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Atmospheric Measurement Techniques
Discussions

Interactive comment on "Evaluation of the MOZAIC Capacitive Hygrometer during the airborne field study CIRRUS-III" *by* P. Neis et al.

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p.neis@fz-juelich.de

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Anonymous Referee #2

Referee #2: We gratefully acknowledge the reviewer's thorough reading of the manuscript and her/his constructive comments and suggestions. Please find detailed

answers in the following.

General remarks

This paper relates to the study of an instrument that has already been extensively described elsewhere, the MOZAIC Capacitive Hygrometer (MCH). However, this present study exploits the opportunity to perform in-flight comparisons on the same aircraft platform with other well-established research-grade humidity measurements. This is a worthwhile objective since it provides additional confidence in the MCH measurements with their stated methods of calibration and their subsequent use, for example, in the assessment of atmospheric model performance. Having sensors mounted on the same platform overcomes some of the limitations of the earlier study of Helten et al. (1999).

As such, I consider that this paper merits publication, but subject to substantial changes as indicated below.

The authors describe early on (page 3/4) reasons by which the operational conditions of the MCH on the Learjet differ from those in its normal operating environment. This is principally a result of the lower operating Mach number of the aircraft, reduced dynamical heating in the instrument intake and hence operation at lower sensor temperatures where the capacitive sensor is known to not perform well. To maximize the value of this present study, this difference in operating conditions should ideally be quantified, for example by presentation of pdf's of sensor temperature from the data used in this study and from a large sample of regular MOZAIC data. Such a presentation is lacking, although the authors subsequently describe why they filter data with Tsensor<-40C.

Reply: We agree and added a figure (see attached Figure 1) where we show the pdf of approx. 15 years of MOZAIC sensor temperatures as well as the pdf of the sensor temperatures during the CIRRUS-III campaign. It can be easily seen, that the amount of data points with Tsensor < -40°C during the 15 years of data collection is statistically insignificant (< 1%). In combination with Figure 7, where differences in relative humidity

RH(liquid) of MCH on one hand and FISH and OJSTER on the other hand, are plotted against the sensor temperature Tsensor, the differences in operating conditions are illustrated.

Referee #2: The reasons by which the air in the MCH sensor housing is dynamically-heated are made clear. However, there is then a possibility that cloud particles may be partially evaporated in the intake and so result in enhanced water vapour content at the sensor location. This process is thought to contribute at least partially to the suppression of temperature measurements in water clouds due to the latent cooling induced by droplet evaporation. There are, therefore, good reasons to examine the performance of the MCH separately for cloud-free and in-cloud conditions although these reasons are not acknowledged in the present text. Observations of the variation of humidity within cirrus clouds are of great value to understanding their subsequent microphysical evolution and there is therefore significant value to be had in describing the ability of the MCH to measure in these conditions.

Reply: Long-time experience shows that liquid water clouds, so called warm clouds, can have a significant impact on the measurements by evaporating liquid water droplets in the Rosemount Housing. The impact of ice particles from cirrus clouds on MCH measurements were part of this study. Therefore, we decided to compare the MCH measurements with in-cirrus and clear sky measurement instruments. As can be seen in Figure 8, the quality of MCH measurement doesn't change towards higher RH values in the cirrus clouds. On the contrary, Figure 9 shows dryer conditions in cirrus for the MCH measurements. This can be explained by the higher response time at colder ambient temperatures whereby small cirrus events can't be resolved.

Referee #2: What is not very clear to me at this point is the rationale for selecting in-cloud data and the choice of different reference hygrometers for in-cloud and cloud-free conditions. The FISH instrument has a forward-facing intake that accepts any cloud particles and so clearly cannot be used as a reference in-cloud. However, it is not clear to me why the OJSTER instrument, an open-path TDL, cannot be used

as a reference out of cloud. From the data presented in Fig.4, there appears to be very good agreement between OJSTER and FISH, such that the majority of OJSTER data points are overlain by FISH and not visible. The method of selecting in-cloud data in this study is the same as that in Kramer et al. 2009, relying on thresholds of ratios of RHice from FISH, OJSTER and other instruments. The reason why this method of classification of incloud points had to be applied by Kramer et al is clear, since they were working with an inhomogeneous dataset from different aircraft with different instrumentation, and some without any cloud particle detection instruments. Since the present CIRRUS-III study was intended also to sample cirrus microphysical properties, it seems likely that some form of in-situ particle measurement would have been available, although none is mentioned. This would presumably have provided a much more straightforward incloud classifier. However, even if this cloud classification method is retained, it ought to be possible to present separate analyses of MCH vs OJSTER for all data (and also separately for in-cloud and cloud-free) and MCH vs FISH for cloud-free data. Can the authors comment on all of this?

Reply: The reason for selecting two hygrometers is given by the fact that the FISH instrument provides internationally established high quality measurements of water vapour mixing ratios. Since the FISH was operated with a forward-facing intake, we had to complement the data set with OJSTER measurements to sample the gas phase inside cirrus clouds. However, the OJSTER data are not available for the complete flights, but predominantly around and inside cirrus clouds. As mentioned above, in our view Figure 8 and 9 show the good quality of a combined data set with the Krämer et al. (2009) algorithm for detecting in-cirrus data.

