In-situ microphysical characterization of low-level clouds in the Finnish sub-Arctic, extensive dataset.

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Abstract. Continuous, semi-long-term, ground based *in-situ* cloud measurements were conducted during eight Pallas Cloud Experiments (PaCE) held in autumns between 2004 and 2019. Those campaigns were carried out in the Finnish sub-Arctic region at the Sammaltunturi station (67º58´24´´N, 24º06´58´´E; 560 m MSL), the part of Pallas Atmosphere – Ecosystem Supersite and Global Atmosphere Watch (GAW) program. Two cloud spectrometer ground setups and a weather station were installed on the roof of the station to measure *in-situ* cloud properties and several meteorological variables. Thus, the obtained data sets include the size distribution of cloud droplets as a measured cloud parameter along with the temperature, dew point temperature, humidity, pressure, wind speed and direction, (global solar) sun radiation and visibility at the station. Additionally, the number concentration, effective diameter, median volume diameter and liquid water content from each instrument were derived. The presented data sets provide a great insight into microphysics of low-level clouds in sub-Arctic conditions over a wide range of temperatures (includes cloud cases with temperature from -25.8 to 8.8 ºC). The data are available from the FMI open data repository for each campaign and each cloud spectrometer ground setup individually: https://doi.org/10.23728/FMI-B2SHARE.988739D21B824C709084E88ED6C6D54B (Doulgeris et al.,2021).

1. Introduction

Clouds are considered as a major component of both the climate system and the hydrological cycle. Nevertheless, our level of understanding of the fundamental details of the clouds microphysical processes is still very limited (Boucher et al., 2013). To gain a deeper knowledge of the formation and development of the clouds more *in-situ* measurements are needed (Morrison et al., 2019). In addition, a correct representation of cloud microphysics in general circulation models for numerical weather and climate prediction is of great importance (Guichard and Couvrex, 2017). Despite that cloud processes can now be studied with much more confidence (Bony et al., 2015), representing the formation and evolution of cloud droplets and the effects of aerosols on clouds at various meteorological conditions remains a challenge (Grabowski et al., 2019). The number concentration and size distribution cloud droplets are considered as key parameters for a quantitative microphysical description of clouds (e.g., Rosenfeld and Ulbrich, 2003; Komppula et al., 2005; Lihavainen et al., 2008, Pruppacher and Klett, 2010, Chang et al., 2019), and are connected with the cloud lifetime and radiative effects as well the rain formation properties of clouds (e.g., Albrecht 1989; Devenish et al., 2012, McFarguhar et al., 2020).

Three general approaches were used in previous investigations for cloud microphysical properties: *in-situ* sampling through airborne measurements by aircrafts (e.g. Heymsfield et al., 2011; Craig et al., 2014; Petäjä et al., 2016) and recently, by Unmanned Aerial Systems (UASs) (e.g. Girdwood et al., 2020; Brus et al., 2021; Harrison et al., 2021); *in-situ* sampling by using laboratory cloud chambers (e.g. Möhler et al., 2003; Stratmann et al., 2004; Nichman et al., 2017; Doulgeris et al., 2018) and *in-situ* ground based measurements (e.g. Guyot et al., 2015; Lloyed et al., 2015; Lowenthal et al., 2019; Doulgeris et al., 2020). *In-situ* airborne and ground measurements (Wandinger et al., 2018) using cloud spectrometers are considered fundamental as they offer instrumental

access to individual droplets within a sampling volume. However, employing any of the above approaches tackle their own difficulties.

Data sets that have been obtained from measurements in Arctic clouds are significant as cloud processes are considered as an important component to investigate the climate change in the Arctic region (Wendisch et al., 2019). Pallas Cloud Experiments
45 (PaCE) took place in the Finnish sub-Arctic. Our main objective during PaCE was to study low-level clouds and their microphysical properties in a background sub-arctic environment. In this work, we present a unique dataset of ground *in-situ* cloud measurements along with several meteorological variables collected at the Sammaltunturi station in eight autumn campaigns conducted between 2004 and 2019. This data set can be used as complementary in investigating cloud microphysics, evaluation and improvement of the models. In further text, we provide the description of the measurement site, the instrumentation, the measurement methodology
50 that was used for the data processing and the quality control.

2. Methods

2.1 Measurement site and PaCE campaigns overview

55 The measuring site was the Sammaltunturi station (67º58´24´´N, 24º06´58´´E); it is hosted by the Finnish Meteorological Institute (FMI) and is located on a top of an arctic fjell (560 m above MSL) in the Finnish sub-Arctic region inside the Pallas–Yllästunturi National Park (Fig. 1). The Pallas area is located around 180 km above the Arctic circle, and it has no significant local or regional air pollution sources. Thus, the Sammaltunturi station provides an excellent location for the monitoring of the background air composition in northern Europe. The station is about 100 m above the tree line and the vegetation around it consists mainly of
60 low vascular plants, mosses, and lichen. There is a long history of atmospheric data collection in the area (Lohila et al. 2015). Monitoring activities of atmospheric composition at Sammaltunturi started in 1991 in a building that originally served the Finnish Broadcasting Company. The new station (102 m^2) opened in July 2001. Since 1994, Sammaltunturi has been established as a node of the Pallas–Sodankylä supersite that contributes to the GAW program of the World Meteorological Organization. The site was described in detail in Hatakka et al. 2003. The main research measurements focus on greenhouse gas concentration, climate effects
65 of atmospheric aerosols, aerosol cloud interaction and air quality (e.g., Komppula et al., 2005; Lihavainen et al., 2008; Asmi et al., 2011; Backman et al., 2017; Doulgeris et al., 2020). The predominant origin of air masses arriving at Sammaltunturi is usually from the Arctic (Asmi et al., 2011).

