We sincerely thank the reviewer for carefully reading of our work, for his review and valuable comments. We have carefully reviewed the comments and have revised the manuscript accordingly. Our responses are given in a point-by-point manner below.

Reviewer comment (RC)

Authors answer (AA)

RC1:

Whilst the title suggests it is an intercomparison between these instruments, it is really a comparison of the rather specific experimental setups employed during this campaign. The paper therefore serves more as a campaign report than a reference on how best to set up experiments for ground-based in-situ cloud measurement. Nevertheless, it does highlight some of the pitfalls.

AA1:

We agree with the reviewer that this was an intercomparison between the specific ground setups and not the instruments themselves and we clarified this through the manuscript (e.g. p1, line 15, "*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*"). We consider that this work was not just an intercomparison but also an operative experiment on how to operate cloud probes for ground based measurements during harsh conditions. We will change the manuscript title to avoid any misunderstandings and possible confusions to: "*In-situ cloud ground based measurements in Finnish sub-Arctic: Intercomparison of three cloud spectrometers setups* ". Also, we clarified in the abstract of the revised manuscript that we intercompared the experimental ground setups of the cloud probes.

p1, line 18: "We investigated how different meteorological parameters affect each instrument operation" to "We investigated how different meteorological parameters affect each instruments' ground based setup operation"

p1, line 20: "we suggested limitations for further use of the instruments in campaigns where focus is on investigating aerosol cloud interactions" to "we suggested limitations for further use of the instruments setups in campaigns where focus is on investigating aerosol cloud interactions"

p1, line 24: "A complete intercomparison between the CAS probe and the FSSP-100 and additionally between the FSSP-100 and the CDP probe was made and presented." to "A complete intercomparison between the CAS and the FSSP-100 ground setups and additionally between the FSSP-100 and the CDP ground setups was made and presented".

RC2:

I am aware of the motivation within communities such as ACTRIS for the establishment of long-term ground-based in-situ cloud measurements, and as such this paper is a step in the right direction with respect to evaluating how these might be established. However, the conclusions do not seem robust enough to form the basis of wider recommendations. The paper does highlight the considerable difficulties faced by any attempt at long-term observations, and it is evident that any plans for unattended operation would pose particular challenges, especially in the sub-Arctic environment. In fairness, the authors are conservative in their recommendations and focus on Pallas campaigns (past analysis and future experiments).

AA2:

We thank the reviewer acknowledging the demand within community for long-term ground-based in-situ cloud measurements and understanding the main motivation of our work. We indeed are conservative and focus on Pallas campaigns. Our recommendations are based on results we obtained from continuous (about two and a half months) PaCE campaign at harsh sub-Arctic conditions. There are two main conclusions that we highlight as basis for wider recommendations. Conclusions were modified accordingly:

P17, line 4: "…were mentioned above. As final suggestions regarding performing continuous ground based in-situ cloud measurements in harsh environments, we would like to highlight two major issues. First, the cloud probes should always continuously face the wind direction to minimize the sampling losses. If this is not secured, only the measurements that were conducted in wind iso-axial conditions can be used for further analysis. However, deriving the sizing parameters *ED* and *MVD* for the whole wind direction spectrum is still possible, but must be done with insight and prudence. Secondly, the cloud probes need necessary daily or more frequent checkups and cleaning of their inlets."

RC3:

I note that this experiment was performed contemporaneously with that at Puy-de Dôme (Guyot et al, 2015) and hence the insight from the findings of the latter were not available to provide guidance on what complementary instruments, based on ensembles of particles, might be installed and used to explore scaling of the number concentration and related parameters. In fairness, the authors do recommend such instrumentation for future campaigns.

AA3: We agree with the reviewer and we indeed recommend that such instrumentation can be really useful for future or similar campaigns, especially for measuring *LWC* (p13, line 22 *". In addition, we suggest the deployment of another LWC sensor, e.g. the particle volume monitor (PVM-100, Gerber 1999) during future campaigns in order to obtain another reference LWC values for inter-comparison in wide temperature range"*).