Detailed remarks

1. Eq.1 and following. The Helten et al (1998) reference makes clear that the measured temperature inside the instrument housing is actually the recovery temperature, which differs from the Total Air Temperature by a factor that accounts for the incomplete recovery of kinetic energy in the housing and losses to the housing itself. It would be

helpful to give some clarification of this point, because although the direct impact on temperature will be relatively small it will, nevertheless, introduce a small bias in RH.

Reply: We agree that there is the need of describing the different temperatures in the Rosemount Housing. The paragraph is expanded accordingly with “The fact that the adiabatic conversion of energy is not exactly 100%, the latter quantity Tsensor is calculated from the actually measured sensor temperature, i.e. the typically 0 - 1K colder recovery temperature (Total Recovery Temperature TRT; see Heltenet al., 1998), and the so-called recovery factor. This aircraft speed depending and empirically determined factor is provided by the housing manufacturer.

2. line 193 and Fig.5. The increased departures between MCH and Reference would be seen more easily if these data were presented as a scatter plot of (RHref – RHMCH) vs. Tsensor.

Reply: We understand your remark. However, the information you would gain with such a scatter plot is already shown in Figure 7 and would be redundant for this reason.

3. Fig.5 caption. The last line should refer to Fig.4. Since Fi.4 also has a different time axis, it would be clearer if ambient temperature data were also included in Fig.5.

Reply: We agreed and revised it after your quick review remarks.

4. Fig.5. It would be helpful to indicate which parts of the time-series correspond to in-cloud data – presumably the section with RHliquid 60%.

Reply: We already did this after your quick review remarks.

5. section 4.2.1 paragraphs 1/2. It would be of interest to know what fraction of the observations was retained after these filtering operations and perhaps also the extent to which this is dependent on the choice of sensor temperature threshold, since the latter is fairly arbitrary.

Reply: The choice of sensor temperature threshold Tsensor = -40 °C is given by the

calibration limit and by the MOZAIC operating. From our understanding, it is therefore justified to limit the analysis of MCH data to operation conditions covered by the sensor calibration procedure. The information about the filtered data fraction is useful and was added in the paragraph and with an associated table accordingly.

6. line 235. This is confusing to me. It states that the increasing difference between MCH and Reference RH shown in Fig.8 above 60% is because the reference sensor is measuring total water. Surely though, the reference sensor used in cloud is the OJSTER which only measures vapour?

Reply: We agree. Hence, we colored separately the associated data points in the scatterplots of Figure 7 and in Figure 8 we introduce the “transition area” were both reference instruments are involved. We can omit FISH data when they are possibly influenced by ice particles with the cloud index of Krämer et al. (2009). The increasing difference with increasing humidity could be mainly explained by the increased response time of the MCH. Small-scale supersaturations are smoothed out, while OJSTER can detect these with response time of $\sim$ 1s.

7. line 249. This is again confusing. I think what the authors intended to say was more like this: At or near cloud edges, conditions may be such that the data are not classified as in-cloud using the algorithm of Kraemer et al (2009). Since reference humidity may then still be taken from the FISH instrument measuring total water they may, therefore be biased high.

Reply: Thank you for this remark. We already fixed this after the quick review.

8. line 263 and Fig.11. Table 1 indicates that only 4 minutes of data from this case are in-cloud whereas the figure suggests 18 min. Can the authors clarify this discrepancy?

Reply: The approx. 4 minutes of in-cirrus data are the sum of all single data points, which the algorithm of Krämer et al. (2009) assumes to be in-cloud. Figures 4 and 5 show time series of measured RH(liquid), which are showing approx. 15 minutes of humidities next to ice saturation. However, values next to ice saturation cannot be equated with in-cirrus data.

9. line 274. These data would presumably be excluded from the analysis in section 4.2.1 due to the ascent/descent rate criterion that was applied. Is this the case?

Reply: We agree. As mentioned before in the manuscript ascent and descent data were excluded from the analysis.

Interactive comment on Atmos. Meas. Tech. Discuss., 7, 9803, 2014.

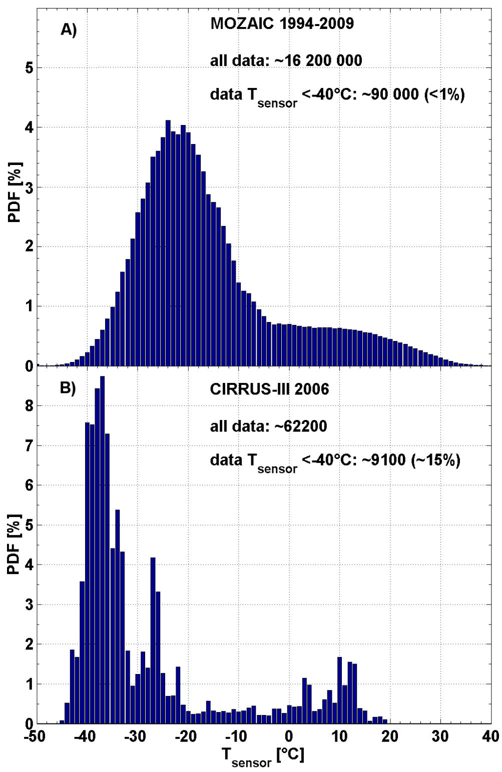

Fig. 1. Frequency of occurrence for observations of Tsensor during approx. 15 years of MOZAIC (top) and CIRRUS-III (bottom), respectively.