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Atmospheric Measurement Techniques Discussions

Interactive comment on "Validation of middle atmospheric campaign-based water vapour measured by the ground-based microwave radiometer MIAWARA-C" *by* B. Tschanz et al.

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Dear Referee #1, we thank you for your helpful and very detailed comments and suggestions. In the following we answer your comments and indicate how we are planning to change the manuscript. We summarise the main points of your general comments in bold and present the response.

The discussion of using MIAWARA-C as a potential travelling standard is postponed to

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future work (also discussed in the response to referee 2). In this paper we concentrate on the validation aspect as the title of the paper suggests. The final version of the paper focuses on a first validation of MIAWARA-C's v1.1.

Stimulated by the comments of both referees we will add an additional data set (Sodankylä 2011-2013, with new receiver) and divided the Zimmerwald campaign into two comparison periods; the first one with the old and the second one with the new receiver set-up. In addition, it turned out that at Zimmerwald we often get interference from some external signals that disturb small parts of the measured spectrum. The affected parts are now excluded from the spectrum for the retrieval.

General comments

1. Previously reported bias and precision:
There is no thorough discussion of previously reported comparison results in the first version of the paper because they are based on retrieval versions other than v1.1. The retrieval version strongly affects the observed bias (e.g. by using a different set of line parameters). In addition, some of the studies use different versions of the satellite data. One of the main aims of this paper is to clearly describe one retrieval version and give first validation results. For future campaigns, we can always use this standard version of MIAWARA-C to allow comparison with previously reported results. In the final version of the paper we add the intercomparison results of Stiller et al. (2012) in section 3.3 and the results of Straub et al. (2010) in section 3.2. We do not include the results of Straub et al. (2011) because the data obtained with MIAWARA-C in this campaign was strongly affected by unfavourable weather conditions.

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2. Influence of substitution of the receiver

We agree with the referee, the data presented in the first version of the paper does not allow to characterise effects caused by the two receiver set-ups.

For a better characterisation of the new receiver and of the differences caused by the upgrade we will include a new data set obtained with the new receiver. MIAWARA-C has been measuring in Sodankylä from June 2011 to March 2013. In total we have now results from three campaigns: LAPBIAT (old receiver, Sodankylä), Zimmerwald (first old, then new receiver) and Sodankylä (new receiver). We split the Zimmerwald campaign into two periods, the first with the old and the second with the new receiver. With these data sets we obtain a better estimation of the data quality with the different receiver types and give first indications about the stability of MIAWARA-C's measurement between different campaigns. The comparison to Aura MLS v3.3 using all data sets is shown in Fig. 1.

As the referee correctly suspects, the differences between the mid- and high latitude comparisons in the discussion paper are mainly caused by different receivers.

3. Forward model parameter uncertainties

As the referee mentions, the uncertainty estimates used in this study are based on Straub et al. (2010). Concerning the uncertainty in the tropospheric correction, Straub et al. state: *It is desirable to provide an upper limit to the errors and thus a conservative calibration error value of 7% of the tropospheric correction factor is chosen.* Haefele presents a detailed calculation for the uncertainty estimation, but these calculation do not include any uncertainty arising from a non-stratified troposphere or variations of the opacity between the tipping curve measurement and the line measurement. Therefore, we are going to keep 7% calibration uncertainty. The calibration schemes of MIAWARA-C and MIAWARA are identical. Therefore, we add the following sentence to the description of MIAWARA (Section 3.1): *The calibration schemes of MIAWARA and*

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MIAWARA-C are identical.

Following your advice, we change the temperature uncertainty from 5 K to 8 K (maximum observed bias in altitude range of interest, Schwartz et al. (2008)). In addition, as recommended by referee 2 we add a random calibration and temperature uncertainty to the measurement noise to get the random error of MIAWARA-C's v1.1. The random error of the temperature profile is assumed to be 3 K and the random error of the calibration factor is estimated as 5%.

4. Dependency of the comparison on season and location

By adding the additional data set and splitting up the Zimmerwald data we can explain the strong changes of the difference mainly by effects of the upgrade of the receiver. Comparing each month separately, we do not observe a clear seasonal dependence of the differences. Therefore, we cannot provide an explanation of the bias found between MIAWARA-C and SOFIE. In order to prevent the paper from becoming lenghty, the monthly comparison will not be part of the final version. Nevertheless, seasonally resolved comparisons will be important for future studies of the data quality of MIAWARA-C.