In the revised manuscript the following will be added after previous sentence

p13, line 23: "… temperature range. The current market does not offer an instrumentation fulfilling our requirements. However, we are continuously following the development of a new generation of counters designed for ground based in-situ cloud measurements. Thus, it is a matter of future deployment during upcoming PaCE campaigns. "

RC4:

Guyot et al (2015) found that FSSP measurements suggested anisokinetic sampling and a high sensitivity to the wind speed and direction. It would be helpful if the authors could comment on how their findings relate to this earlier analysis.

AA4:

According to Guyot et.al. (2015) for wind speeds larger than 3 m/s, the sensitivity of FSSP to the wind direction was high (wind speed average value in Pallas was 6.8 m/s) (page4360 in Guyot et al (2015) "*On average, the greater the angular deviation from isoaxial configuration is, the more the size distribution is reduced, except for a 3 m/s wind speed*"). We agree that this was the main reason that caused discrepancies to the fixed direction of CAPS cloud probe ground setup (the only instrument with fixed direction, discussed in detail (section 3.3)) and it mainly affected its size distribution and hence the number concentration. In our case FSSP was continuously following the wind direction without the need of man force in comparison with Puy-de-Dôme. For this reason, FSSP sensitivity was mainly connected with its brake installation and not the anisokinetic sampling. We should also highlight that in comparison to Guyot et.al. (2015) where they conducted measurements in temperatures above zero, we were usually facing temperature below zero. In revised manuscript section 3.3 was modified to clarify the possible relation.

P12, line 31: "… ~ 40 observation hours. Guyot et al. (2015) performed a similar experiment to investigate the sensitivity of the cloud spectrometers to meteorological parameters. Despite the fact that we conducted the measurements in different temperatures (in Puy-de-Dôme they sampled clouds only above zero) we found that our results were related. The main reason that caused discrepancies (mainly in deriving N_c and *LWC*) to the fixed direction cloud spectrometers ground setups (Pallas – CAPS and Puy-de-Dôme - FSSP) was the wind direction. The strong sensitivity to the wind direction suggested that the cloud spectrometers were sampling anisokinetically in both cases.

RC5:

The authors go into great detail regarding alignment relative to the wind direction, and the discussion is rather laboured and lengthy. The effects on number concentration are not particularly surprising, but are elaborated in great detail, no doubt because the specific instrumental setups (e.g. the brake on the FSSP) require it. This discussion may benefit from being shortened.

AA5:

As was discussed above, CAPS (our only fixed direction ground setup) was sensitive to the wind direction. Our main motivation during this section was to highlight this issue and explain our choice to limit our data and restrict them to isoaxial conditions when deriving N_c and *LWC*. On the other hand, our detailed analysis indicated that derived parameters *ED* and *MVD* were not as sensitive to wind direction as N_c and *LWC*. We would like to keep the detailed description and reasoning that support our results and conclusions even though they might seem to be lengthy for some readers. We also provide detailed guidelines on the data quality assessment since it is very hard to find it in literature.

However, we moved the detailed discussion on remained wind sectors of CAS and FSSP setups inter-comparison (p.12 line 4-25) to Supplementary Materials including Fig. 9 and 10.

RC6:

I note the authors specifically mention the frequent occurrence of supercooled clouds at this location. Do they have further corroborative evidence that the clouds being sampled contained only supercooled liquid water drops. Whilst LWC is readily calculated in terms of the measured parameters, it would be useful if the authors could comment on whether any data relate ice particles.

