

Comments on the manuscript

Comparison of the fast Lyman-Alpha and LiCor hygrometers for measuring airborne turbulent fluctuations

Submitted by

A. Lampert, J. Hartmann, F. Pätzold, L. Lobitz, P. Hecher, K. Kohnert, E. Larmanou, A. Serafimovich, and T. Sachs

For publication in **Atmospheric Measurements Techniques**

The paper addresses the question, whether the infrared gas analysers LI7200/LI7500 (and followers) – which are standard instrumentation today for the measurement of turbulent water vapor and carbon dioxide concentration fluctuations and hence for the determination of the turbulent fluxes of water vapor and carbon dioxide at fixed installations (bars, masts, towers) in the surface and lower boundary layer – are as well suited for aircraft operation and might be considered as a candidate for replacing the Ly- α instruments that have been employed for airborne flux measurements over decades, but are not available on the market anymore. The authors compared the different hygrometers during two flights on two different airborne measurement platforms, the DO-128 research aircraft and the Helipod sonde. The flights have been well designed and the data analysis follows scientific standards and principles. Together with the technical-scientific relevance of the research topic this certainly justifies publication. However, I see considerable room for improving the manuscript. Some generalizations appear to be not well founded and the writing suffers from redundancy, sloppy or not very precise wording, and a rather German-language style sentence structure in several places. Detailed comments on that are given below.

General Issues

1. Some statements appear too general, e.g.,
 - P. 1, Line 20: “Measuring humidity in-situ with high accuracy is challenging”. What is high accuracy? Probably this conclusion holds for any variable?
 - P. 4, Line 11: “The Licor is the fastest and cheapest water vapor sensor commercially available” – this is too general, it is probably the cheapest fast-response sensor.
 - P. 4, Line 15f: Is it possible to “determine the required measurement frequency for humidity fluctuations to derive reliable latent heat fluxes”? Doesn’t this depend on the environment, on the turbulent state of the atmosphere, on the height of measurements, on the aircraft flight speed?
 - P. 11, line 2f: Here the authors state that a temporal resolution of 20 Hz is sufficient for humidity flux calculations, while on p. 10, line 27, it is said that “fluctuations in the frequency range higher than 2 Hz do not contribute significantly to the overall humidity fluxes for an air speed of 70 ms⁻¹” – how can these two statements be brought together?
2. Some relevant information appears not at the place where it might be expected or is missing totally. E.g., information on aircraft flight speed appears when discussing the delay times

between the sensors (instead of when describing the aircraft or the flight). Flight speed information for the Helipod flight is not given at all. The vertical wind component is needed for determining the turbulent fluxes, but no information is given on how these values were determined.

3. As a boundary layer scientist, the reader might be interested to learn something about the absolute values of the latent heat fluxes that were determined for the flights. The more since in the discussion the authors state that “especially for small fluxes, the relative errors might be significant”. It is not completely clear, where this conclusion comes from. On the other side, significant relative errors for small fluxes might still mean small absolute errors, while even small relative errors for high flux values could mean significant absolute errors, which would have implications for budget studies. This aspect is not discussed in the paper, may be due to the limited representativeness of the data set.

Specific Issues

- The title of the paper appears somehow incomplete – the two types of hygrometers are differently named, one by the method, the other by the manufacturer, I suggest to modify it as follows: “Comparison of Lyman-Alpha and infrared hygrometers for measuring airborne turbulent fluctuations of water vapor”
- The first paragraph of the introduction consists of a series of statements which are not always in a good logical context to each other.
- P. 1, Line 14: What is “surface air moisture”? Isn’t the surface layer part of the troposphere?
- P. 1, Line 15: I wonder whether Klaus et al. (2012) is really a proper reference to the difficulty of measuring and modelling global water vapor distribution.
- P. 1, Line 19: Point measurements are point measurements – what is the “horizontal extent” of a point?
- P. 1, Line 21ff: What is the relevance of the cloud chamber measurements under UTLS conditions for the present study?
- P. 2, Line 3-4: Again, two sentences with no obvious clear context: The authors want to quantify moisture transport, but speak about latent heat flux. Why not to start: 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 method requires ...
- P. 2, Line 5: What are “fast fluctuations”?
- P. 2, Line 7: Isn’t the high temporal resolution requested by the method, independently of whether it is used for research or not?
- P. 2, Line 9: Do the authors trust a sensor that has never been calibrated? I suggest to write “frequent re-calibration”.
- P. 2, Line 9-10: Hence, there is no sensor available that meets both requirements? If this is the case you should state it.
- P. 2, Line 17: What is “sufficient humidity”?
- P. 2, Line 32: A comparative is missing here: 100 times weaker / stronger?
- P. 3, Line 1: “same order” with respect to water vapor or to the previously discussed oxygen?

