Deliverable D3.12: Standardization and data submission protocol for PVM measurements

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Comments	The submission of this deliverable, initially due the end of August 2017, is delayed due to a combination of both logistics and the need to finalize results obtained from the recent cloud microphysique inter-laboratory comparison (ILC). The first Cloud Microphysique ILC within ACTRIS 2 was held in October 2016. This involved 7 different research groups and 2 private companies working together at the Puy de Dome station, in Clermont Ferrand. The analysis of the data from the ILC coincides with the due date for this WP deliverable. This

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	together with the change in the organization of the personnel involved in this work package required more time than initially estimated to prepare this report.

1.0 Background and objectives of Task 3.12

A number of instruments available that are used to characterise cloud properties, the most commonly used of these instruments is the Gerber particulate volume monitor (PVM) probe. This instrument provides a measurement of aerosol liquid water content (LWC) and effective droplet diameter (Re). There are approximately 5 of these instruments operating at ACTRIS facilities throughout Europe. The aim of task 3.12 is to harmonise the operating and analysis procedures of these probes within the ACTRIS community. This will be achieved by providing recommendations and standard operating procedures (SOPs), and to define a format for the data submission to the data portal. .

These recommendations and SOPs are developed in collaboration with the ACTRIS community by comparing all instruments together during an intercomparison exercise. The intercomparison field campaign, organised by CNRS-LaMP, of cloud relevant products, took place at the PUY station in October 2016 (3-5 Oct: set-up, 6-25 Oct: measurements, Oct 26-28). Three weeks of measurements have been chosen so as to maximize the chance to measure clouds at the Puy-de-Dôme station. The month of October was choosen as it is a period with a high frequency of clouds, without being exposed to low temperatures that can often lead to the formation of ice on probes and inlets. The principal aims of this first intercomparison was to compare the PVM probes, evaluate their performances and to compare them to other cloud measuring instrumentation.

The first phase of the campaign preparation involved the identification of potential groups within Europe, but also outside Europe (for companies) that would be interested in such a campaign. For the campaign, the objectives were to first evaluate the intervariability of LWC and Re measurements, and secondly, to provide a set of recommendations and standard operating procedures to the ACTRIS community, define data format for submitting data through the ACTRIS data portal.

Part I First interlaboratory intercomparison

During the EU FP7 ACTRIS, the first ILC intercomparison took place in October 2016 at the PUY station, allowing the simulataneous sampling of 17 natural cloud events. A total of 10 different types of cloud microphysics instruments were tested, with 4 of these being PVM ground based probes, 1 airborne PVM probes, 2 cloud droplet probes (CDP) (Table 1). 11 Research groups from 6 different countries participated in the intercomparison. Of these one research group was an external user and two participants were from private companies, ADDAIR and PALAS. The four ground based PVM probes were located in the roof and the remaining probes were tested in the wind tunnel. Measurements of aerosol concentrations behind the whole air inlet (WAI) was performed using several types of OPC instruments, providing information on cloud droplet residues number concentrations, when compared to the interstitial inlet measurements.

In the present deliverable, we assess the intervariability of two parameters describing the general properties of clouds, for a single type of probe (PVM). Four PVM (Gerber manufactured) probes participated to the roof platform intercomparison campaign, as well as a fifth custom-made PVM probe (CNRS LaMP) (not included in the intercomparison results). These PVM probes use an optical measurement to determine the liquid water content (LWC) of individual droplets. The measurement generates a voltage, which is converted to LWC using the calibrated values. Calibration values are determined using a disk supplied with the instrument. It is important to note that each calibration disk is specific to the instrument and therefore cannot be interchanged. The value of LWC is provided in grams of condensed liquid water per cubic meter of air (g m-3), while the effective radius (Re) is a measure of the average size of the cloud droplets population, measured in microns.

This report aims to summarise the comparison of the four PVM located on the roof of the PUY de Dome station. The complementary exercises in the wind tunnel will not be included here but in a separate manuscript.