Other comments and suggestions:

P1312L21 mid-latitudinal → mid-latitude Done.

P1312L25 Write a sentence summarizing the estimated systematic errors and the main sources. Done.

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P1312L28 Add 'between 45 and 70 km' and a sentence summarizing the observed variability and the estimated random errors. Done.

P1313L9 'The latitudinal distribution of water vapor in the middle atmosphere ...' Done.

P1317L18 Please, include the 'spectral baseline' definition in P1319L7 here. Also, give a short list of 'contributions to the spectrum not covered by the forward model'. Done.

P1318L10 Even if it is clear that, as shown in Fig. 4, MIAWARA-C's retrievals clearly deviate from MLS climatology, have you tested the sensitivity of your result to the a priori? Yes, we analysed our retrieval versions using different a priori profiles (e.g. constant in time and altitude). The retrievals are most sensitive at the upper- and lowermost altitudes as expected for OEM. By restricting the reliable altitude range using the area of the averaging kernel the resulting profiles are dominated by information obtained from the measurement.

P1319L1 Write the spectral resolution of your instrument, please. Done.

P1319L15 What is meant by 'nominal altitude'? The altitude the averaging kernel has been calculated for. There is a averaging kernel calculated for each point of the pressure grid of the retrieval.

P1320L8 Name the uncertainties, besides elevation pointing, included in the 'calibration family'. Explain why they can all be considered as a fraction of the tropo-

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spheric correction. All information concerning the calibration scheme, tropospheric correction and error estimation can be found in Straub et al. (2010). We would prefer not to repeat it in the current paper. For consistency, *(including pointing uncertainty)* is removed in P1320L8 in the revised version.

P1320L10 The smoothing error can also be ignored when you smooth the high vertical resolution measurements using the averaging kernels of the low-resolution instrument. You are right. Section 2.3 concerns the error estimation of MIAWARA-C, we do not think that this is the right place to discuss smoothing with the averaging kernels.

P1320L24 I miss a detailed discussion on the relative importance of the systematic errors. Mention the major source and contributions from other sources, and explain the uncertainty profile shapes. Done.

P1322L15 How is that the vertical resolutions of MIAWARA and MIAWARA-C are the same but not their spectral resolutions? In our frequency range, the spectral resolution does hardly influence the vertical resolution. The vertical resolution is mainly given by the pressure broadened emission line shape. If the spectral resolution cannot resolve the frequency region, where Doppler and pressure broadening are comparable, it determines the upper limit of the retrieval.

P1323L14 Please, indicate the new MIPAS reduced spectral resolution. Added: *(0.0625cm^{-}1)*

P1323L24 Include also Stiller et al. (2012) as reference for the MOHAVE-2009 MIPAS comparisons. Done.

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P1324L4 If difference between V5R and V4O is MIPAS spectra, why should the altitude behavior of the bias be the same in both versions just because the non-LTE effects are not included in any of them? In other words, why do you expect the difference between V5R_H2O_220 and V4O_H2O_203 being constant with altitude? The MIPAS team has checked the altitude behaviour of the bias of version V5R and found indeed similar behaviour as for version V4O; however, this result has not yet been published, and therefore we refer here to the validation of V4O. A careful validation of all the V5R trace species is underway. For the time being, we have re-formulated the respective statement as follows: *...MIPAS V4O_H2O_203 showed a wet bias of up to 10% and above 55 km a dry bias caused by neglecting non-local thermodynamic equilibrium (non-LTE) effects in the retrieval (Stiller et al., 2012). V5R_H2O_220 does not yet include non-LTE effects and therefore, a similar behaviour with altitude was expected, and indeed confirmed by internal delta validation versus version V4O_H2O_203. For that reason MIPAS V5R_H2O_220 data are not used for altitudes above 0.1 hPa.*

P1325L3 I think it is important that you mention any differences between SOFIE and other instruments below 45 km since MIAWARA-C and SOFIE H2O differ up to 10% at those altitudes, the largest differences found which, additionally, overcome the MIAWARA-C estimated systematic uncertainty. The study of Rong et al. (2010) only shows validation results above 45 km altitude. We could not find other sources showing comparisons of SOFIE below 45 km.

P1326L9 periods → locations Done.

P1326L23 numbers → number Done.

