We sincerely thank the reviewer for carefully reading of our work, for his review and valuable comments. There seems to be a misunderstanding about our main motivation, which we hope to clear through our responses below.

Reviewer comment (RC)

Authors answer (AA)

RC1:

The study that is discussed in this submission focuses on the performance of three cloud probes that were originally designed for operation on aircraft but an attempt has been made to adapt then to a ground based location where the environment can often be quite harsh with respect to icing conditions. I think that given the multiple issues with how the instruments were operated, this paper is overly lengthy. It could just as easily have been a very short technical note that points out how you should NOT mount and operate instruments on the ground that are designed to be used for aircraft.

AA1:

This aspect will be elaborated in the introduction of the revised manuscript. There is lately an increased demand for long term continuous ground based in-situ cloud measurements. The approaches are solidified slowly but continuously. Unfortunately, there is more or less nonexistent instrumentation to cover such demand, moreover continuous in-situ cloud measurements in conditions similar to those at our sub-Arctic location are very challenging. All three ground based setups were designed by the manufacturers (PSM and DMT). Our FSSP-100 ground set-up allows us to continuously follow the wind direction. CAPS was installed in fixed direction and we reported in our manuscript that wind direction was a crucial factor for its performance and caused artifacts in conditions with winds not iso-axial to CAPS. However, the decision to use CAPS was due to two reasons. 1) To perform a full benchmarking and intercomparison with FSSP-100 and evaluate the results and 2) to quantify the usability of data that were not collected in the most favorable conditions – wind iso-axial direction. CAPS inhalation system (high flow pump and wide diameter hoses) is unfortunately so big that using rotational platform is not feasible. Our analysis clearly shows that for some parameters like number concentration and liquid water content the iso-axial direction plays a significant role, but for the derived parameters effective diameter and median volume diameter it seems not to be disqualifying at all. This behavior of the instrument is extremely important to us because we are highly interested in semi and long-term continuous measurements. We do not consider this work just merely an instrument comparison but also as an experiment on how to operate the cloud probes to perform ground based measurements in harsh environments.

RC2:

What is puzzling is why the decision was made to use these instruments rather than the DMT Fog Monitor that utilizes the same measurement theory but was intentionally designed for ground based measurements

AA2:

We are aware of the DMT Fog Monitor and its features and we agree with the reviewer that the Fog Monitor is the best choice for in situ ground based measurements, however only for warm clouds. Unfortunately, based on our experience, the fog monitor is not suitable for measurements in Pallas and similar environments. Spiegel et al. (2012) published a detailed investigation of the FM-100 (https://www.atmos-meas-tech.net/5/2237/2012/amt-5-2237-2012.pdf) where she analytically evaluated the instrument during its operation in Jungfraujoch and reports that FM-100 had issues in sub-zero temperatures due to icing conditions. There, the Fog Monitor showed several artifacts in temperatures below zero (page 2239 Table 1 and page 2250 "*Due to the mounting position of the FM-100, the inlet often was completely closed by frozen cloud droplets as the cold and humid updraft blew into the inlet of the FM-100. We therefore excluded periods with temperatures below 0 ◦C from data evaluation in order to exclude potential measurement artifacts that might arise due to freezing*." Also, as we can see in fig 9d) in Spiegel et al. (2012), the median wind speed in Junfraujoch was less than 2 m/s, and 75th percentile less than 3 m/s. During PaCE, average wind speed was 6.8 m/s; increasing especially the aspiration- related losses at non-isoaxial conditions. High wind speeds with varying wind direction, together with sub-zero temperatures make the Fog Monitor unusable in conditions similar to those at our measurement site. We should also note that FM-100 was operated in Pallas during our cloud campaign in 2009, and the aforementioned issues prevented any decent utilization of the data (Spiegel, private communication 2020).

RC3:

They do not explain why they chose to mount and operate the instruments in the way they did instead of using a wind tunnel set up that would have circumvented the problems that arose.

AA3:

Methods section will be revised to reflect reviewer comment. The reason behind our choice is that the atmospheric in-situ measurements community (in our case the European Research Infrastructure for the observation of Aerosol, Clouds and Trace Gases, ACTRIS) has identified these cloud droplet probes with surface installation as a potential method for continuous cloud in-situ measurements (ACTRIS-PPP Deliverable D5.1: Documentation on technical concepts and requirements for ACTRIS Observational Platforms, https://www.actris.eu/Portals/46/Documentation/ACTRIS%20PPP/Deliverables/Public/WP5_D5.1_M18.pdf?ver=2018-06-28-125343-273). There are not ready standard operating procedures (SOP's) how to utilize these probes in continuous operation in practice, and our paper helps exactly towards this objective. Wind tunnel is a well-known approach and we agree with the reviewer that it might be considered as the optimal choice. Unfortunately, several measurement sites (e.g. in sub-arctic) do not have this possibility. This is due to both practical (e.g. our site is part of a natural

park where big construction projects are prohibited) and budgetary reasons; Building a wind tunnel in many locations where cloud in-situ measurements could be conducted is not financially feasible.

RC4:

As a three page note, there would be two principal conclusions: 1) Cloud probes with inlets should always be mounted into the wind and 2) proper deicing is always necessary when conditions dictate it.