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Group	Contact person	Instrument	Location
OPGC/LaMP (France)	Jean-Marc PICHON	Gerber-PVM-100, , OPC-WELAS DMT CDP-2-PbP	Roof Behind WAI Wind tunnel
FMI (Finland)	David Brus, Konstantinos Doulgeris	Fssp-1000 (Rotating plateform)	Roof
PALAS (Germany)	Maximilian Weiß, Boris Walter	FIDAS (Dry)	Behind WAI
ADDAIR (France)	Alexandre Marpillat, Ayoub Hjirate	FIDAS (Wet)	Behind WAI
PSI (Switzerland)	Günther Wehrle	Gerber-PVM-100, Dew point mirror	Roof Behind WAI
LMD (France)	Jean-Charles Dupont	Diffusometer, Degreanne, DF20+ Fog monitor on swivel LOAC	Roof
CNR-ISAC (Italy)	Leone Tarozzi	Gerber-PVM-100	Roof
ETHZ (Switzerland)	Jan Henneberger, Fabiola Ramelli	**Fog Monitor on rotor** Holograophic imager, HOLIMO	**Roof** **Roof**
Univ. Hertfordshire (UK)	Helen Smith	UCASS-dropsonde Ground-based UCASS	Wind Tunnel Roof
IFT (Germany)	Kai Szodry Holger Siebert	Gerber-PVM-100 Airborne PVM Gerber DMT-LWC -300 (King Probe)	Roof Wind tunnel Wind tunnel

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DMT (USA)	Matt Frier	BCPD	Wind tunnel

Table 1. Summary of the participating groups and instruments during the intercomparison exercise.

I.1 Description of the campaign

The overall meteorological conditions (global solar radiation, temperature, relative humidity, wind speed, wind direction, liquid water content) covering the intercomparison field campaign (Figure 1) show a high variability in wind speed (0.2 to 19.8 m s^{-1}), direction, temperature (-1.7 to 11.5 °C) and LWC (up to 1.2 g m-3) **(Figure 1)**. The meteorological conditions during the campaign in terms of cloud events were sufficient and allowed us to do pertinent intercomparison of cloud parameters and to evaluate the critical operating conditions of the instrumentation. Therefore the main objectives of this ACTRIS campaign could be reached.

