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Comment on amt-2022-236

Anonymous Referee #1

Referee comment on "Drone-based meteorological observations up to the tropopause – a concept study" by Konrad B. Bärffuss et al., Atmos. Meas. Tech. Discuss.,
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The manuscript "Drone-based meteorological observations up to the tropopause" by Konrad Bärffuss, Holger Schmithüsen, and Astrid Lampert, presents the development and first results of an uncrewed aircraft system (UAS) capable of sounding the atmosphere up to 10 km. This is an outstanding achievement and can have a major impact on improving in-situ atmospheric measurements for a future use in the operational network of a met service. The content gives a valuable contribution to the community, however some major changes have to be implemented before publication. I am going to explain why below:

General comment:

The manuscripts present the use and first deployment of a novel UAS for atmospheric sounding up to 10 km. The airborne platform is introduced and discussed, including the design envelope of the aircraft.

Measuring up to 10 km is challenging as the sensors have to handle and withstand a wide range of environmental conditions. The authors explained this in much detail in Section 2.2 in their manuscript. The sensor package is mentioned, but a proper sensor introduction, or the methodology of wind measurement including an adequate error discussion, is missing. However, due to the harsh conditions the sensors are exposed to, a detailed discussion is essential. The authors give some information in the caption of Table 1. Still, it remains unclear what is the temporal, thus the spatial or vertical resolution of the sensors or the absolute uncertainty depending on the flight trajectory or how well the sensors perform in e.g. very low temperatures, high humid conditions etc. Also, the methodology of the wind estimation remains unclear. Although the author claims that calibration and removal of installation errors are an own branch of science, validating the

LUCA system with commonly used systems such as a met tower or a validation in a climate chamber is required. The authors show a comparison with radio sondes, but due to a time differences of several hours between the radiosonde and the aircraft measurement, the comparison remains insufficient and shows large deviations.

Specific comments

4: What do you mean by environment friendly additional data?

84: Usually UAS stands for uncrewed aircraft system

102: Authors could add this citation:

Jensen, Anders A., et al. "Assimilation of a coordinated fleet of uncrewed aircraft system observations in complex terrain: Observing System Experiments." *Monthly Weather Review* 150.10 (2022): 2737-2763.

165: Does this also account for take-off and landing?

203: Is 13:00 UTC or local time. Does LUCA have a real-time downlink and can provide data during the flight at 12 UTC? This is not clear here.

Section 2.2: A clearer description of the aircraft system is missing. What kind of engine, autopilot, C&C link etc. is used ?

Section 2.2: Why does the aircraft not perform a normal landing with a flare? Common open-source autopilots such as the one used in LUCA can handle this.

Section 2.3 How is the measured data stored?

218: 'closed sensing path'. An illustration or a picture of the sensor system would be very helpful. What is the mass flow around the sensor?

219: For what errors are they corrected?

221: How does the flight trajectory of a mission look like? The authors should show the flight trajectory at least of one flight mission.

221: What do you mean by heading output? How is the horizontal wind, using the heading information, calculated? Please explain the method of your wind estimation in detail and please elaborate on:

- How does the flight trajectory impact the wind estimation, and how does this effect the measurement error?
- How does the wind speed influence the wind speed uncertainty?
- Is the wind measured during turns or during the ascent or descent in straight flight?
- During which trajectories is the wind estimation bad?
- What is the overall error of the wind estimation, and how do you calculate it?

224: In addition, magnetic vector measurements to be fused in the attitude estimation might be deteriorated. Is the magnetic sensor fused or not?

225: How can a camera be a reliable ice detector? Please explain in more detail.

Table 1: A real discussion of the sensor error in the text is missing. The authors give some information in the caption of Table 1, however this is hard to follow and mainly cites further publications using similar sensor but on different platforms. It remains unclear what is the temporal, thus the spatial or vertical resolution of the sensors during the ascent and descent, the absolute uncertainty depending on the flight trajectory and the relative error (see also my comment for line 221). Although the author claim that calibration and removal of installation errors are an own branch of science, at least a comparison of the LUCA system with commonly used systems such as a met tower should be performed to enable a real sensor error estimation or a validation in a climate

chamber. Also, it is not clear what is meant by calibration and removal of installation errors.

257: '... which equals the minimum horizontal component of the true airspeed during the ascent.' Why minimum?

265 ff: Part of this has been mentioned also earlier in the text. I would recommend skipping this and refer at an earlier stage to the aerospace journal, e.g., in Section 2.2.

261: Where did the flight take place? An overview of all analysed flights described in this study should be presented.

283: The word simultaneous is misleading, as even the authors claim that there is a time gap up to three hours between the flights and the radio sonde ascent.

294 and 301: Plots in Fig. 5 are too small to identify the ABL structure and follow the explanation in this paragraph. I would suggest increasing the resolution at least for the lower part of the atmosphere.

305: 'multiple times' What is the frequency? See also comment for Table 1.

Fig 6. Part of the caption belong to the Section. It is not clear what is meant by 'on

decomposing the time signal in sinusoids with differing frequencies (cycles per day), and higher harmonics (natural products of the fundamental frequency) reveal the non-sinusoidal waveform of the diurnal cycle' A more detailed explanation should be already implemented in the Method Section of the study. Also, it remains somehow unclear to me, what the benefit of Section 3.3 in relation to LUCA is.

For instance, the sentence 'Interestingly, temperature variability at a cycle of 6 per day is low below 5 km altitude, pronouncing the importance of profiling the atmosphere to higher altitudes', which only appears in the caption of Fig. 6 should be stressed more in the text.

350: Minor drawbacks in the measurements occurred as expected due to the simple sensor setup. What are these? This is not clearly described in the previous Sections.

354ff: 'Using a more sophisticated measurement package, standard radiosonde accuracy is expected to be reached or even surpassed. By design, the UAS technology bears the pivotal advantage of re-using sensors and the possibility of pre- and post-flight calibration....' This is very speculative and should be addressed as an outlook.

367: I disagree with this to claim a camera a 'dedicated sensor' (see also comment above)

Technical comments:

2: In the ABL, above the oceans and in polar regions

146: ... the UAS of type LUCA