The main motivation to perform in-situ cloud measurements at the Sammaltunturi was that the station was occasionally inside a cloud. Based on analytical data the most suitable time of the year for in-situ cloud measurements was autumn because the
70 horizontal visibility was below 1 km around 40 % of the time (Hatakka et al. 2003). Thus, we started to conduct ground-based *in-situ* measurements and study cloud formation. The "Pallas Cloud Experiments" were usually 6-8 weeks long and lasted approximately from the beginning of September until the end of November, occasionally to the beginning of December. The first attempt of measuring in situ cloud properties was made in 2004 using the forward-scattering spectrometer probe (FSSP-100) ground setup that was the only available cloud spectrometer at that time. The next campaigns, in 2005 and 2009, were done using the same
75 instrument setup (Lihavainen et al., 2008). Later, in 2011 the cloud, aerosol and precipitation spectrometer (CAPS) ground setup (includes two instruments; the cloud and aerosol spectrometer (CAS) and the cloud imaging probe (CIP)) was purchased and during January and February 2012, it was tested for a first time during two short periods during winter at the Sammaltunturi site. In 2012, 2013 and 2015 both instruments were installed and used during PaCE (Doulgeris et al., 2020). In 2017 and 2019, only CAPS was used (Girdwood et al., 2020). An overview of each year's campaign duration and the cloud spectrometer ground setups' availability
80 is presented in figure 2. Instruments that were used for measuring the meteorological variables and the solar radiation were operating continuously during all PaCE years. The instrumentation used during PaCE campaigns is described in detail in the following section.

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2.2 Instrumentation

In order to monitor meteorological variables, the station was equipped with an automatic weather station (Milos 500, Vaisala Inc.). A weather sensor (model FD12P, Vaisala Inc.) was used for measuring the horizontal visibility; the Vaisala HUMICAP was used

90 for measuring the relative humidity; BAROCAP sensors were used for measuring the barometric pressure and PT100 sensors were used to measure temperature at 570 m. Global radiation and photosynthetically active radiation were measured with a pyranometer and a photovoltaic detector, respectively. Additionally, the wind speed was measured with a heated cup and the wind direction with a heated wind vane. All the above meteorological variables were saved as one-minute averages. A detailed description of the weather sensors was given in Hatakka et al., (2003).

95   In order to conduct in-situ cloud ground-based measurements, we deployed two instruments. The cloud, aerosol and precipitation spectrometer (CAPS) and the forward-scattering spectrometer probe (FSSP-100), (Droplet Measurement Technologies (DMT); Boulder, CO, USA) (Fig. 3). The FSSP (model SPP-100, DMT) was originally manufactured by Particle Measuring Systems (PMS Inc., Boulder CO, USA). Both instruments were originally developed for airborne measurements but modified as ground setups by the manufacturer (DMT, USA). They were installed on the rooftop of the Sammaltunturi station. CAPS was fixed and

100 heading always to the main wind direction of the station southwest, ~225°, while the FSSP-100 was installed on a rotation platform to continuously face the wind. CAPS had a total height of 0.6 m on the roof where it was installed and a height of 4.5 m from the ground. FSSP had a total height of 0.6 m on the roof where it was installed and a height of 5.5 m from the ground. The two setups had a horizontal distance of ~10 m and vertical distance of ~1 meter between them. From 2004 until 2012 a flow laminator was used inside the FSSP inlet (Lihavainen et al. 2008). However, the flow laminator was often blocked by supercooled cloud droplets

105 at sub-zero temperatures and for this reason it was cleaned every hour if subcooled water was occurring. The laminator blockage was evident both during everyday instrument inspection and from the raw data. Only data cleaned of this artefact were used in the FSSP data set. However, without placing the laminator the Reynolds number indicates that the flow inside the inlet was still laminar. As a result, in 2012 we decided that the laminator would not be used in the FSSP setup anymore. Thus, the amount of data after 2012 were more extensive and the cases when the FSSP inlet was plugged were significantly less. A detailed description of both

110 ground setups and the methodology we used for obtaining the ground-based cloud microphysical properties with in-situ method was documented in Doulgeris et al., 2020. Only a short overview is given here.

       The CAPS has been widely used in airborne measurements for investigating the microphysical properties of clouds (e.g., Baumgardner, 2001; Baumgardner et al., 2011). The CAPS probe includes three instruments; the cloud and aerosol spectrometer (CAS) which measures smaller particles, the cloud imaging probe (CIP) and the hot -wire liquid water content (LWC_{hw}) sensor. For

115 the ground setup we deployed, the hot-wire LWC faced difficulties to operate in such extreme conditions; after operating in supercool liquid clouds (even for a short time) the sensor was accumulating ice. In addition, the lifetime of the sensor is limited and significantly smaller than the duration of the campaign. FSSP-100 was widely used for measuring droplet size distribution (Brenquier, 1989). CAS and FSSP-100 calculate the size of the particle from the intensity of the scattered light, using the Mie theory (Mie, 1908). Furthermore, backscatter optics measure light intensity in the 168 to 176° range. This allows the determination of the

120 real component of a particle's refractive index for spherical particles. The CIP is a single particle optical array probe. Its design is based on optical measurement techniques whereby single optical imaging passes through a collimated laser beam and is projected onto a linear array of 64 photodetectors. The count of the particle is dependent on a change in the light level of each diode.

