Interactive comment on "Technical Note: Reanalysis of upper troposphere humidity data from the MOZAIC programme for the period 1994 to 2009" by H. Smit et al.

Authors Reply to Anonymous Referee #1

We would like to thank Referee #1 for the useful comments, which help clarifying and improving our paper. Answers to specific issues of broader relevance are addressed below, while detailed suggestions for rephrasing sentences and correcting typos will be considered accordingly in the revision of the manuscript.

General Recommendation

Users of the MOZAIC relative humidity data have long waited for a fix of the problem that appeared after 2000. In this paper Smit et al. now describe the cause of the problem and how it has been solved. Most importantly they state that the corrected data are available to interested researchers, and thus the paper is a very welcome contribution. It is appropriate for publication in ACP. I have only a couple of minor comments which might help to make the paper clearer at some points.

Reply: We appreciate the very positive response to our efforts of fixing the problem which has occurred in the MOAZIC data on relative humidity (RH) since 2000.

Minor Comments

Page 18906, Line 11: "is not possible from thermodynamical principles" is not correct. It does not occur in the atmosphere because there are plenty of condensation nuclei that trigger condensation as soon as liquid saturation is slightly exceeded. Please rephrase.

Reply: We rephrase the sentence to: "As a result, PDF of UTH data show a substantial fraction of observations above 100% RH_{liquid}, which, however, does not occur in the atmosphere because there is always a sufficient number of condensation nuclei available, that trigger condensation as soon as liquid saturation is slightly exceeded."

L. 22: "large variability of observations" is a bit unclear. Is it the humidity field that has large variability (I think so) or are the observations so imprecise?

Reply: We rephrased the sentence to:"… because of its large natural variability in the troposphere and relatively short records of observations."

P. 18910, Ll. 1-8, Figure 5: Please define what you mean with "fractional coverage of MOZAIC upper tropospheric humidity data". Explain what it is good for.

Reply: We rephrased the sentence to: "The regional distribution of data coverage by MOZAIC UTH observations is shown in Fig. 5 for the period 1994 to 2009, emphasising that the horizontal coverage by MOZAIC observations is highly inhomogeneous and dominated by the major global flight routes".

P. 18912, Ll. 20-25, Figure 7: I do not see what you want to say here. Is it good or bad? My impression is that this paragraph should be shifted into the next section, after the first paragraph there. The figures 7 and 8 should be interchanged accordingly.

Reply: We agree, the paragraph was shifted to the next section and the figures were interchanged.

P. 18915, L. 6: "differences of slopes are close to zero", fortunately not the slopes themselves.

Reply: Fully right, changed into: “"differences of slopes .... are close to value zero"

P. 18915, L. 8: The word "reduces" is misleading here. The impression is that the problem gets smaller, but since the offset *a* is often negative, the problem gets worse. You could simply state $a_{post} - a_{pre} - 0.2 \cdots - 0.4$.

Reply: We rephrased the sentence to: “On the other hand, the differences of offsets between pre- and post-flight calibrations are significant from -0.2 to -0.4, which however is a consistent finding for the periods 1994 to 1999 and 2000 to 2009.”

P. 18916, L. 23/24: what is the recovery factor?

Reply: We added the following explanation of the recovery factor: “[This factor] expresses the effect that the adiabatic conversion of energy into heat is not exactly 100% such that the temperature measured inside the housing, the total recovery temperature, is about 0-1.0 K lower than TAT, depending on aircraft speed. The housing manufacturer provides an empirical recovery factor to determine the real TAT from the measured recovery temperature.”

L. 28: How small?

Reply: We refer to the values given in Table 2 from the analysis of the statistical distribution of calibration factors. Thus we complemented the sentence: “If these differences are in a similar range as the values listed in Table 2 and shown in Figure 9, …”

P. 18917, L. 12-17: I suggest to state typical values in this paragraph.

Reply: We agree to add typical values to this paragraph. The entire paragraph is rephrased as: “Figure 11 show the variations of uncertainties of the RH measurements in $\%RH_{liquid}$ for the altitude range covered by the observations. Uncertainties are calculated from the mean plus standard deviation of the individual total uncertainties over all MOZAIC data of 1994-1999 and 2000-2009 period. In the middle and upper troposphere the total uncertainties centre at approx. 4.5% RH_{liquid} (2.5 - 6.5 % RH_{liquid}) for both periods. In the lower troposphere the total uncertainties for the first period of approx. 6% RH_{liquid} are slightly higher compared to the value of <5% RH_{liquid} for the second period due to the missing calibrations at temperatures above -20°C. “

P. 18918, L. 27/28: 1) "ppmv". 2) how can the FISH instrument become optically thick?

Reply: The FISH instrument is based on the absorption of Lyman(α) radiation by H_2O molecules. For high VMR values the absorption of Lyman(α) radiation along the light path inside the instrument is so strong, that the detector becomes insensitive to further changes of the VMR, and thus the

instrument is opaque or saturated. We added one sentence for explanation to the text, saying that : "For the sensor intercomparison study, data for H_2O VMR > 1000 ppm were excluded because at these large water vapour abundances the FISH instrument, which is based on the absorption of Lyman(α) radiation by H_2O molecules, becomes optically opaque and thus insensitive to further changes in VMR (Zöger et al., 1999)."