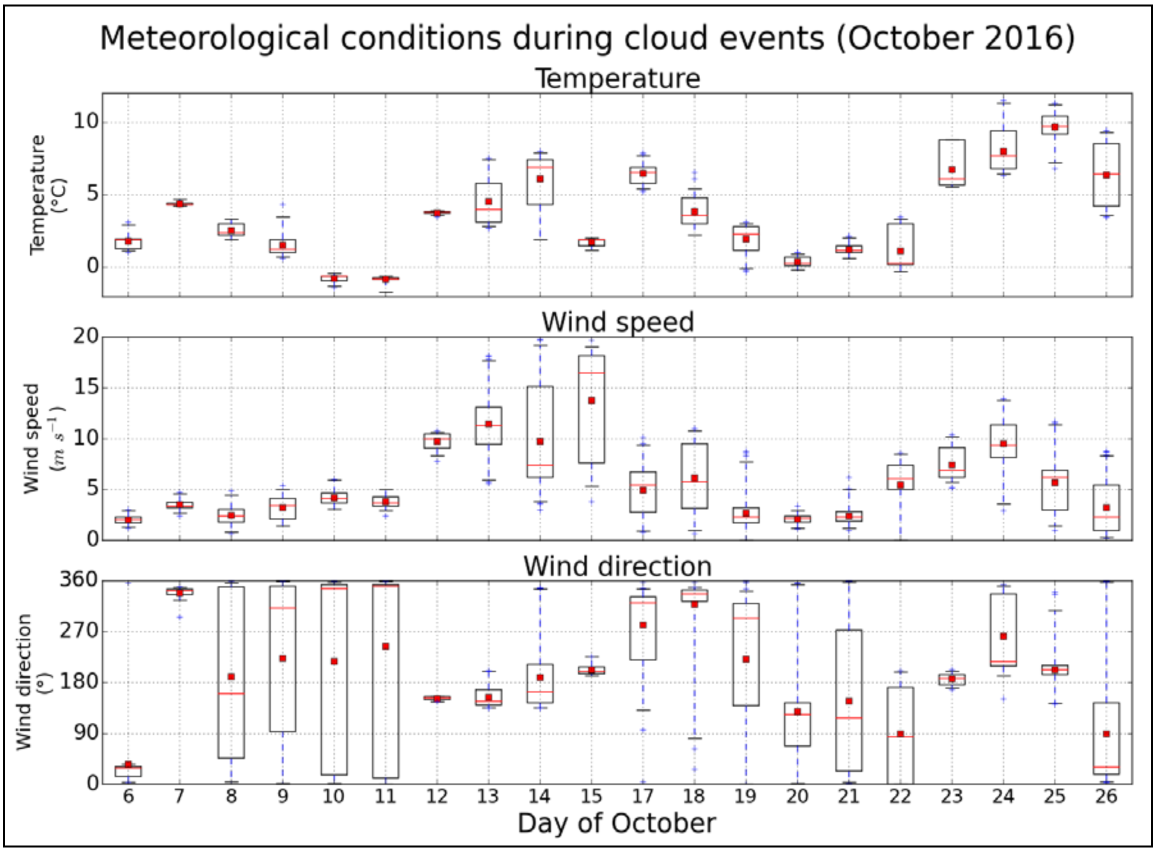

Figure 1. Meterological parameters measured during the cloud intercomparison campaign on the puy de Dome.

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Clouds were measured during 193 hours (equivalent of 8 days) between the 6th and the 26th of October (21 days of measurements). During 38 % of the time, the station was in clouds. The 193 hours of cloud data were divided according to different classes of wind speed underwent during the measurements (figure 2): around a half of cloud data (54 %, 104 hours) was obtained during a low wind speed (below 5 m s^{-1}), a third (29 %, 56 hours) during an intermediate wind speed (between 5 and 10 m s^{-1}) and 17 % (33 hours) with a relative high wind speed (higher than 10 m s^{-1}). As a first approach, the liquid water content of the clouds was quantified according to the classes of wind speed to see if the more consistent clouds were measured depending on the wind speed (Figure 2.0). We observe that low wind speeds (<10 m s^{-1}) favour low LWC clouds (LWC < 0.4 g m^{-3}) while high wind speed favour high LWC, likely due to higher updraft velocities during high wind speed conditions. The insrument intercomparison will be performed for these two wind speed ranges. A dependance of the instrument interoperability will also be performed as a function of wind direction and temperaure.

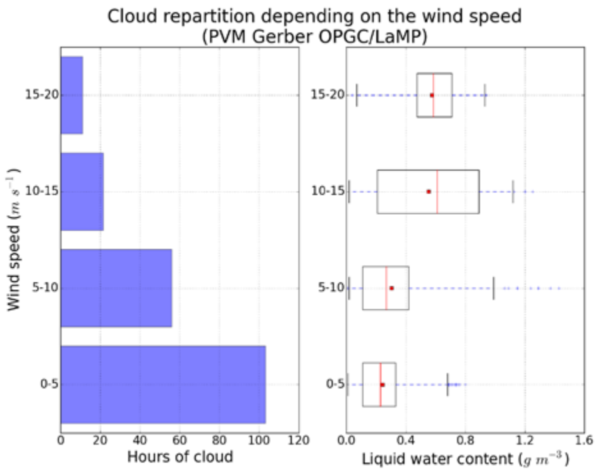

Figure 2. 0 Classification of LWC of the clouds as a function of average windspeed

1.2 Variability of measurements of LWC and Re by PVM cloud droplet probes

A total of 4 PVM instruments were installed on the roof of the Puy de Dome station, additional PVMs and other probes were situated in the wind tunnel, as well as a dew point mirror and aerosol particle measurements operating behind the WAI. (Table 1),

(Figure 2). For the principal intercomparison exercise we will focus on the PVM measurements installed on the top of the roof.

All instruments were installed and calibrated prior to the measurement campaign. The calibration was performed by each of the instrument users using the calibration disk corresponding to their PVM instrument. Instruments were then installed on the roof (Figure 3) and operated on a continuous basis for the duration of the three weeks. No additional calibrations were performed during the intercomparison. Instrument operation was validated during clear sky episodes, where all instrument measurements should fall to 0.