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P1328L13 'assumed to be negligible' → 'is not considered', which, by the way, is not fully appropriate and might lead to misinterpretation of the differences (see comment P1325L3). Changed to 'is not considered'. We are aware that neglecting the systematic error of the reference instruments can cause problems. Nevertheless, we will stick to this strategy as it is hardly possible to get realistic error estimates for all instruments, locations and times. We think that drawing attention tho possible consequences, as mentioned in Sect. 4.2 and repeated in the summary (P1324 L22-26), should be sufficient.

P1328L21 'standard deviation of the mean difference' Done.

P1328L27 Add 'or both' Done.

P1329L23ff Additional to line parameters and temperature, some of the uncertainty sources for calibration (e.g., tropospheric effective temperature) are of the same nature for both instruments so that MIAWARA-C and MIAWARA H2O estimated errors due to calibration are also somehow correlated. Thus, in order to explain the mean differences, they should be compared, as even you suggest, only with systematic errors not affecting both retrievals the same way. Please, change dashed lines in Fig. 8b accordingly and include a short discussion in the text. Done.

P13230L19 and v3.3 → (v3.3) Done.

P1330L23 delete and add a space before and after the comma, respectively Done.

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P1331L2 'the combined random error' Done.

P1331L9 'MIAWARA-C estimated systematic errors' Done.

P1331L11 'combined estimated random errors' Done.

P1331L22 I don't think that results are similar for both periods above 45 km. In fact, differences are similar to those with MLS over the arctic but not over Zimmerwald. Thank you for pointing this out. Changed.

P1332L4 It is important to explain the persistent different behavior in the two locations since MIAWARA-C is transportable By adding the new data set and separating the Zimmerwald data we can present a better characterisation of MIAWARA-C's v1.1. However, we cannot find an explanation for the observed random variation (compared to MIPAS).

P1332L23 Add 'and MIPAS' Done.

P1333L9 Mention that MIAWARA-C's H2O maximum is located at lower altitudes than SOFIE's. That might also be true for other comparisons in LABPIAT (not over Zimmerwald, though). Please, check. Thank you for pointing this out. The fact that SOFIE's maximum is located at higher altitudes than MIAWARA-C's strongly affects the shape of the bias. It is added to both the results and the summary section. We checked the other comparisons and found that the altitude of the maximum for MIPAS is slightly higher than MIAWARA-C's whereas it is the same for ACE-FTS and Aura MLS.

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P1333L22 Delete 'of' Done.

P1334L8 Surprising since Carleer et al. (2008) found that ACE is wet by 10%. Any comment on this? Yes, we cannot find agreement with Carleer er al. (2008). We could not find an explanation in our data sets.

P1334L15 Mention that comparisons with SOFIE show a similar bias (Rong et al. (2010) did not) Done. As pointed out by the referee, the bias of SOFIE is strongly influenced by a mismatch in the altitude of the maximum.

P1334L14-18 If non-LTE explains the bias at 58km over Zimmerwald, how is that a larger bias is not seen over Sodankylä, where the non-LTE effects should be larger, at least during daylight? We analysed night- and daytime data separately and came to the conclusion that we cannot explain the observed bias at 58 km for Zimmerwald observations with non-LTE effects. In the revised paper P1334L15-18 is removed (*As no similar bias is seen with respect to the other reference instruments, it is attributed to the influence of neglecting non-LTE effects in MIPAS V5R_H2O_220 as discussed in Stiller et al. (2012) for V4O_H2O_203.*).

P1334L26 Although differences are within MIAWARA-C estimated systematic errors, there is no discussion about their potential specific sources. If those are identified, retrievals can be improved in the future. E.g., even if there is no consistent bias (as you mention in P1337L1), the mean differences have a persistent vertical structure, with local maximum at 40km, minimum at 50km and maximum at 65km. Does any known uncertainty or combination of uncertainties produce such a shape? We are currently working on this. So far we could not identify the source of the shape of the bias.

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P1335L20-23 If that is true, the standard deviation of the mean difference should be reduced when reducing the time lag and/or the distance between measurements. Does that happen? We did change the coincidence criterion but with the data sets available we could not observe a decrease of the standard deviation of the mean difference with a narrower coincidence criterion.

P1336L12 'receiver of MIAWARA-C, upgraded in December 2010,' Done.

P1336L14 Add 'particularly, between 45 and 70km' Done.

P1336L16 Add dates of campaigns Done.

P1337L4 MIAWARA-C is also wetter below and drier above 45 km than MLS at Sodankylä. Done.

