Reply to Reviewer #3

We would like to thank you for providing highly technical comments regarding our manuscript. We substantially modified the content in the revised form and believe the modifications will be satisfactory and suitable for publication. The point-by-point responses (in blue) are made below.

Overview of the revision

The reviewer may consider that we are the original members who developed the CPS sondes (this is probably because the title of our original manuscript might provide misleading information); however, this is not the case. Note that we have not been involved in the development of the CPS sondes. We contacted the manufacturer (i.e., Meisei Electric, Co. Ltd.) to obtain the technical information.They explained to us that the shape of the laser beam is not uniform as it is but is adjusted to be uniform with Biconvex lends (the reference is not available); the actual dimensions of the two parallelograms are not evaluated by a optical software.

We substantially revised the paper, including its title, from the viewpoint of a CPS sonde user to clarify our approach and deliver the message to the manufacturer for further development and experiments (e.g., mapping of the sampling area as suggested by the reviewer). Based on CPS sonde measurements of Arctic low-level clouds, we demonstrated that the original approach published in AMT (Fujiwara et al., 2016) should be improved. For this reason, we still believe that AMT is the best platform for reporting our experiences of CPS sonde measurements in the Arctic and then discussing the need for a new correction method.

The structure of this paper has been simplified as (1) Introduction, (2) Experimental designs, (3) Data processing, (4) Comparison with other data sources, (5) Discussion, and (6) Conclusions. The previous Figs. 3 and 7 and their explanations related to the optical design and sampling area mapping have been deleted because we would like to highlight the observed data, particularly the smaller particle signal widths (PWDs) than those expected by Fujiwara et al. (2016). We also removed some simulated results (previous Figs. 9 and 13) to keep the manuscript simple. Since we realized that additional laboratory experiments would be necessary in future work, their needs have been discussed in the new section by citing literature. The correction factor was newly estimated in section 3.4 by the idea of collection efficiency based on Noll and Pilat (1970), improving the theoretical robustness of estimation of the factor, although the main result was not changed.

*How does the laser beam profile look like? In optical particle detection, the laser beam profile in the sample volume plays an important role. This is a major point that needs to be added to this manuscript. Best practice is to use optical modeling software and also measure the intensity profile at different places within the sample volume with a photodiode on a translation stage or a* *camera.*

We communicated with the manufacturer to obtain the information on the shape of the laser beam (the reference is not available). The manufacturer did not conduct the optical modeling, but the shape of the laser beam is adjusted to be uniform by using the Biconvex lens. The issue has been included in the new section 5.3.

*Another point that deserves more investigation is the correction factor for the total particle counts. The authors already mentioned inhomogeneities in the sample volume, so one of the basic assumptions is actually violated. In my opinion, this issue can only be resolved by intercomparison with state-of-the-art optical cloud particle spectrometers in a laboratory setup.*

As suggested by the reviewer, additional laboratory experiments using optical spectrometers and precise droplet generators would provide more realistic data but we consider that it is beyond the scope of this research because the aim of this study is to provide a practical method to correct the CPS data under the existing system from a user perspective. However, we also agree the need for some laboratory experiments as suggested by the reviewer, we cited papers Lance et al. (2010) and Beswick et al. (2014) to introduce how the state-of-art has been applied to calibrating cloud microphysics probes, which must stimulate the manufacturer (i.e., Meisei Electric, Co. Ltd.) for further development of CPS sonde. This issue is discussed in the first paragraph of the new section 5.3. The correction factor was introduced by the idea of collection efficiency in the new section 3.4 based on Noll and Pilat (1970). The value has been changed from 5.8 to 7.5; however, the conclusion did not change.

*Although the flow conditions have been investigated via CFD modeling, there are no results from real measurements shown. In particular, boundary layer effects and "slow flow zones" are much clearer to see in an experimental flow characterization in a wind tunnel. Ideally, a particle generator is part of the laboratory setup to also investigate how the flow conditions influence detectability of cloud hydrometeors. In addition, a particle generator producing water droplets should be used to calibrate the CPS sondes. Further experiments in an icing wind tunnel would be helpful to investigate the ability of the sensor to distinguish ice from supercooled liquid water under realistic conditions.*

In the revised form, we compared the simulated flow speed with the flow speed data at the bottom of the CPS inlet observed by anemometers by Fujiwara et al. (2016). The flow speed was 15% smaller than the ascending speed. Our simulations also have the same rate even if the ascending speed is changed from 4 m/s to 6m/s, suggesting that our simulations are valid for further investigating flow characteristics around the CPS housing. This content has been included in the new section 3.4. Although we do not have the observed data of the "slow flow zones" by using a particle generator, the hypabolic flows would be common feature at the plane surface. Further experiments for distinguishing ice from supercooled liquid water would be desired; however, we think it is beyond the scope of this study.

References newly included


1. Baumgardner et al. (2017), Cloud ice properties: In situ measurement challenges, Meteorological Monographs, 58, 9.1–9.23.

2. Beswick et al. (2014), The backscatter cloud probe – a compact low-profile autonomous optical spectrometer, Atmospheric Measurement Techniques, 7, 1443–1457.

3. Craig et al. (2013), Design and sampling characteristics of a new airborne aerosol inlet for aerosol measurements in clouds, Journal of Atmospheric and Oceanic Technology, 30, 1123–1135.

4. Lance et al. (2010), Water droplet calibration of the Cloud Droplet Probe (CDP) and inflight performance in liquid, ice and mixed-phase clouds during ARCPAC, Atmospheric Measurement Techniques, 3, 1683–1706.

5. Murakami and Matsuo (1990), Development of the hydrometeor videosonde, Journal of Atmospheric and Oceanic Technology, 7, 613–620.

6. Noll and Pilat (1970), Inertial impaction of particles upon rectangular bodies, Journal of Colloid and Interface Science, 33, 197–207.