

Answers to the Editor: Comparison of the fast Lyman-Alpha and LICOR hygrometers for measuring airborne turbulent fluctuations, revised version

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The authors would like to thank the editor for the questions and remarks which helped to further improve the manuscript. In the following, each comment of the editor (in italic) is answered separately. The answers are provided in normal style, and the changed text of the manuscript is given in quotation marks. Further, changes to the manuscript are highlighted in the latexdiff version.

5 *Abstract:*

Maybe add a sentence that explains your motivation. Why are you conducting this study, why is this comparison important?

We changed the first sentence to: "To investigate if the LICOR humidity sensor can be used as a replacement of the Lyman-Alpha sensor for airborne applications, the measurement data of the Lyman-Alpha and several LICOR sensors are analysed in direct intercomparison flights on different airborne platforms."

10 *Introduction:*

p1, l19: Maybe add an example (e.g. "as towers"): " ... and measurements at fixed locations, as towers, providing higher vertical and temporal resolution." (In accordance with reviewer 1 – it's a point measurement - I would omit the part "but representative only for a small area")

We changes as suggested.

15 *p1, l21ff: This small section about the turbulence and fluxes stands a bit out of context here. However, as it talks about essential properties for your study, I suggest better integration it in the text and extension of the content.*

We expanded the text to "The most effective way for moisture transport from the surface to the atmosphere is turbulence. Turbulent fluxes are commonly determined with the eddy-covariance method. This technique requires accurate and high resolution measurements of the fluctuations of the vertical component of wind speed and humidity." Further, we put the text in a more
20 suitable place in the introduction, before introducing the requirements for airborne measurements of humidity.

p2, l4-6: I feel that your explanation to the reviewer regarding the relevance of cloud chamber studies to your study does a better job than the sentence you write there. Maybe rephrase similar to: "Since measuring atmospheric water vapour pre-

cisely is difficult, the uncertainties of atmospheric water vapour measurements are high. Even with the best systems under well controlled conditions in the laboratory, there are large discrepancies between different measurement systems, e.g. intercomparison measurements of different hygrometers probing the same air simultaneously revealed discrepancies between different measurement systems of around 10 %.”

5 We changed as suggested.

Please also include a reference for your last statement (“discrepancies between different measurement systems of around 10 %”).

It is the same as for the next sentence. We clarified in the text.

p2, l16: ..., which is used...” (is instead of are)

10 We corrected this.

p3, l9-11: Maybe better: “However, with the end of the life time of the radiation sources (glow discharge lamps) and difficulties in replacing them, other humidity sensors become more important, and a variety of fast-response sensors is now available.”

We changed as suggested.

15 *However, in the following you only mention two more sensors (one not being applied for atmospheric research, the other specific to one research aircraft), this does not sound like a “variety of fast-response sensors”? Please clarify! We added in the text: “e.g. the following two sensors”*

Section 1.2/1.3:

I find it somewhat confusing that you refer to molecular absorption (and their deficiencies compared to atomic absorption) in

20 *Section 1.2 before introducing molecular absorption in Section 1.3. Either swap these sections or refer to atomic absorption from section 1.3 instead.*

Agree - we deleted the comparison with molecular absorption in Sect. 1.2, and compare the required length of the measurement cell in Sect. 1.3, after having introduced molecular absorption.

p3, l11: “A similar system is the Krypton hygrometer KH20” similar to what? State!

25 We changed the text to: “A system similar to the Lyman-Alpha is the Krypton hygrometer KH20”

p3, l13: “It is, however, not broadly present in airborne applications.” Maybe drag some text of your reply to the reviewer into the manuscript: “It is, however, mostly used for ground-based measurements. Furthermore, the instrument is very sensitive to path length, and calibration is difficult even for the ground-based applications (Foken and Falke, 2010).”

We changed as suggested.

30 *p3, l19: “...are now easily available...” Do you mean “readily” available?*

Yes, we changed that.

p4, l8ff: I find this little section deserves more attention, as it points out the importance of your study. I recommend strengthening this part, stating your motivation more clearly (cf your reply to reviewer comment “I have a concern that the authors and other research groups are using LICOR sensors in an environment that the manufacturer does not recommend. We understand
35 *that the manufacturer does not sell the system for airborne applications, as they are aware that vibrations may hamper the*

data. For that reason, we consider it even more important to figure out the limitations of the sensor in terms of vibrations.)” Maybe add something along the line: “...its airborne applications will very likely increase. Therefore, knowing the limitations of the LICOR sensors with respect to vibrations is important, and one of the main aims of this study.”

We changed as suggested.