       All the instruments were calibrated before and after each campaign. Until 2011, we relied on the manufacturer calibration that was done at DMT. After 2011, we also started to perform calibration at the FMI on top of manufacturer calibration to ensure

125 the quality of the produced data. For the calibration of the CAS and FSSP-100 glass beads in the diameter size range 2-40 μm and

polystyrene latex sphere (PSL) standards in the diameter size range 0.74 - 2 µm were used. To calibrate the CIP, a spinning glass disk with opaque dots of known size was used.

The CAPS ground setup included a high-flow pump (Baldor, Reliance, USA) which was working as an inhalation system. The inhalation system was made and provided by the manufacturer (DMT). A custom inhalation system with high flow ventilator

130 was also made by the manufacturer (PMS) and employed through FSSP-100 inlet to make sure that we will maintain a constant flow through it. A digital thermo-anemometer (model 471, Dwyer Inc.) was used during each campaign for checking daily cloud spectrometers' air speed. The FSSP air speed inside the inlet was calculated from the measured airspeed in front of the inlet, except in 2004 and 2005 when the air speed was calculated with measured volume flow rate through the inlet. There, a necking inside the inlet led the flow from inner diameter 3.8 cm to 2.0 cm. Both spectrometers were equipped with anti-ice systems as they were

135 modified by the manufacturers (DMT for CAPS and PMS for FSSP-100) for ground-based use. Despite the existing anti-ice features, due to the subzero temperatures that they were facing, snow or ice could accumulate and affect the airspeed inside the probe inlets. For this reason, to ensure the proper operation of the instruments, they were inspected and cleaned twice per day, every morning and evening (approximately every 12 hours).

The ground-based in-situ cloud measurements provided the cloud and precipitation size distribution. On top, the PADS

140 software that was used for the data acquisition of CAPS measurements (DMT Manual, 2011), derived the number concentration (N_c, cm^{-3}), liquid water content (LWC, g cm^{-3}), median volume diameter (MVD, µm) and effective diameter, (ED, µm). For the FSSP-100, N_c, LWC, MVD and ED were also derived using the same equations (Doulgeris et al., 2019), since we have used an older software for data acquisition (PACS 2.2, DMT).

An overview of the instrumentation and their operational characteristics we used for cloud measurements are e summarized

145 in Table 1.

3. Overview of data set and quality control description

In the given data set, only measurements when the station was inside a cloud were used. Data from each cloud probe and the weather station were quality controlled and unified in a common format for any further analysis. The presence of a cloud at the station was identified with three different factors. First, we checked the droplet size distribution measured from both the cloud spectrometers.

150 This was the main parameter to consider that the station was inside a cloud. Then, to confirm this assumption, we crosschecked the droplets counts with two meteorological variables; the relative humidity at the measurement site which was expected to be ~100 % and the horizontal visibility which should be less than 1 km, when the Sammaltunturi station is in the cloud. In case that one of the factors was not fulfilled, a final inspection was done visually using pictures recorded by an automatic weather camera installed on the roof of the station.

155 During PaCE 2004 and 2005 the sampling time of the FSSP-100 was 15 s. During Pace 2009 the instrument was set to sample at 10s. From 2009 until 2019 the sampling time was set to 1 s (1 Hz) for both instruments. PT100 sensor, Vaisala HUMICAP and BAROCAP sensors, the pyranometer, the heated cup and wind vane were also set to sample to 1 s. FD12P Vaisala weather sensor sampling frequency was 15 s. For every year, minute averages were calculated for each cloud spectrometer and each meteorological variable. As a result, we obtained the cloud droplet size distribution and several meteorological variables for each

160 minute and as derived parameters the N_c (cm^{-3}), LWC (g cm^{-3}), MVD (µm) and ED (µm). All data sets were converted to NetCDF format. All times in this work are given in UTC time. Our dataset includes a separate NetCDF and .cvs file for each cloud spectrometer and for each year under the file name PACE.yyyy.cloud_spectrometer.nc and PACE.yyyy.cloud_spectrometer.cvs. (example names). For every file, the sampling area (mm^2) and the probe air speed (ms^{-1}) that was used to derive each parameter is provided. In addition, it includes the cleaned timeline data set of the following cloud properties and meteorological variables: Year

165 (YYYY), day (DD), month (MM), hour (HH), min (MN), size bin lower limit, size bin higher limit, number concentration (cm^{-3}), liquid water content (g cm^{-3}), effective diameter (µm), median volume diameter (µm), the calculated dN/dlog$D$p (cm^{-3}) values in

each bin, temperature at 570 meters (ºC), dew point (ºC), humidity at 570 meters (%), pressure (hPa), wind speed (m s^{-1}), wind direction (degrees), global solar radiation (Wm^{-2}), photosynthetically active radiation (μmol m^{-2} s^{-1}) and the horizontal visibility (m). The derived cloud parameters (number concentration (cm^{-3}), liquid water content (g cm^{-3}), effective diameter (μm), median volume

170 diameter (μm)) were not included in the CIP files. The number of cloud droplets per minute in CIP size range lead to statistically biased values and for this reason we decided to exclude them. The variables, naming abbreviations and units are summarized in Table 2.