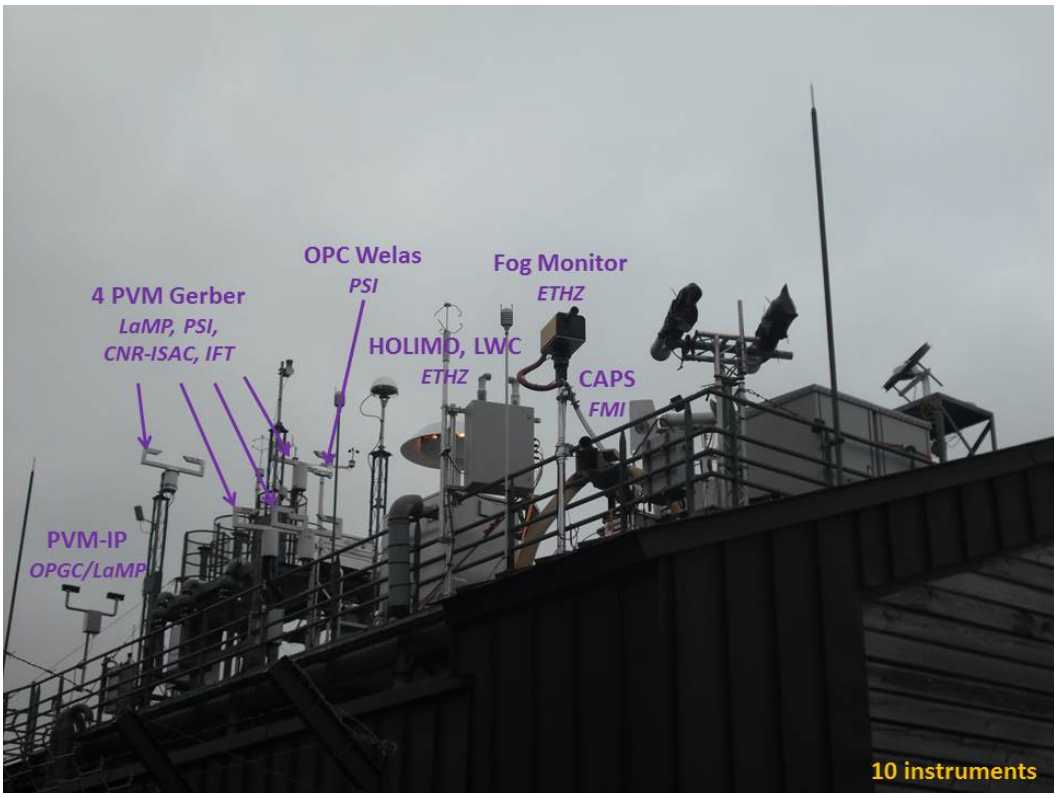

Figure 3: Instruments installed on the sampling plateform of the puy de Dome station.

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The time series of the four operating PVM instruments is illustrated in Fig. 4.

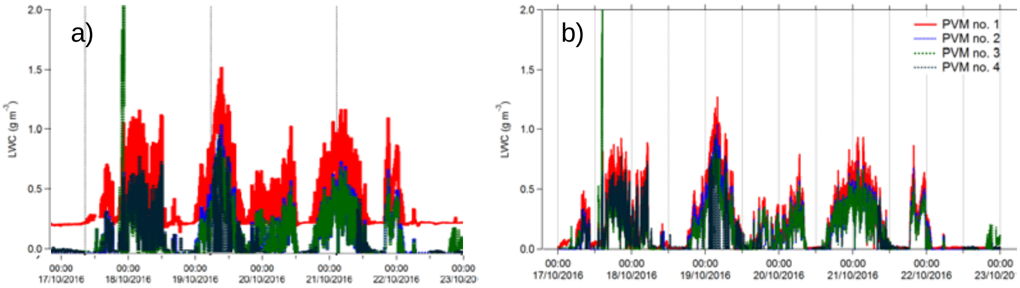

Figure 4. Intercomparison of the four operating PVM instruments a) before correction for offset b) after correction for offset.