P. 18919, L. 1: "neglect" sounds a bit strange here. What about refuse, reject, dismiss, avoid...

Reply: Agreed, we changed the text to "…avoid…"

Ll. 16-22: To my view the comparison with OJSTER does not look very well, at least not at the higher RH values. Don't overstate.

L. 23: "proof of validity". Please change this. There is no proof of whatever. All that we see is that the pdfs look quite similar and this underpins a good quality of the MHC data in a statistical sense, but it does not prove anything.

Reply: We substantially revised the paragraph related to Fig. 12. The section reads now:

"In a cloud-free atmosphere, MCH and reference instrument FISH agree very well. Linear regression analysis provides a correlation coefficient R^2 = 0.97 and a slope m = 0.96 $\pm$ 0.05 while the y-axis intercept equals zero within the limit of uncertainty (2.2 $\pm$ 2.0 % RH_{liquid}). The data for $RH_{liquid} \geq 75\%$ and $RH_{liquid} \leq 10\%$ suffer from a small number of counts and are not considered for the MCH performance analysis because of limited statistical significance.

At cloud edges and inside cirrus clouds, i.e., RH_{liquid} > approx. 60%, deviations between instruments are larger, with a systematic bias of the reference instrument towards higher RH_{liquid} values than measured by MCH. One potential and likely explanation is related to the fact that both reference instruments FISH and OJSTER report data on a 1 Hz basis while the response time of the MCH is of the order of one minute or longer at these temperatures (Helten et al., 1998). Hence, small scale fluctuations of high RH_{liquid} values are captured by the reference instruments but missed by MCH.

Despite the weaker agreement between MCH and reference instruments near to and inside cirrus clouds, the data shown in Fig. 12 rule out the speculated contamination of MCH data by partial or complete evaporation of hydrometeors via adiabatic heating in the sensor housing; see e.g. Helten et al. (1998). This type of contamination would result in systematically higher RH_{liquid} values measured by MCH inside clouds, compared to the reference instruments. However, the opposite behaviour was found; for details see Neis et al. (2014).

The good quality of the MCH RH_{liquid} data in a statistical sense is shown in Fig. 13. The PDF for RH_{liquid} agree very well between MCH and the reference instrument (FISH or OJSTER, resp.) for the entire CIRRUS-III data set. An in-depth analysis of the MCH performance including implications for the MCH data analysis is provided separately by (Neis et al., 2014)."

We believe that this interpretation is justified and more clear now.

Figure caption of Fig. 7, L. 3: delete "for details" once.

Reply: Done.

Figure 8 (now 7): Although the linearity is very good with respect to RH_{UC}, the relation is not at all linear with respect to T. How do you define calibration coefficients at untested T values? A simple linear interpolation might be insufficient.

Reply: The complete calibration procedure is described in the manuscript and in (Helten et al., 1998). However, for clarity we added one sentence to the figure caption: "Displayed are hygrometer measurements (crosses) together with corresponding linear regression fits. Offset *a* and slope *b* are determined as function of temperature from a functional curve fit through the calibration coefficients obtained at the five different calibration temperature levels; see also Eq. (1)."

Figure caption of Fig. 11: explain meaning of the bars and the central lines.

Reply: The revised figure caption reads now: "Mean uncertainty of MOZAIC relative humidity measurements in % RH_{liquid} as a function of altitude (blue solid line) for periods 1994-1999 (left) and 2000-2009 (right). Horizontal bars represent the standard deviation of the mean uncertainty."

Figure 14: too small, noisy, and hardly readable.

Reply: Agreed, both diagrams will be sized larger by factor 2 and expanded with two similar annual PDFs, but then for period 1994-1999 (Request of Reviewer#2); see figure below:

