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Atmospheric Measurement Techniques
Discussions
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Interactive comment on "The Universal Cloud and Aerosol Sounding System (UCASS): a low-cost miniature optical particle counter for use in dropsonde or balloon-borne sounding systems" *by* Helen R. Smith et al.

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Response to reviewer #1

responses are shown below reviewer comments

1. The instrument uses 658 nm laser light with an open-path configuration. Isn't there any influence of stray sunlight on the measurements? If not, is there any special measure for the daytime use?

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response: The electronic circuit removes the background signal to account for stray light effects. In addition to this, the inside of the instrument is coated with an absorptive paint, preventing reflections down the inlet and therefore minimising the amount of stray light incident on the detector. In lab tests, these two methods have proved to eliminate counting/sizing errors due to stray light. This was not originally included in the manuscript for brevity, but will be amended in the revised version.

2. The authors wrote at page 9 that Time-of-Flight (ToF) data is used to “reject” signals that may come from “a large body or agglomeration of particles.” Does this mean that such particle signals are not on the record? There is alternative approach in that such signals (including ToF data) are also recorded, processed, but may be removed in the data analysis phase. Is there any reason to reject those at the onboard circuit? I ask this question because this treatment may miss cloud signals if particles are greater than 40 μm. For example, in Figure 14, at 5 km, there is another $\sim$100 % relative humidity layer. It is not clear whether there was no cloud or there were clouds with particles much greater than 40 μm.

response: Due to limited bandwidth, we do not record particle-by-particle data, and only a subset of time-of-flight data is recorded for quality assurance. Therefore it is not possible to record all of this data and deal with it in the data analysis phase. The measurable size range is based solely on the pulse-height produced by the scattering particle, the pulse is digitised to a value between 1 and 4095 and so pulses too small or too high will not be recorded. Therefore, if the upper measurement limit of a unit is 40microns, then a particle larger than this will not be counted regardless of the time-of-flight. There is a relationship between the time-of-flight and particle size, which allows us to exclude erroneous data. i.e. if the upper measurable limit is 40microns, and given the ToF-size relationship, a particle with a pulse height (size) within the measurable range, but a time-of-flight much higher than the upper limit is likely to be some erroneous count. This could happen in the case of an agglomeration of particles. I will include some clarification in the revised manuscript

3. The description of the assembly, optical set-up, and sensing area is sometimes not easy to follow. I understand this because the instrument is three dimensional, but I have some ideas to improve this. I suggest the authors to (1) define the common x, y, and z axes for Figures 1 through 4, (2) show the axes explicitly in each of Figures 1 through 4, (3) avoid terminologies such as “width/depth”, “left/right”, “above/below” etc., but use the axis to specify the direction. Furthermore, please consider to use a common set of identifiers e.g., (a), (b), . . . in these four figures; for example, in Figure 2, (a)→(b1), (b)→(b2), (c)→(b3), (d)→(b4) (and keep Figure 1 as it is), and use e.g., (i), (ii), . . . instead of (a), (b), . . . in Figures 3 and 4. The mirror schematic in Figure 2 is very different from those in Figures 3 and 4, which made me confused at first. The laser light schematic in red in Figures 2, 3, and 4 may be improved by making them more consistent across these figures, and add an explanation in caption Figure 5 about how the “major axis” and “minor axis” correspond to the laser light schematic in Figures 2 through 4. Finally, please add the dimension information to Figures 1 through 3 as much as possible, so that it becomes easier to read the text by referring to these figures.

resonse: These are good suggestions and the diagrams will be amended accordingly. The mirror looks different in diagrams as sometimes a cross section is used and other times the entire unit is shown. I will stick with the cross section for all diagrams.

Section 1 Introduction: - I think MODIS and MISR are not lidars. –

response: I will amend this in the revised manuscript

There have been several particle instruments for balloon sounding. Some examples can be found in the Introduction of Fujiwara et al. (2016). Other instruments include LOAC (Renard et al., 2016) and POPS (Gao et al., 2016). - I think that an OPC for dropsonde may be new. I assume that the dimension, shape, and configuration of the UCASS was determined so that it can be mounted in the dropsonde launcher. If so, please explicitly write the conditions under which an instrument can be used as a dropsonde. Also, the strength of the dropsonde over the balloon sonde system may be discussed (e.g., the former can be more easily targeted to a specific airmass including a specific cloud system). - Because the examples of aerosol particle measurements shown in this paper are actually only for Saharan mineral dust, the role of mineral dust particles on the climate may be explicitly discussed. - The mass of the instrument 280 g should be explicitly written here (near the term “lightweight”; and also in Section 2).

response: I will add in a discussion of balloon based instruments in the introduction. You are correct in that the shape of the UCASS was determined by the initial dropsonde design, in which the KITsonde had to fit entirely inside the UCASS, which in turn had to fit inside the drop tube. I will clarify this in the revised manuscript.

