

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

**Anonymous Referee #1**

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This paper describes a comparison of the MOZAIC Capacitive Hygrometer (MCH) with two other "reference" water vapor instruments, FISH and OJSTER, during four aircraft flights in November 2006. The results depict good agreement between the MCH and reference instruments within a limited set of environmental parameters, including a lower limit for MCH sensor temperature and a need for general uniformity in the water vapor field being measured at low temperatures. MCH measurements of water vapor do not appear to be affected by ice particles owing to the design of the sensor inlet.

The manuscript is generally well written, succinct and appropriate for AMT. In some instances there is room for improvement in grammar, clearer explanations, removal of Figure Caption information from the main body text, and a need to present more quantitative rather than qualitative information. I feel that the number of Figures can be

C3174

reduced as some repeat information presented elsewhere, some provide information deemed non-critical to the conclusions and one can be simply presented as text instead of graphically.

Major Comments:

The comparison results are mainly presented in units of RH(liquid), but in my opinion RH(ice) is more relevant for the vast majority of atmospheric conditions sampled by the Learjet and by MOZAIC aircraft. This would eliminate the need to identify ice saturation in terms of RH(liquid). It is also of interest for the reader to be shown the high end of RH(ice) to reveal the frequency and magnitude of ice supersaturations measured, if any. I understand that the direct MCH measurement is in units of RH(liquid), but the conversion to RH(ice) requires only temperature, which you are already using along with pressure, to interconvert between RH and volume mixing ratio.

For Figure 8 and all descriptions of it - at Reference RH(liquid) > 70% the MCH signal is flat (~70%) while OJSTER RH continues up to 85%. It is claimed that both MCH and OJSTER measure only water vapor, so why does this strange behavior exist? There is a good reason for this: FISH total water data (apparently with some contributions from condensed water) are included at RH>60% even though the reference data are clearly labeled "OJSTER" (i.e., water vapor only). This needs to be explained very prominently and clearly in the manuscript text and in both the Figure 8 Caption and Legend. If possible it would be beneficial to remove these FISH data from the comparison. Please see my specific comments for Figure 8 below.

Figure 11 shows approximately one more hour of the same data already shown in Figure 5. Why can't the time axis in Figure 5 be expanded to 08:30-11:50 (the relevant time window of Figure 11) and Figure 11 be removed?

For all Figures showing "Reference" data or differences between the MCH and "reference" it would be more informative to show FISH and OJSTER data in different colors. For example, the dots in Figure 6 and Figure 7 could be color-coded to show which

C3175

reference instrument is being compared to each MCH measurement. Also for Figure 5 it would be interesting to see the independent time series of FISH and OJSTER (FISH total water values will clearly show when ice particles are present).

I don't see a compelling reason to include Figure 9. This information can be easily described in the body of the paper and does not need to be shown graphically.

I don't find Figures 10 or 12 to be very convincing of good agreement between MCH and the reference instruments. Figure 13 is much more convincing and, in my opinion, eliminates the need for Figures 10 and 12. The fact that the MCH and reference instrument have similar PDFs with respect to 5% RH(liquid) bins doesn't attest to the point-to-point agreement between them like the correlation analysis does (Figures 7 and 8). The PDFs are just the distributions of thousands of RH measurements - if the MCH is low biased by during a flight and high biased during another we can't assume the PDF will clearly reveal this. Figure 13 does a much more complete job of describing measurement biases at specific ambient temperatures than do Figures 10 and 12.

Specific Comments: (P=page, L=line)

P9804, L12: What is the "entire range of observations"? This statement provides no information to the reader. (refer to "quantitative vs qualitative" comment above).

L26: Limb sounders like Aura MLS are providing water vapor measurements at spatial and temporal resolutions adequate for many type of studies. It would help here to be more specific about the types of investigations that require higher resolution measurements unavailable from satellite sensors.

P9805, L1-2: Why is the "regular in-situ measurements of UTH still difficult" ?

L22, L28: The term "wing-by-wing" (should be "wing-to-wing") is used several times in the manuscript. To pilots this term literally means flying two aircraft beside one another such that the wingtips are nearly touching. If that is what you mean every time you use this term please ignore this comment. However, if you mean something different

C3176

please change the terminology.

P9806, L2: What exactly is a "sophisticated" instrument? This term is used several time in the manuscript. Does it mean "more complicated" ... "more mature" ... "measurement validated" ?

L18: "linearized" sounds like some sort of black magic. What exactly does this mean? Raw capacitance signals are processed into RH values?

L19: It would be good to know at what rate the MCH reports RH values. Actually, it would be good to know this for all the instruments. If instruments report at different rates how is this handled in the comparison of their data?

L26: What exactly are "internal boundary layer effects" ? Are you addressing memory effects of the housing walls (i.e., that may take some time to dry out after sampling a wet air mass?)

P9808, L5-8: It would be informative to know how much the MCH calibration changes after 500 flight hours. How many real-time days elapse during 500 flight hours?

L18-20: this is a perfect place to add quantitative information about offset and sensitivity drift.

P9809, L19-21: Which reference instrument(s) experienced inlet heating problems?

L26: The "condensed phase of water" was not measured by a dedicated instrument. Instead, condensed phase water is inferred as the difference between total water and water vapor measurements by FISH and OJSTER, respectively. How does FISH evaporate liquid water and sublimated ice to measure total water? Is the contribution of the condensed phase to total water "enhanced" or proportional to the pure vapor signal?