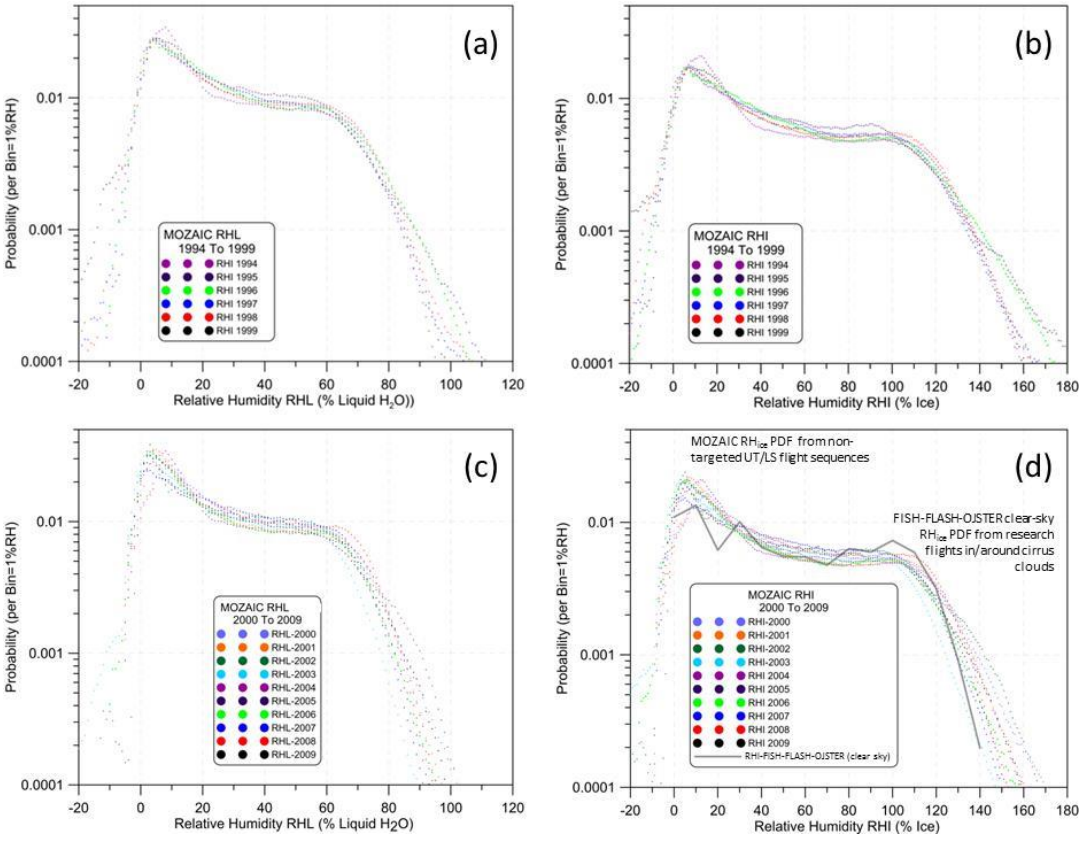

Figure 14. Annually averaged probability distribution of UTH observations from the MOZAIC Capacitive Hygrometer with respect to RH_{liquid} (a, c) and RH_{ice} (b, d) for the indicated periods; the solid line in panel (d) represents the average RH_{ice} PDF for the UTH clear-sky data set reported by Krämer et al. (2009).

Typological errors and other issues

P. 18912, Ll. 23-25: I suggest to avoid the use of "=" in these sentences. *Reply:* All “=” are replaced by “is” or “are”.

Eq. 2 and text thereafter: write pair consistently. *Reply:* Done.

P. 18915, L. 29: I suggest to replace "and co-workers" with "et al.". *Reply:* Done.

P. 18916, Ll. 4-16: Is there a difference between RH and RHD? Both are described as "ambient relative humidity". *Reply:* We clarified the sentence which reads now: “The transformation of RH values measured by the capacitive sensor of the MCH (RH_D; Helten et al. (1998)) to RH values for ambient air temperature and pressure conditions (RH_S; Helten et al. (1998)) requires knowledge of the static air temperature (SAT) of ambient air and of the total air temperature (TAT) at the position of the capacitive device inside the MCH housing.”

Reference Neis et al. This is unpublished material "in preparation". It should not appear in the references list. The text should reflect that it is a planned publication, e.g. "will be provided elsewhere (Neis et al.). The use of two figures from a planned publication is unusual as well. I suggest not to cite Neis et al. in the figure captions. Instead Smit et al. should be quoted in the planned paper once these figures are re-used.

Reply: The reference Neis et al. (2014) is now available in AMTD. Therefore we updated the reference in the manuscript and removed the suffix “in preparation”.

References

Helten, M., Smit, H. G. J., Strater, W., Kley, D., Nedelec, P., Zoger, M., and Busen, R.: Calibration and performance of automatic compact instrumentation for the measurement of relative humidity from passenger aircraft, J. Geophys. Res., 103, 25643-25652, doi: 10.1029/98jd00536, 1998.

Neis, P., Smit, H. G. J., Krämer, M., Spelten, N., and Petzold, A.: Evaluation of the MOZAIC Capacitive Hygrometer during the airborne field study CIRRUS-III, Atmos. Meas. Tech. Discuss., 7, 9803-9838, doi: 10.5194/amtd-7-9803-2014, 2014.

Zöger, M., Afchine, A., Eicke, N., Gerhards, M. T., Klein, E., McKenna, D. S., Morschel, U., Schmidt, U., Tan, V., Tuitjer, F., Woyke, T., and Schiller, C.: Fast in situ stratospheric hygrometers: A new family of balloon-borne and airborne Lyman alpha photofragment fluorescence hygrometers, J. Geophys. Res., 104, 1807-1816, doi: 10.1029/1998jd100025, 1999.