During the ILC period, one out of the four instruments was not functioning correctly (showing variable readings of LWC during clear sky periods). Although, this can be considered to be part of the intervariability of measurements across European stations we chose to remove the instrument from the intercomparison since it was clearly not functioning correctly, and would bias the median values. The following discussion will only include the comparison of the three PVM probes on the roof of the PUY station. Instrument no. 3 had to be corrected using a constant offset of 0.23 (Fig. 4a and b, Fig 5). This offset was chosen as the average value that the instrument measured during clear sky periods. Despite this offset being applied this instrument measures approximately 20% higher LWC concentrations that the two other instruments (Fig. 6). Instruments 2 and 3 operated without issues for the duration of the sampling campaign with no change in the offset observed during the sampling time.

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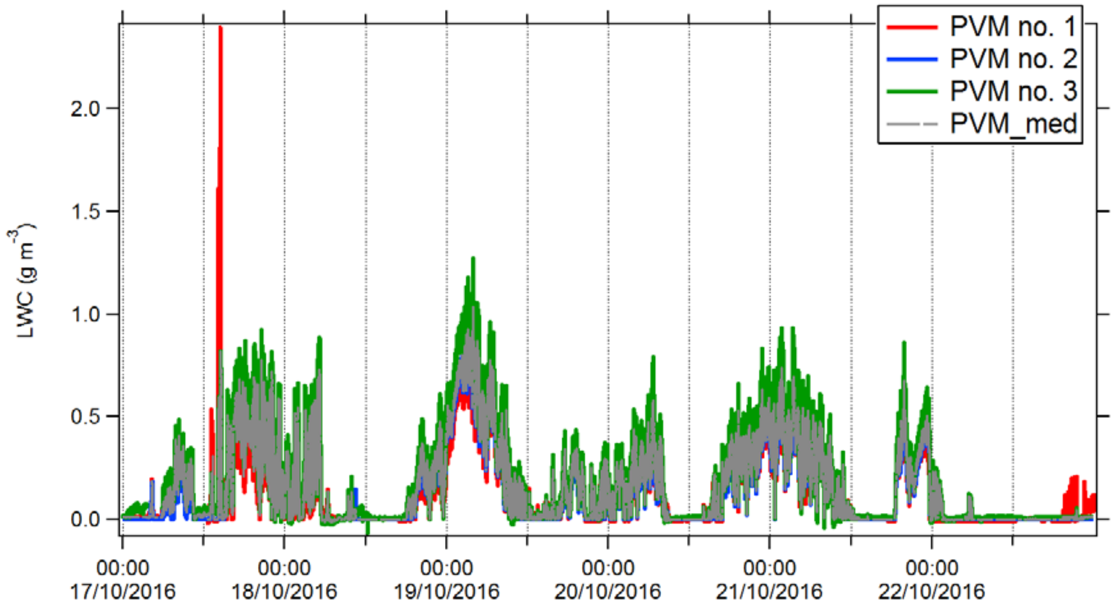

Figure 5.0 Time series of the three operating PVM instruments and the Median values of these three instrument.

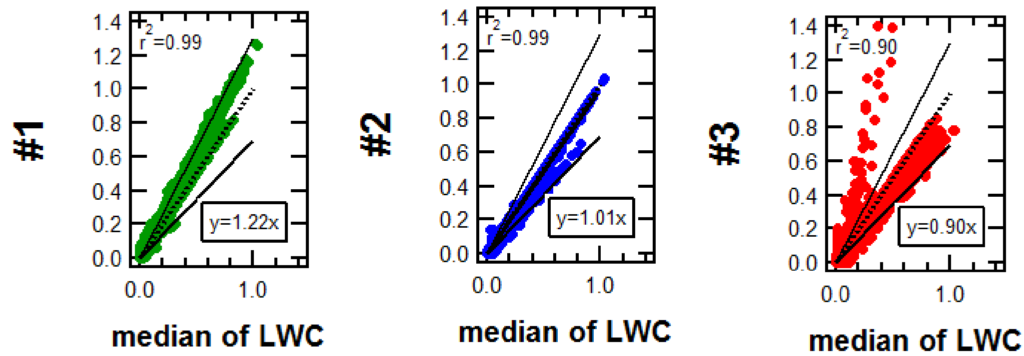

Figure 6.0 Scatter plots illustrating the agreement of the three instruments with the mean values.

