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Atmospheric Measurement Techniques Discussions

Interactive comment on "MIAWARA-C, a new ground based water vapor radiometer for measurement campaigns" *by* C. Straub et al.

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Dear Referee, thank you for carefully reading our paper and for your comments and suggestions. They will help to improve the article. To answer your comments we will always print your comment first and then our answer to it.

The most serious omission, which I would consider serious enough to prevent publication in the present form, is that there is almost no discussion of instrumental baseline and how it is handled in the retrieval process. Such a discussion needs to include a figure showing the difference between the measured and modeled spectra from the atmosphere (i.e. something like Figure 10, but with the model spectrum

subtracted). This should be shown with and without any subtraction of retrieved instrumental baseline. Without such a plot, it is extremely difficult to determine how well the instrument is working.

Answer: We agree that the instrumental baseline is an important parameter in a microwave radiometer.

In the case of our balancing calibration scheme it is difficult to distinguish the instrumental baseline from the frequency dependent residuum term originating from the difference in the tropospheric emission in the line and the reference signal. Therefore the two parameters are regarded combined in the frequency dependent residuum term $T_{b,res}$, as described in the first section on page 21.

You are right that we forgot to describe how we handle this term during the retrieval process. It is basically considered as a retrieval parameter which consists of a polynomial, in this case of second degree, and sinusoidal curves, here with 3 periods (181MHz, 102MHz and 55MHz). An illustration of the measured and estimated spectrum together with the fit of $T_{b,res}$ is given in the top panel of the first of the included figures. The middle panel shows the measured and estimated spectrum with the fit of $T_{b,res}$ subtracted and the bottom panel the residuals between estimation and measurement. We will include this figure instead of the original Figure 10 in the final version of the paper.

Also, it appears that an external microwave absorber is required to make this system work, yet it doesn't appear in the picture shown in Figure 1. Is Figure 1 an accurate representation of a working instrument? This may seem like a trivial point, but given the importance place on this being a transportable campaign instrument, the operational set-up should be shown (unless perhaps the absorber is hidden somewhere in this picture). It's also confusing to leave this out, since Figure 2 shows the original instrument design which, if I understand the paper correctly, is not what is being used in the measurements shown here (which use an external absorber instead of the Colfet).

Answer: Yes, an external absorber is used for the balancing and it does appear in Fig. 1. To make the reference absorber and the parabolic mirror visible more clearly we replace the foto in Fig. 1 of the paper with the foto shown in the second of the attached Figures. To illustrate the balancing scheme we include it in the block diagram in Figure 2 of the paper as shown in the third of the attached figures.

I'm not sure, but I would be worried about the almost 1 degree azimuthal pointing error. The geometry of a rotating angled mirror is quite complicated, and any inaccuracies in the angle between the mirror and the antenna will result in an error in the measurement. The authors should check this.
and *I think this pointing error is related to the statement: "There exists small asymmetry between the H-plane in the zenith and the E-plane in the horizon which is attributed to the off-axis 10 orientation of the mirror. Since this asymmetry does not lie in the scanning direction of the mirror it does not affect the measurements." I have to admit that I don't really understand this statement.*
Answer: The azimuthal pointing has no effect on the a pointing error but the Sun scanning is a way to actually determine the pointing in azimuth direction quite accurately, even though this is not very critical for measurements in the middle atmosphere. The pointing in azimuth does not have anything to do with the alignment between mirror and horn antenna but with how the instrument is oriented on the site.
The pointing is also not related to the statement *"There exists small asymmetry between the H-plane in the zenith and the E-plane in the horizon which is attributed to the off-axis 10 orientation of the mirror. Since this asymmetry does not lie in the scanning direction of the mirror it does not affect the measurements."*. The small asymmetry mentioned here is expected from the physical optics simulations and lies below the -20dB level and is therefore uncritical for our measurement. We will state this in the final paper in this way instead of the statement above, since this can really be confusing. We will leave the horizontal pointing out in the paper, since it really is no critical parameter for the measurement.

There is a slope indicated in the title of the right hand plot of Figure 7? What are the assumptions on the relative errors of MIAWARA and TROWARA that are used in this slope calculation? These numbers (slope and errors) should probably be included in the text.
Answer: Here we just used the classical linear least square approximation, resulting in the regression line indicated in the title of the right hand plot of Figure 7. We did not assume any errors to calculate this regression.

"Since the positive slope in the opacity decreases with increasing frequency the mean value is expected to be higher for the smaller bandwidth" ? This may be true, but it sounds like the authors haven't really tried to quantify this properly. They could, perhaps, try to quantify this effect by calculating the MIAWARA results using only 100 MHz bandwidth and then comparing to the 200 MHz bandwidth.
Answer: We will leave the whole section with this explanation away since the 0.1% bias between the two instruments is well within the standard deviation of 5.7%.