- 5 *p4, l21: “The spectroscopic sensors are experimental systems and not commercially available yet.” Remove “yet”, these systems probably remain experimental and will never be commercial.*

We removed "yet".

p4, l25: “... for the typical flight altitude of few 100m and airspeed...” – “of a few 100m”

We changed as suggested.

- 10 *p5, l12/13: Regarding your reply to reviewer comment about the “delay time”: “How can you carry out successful fast measurements with the closed-path LICOR if there is a 250-millisecond calculated delay? Have you tested the delay? What is the residence time in the sample cell? The delay is just a temporal offset, which can be corrected. The residence time in the sample cell depends on the air flow speed, and is taken into account in Sect. 2.2.” also: “Furthermore, it is unclear from this manuscript whether the LICOR has an actual temporal resolution of 20 Hz (when the sampling delays and internal processing*
15 *are included). The delays are constant temporal offsets, which do not influence the capability of the sensor to provide data at 20 Hz resolution.)” Maybe better say “temporal offset” “or “time shift” instead of “delay time” or “time delay” to avoid confusion here and in other places?*

We replaced "time delay" by "time shift" throughout the text.

p5, l19/20: “...a slow, but highly accurate Rosemount DB102 temperature sensor...” Please specify slow and highly accurate.

- 20 We changed the text to: "a long-time stable Rosemount DB102 temperature sensor with slow response time of around 1 s"

p5, l20: “... and a fast response (100Hz) Rosemount EL102 sensor.” Remove one “a”, and add what quantity the Rosemount EL102 sensor is measuring.

We added "temperature" sensor.

- p5, l22/23: Regarding the reviewer comment about Humicap: If you do not use data from this instrument, I suggest not*
25 *mentioning it, or at least say “(not operational in this study)” instead of “(not used for this study)”.*

This comment refers to the dew point mirror, not the Humicap. For the Do128, we changed the text to "not operational for this study"

p6, l3-9: I agree with the reviewer comment about the time resolution discussion being split up in too many places, but also understand your reasoning. The discussion here in Section 2.2 could be moved into and combined with Section 3.2?!

- 30 As a compromise, we changed the order of the Sections. Now we have the Section Do-128 Instrumentation, then the Section Do-128 time synchronisation, then the same for Helipod.

former p6, l20ff: reply to reviewer comment: “We added in the text: “These small sub-legs were chosen with different but homogeneous surface conditions and different but constant flight altitudes to compare if there are systematic differences in the parameters like the vibration level.” “ I could not find the added text in the revised manuscript!

- 35 Sorry, this sentence got lost. Now we added in the text: "Such small sub-legs were chosen with different but homogeneous

surface conditions and different but constant flight altitudes to compare if there are systematic differences in the parameters like the vibration level."

p7, l30: Fig. 9 referenced before Fig. 4. Please number figures in accordance with their mentioning in the text.

We checked again the order of the figures according to the text.

- 5 *p8, l2: "The overall aim of the Helipod measurements was to study greenhouse gas emissions on a scale of up to 100 km..." What does the scale of up to 100km refer to?*

We re-phrased the sentence: "The overall aim of the Helipod measurements was to study greenhouse gas emissions on a climatically relevant sub-regional scale of up to 100 km to investigate the spatial variability, and to analyse how representative the continuous emission measurements on local scales are on this larger scale."

- 10 *former p10, l12: reply to reviewer comment: "... covariance of the vertical wind speed and the humidity values from the different sensors..." We changed as suggested. The change got lost in the revised manuscript?!*

Thank you for the hint! We corrected this as originally planned.

Figures:

General: I recommend using 90 degree turned y-axis labels in all figures (not all labels turned in figures 3, 5, 9, and 10)

- 15 For the time series with multiple panels (Fig. 3 and 5), we prefer to use horizontal y-axis labels, as there is not enough space otherwise. We changed the orientation of the labels for all sub-plots in Fig. 9. Also for Fig. 10, the y-axis is only labelled with a short formula, which is much easier to understand if it is not rotated.

Fig. 5: "For the spectral analysis, the part of the data shaded in grey were used, excluding segments indicated in the last plot." You mean "... lowermost panel" or "...panel e" (not "last plot")?

- 20 We changed this.

Also change "...the part of the data... was used..."

We corrected this.

Fig. 6: Does it refer to the shaded area in Fig.3? If yes, please state explicitly; if no, please indicate the relevant section in Fig. 3 (e.g. with a bar on top or bottom of the figure if you wish to add no further shadings).

- 25 We indicated the part of the flight used for the vibration analyses in the time series, and added a reference to the time series in the caption of the figures showing the vibration time series and spectra.

Fig. 9: Some labels and y-axis annotations of the left plot overlap: "180 degree" phase and "0" coherence, "phase" and "0 degree" phase.

We changed that.