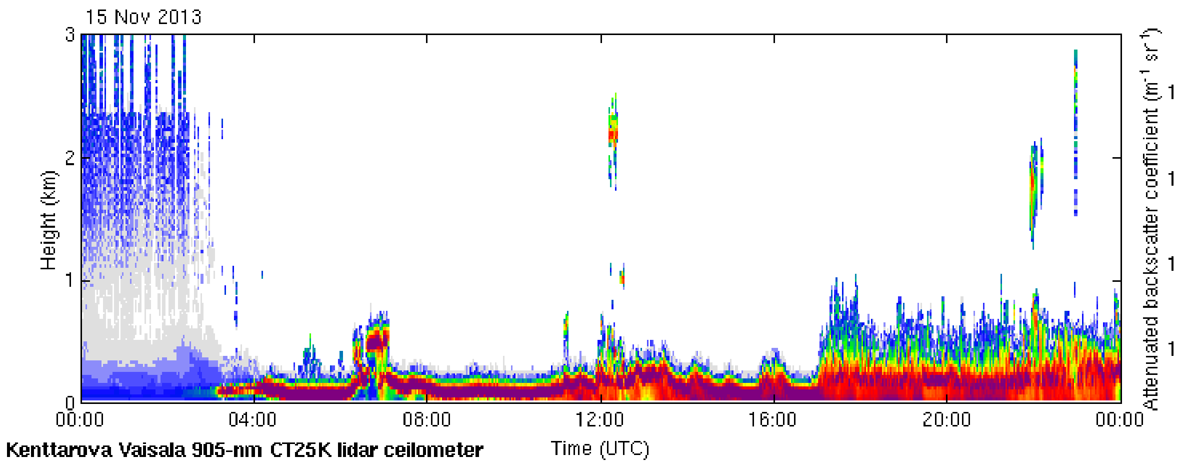
AA6:

We used three approaches to investigate ice particle content. Our analysis supports our claim on sampling mostly supercooled liquid water drops. Here, we will present a typical example of a cold day (15.11.2013 with temperature values around -10 ºC).

First, the CAS Dpol depolarization features including particle-by-particle data were used to investigate asphericity of particles, similarly as described in detail by Meyer, (2012). For the detection of the particles asphericity, the polarized components of the scattered light are usually measured in backward direction because the scattering in that direction is influenced by the particle shape. In our case, during 15.11.2013, average value of the polarized component of the backscattered light for each particle was 0.27 (std 0.01). Meyer (2012) sampled natural clouds while facing similar temperatures as we faced during PaCE. She explained in p. 74 "*the fraction of frozen cloud particles in the COALESC natural clouds is generally low. Especially above −13 ◦C/260 K, only few ice crystals are observed*".

Secondly, we performed Cloud Imaging Probe (CIP) data analysis and found that vast majority of the small drops in nonprecipitating clouds were spherical. However, we are familiar that spherical cloud droplets could also be connected with additional possible crystal rounding mechanisms (e.g. Nichmann et al, 2017)

Thirdly, we also used data from ceilometer that continuously measures at Kenttarova station - about 6 km downwind from Sammaltunturi station.



Sammaltunturi station altitude is 565m a.s.l. The highest values (purple) indicate liquid, low values (blue) are aerosol, and orange-red is snow. This day started off clear. Then, there was a supercooled liquid layer present close to the surface during the morning starting from just before 04:00. After 08:00, ice begins to precipitate through the layer, becoming stronger by midday. After about 17:00, this ice precipitation is becoming strong enough to almost fully glaciate the supercooled liquid layer, especially after 23:00. There, ice particles were expected to generate. However, the number of supercooled liquid droplets greatly exceed the number of small ice particles.

The possibility that we also sampled ice particles will be commented in results section of the revised manuscript.

P15, line 26: "…supercooled clouds. Although there is a possibility we sampled ice particles in some cases, it is expected that the number of supercooled liquid droplets greatly exceed the number of small ice cloud droplets"

RC7:

Whilst the manuscript appears to be in scope for the journal, I would recommend revision before it could be considered for publication.

AA7:

Major revision of the manuscript will be done according to both reviewers' recommendations.

RC8:

On a technical level, I believe the quantity proi defined on p.7 line 22 should be the reciprocal of that displayed. Also, the quantities bi+1 should, I believe, be bi ∗+1.

AA8:

The typo was corrected.

References

Guyot, G., Gourbeyre, C., Febvre, G., Shcherbakov, V., Burnet, F., Dupont, J.-C., Sellegri, K., and Jourdan, O.: Quantitative evaluation of seven optical sensors for cloud microphysical measurements at the Puy-de-Dôme Observatory, France, Atmos. 20 Meas. Tech., 8, 4347-4367, https://doi.org/10.5194/amt-8-4347-2015, 2015.

Meyer, J.: Ice Crystal Measurements with the New Particle Spectrometer NIXE-CAPS, Schriften des Forschungszentrum Jülich, Reihe Energie und Umwelt, 160, 2012 (https://core.ac.uk/download/pdf/34903548.pdf)

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