The CAS contains 30 size bins with forward scattering upper bin size of 0.61, 0.68, 0.75, 0.82, 0.89, 0.96, 1.03, 1.1, 1.17, 1.25, 1.5, 2, 2.5, 3, 3.5, 4, 5, 6.5, 7.2, 7.9 10.2, 12.5, 15, 20, 25, 30, 35, 40, 45 and 50 μm and the CIP contains 62 size bins with bin

175 size of 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 165, 180, 195, 210, 225, 240, 255, 270, 285, 300, 315, 330, 345, 360, 375, 390, 405, 420, 435, 450, 465, 480, 495, 510, 525, 540, 555, 570, 585, 600, 615, 630, 645, 660, 675, 690, 705, 720, 735, 750, 765, 780, 795, 810, 825, 840, 855, 870, 885, 900, 915 and 930 μm. For the FSSP-100 two different bin size ranges were used. During 2004 and 2005 the instrument was set up to use 30 size bins with forward scattering upper bin size of 3.0, 4.5, 6.0, 7.5, 9.0, 10.5, 12.0, 13.5, 15.0, 16.5, 18.0, 19.5, 21.0, 22.5, 24.0, 25.5, 27, 28.5, 30.0, 31.5, 33.0, 34.5, 36.0, 37.5, 39.0, 40.5, 42.0, 43.5, 45.0, 47.0.

180 From 2009 until 2015, the FSSP was set up to use 40 size bins with forward scattering upper bin size of 1.2, 2.4, 3.5, 4.7, 5.9, 7.1, 8.2, 9.4, 10.6, 11.8, 12.9, 14.1, 15.3, 16.5, 17.6, 18.8, 20, 21.2, 22.3, 23.5, 24.7, 25.9, 27, 28.2, 29.4, 30.6, 31.7, 32.9, 34.1, 35.3, 36.4, 37.6, 38.8, 40, 41.1, 42.3, 43.5, 44.7, 45.8 and 47 μm.

Measurements of each year were inspected to ensure a good quality in this data set following the same steps. First, the raw data set was checked in order to eliminate and exclude from further analysis any case when each cloud probe was partially or fully

185 blocked. Then, we used the suggested limitations (Doulgeris et al., 2020) for the data analysis of the CAS and FSSP-100 ground setups. There, it was pointed out that the CAPS (that was fixed to one direction) showed significant sampling losses when it was not facing the wind direction. For this reason, the data that were obtained in the wind iso-axial conditions were considered to have the best quality. Thus, regarding CAPS, only the measurements when the instrument was facing the wind direction were included. FSSP-100 ground setup was always directed against the wind direction and as a result we provided measurements from all wind

190 sectors. Missing data points were marked as -9999.9.

As it is shown in Fig.4, the observation hours after PACE 2013 when the campaigns had longer duration are significantly more. The amount of data set in these years is unique and provides a significant source of information. An overview of meteorological variables is presented for each campaign during the FSSP-100 and CAPS ground setups were operative. In Fig. 5, a statistical description of the temperature at 570 MSL for each campaign is illustrated. In Fig. 6, the percentage of the data set for

195 each year that the Global solar radiation was more than 0 is shown to estimate the amount of data we had for each campaign during sunlight. Moreover, an overview of the microphysical derived cloud properties data from each campaign is presented. Thus, in Fig.7, Fig.8 and Fig.9, the number concentration, the effective diameter and the liquid water content are presented for each campaign and f the FSSP-100 and CAS ground setups respectively.

4. Data availability

Each described data set was collected by Finnish Meteorological Institute during PaCE campaigns and was published in the described form at FMI open data repository. All data sets have undergone thorough quality control and false readings were eliminated. Datasets can be all found here: https://doi.org/10.23728/FMI-B2SHARE.988739D21B824C709084E88ED6C6D54B

205 (Doulgeris et al.,2021).

5. Code availability

210 Software developed to process and display the data from the cloud ground base spectrometers are not publicly available and leverages licensed data analysis software (MATLAB). This software contains intellectual property that is not meant for public dissemination.

6. Summary

215 In this study we produced and summarized data sets obtained from two cloud ground base spectrometers (CAPS and FSSP-100 ground setups) owned by the FMI during eight years of PaCE campaigns conducted during autumns from 2004 until 2019 along with several meteorological variables. PaCE campaigns took place in the Finnish sub-arctic region in a clear environment in temperatures that were usually below zero. In section 2, we describe the measuring site where PaCE campaigns took place and the cloud ground spectrometers setups that were used to obtain the cloud data along with the instrumentation that was used to monitor

220 the weather conditions. In Section 3 an overview of the presented data set is presented.

       These observations gathered in sub-arctic conditions are a unique source of *in situ* cloud measurements, which can contribute to the understanding of the cloud dynamics and formation in a sub-arctic environment in different meteorological conditions. Such semi long observations are difficult to obtain in similar environments due to current lack of instrumentation. Each data set includes a combination of cloud microphysical properties (size distribution as a measured parameter and additionally as

225 derived parameters the number concentration, effective diameter, median volume diameter and the liquid water content) along with several meteorological variables (temperature, dew point temperature, humidity, pressure, wind speed, wind direction, (global solar) sun radiation and visibility). Even though the data set includes measurements from eight campaigns, we would propose a case-by-case cloud investigation. Due to the inhomogeneity of the presented cloud cases, it is challenging to retrieve any trend that can be unambiguously connected to changes in the atmosphere. Also, the quality of data set may differ for each campaign due to the

230 different amount of observations per year and our experience to operate the ground-based spectrometers through the years. In addition, each cloud case could be of different mass origin. We therefore strongly recommend avoiding any trend analysis based on the presented data set. However, this data set provides a helpful contribution to cloud microphysics processes on shorter timescales. Furthermore, it can be used as complementary in model development.