- P. 3, Line 4: What is “long-term” here? May be better write “(slow) drift”. Normally with long-term one would think of weeks or months, however, for Ly- α we often think of the magnitude of hours.
- P. 3, Line 10: This sounds like the need for careful calibration is a disadvantage of the KH20 which however is essentially the same for the Ly- α .
- P. 3, Line 11: What about this new sensor? If it showed promising results five years ago, is it expected to become broadly introduced? Moreover, if there is this new instrument, “THE Lyman-Alpha” (as you name it throughout the manuscript) does not exist, it could be thus wise at one place to state that “the Ly- α ” in this paper is a synonym for “the Ly- α absorption hygrometer by Buck Res.”.
- P. 3, Line 19-20: This sentence does not become clear here.
- P. 3, Line 22: Here the authors speak about the LICOR sensor without having introduced this. I suggest first to characterize the LICOR sensors before describing the TDLAS which is still experimental.
- P. 3, Line 26: what is “fast humidity”? Please avoid this slang in a scientific paper. Humidity is a scalar property of air, it is not fast nor slow, it is just highly variable in space in time such that you need fast-response instruments to resolve this variability.
- P. 3, Line 27: I wonder whether it is correct here (and in other places as well) to speak about a measurement chamber. LI7500 basically is an open-path sensor, even if the distance between the sensor head and base can be bridged with a “chamber”. And the Lambert-Beer law underlying the physics of measurement considers the distance or length of the absorption path. Insofar, one might prefer “path” instead of “chamber”.
- P. 4, Line 27f: It is not the wavelength that is absorbed but light at a wavelength of ...
- P. 5, Line 11 (and also P. 6, Line 7): What makes the Humicap superior to the dew point mirror such that the latter one has not been used?
- P. 15, Line 15: What does this mean “is calibrated regularly”? How often? How?
- P. 5, Line 29f: Why has the full length of the measurement path (instead of its center length) to be considered when determining the delay time?
- P. 6, Line 18: “agricultural grassland” – do you really mean “grassland”, or “farmland”?
- P. 6, Line 20ff: What was the motivation to define these six small sub-legs, knowing that the “sampling-length” requirements according to Lenschow et al. are not fulfilled here?
- P. 7, Line 1: The Ly- α data were shifted, not the instrument.
- P. 7, Line 2: Mathematically speaking the co-variance (or the correlation) is maximized.
- P. 7, Line 8, 11: On p. 5 the internal delay is given with 123 ms.
- P. 7, Line 21: The “best value” can only be one value, a range “between 0.5 and 0.9” is not a very specific information.
- P. 8, line 4: Was this the mean wind at the surface or at flight level?
- P. 8, line 14: Where is this additional time lag attributed to?
- P. 9, line 5: Why choosing a different flight section here when compared to Figure 7?
- P. 9, Line 19: Why do the authors speak of “decaying turbulence” here, the -5/3 law holds for the inertial subrange of developed turbulence.
- P. 10, line 12: ... covariance of the vertical wind speed and the humidity values from the different sensors ...

- P. 10, line 33: ... a phase shift around 0 °C ... ???
- P. 11, line 12-19: This paragraph bridles the horse from the tail. The underestimated fluxes are a consequence of the noisy, vibration-affected humidity measurement of LI1 and LI3. I suggest to organize the paragraph along this line which was followed through the paper.
- At some places, the structure of sentences is very German style, e.g., P. 1 - line 20, P. 9 – line 32f, p. 10 – line 9f, p. 11 – lines 20-21.
- In a few places there are unnecessary redundancies: P. 2 – Line 27 / Line 30, P. 4 – Line 24 / 25, caption of Figures 8, 9 (repeating the whole Figure legend).

Figures

- Figure 3
 - Would it be possible to indicate D1 .. D6 in the graph
 - Don't numerate the subplots without a reference, do not write "first subplot" and "main plot" etc., but "upper", "central", "lower", or label the subplots with a) ... d)
 - Unit of potential temperature should be K.
 - The lower panel does not show the invalid data, instead it marks the "periods of invalid data"
 - Could the part of the flight that was used for the spectral analysis (grey shading in Figure 3, marked by a different colour in Fig. 1)?
- Figure 4: This Figure is not really needed.
- Figure 6:
 - See also my remarks to Figure 3.
 - When looking at the vertical wind speed plot one gets the impression that the plot basically shows the movement of the Helipod for the ascent / descent flight periods. Shouldn't this component be removed in order to see the turbulence intensity?
- Figure 7: In fact, this plot shows the time series of accelerations in z direction which illustrate the vibrations the LICOR sensors were exposed to.
- Figure 10: Right graph should better be named as "Co-spectra of humidity from the different sensors and vertical wind speed ..."
- Figure 11: I would be a bit hesitant to present a flux derived from the Humicap humidity signal in this plot without further discussion; it might be interpreted in a way that the Humicap is still much better than the vibration-sensitive LICOR instrument.

Some minor language issues / misprints

- P. 2, line 22: and make → making
- P. 2, line 25: with → allowing for
- P. 3, line 25: ... available yet.
- P. 6, line 27: above → over
- P. 6, line 29: humidity fluxes → humidity fluctuations
- P. 8, line 1: urface → surface
- P. 9, line 24: cn → can
- P.9, line 26: sonzor → sensor