Of the three remaining PVM instruments, all measurements tend to fall into ±30% of the 1:1. A detailed calculation of the error associated with these measurements is required in order to assess an acceptable range of measurements. Using co-located measurements of wind speed and direction we classified these measurements as a function of wind speed and assess their interomparability. No biases in the measurements were observed over the wind speed and direction measured during this experiment.

For the measurements of the effective diameter only two instruments provided measurements (PVM no. 2 and no.3) (Fig.7). It is noted that during the intercomparison period, Re calculated by these two probes changed considerably, having a slope of 0.90 during the first phase of the experiment and 1.49 during the last part of the intercomparison (Fig. 7b). The instrument operation was modified and recalibrated between the two periods. The difference seen here highlights the need for strict and reproducible calibration protocols. These protocols would avoid such variability in the measurements.

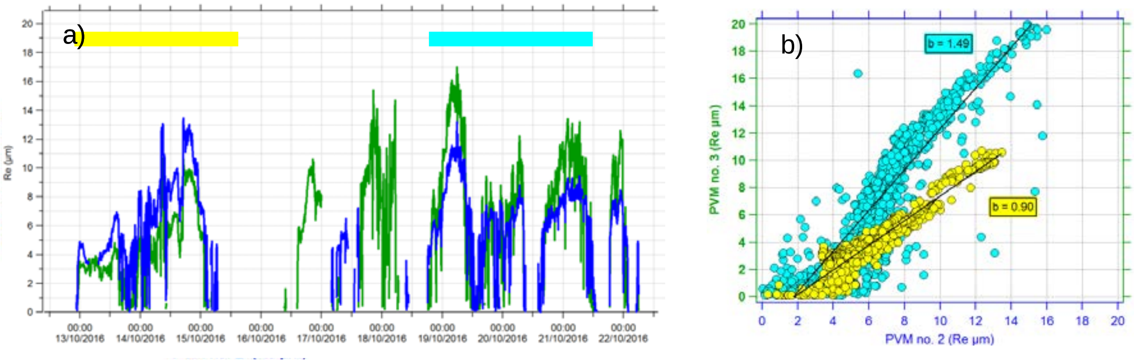

Figure 7.0 a) Timeseries and b) scatter plot of the effective diameters of the two PVM probes that were operating during the intercomparison.

I.3 Outcomes

The PVM instrument is a valuable tool to any observation station exposed to cloud cover. One of the main advantage of the instrument is the independence of the measurements to wind speed and direction. The PVM instrument is capable of providing high resolution data on a continuous basis, however, under harsh conditions with low temperatures or high humidities, the instrument requires regular interventions.

During the intercomparison, 3 out of the 4 instruments worked correctly. After post data processing satisfactory agreement of the remaining three instruments was obtained. Further analysis of co-located instrumentation is required in order to determine how PVM probes compare with similar microphysical instruments.

Part II: Data submission protocol

This template is a first step towards collecting data for in-situ cloud liquid vapour content (LWC) and cloud droplet effective radius (Re) measured at ground stations. A regular submission or level 2 file contains the data referenced to standard conditions of temperature and pressure (273.15 K, 1013.25 hPa).

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Data from the PVM gerber should be acquired every second, however data submission should be averaged over 5 minutes. This ensures that files sizes are manageable.