"An offset in the elevation pointing would lead to a systematic error in the sky brightness temperatures" - Please provide an estimate for how much a given angular offset affects the error.
Answer: Here we plan to change the text as follows:

An offset in the elevation pointing would lead to a systematic error when correcting the measured spectrum for use in the retrieval as described in Section 5. For realistic values of the equivalent transmission of the reference absorber t (0.85) and the tropospheric opacity τ (0.1) this is around 5%/0.5% of the tropospheric correction factor for a pointing offset of 1°/0.1° in the angular range of our measurement, as the fourth of the attached figures illustrates.

Some estimate of uncertainties would be appropriate in Table 2. The single scans shown in Figure 9 show quite a large variation, suggesting that this uncertainty (at least from the sky scan) is probably quite large. The quoted value:"From these results it is concluded that the MIAWARA-C pointing accuracy is better than 0.05 degrees" seems to be plucked out of the air.

Answer: You are absolutely right with this statement. We are planning to change this section in a way that we first give a value for the maximum pointing uncertainty based on the fourth of the attached figures. Then we describe the sky scanning method and show that this method is not suited for the determination of the elevation pointing because of too large random errors. After that we describe the sun scanning method, which is the way we actually determine the elevation pointing. For the error quantification we give a random error determined from the standard deviation of 10 sun scans performed during the Lapbiat campaign in winter 2010, which is 0.02°. We do not expect any significant systematic bias from this method since the ephemerides of the Sun are known with a high precision.

"The spectrum relevant for the retrieval of water vapor profiles from MIAWARA-C is at the tropopause level in the zenith direction" It took me some time to understand what this means. I assume what the authors are trying to say is something like:"For use in the retrieval, we calculate the spectrum of emission in the zenith direction from the tropopause upward".

Answer: This really is unclear and we will replace it with a sentence based on your suggestion.

It would be nice to show in the right hand panel of Figure 11 something like the"measurement contribution" or perhaps the sum of the averaging kernels.

Answer: We will add this.

Interactive comment on Atmos. Meas. Tech. Discuss., 3, 2389, 2010.

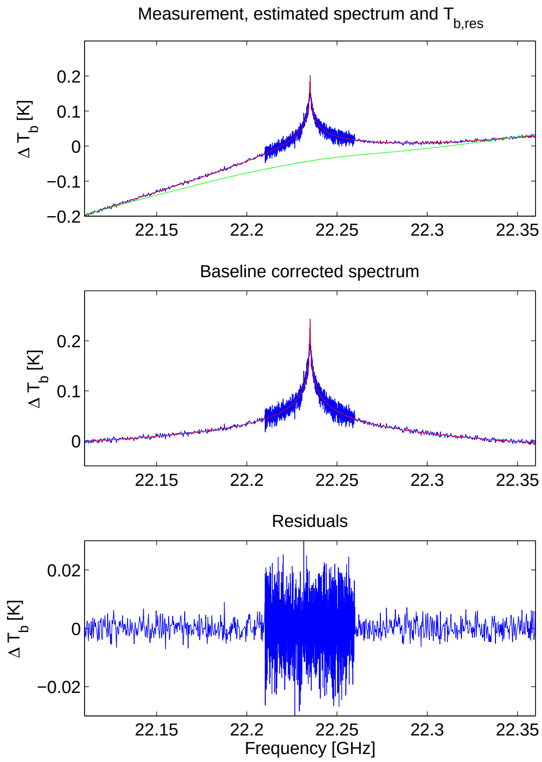

Fig. 1. Measured and estimated spectrum. The difference in the noise levels in different frequency ranges is due to a frequency binning of 10 channels used on the wings of the spectrum for data reduction.