Section 2 Instrument Design, subsections 2.1 through 2.2: - See the major comments. - Why is the sensing area (“0.5 mm2”) an area, not a volume? - It is helpful for the readers to summarize (e.g., to prepare a summary table for) the particle signal data (i.e., I1, I2, ToF, pulse height, etc.) and their relation with the criteria for data quality assurance (i.e., particle path inside/outside the sensing area, agglomeration of particles, etc.) Please also add the information how the numbers 0.4, 17, 1, and 40 μm for the particle size limits were actually determined. - Figures 3 and 4 indicate that the detector only collect light reflected on the mirror. There is no contribution from the directly scattered light (i.e., around 120 deg.)?

response: You are correct in that any particle passing within a particular volume will cause a pulse on the detector. However, we discuss a sensing area, as the airflow is perpendicular to the laser beam. Therefore, any particle passing through a particular AREA will travel through the depth of the beam. It is the area presented orthogonal to the airflow that dictates the sampling rate. The depth of the laser does not impact the sampling rate, it only affects the time-of-flight. I will clarify this in the revision, perhaps with a diagram.

Section 2.3 Electronics: Perhaps, the explanation of the “gain” i.e., “high gain version”

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and “low gain version” is first described here at page 8. In the current manuscript, the gain is mentioned first in the Calibration section at page 13, and it is not very clear what the “gain” actually is.

response: We will add in some extra description where needed

Section 2.4.2 Calibration Measurements - Have you used all the calibration particles for each of the two different gain versions? In Figure 8, the set of particles shown is different between the two. For example, what is the response of the high-gain version to soda-lime 37.36 μm particles? - What were the ToF values for these experiments? How about the frequency distribution? Were the ToF values simply used onboard for removing agglomeration cases?

response: The high gain version has a smaller upper size limit. In each panel, the x-axis represents the full 4096 bins available. On the top panel, you can see that the measured size distribution for the 14.4micron calibration beads is cut off at the larger sizes, and the full distribution is not captured. Any pulses above 4095 cannot be counted. Therefore, the additional particles used for the low-gain calibration would not be seen at all by the high-gain version as they are off the scale. The ToF data during calibration is used in the same way that Tof data is used in experiments, where only overly low or high ToF values are rejected, corresponding to particle sizes below/above the measurable size range are rejected. I will clarify this in the revision

Section 2.5 Air flow Management: - It looks strange that the air flow inside the instrument can be greater than the background air flow because the drag on the inside wall would reduce the air flow speed inside. Do you have some actual measurements showing this (see e.g., Appendix B of Fujiwara et al., 2016)? - It is not clear why a double pendulum system would “inhibit the movement of UCASS”. Is that due to a rather heavy radiosonde located below that acts as a drag? A double pendulum system might even give chaotic motions (depending on the mass of the second object and the air drag). Furthermore, in general, the payload may also move along a circle or ellipse in the horizontal plane. - Related to the above two comments, in Section 1 or 2.1, an explanation is necessary why the instrument shape has been designed like this, i.e., not symmetric along the air flow; this would give additional complication here. - In the end, all these factors go to the uncertainty of the measurements. The term "Management" in the section title may not be appropriate; more appropriate would be something like, Evaluation of the measurement uncertainty due to air flow uncertainty?

response: You are correct in that the drag on the inside wall reduces the air speed in the boundary layer of the surface, however the sample area is outside this region and thus experiences a higher air flow. We can include measurements in the revision. Although a double pendulum is indeed chaotic, the maximum angle of tilt for the central element is very much limited in this configuration when compared to a single pendulum system. For the CFD modelling, we only showed the effects of tilt along one axis, because this is the only direction that has an impact on the airflow due to the location of the sample area close to one edge of the inlet. Along the other axis (I will define this in the revised manuscript using your suggestion of a universal coordinate system), the sample volume is sufficiently far away from the inlet edges, such that the tilt has no effect. I will try and explain this further in the revision, and will change the section title as suggested.

Section 3.1.1 Dropsonde system - The date information for the sounding in Fig. 14 is necessary. (See also the major comment on this sounding.) - What about the results from the other 5 soundings? I will add the date information.

response: Not all data is shown for brevity, the purpose of the paper is to give the technical information on the instrument. Some field data is included to show the various applications of the instrument (i.e. droplets/aerosol upsonde/dropsonde) but we don't think it is necessary to include all data from all campaigns. For the dropsonde tests, the other drops did not have comparative data available, or were tested in clear skies and so these data sets add little scientific value.

Section 3.1.2 Upsonde system - Description on the PCASP onboard the research aircraft is necessary.

response: I will add this.

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