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Appendix A: Abbreviations

PaCE	Pallas Cloud Experiment
GAW	Global Atmosphere Watch
UAS	Unmanned Aerial System
FMI	Finnish Meteorological Institute
CAPS	Cloud, aerosol and precipitation spectrometer
CAS	Cloud and aerosol spectrometer
CIP	Cloud imaging probe
LWC_{hw}	Hot -wire liquid water content sensor
FSSP -100	Forward-scattering spectrometer probe
DMT	Droplet Measurement Technologies
PMS	Particle Measuring Systems
PSL	Polystyrene latex sphere
N_c	Number concentration
LWC	Liquid water content
ED	Effective diameter
MVD	Median volume diameter
T	Temperature at 570 MSL
T_{DP}	Dew point temperature
RH	Relative Humidity at 570 MSL
P	Pressure
W_s	Wind speed
W_{dir}	Wind direction
S_{rad}	Global solar radiation
PAR	Photosynthetically active radiation
V	Horizontal Visibility

260   *Author contributions.* KD wrote the paper with contributions from all co-authors. HL planned and coordinated PaCE 2004, 2005, 2009. HL and DB planned and coordinated PaCE 2012 and 2013. KD and DB planned and coordinated PaCE15, 17 and 19. KD and DB processed, analyzed and quality controlled the data set. VMK and APH reviewed and edited the manuscript.

Competing interests. The authors declare no conflict of interest.

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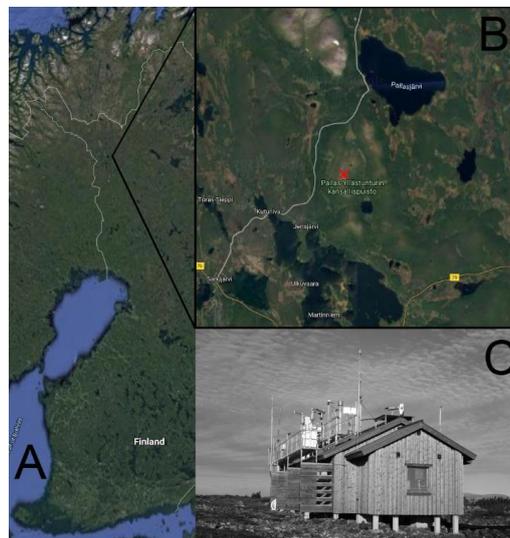
Figure 1. (a) Map of Finland showing the location of the measuring station, and (b) map of the wider Pallas area showing the
Sammaltunturi measuring station (red cross). © Google Maps (c) The Sammaltunturi measuring station during PaCE.

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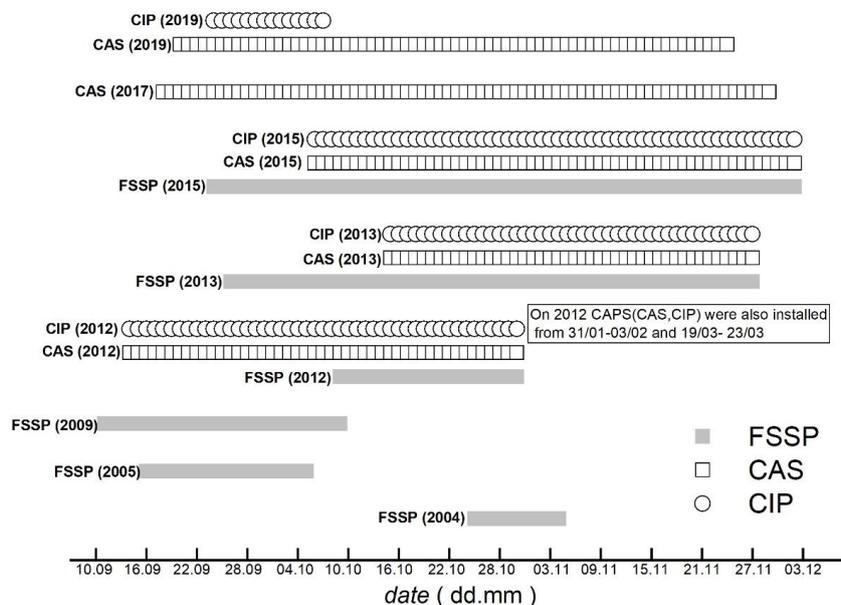
Figure 2. Cloud spectrometer ground setups' availability during PaCE is presented for each year.

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Table 1: An overview of instrumentation and their operational characteristics provided by manufacturer.