P9810, L7: What is the threshold for the ratio of RH(ice) that indicates a cirrus cloud?

L8: How is it guaranteed that OJSTER measures only water vapor and is not affected by ice particles entering its inlet?

C3177

L11-13: As written, it sounds like the MBW was also flown on the Learjet. I think it is used in the laboratory to calibrate FISH.

L21: How "significantly" can the offset change and how "almost stable" is the sensitivity? Please be more quantitative.

P9811, L3-5: How do you know the drift in offset is linear with time between pre- and post-flight calibration? Aren't there really dry and cold periods of flights where the predominant MCH signal is offset, not gain? Can these be plotted against time to show that the offset drift is linear with time?

L22: "signal saturated" is more accessible to the reader than "optically thick"

L24-2: This is Figure Caption information (e.g., "green line", "black line", "shown in the bottom panel"). Instead, describe what is revealed by the Figure and what can be concluded from it - rather than what is shown in the Figure ("sensor temperature = black line"). This occurs several times in the manuscript so please try to change all instances because the reader doesn't want to read the Figure Caption in the text and then read it again in the Figure Caption.

P9812, L13: "the agreement with the research-grade reference instruments" - is the MCH not a research-grade instrument?

L23-25: you may want to further describe the "effects of warmer clouds" since this may not be obvious to all readers. I assume you are referring to liquid water problems with inlets, housings and sensors (i.e., "memory effects"). Is this what you mean here?

P9813, L21-22 and Figure 8: Why does MCH RH(liquid) top out at 70% while OJSTER continues up to 85%? In the text (L21-22) you state that the "reference measures total water while the MCH measures water vapor". But at RH(liquid) > 60% in this Figure you indicate that these data are only from OJSTER that measures only vapor (P9810, L8). Also see my comment for P9814, L6-9 below.

L22-24: Do the linear regression results include the data > 70% RH(liquid) that are  
C3178

clearly not linear between MCH and the Reference?

P9814, L3: What exactly is "proof of validity"? Again, I don't think the PDFs in Figures 10 or 12 prove much at all.

L6-9: Here I think I've found the source of confusion with Figure 8. This information cannot remain buried in the final paragraph of the Evaluation section! If FISH total water data contribute to RH > 60% bins in Figure 8 this needs to be stated more prominently (and earlier) in the text and in the Figure Caption and Legend. Currently the Figure Legend shows that the Reference RH > 60% data are only from OJSTER. Can you omit FISH data when they are possibly influenced by ice particles? Is there another method for doing this other than the "cirrus cloud algorithm" mentioned?

L21: "phases of interest" is awkward, "intervals" or "periods" of interest is better.

L25-27: The data in Figure 11 disagree with this claim of "no statistically significant effect". Between times 08:40 and 09:20 the MCH is biased high by 5-20 %RH. There may be some evidence of MCH lag at the RH "peaks", but mostly the MCH is biased high during the RH "valleys". To me this represents a "statistically significant effect".

P9815, L4: "reduced performance" is not specific - what part of the measurement quality is reduced at low sensor temperatures?

L6-10: This sentence is far too long and does not provide an adequate explanation of the MCH high bias from 08:40 to 09:20.

L11: Please use "Despite" or "In spite of"

L15: The cut-off in Figure 13 appears to be  $T(\text{ambient}) > -42^\circ$ , not  $> -40^\circ$

Table 1: "divided" not "devided". Why is 125 ppmv ozone the magic divider between the troposphere and stratosphere?

Table 2: I prefer "Measurement Technique" over "Remarks" and "Reference" instead of "Source".

Table 3: add "These values are plotted in Figure 7a."

Table 4: the same argument for omission of Figures 10 and 12 applies to this table. Do these values really demonstrate agreement between the MCH and reference any better than Figures 7, 8 and 13 (and the values for Figure 7a in Table 3)?

Figure 1: "neglect" (meaning ignore) is not used correctly here - how about "minimize" or "eliminate" instead? Also, the "H2O-Sensor" label at the bottom of the Figure is confusing because the sensor location is right next to the external housing, not inside the aircraft.

Figure 4: The OJSTER data are not really visible here. Since mixing ratios > 1000 ppmv are least important in this study please change the VMR scale to a maximum of 1000 ppmv to (hopefully) better show the OJSTER data.

Figure 5: I suggest putting the panels showing absolute measurements (ppmv and RH) at the top and the deltaRH panel beneath the RH panel. Please color FISH and OJSTER differently (see Major Comment above). Mention that the deltaRH values are in absolute %RH values, not relative (%) values because the nomenclature deltaRH (%) can be easily misinterpreted.

Figure 7: What are the "outer values" shown by whiskers? 5th and 95th percentiles? Something different? Please color the FISH and OJSTER data differently (same for Figure 4).

Figure 13: The cut-offs for "reduced data" in this graph appear to be  $-62^{\circ} < T(\text{ambient}) < -42^{\circ}$ , not  $-40^{\circ}$  and  $-60^{\circ}$  as stated in the text. Please mention in the caption that the differences are MCH-Reference. Why is the y-axis label "SAT" instead of T(ambient) as it is called throughout the paper? The dry bias of MCH extends down to about  $-52^{\circ}$ , not just "for the coldest T(ambient) of  $-60^{\circ}\text{C}$ " as stated in the text (P9816, L1-2).

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

C3180