P1337L23 'to the small seasonal variations typical of those altitudes.' Done.

P1338L11 Delete this last sentence. It is written twice in the acknowledgements. Done.

Tables and figures: Dear referee, we thank you for carefully studying our figures and giving helpful suggestions for improvement.

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Table 1 Define the variables in the caption or elsewhere. Done.

Table 2 Include reference to Haefele (2009) Done.

Fig. 2 Fig 2b is not necessary and could be deleted. The information it provides is easily included in one sentence (see P1316L26). I would better include instead a figure similar to Fig.2a but for LABPIAT. In order to make Fig. 2b more meaningful, we added all data sets used for the intercomparison to both panels a and b.

Fig. 6-caption comma after '(maroon)'; maroon → brown? Changed.

Figs. 8-12 Remove the y-axis title in b-d so panels can be enlarged. Something happened to the x-axis in the d) panels. Remove '[]' in the x-axis title of d) panels. Mention how you estimated the approximate altitude. Legends for MIAWARA-C measurements in panels a) are confusing: change black legends to 'MIAWARA-C' instead of the name of the instrument you are comparing with. Thank you for the practical suggestions, changed.

Fig. 11 maroon → brown?. Legends for MIAWARA-C in panel a) are even more confusing here. There are two lines (which, by the way, I can't hardly see), blue and black but only one legend. Changed.

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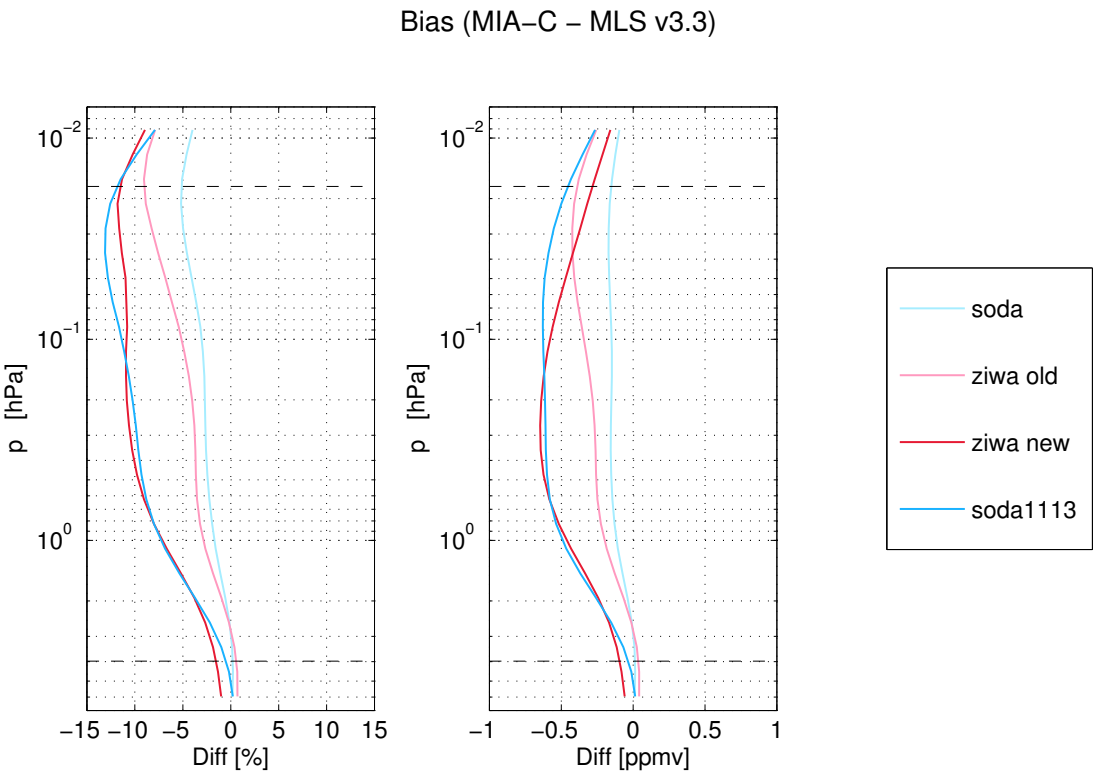

Fig. 1. Relative and absolute bias compared to MLS v3.3 for all campaigns. Soda (green) and ziwa old (cyan) data are obtained with the old receiver and ziwa new (blue) and soda1113 (red) with the new receiver

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