ground at Zimmerwald) and a resolution is something between 3 and 5 km means that the resolution is only marginal different from the entire measurement range. I suggest to discuss about domains (e.g., boundary layer and free troposphere). A correlation of 0.7 does definitely not prove a good agreement! This correlation more or less reflects the ability of both measurement techniques to measure water vapour. Due to the high variability of water vapour the correlation tells probably nothing about the quality of the instruments.

Generally, retrievals of water vapour profiles using microwave radiometry have a reduced vertical resolution. As we are comparing with data with much higher vertical resolution, a correlation of 0.7 has to be seen as rather high in our case. Further 0.7 is

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only a minimal value, in fact the newest calculations delivered correlations above 0.8 in the middle troposphere.

2. P1428: The location and altitude of the radiometer instrument is missing in the abstract.
The instrument is located in the south of Bern at 905 m a.s.l. The missing informations will be added

3. P1428 L18: Schneider et al. (2010) is not an adequate citation for the topic of global warming in the context with water vapour. There was a lot of work about this topic done by others before and this should be cited correctly (e.g., Harries (1996, 1997), Lindzen, Hansen and many others).
Schneider et al. (2010) is a review paper about the current state of knowledge in this subject and cites a lot of former works, including some of the ones requested by the reviewer, therefore in our opinion, the citation can be seen as adequate. To clarify, the term ”and references therein“ is added.

4. P1428 L23: Delete sentence "For this, there exist several measuring techniques." This is obvious if comparing different methods.

5. P1428 L23-25: The altitude range up to 7 km is not "large" compared to other techniques (e.g., GPS, lidar, radio sounding, aircraft, FTIR,...).
Here we are talking about microwave radiometry in general, not our retrieval approach. The altitude range of microwave radiometry covers the troposphere up to the mesosphere (except a gap in the UT/LS range from $\sim$10 to 25 km). Multi channel radiometers without a spectrometer of the HATPRO-type cover the troposphere, 22 GHz-radiometers as MIAWARA cover stratosphere and mesosphere with a poten-

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tial to cover also a part of the troposphere, what we try to show. For clarification, "from surface to mesosphere (with a gap in the UT/LS-range)" is inserted in the text.

6. P1430 L1: Altitude of Zimmerwald is missing.
The altitude of 905 m a.s.l. was somewhat lost in the preparation of the manuscript and is stated in the revised version.

P1431 L6: An averaging time of 2 - 4h is rather long and limiting the significance of the comparison study. This should be discussed here.
It is important to consider, that a small bandwidth is used and the tipping curves are performed by the instrument only in second priority. An averaging time of 2-4h not necessarily limits the significance of our study, as a sonde profile is in fact also a measurement over a certain time frame (the ascent from surface to tropopause usually takes around 30 minutes) and an exact matching of the observation time of MIAWARA with the ascent time of a specific radio sounding is anyway hardly possible. In the revised version, the mentioned text is adapted to: "Usually 8 to 16 spectra are averaged (corresponding to 2-4 hours) as a small bandwidth is used and the tipping curves are performed by the instrument only in second priority. Further, the natural variability of water vapour in the altitude range of the highest sensitivity of our retrieval ($\sim$4-5 km) is not as large as in the lower troposphere"

P1432 L2: Define Bayes' probability theorem!
The Bayes' probability theorem is a fundamental base of most retrieval algorithms and is described in standard textbooks (e.g. in the book by Rodgers 2001, p22ff).

P1433 L16-21: At first, I do not understand that the FWHM of the AVK is a direct measure for the vertical resolution. This needs a more detailed explanation.

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This is also a standard concept in retrieval theory (see e.g. in the book by Rodgers 2001, p54)

P1434 L9: Explain the Curtis-Godson approach or at least insert a citation.
The Curtis-Godson approach is a standard approach for approximating lower resolution data and can be found in various textbooks, as e.g. in the book by D.G. Andrews 2010, p 94 (reference added in the revised version).

P1434 L11-L16: I would not call this a good reproduction! A correlation of the order of 0.7 is rather poor for a measure that varies more than one order of magnitude! To me, this does not automatically mean that the measurement quality is bad, but other impacts as small-scale and short term-variability blur out any information about the quality of the measurements.