Instrument	Operating range	Number of bins	Sampling frequency	Air speed range	Accuracy	Uncertainties
Cloud instruments						
CAS, DMT	0.51 µm to 50 µm	10, 20, 30, or 40	0.05 to 40 Hz	10 - 200 ms^{-1}	upper N_c > 1,000 cm^{-3} after corrections for coincidence that are about 25% at 800 and 30% at 1,000 particles/cm³ Sizing accuracy: 20%	ambient N_c of 500 cm^{-3}: 27% undercounting and 20%–30% oversizing bias Lance et al. (2012) *LWC*: 40% (DMT Manual)
CIP, DMT	12.5 µm to 1.55 mm	62	0.05 to 40 Hz	10 - 300 ms^{-1}	upper N_c range up to 500 particles/ cm³ for a CIP with standard tips and arm width sizing accuracy: 1 µm	digitization uncertainty of approximately 61 size resolution that depends upon where the particle passes across the array Baumgardner et al. (2017)
FSSP-100, PMS	0.5 µm to 47 µm	15,30 or 40	0.05 to 40 Hz		N_c accuracy: 16% sizing accuracy: ±3 µm *LWC* accuracy: 30%–50% Baumgardner (1996)	derived *ED*: 3µm derived *LWC*: 30% Febvre et al. (2012)

	Range	Resolution	Sensitivity	Accuracy
Meteorological instruments				
PT100 sensor, Vaisala	-70 – +180 (°C)	0.01 (°C)		±0.1 (°C)
HUMICAP sensor, Vaisala	0 – 100 (%) RH	<0.01 (%) RH		±0.8 (%) RH
BAROCAP sensor, Vaisala	500 – 1000 (hPa)	0.01 (hPa)		±0.15 (hPa)
heated cup and wind vane, Vaisala	0.4 – 75 (ms^{-1}) 0 – 360°	0.1 (ms^{-1}) 1°		±0.17 (ms^{-1}) ±3°
Pyranometer, Vaisala	305 – 2000 (Wm^{-1})		9– 15 (µV Wm^{-2})	< ±20 Wm^{-2} at 1000 Wm^{-2}
FD12P, Vaisala	10 - 50000 (m)			±10 %, 10 –10000 m ±20 %, 10000 –50000 m

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Figure 3. CAPS (left) and FSSP-100 (right) ground setups as installed on the roof of Sammaltunturi station.

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Table 2: Cloud properties and meteorological variables along with abbreviations and units as they are included in each data set.

Variable name	Abbreviations	Units	Comments
Cloud properties			
Number concentration	N_c	cm^{-3}	derived parameter
Liquid water content	LWC	g cm^{-3}	derived parameter
Effective diameter	ED	µm	derived parameter
Median volume diameter	MVD	µm	derived parameter
Size distribution	dN/dlog$D$p	cm^{-3} µm^{-1}	calculated from min averages counts per bin
Meteorological variables			
Temperature at 570m	T	°C	PT100 sensor
Dew point temperature	T_{DP}	°C	
Relative Humidity at 570m	RH	%	Vaisala HUMICAP sensor
Pressure	P	hPa	Vaisala BAROCAP sensor
Wind speed	W_s	ms^{-1}	measured with a heated cup
Wind direction	W_{dir}	degrees	measured with a heated wind vane
Global solar radiation	S_{rad}	Wm^{-2}	Pyranometer
Photosynthetically active radiation	PAR	µmol m^{-2} s^{-1}	Photovoltaic detector
Horizontal Visibility	V	m	FD12P Vaisala weather station

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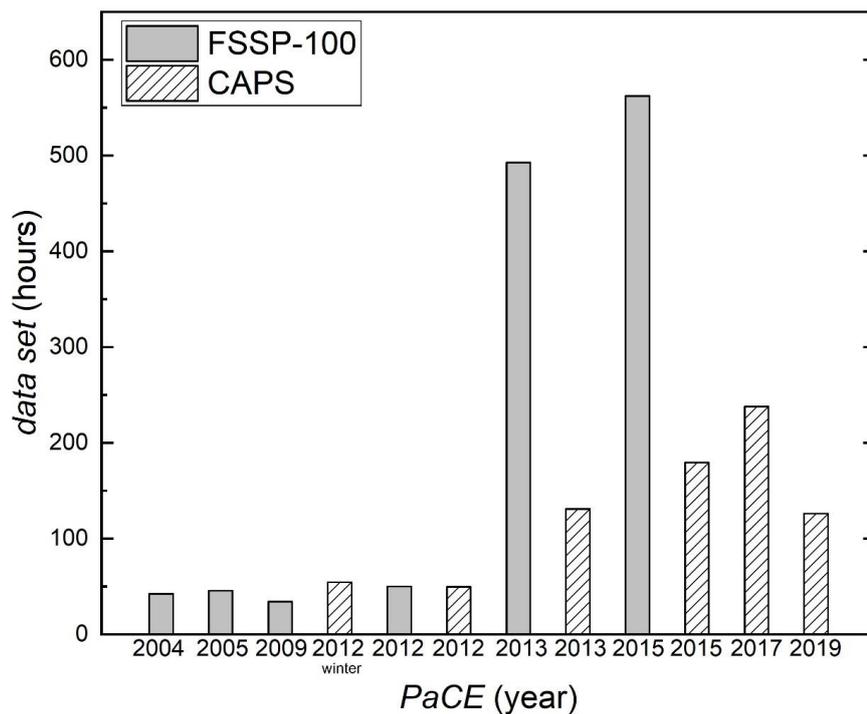
Figure 4. Hours of observation data collected for each PaCE campaign when the FSSP-100 and CAPS ground setups were operative.