AA4:

Conclusions section will be modified accordingly to highlight the first conclusion. We agree that cloud probes with inlets should be mounted into the wind. Two of the ground setups (FSSP and CDP) that were installed and operated were following the wind direction and only CAPS was fixed to one direction. The role of the mutual direction of probe heading and the wind direction is one of our main conclusions (e.g. p16, line12, "*Results indicated that when we were deriving Nc, the mutual direction of probe heading and the wind direction were playing the most significant role. From the inter-comparison of the CAS (fixed orientation) against FSSP (rotating platform), it was found that the CAS probe had the best agreement (R^2 =0.70) with the FSSP during wind iso-axial conditions (200 to 235°). The CAS probe counting efficiency was strongly dependent on the wind direction, this can be clearly explained by its installation to fixed orientation*". However, we show that this was not valid when deriving effective diameter and median volume diameter.

FSSP and CAPS anti-ice feature was modified by manufacturer (DMT for CAPS and PMS for FSSP) for ground based measurements. CDP have used standard heating.

RC5:

As a study comparing three instruments with similar measurement techniques it is not as useful or relevant as the number of other studies where instruments are compared in wind tunnels, such as the study done at Puy-de-Dôme referenced in the current study.

AA5:

As we mentioned above in this text but also in the manuscript we do not compare the instruments themselves but three different setups developed for continuous in-situ cloud ground based measurements (e.g. p1, line15, "*The main motivation of the campaign was to conduct in-situ cloud measurements with three different cloud spectrometer probes and perform an evaluation of their ground based setups*").

RC6:

The current study would be much more useful and relevant if it encompassed not only the measurements at their site but discussed why they chose to operate their instruments as they did compared to other sites such as Storm Peak, Elk Mountain, Puyde-Dôme, Jungfraujoch, and the Zugspitze where similar studies have been done but more successfully. Storm Peak, Elk Mountain and Puy-de-Dôme all use a wind tunnel to introduce cloud air to the instruments so that the sensors are being under conditions more like they were designed for, i.e. aircraft.

AA6:

We thank the reviewer for this comment and as mentioned above we agree that wind tunnel might be considered as an optimal choice and colleagues at those sites did a great job. Methods section will be revised to explain our choice. References from measuring sites where they use ground based setup of the cloud probes without using a wind tunnel will be added in the revised manuscript. We deeply believe that ground based setup with inhalation system can also be considered as an acceptable approach. Further, there exist several studies where researchers performed ground based measurements with cloud probes without using a wind tunnel. However, we would like to highlight that our main goal is not to show that our approach is the best for ground based measurements (we don't aim to compare ways of using the instruments in several measurement sites) but that it is an approach which is suitable in conditions where options are limited.

Puy de-Dome is a site where we several times contributed during intercomparison campaigns and we are aware of the way they perform cloud measurements. They obtained data not only from the wind tunnel but also from the roof top. FSSP-100 they use on the roof top was fixed or manually rotated (our FSSP-100 setup follows continuously the wind direction without need of manpower). In the study done at Puy-de-Dôme we referenced (Guyot et al.2015, https://doi.org/10.5194/amt-8-4347-2015) we can see in Fig.2 in there that when the wind direction was favorable **both approaches (wind tunnel and roof top mount) provide data of the same quality**. Also we can see in Lowenthal et. al 2019 (https://www.atmos-chem-phys.net/19/5387/2019/acp-19-5387-2019.pdf), that in Storm Peak, ground based cloud measurements were conducted without using a wind tunnel (Fig. 1 in there). They explain in p.5389 that "*The cloud probes were mounted on a rotating wind vane (to orient them into the wind) located on the west (upwind) railing of the roof approximately 6 m above the snow surface*"). In addition, they highlight the need for higher resolution instruments for distinguish between liquid and ice particles in mixed phase clouds in p.5399 *"They also demonstrate the limitations of instrumentation such as the FSSP-100 and CIP (2-D optical array probe) for distinguishing liquid droplets from small ice crystals in mixed phase clouds. Higher-resolution instruments are required for this purpose."* Their statement highlights the importance of CAPS ground setup due to CAS depolarization features (note: not a subject of our current manuscript). Finally, Lloyed et al., (2015), during the Cloud Aerosol Characterisation Experiments (CLACE) and the Ice Nucleation Process Investigation and Quantification project (INUPIAQ) in Jungfraujoch also used cloud probes for ground based measurements without using a wind tunnel. (Fig. 2 in there) p12954 "*An overview of relevant instrumentation at this site can be found in Table 1, and some of these instruments (that were mounted on a pan and tilt rotator wing) are labelled in Fig. 2. The rotator allowed us to automatically adjust the position of the instruments based on information about the wind direction and vertical wind angle from a sonic anemometer*".

RC7:

I can't recommend this manuscript for publication in its present form as I don't find the results that useful other than as a warning about how not to operate these instruments. A more comprehensive review of ground based measurements with sensors designed for aircraft would be far more useful.

Although I am the chief scientist and founder of Droplet Measurement Technologies, I was not involved with the setting up of the instruments that were involved in this study or the ventilation systems used to introduce cloud air. I have tried to ascertain how this all evolved but the technical staff who were involved are no longer with the company so I have no way of understanding the history of this project. I would recommend that the authors consider a different approach for future studies.

AA7:

As it was discussed already above, our aim is long term continuous in-situ ground based measurements and unfortunately current cloud probes do not fulfill such requirements. They are difficult to be installed facing automatically towards the wind due to their shape. Results section will be modified to note the need for new instrumentation to fulfill those requirements.

All three cloud probes (FSSP, CDP and CAPS) and their setups discussed in this manuscript were designed and sold to FMI as "in-situ cloud ground based measurement setups" by the manufacturers (PSM and DMT).

References (will be included in revised manuscript)

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