Due to the limited vertical resolution of the retrieval compared to the high resolution of sounding profiles, very high correlations cannot be expected. Nevertheless, newest calculations show correlations of above 0.8 for middle troposphere, thus the value of 0.7 is corrected to 0.8 in the revised version. Further we used a dataset extending over several years, what should sufficiently damp impacts of short term and small-scale variability.

P1434 L17-26: Why not comparing column integrated water vapour between ground and 7 km or even only 5 km as suggested above? This would eliminate problems with different resolutions and work also as smoothing filter to small-scale variability.
Comparing the water vapour column is not the idea of this paper, as it is well-known, that microwave radiometers are able to deliver good IWV-measurements. We are interested in the ability and performance of our retrieval approach to invert the

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water vapour profile from tipping calibrated spectra, regarding averaging kernels and information content.

P1435 L4-13: This proves, that the intercomparison is probably more a measure of atmospheric "noise" than a validation.
If it really merely would be some noise then it is not understandable why the profiles from MIAWARA and Payerne agree so well in Figure 7 and 8 (12 and 13 in the revised version) or in the adapted version of Fig.15 (now Fig. 9).

P1435 L18: techn. corr. "Institute".

P1436 L12-14: It is better to write that the HATPRO has a wet bias compared to the lidar, because presumably the lider is much more accurate.

P1436 L24 - P 1437 L16: I suggest to erase the MIAWARA - FTIR comparison from this validation study. It is known from radion-sonde launches that water vapour is too variable to learn anything about the quality of single measures from two instruments having a distance of 50 km from each other, in particular within complex terrain!
For the lower troposphere we can indeed not learn a lot out of this comparison. But for the upper troposphere, where the horizontal variability is not as high, this comparison give us some hints regarding the performance of our retrieval in this altitude range.

P1436 L28: There was former work done by others, this should be cited correctly.
Here we decided to cite the Davis textbook as a general book about the technique, with references to other standard literature. The techniques described in the Schneider et al. 2006 paper are close to what is done on Jungfraujoch.

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P1441 Conclusion: It should be stated that a better spatial matching (with the radio sondes) leads to significant better intercomparison results.

Comments made above should make clear that we consider our validation approach as the best possible under the given circumstances.

Interactive comment on Atmos. Meas. Tech. Discuss., 4, 1427, 2011.

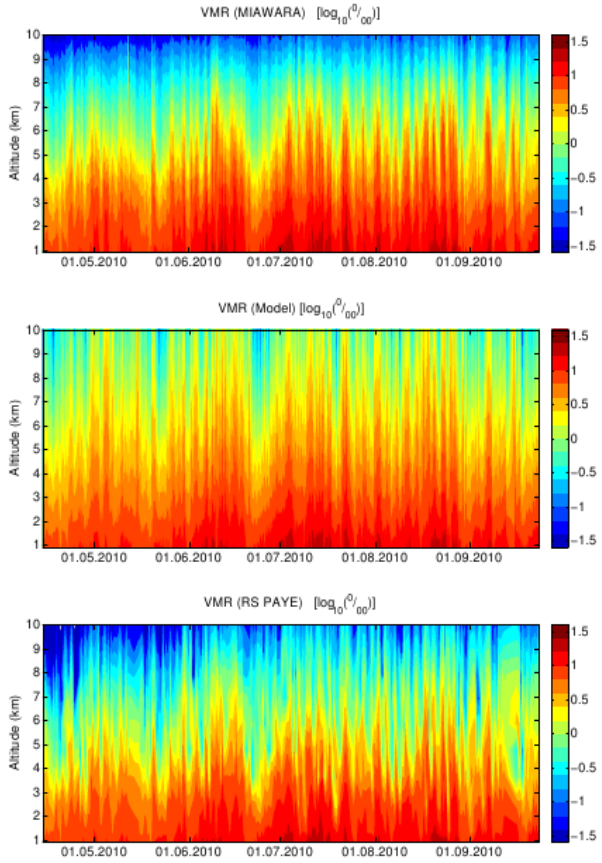

Fig. 1. Adapted version of Fig.15: H2O vmr from Payerne soundings is plotted additionaly

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