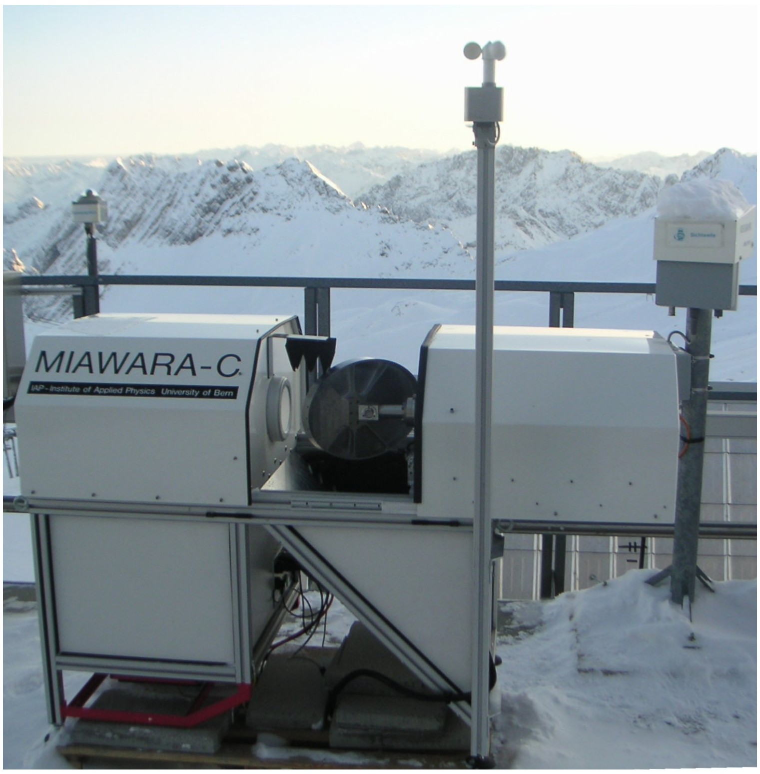

Fig. 2. MIAWARA-C during the ARIS-Campaign on the Zugspitze. The small black absorber above the mirror is used for balancing.

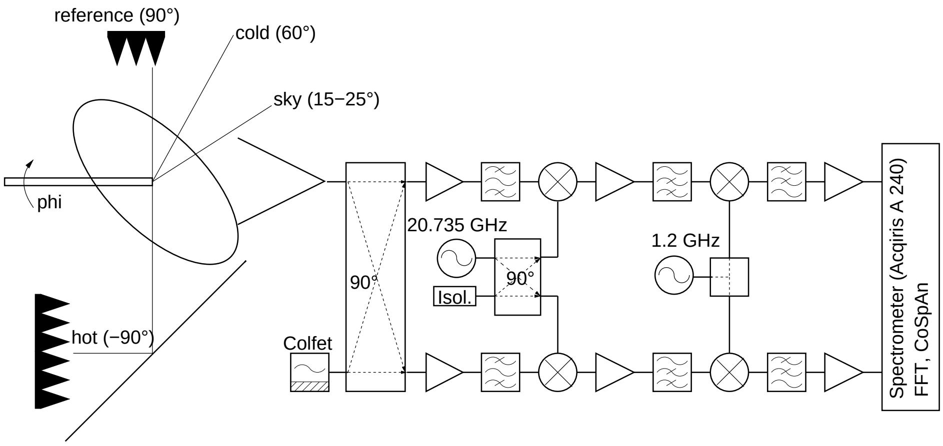

Fig. 3. Block diagram of the correlation receiver of MIAWARA-C.

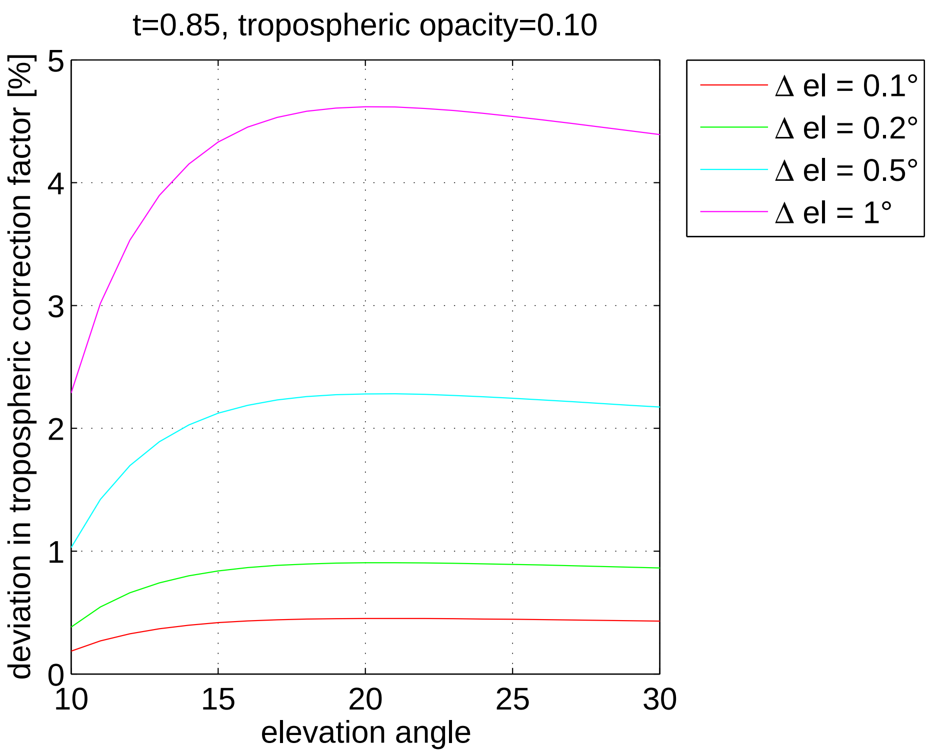

Fig. 4. Influence of a pointing offset in elevation on the tropospheric correction factor $(A_{line}^{ma} e^{-A_{line}^{trop}\tau_{z}}-t A_{ref}^{ma} e^{-A_{ref}^{trop}\tau_{z}})^{-1}$.