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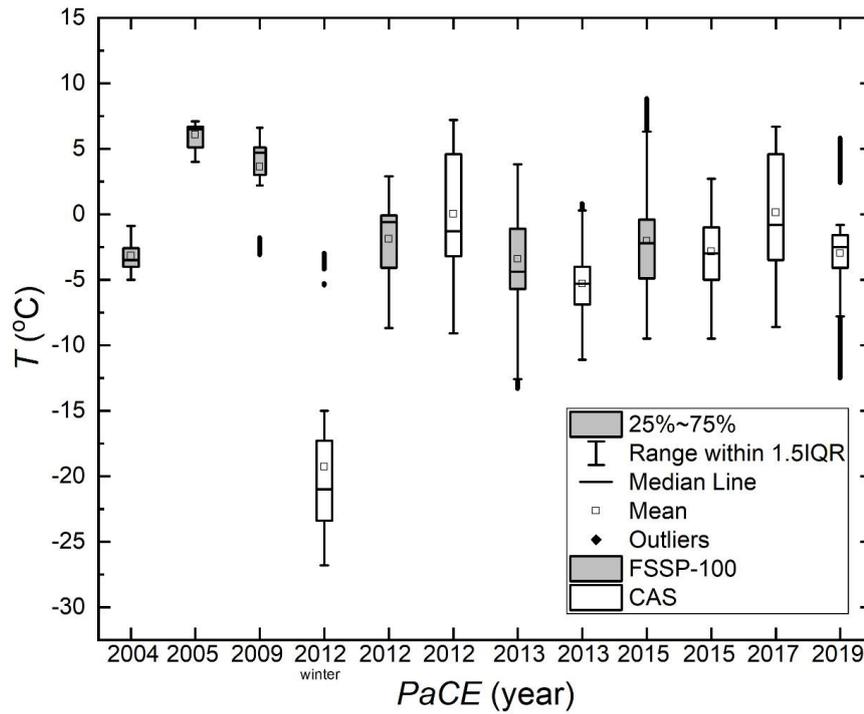


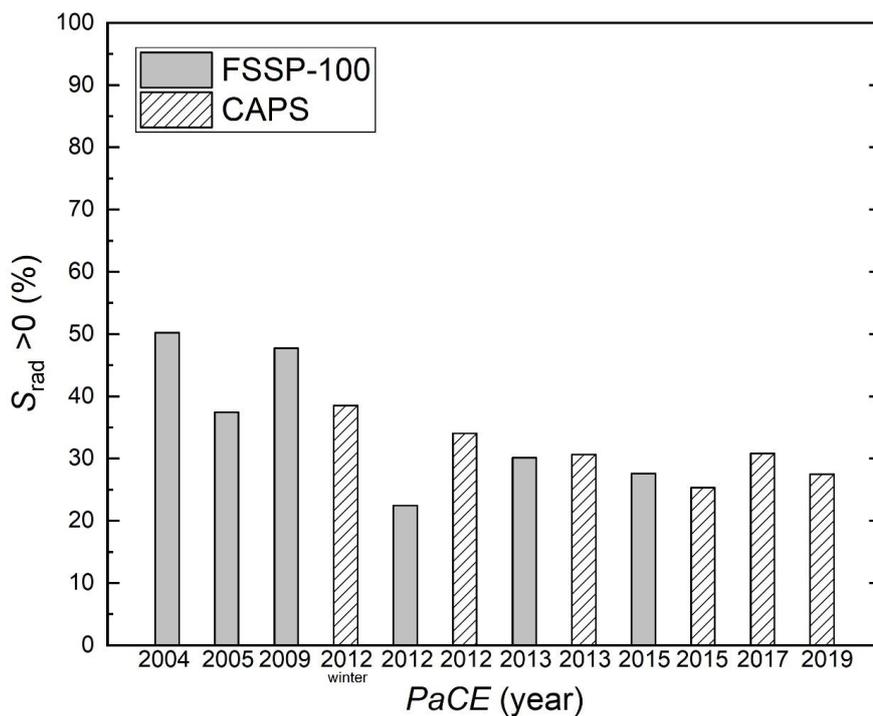
Figure 5. Statistical description of the temperature at 570m above MSL for each PaCE campaign when the FSSP-100 and CAS ground setups were operative.

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Figure 6. The percentage of the global solar radiation that was more than 0 during each campaign when the FSSP-100 and CAS ground setups were operative.

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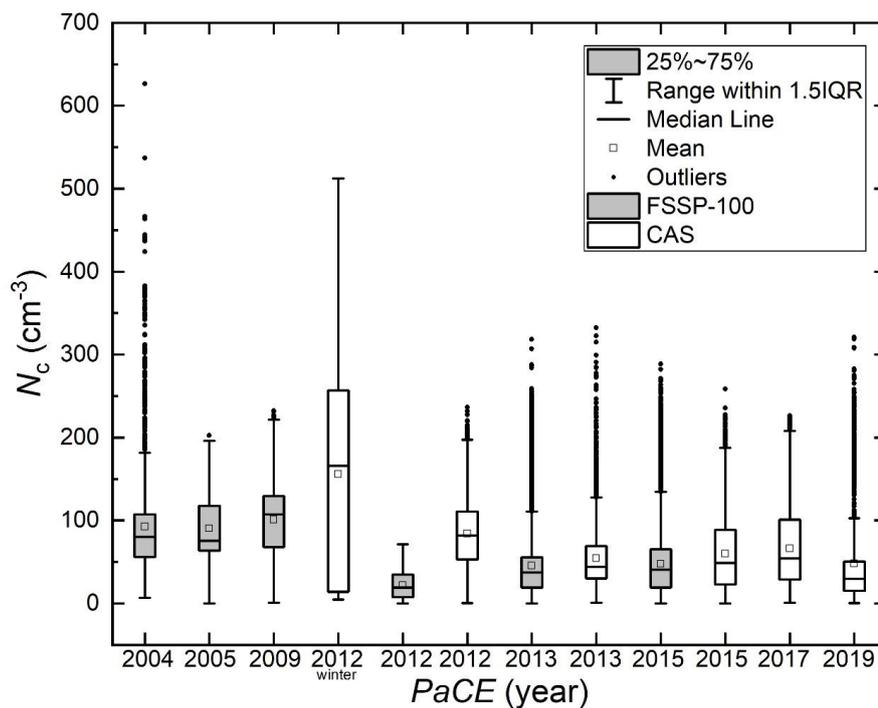
560   Figure 7. Statistical description of N_c for each PACE campaign during the FSSP-100 and CAS ground setups were operative.
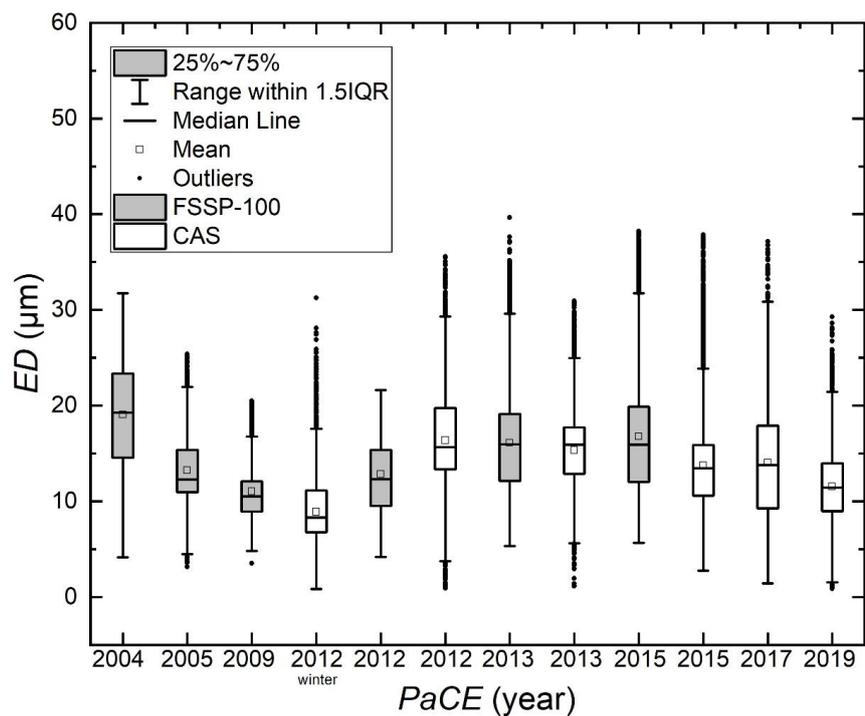
Figure 8. Statistical description of *ED* for each PACE campaign during the FSSP-100 and CAS ground setups were operative.

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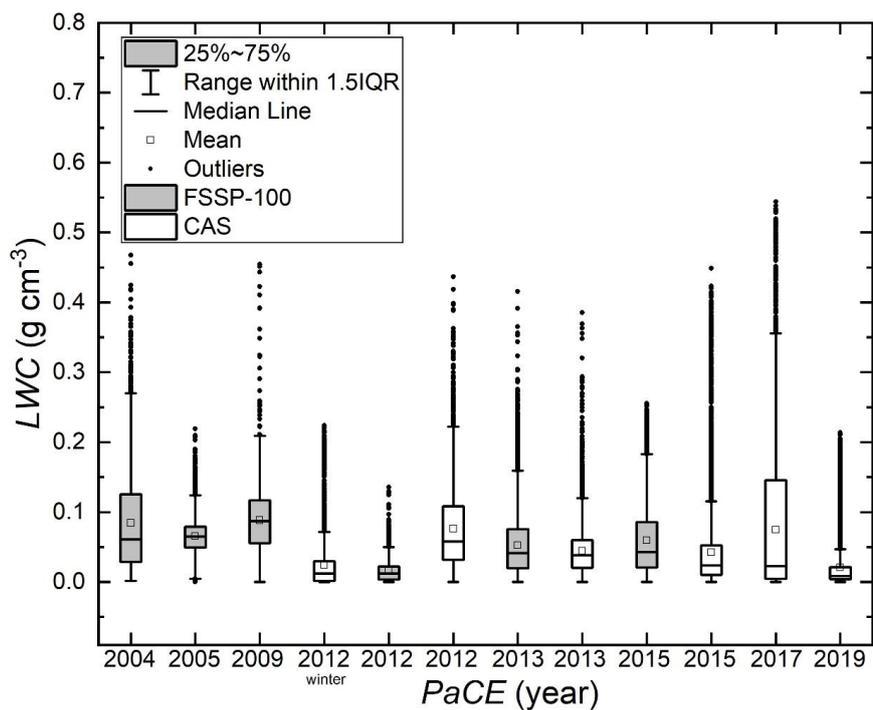
Figure 9. Statistical description of *LWC* for each PACE campaign when the FSSP-100 and CAS ground setups were operative.

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