➔ **<u>Data 0</u>**: Data acquired directly from the PVM gerber and averaged over 5 minutes.

```
99 1001
PRINCIPLE investigator
Name of research group, and full address
PERSON responsible for analyzing data.
Networks concerned by measurements: ACTRIS
1 1
2014 04 14 2016 02 18
0.041667
days from file reference point
25
1 1 1 1
9999.999999 9999.999 9999.999 9.999 9999.999
end_time of measurement, days from the file reference point
LWC, g/m3, Statistics=arithmetic mean, Detection limit=0.05 g/m3
LWC, g/m3, Statistics=Standard Deviation calculated from Mean values
numflag, no unit
Re, um, Statistics=arithmetic mean, Detection limit=0.01 um
Re, um, Statistics=Standard Deviation calculated from Mean values.
numflag, no unit
PSA, Statistics=arithmetic mean, Detection limit=0.005 ug N/m3
PSA, Statistics=Standard Deviation calculated from Mean values
numflag, no unit
RH,(%) Statistics=arithmetic mean
RH (%), Statistics=Standard Deviation calculated from Mean values
Temperature (°C),  Statistics=arithmetic mean,
Temperature (°C), Statistics=Standard Deviation calculated from Mean values
```

➔ **<u>Data 1</u>:** Comparison of PVM gerber with RH and temperature sensors to identify periods when LWC was not operating correctly. (Low RH is a good indicator for clear sky periods, negative temperatures will help identify if ice is accumulated on the probes)

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Code	Valid/invalid	Description	Comment
0	V	**Valid Measurement**	**Used for valid data higher or lower than the 2 sigma range at the station.**
110	V	**Episode data checked and accepted by data originator.**	**Unexplained extreme values, technical problem suspected.**
459	I	**Extreme value, unspecified error**	**For example, peak not seen by other co-located instruments.**
499	V	**Inconsistent with another unspecified measurement.**	**Relative humidity < 40% during high LWC values.**
662	V	**Too high sampling flow, data considered valid.**	**Only valid for CDP instruments.**
672	V	**Station inside cloud**	**Visual inspection of camera images, when available**
677	I	**Icing or hoar frost in the intake.**	
699	I	**Mechanical problem, unspecified reason.**	
980	I	**Missing due to calibration or zero/span check**	
999	I	**Missing measurement, unspecified reason**	

Table 1 List of flags for data submission.

Suggested operating procedure/best practices

This document contains recommendations for setup, operation, maintenance and data analysis procedures for the PVM Gerber 100; Information in this reference is drawn from the PVM gerber manual. The manual outlines the field sample set up as well as calibration and maintenance procedures. A very brief description of these procedures will be provided below.

Accessories needed

Calibration disk (specific to the PVM-100 instrument)

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Alcohol (Cleaning of instrument optics)

Maintenance.

Calibration of the signal (*Monthly*)

It is recommended to calibrate the PVM gerber once a month. The calibration of the PVM gerber is performed using the calibration disk specific to each instrument. The full calibration procedure is outline on page 20 of the manual.

Cleaning optics (*when needed*)

The successful long-term operation of the PVM-100 in the field depends strongly on keeping the instrument optics clean. The recommended procedures for cleaning and maintaining the instrument optics are outlined on page 23 and 24 of the manual. The optics can be cleaned once every month or when the offset during clear sky periods is greater than 0.

Yearly maintenance:

It is recommended to change the air pump every year. Replacement pumps can be purchased directly from GSI.

Operation analysis

Sampling time

- ➔ It is recommended to acquire data every second but for the data submission to average data over 5 minute periods. This has the advantage of having sufficient temporal resolution with file sizes that are reasonable for submission.

5 .0 Future plans for the PVM within ACTRIS

The ACTRIS-2 WP3 Task 3.2.1 deliverables related to the PVM measurements are to first include these measurements as a new parameter being measured at a number of relevant sites. Data will be submitted to EBAS.

There are currently 5 stations within ACTRIS that are measuring these parameters. It will be necessary to identify other suitable stations to increase the size of the network.

The chain of events is:

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i. *Publication outlining the results on ILC1 for all PVM instruments together with measurements made in the wind tunnel.*
ii. *Provide up to date SOPs, and data submission protocols for the PVM instruments.*
iii. *Determine frequency for intercomparisons exercises*

References:

Guyot, G. ; Gourbeyre, C. ; Febvre, G. ; Shcherbakov, V. ; Burnet, F. ; Dupont, J-C ; Sellegri, K. Jourdan, O., 2015 Quantitative evaluation of seven optical sensors for cloud microphysical measurements at the Puy-de-Dôme Observatory, France Atmos. Meas. Tech. Vol. 8 , p. 4347-4367 DOI 10.5194/amt-8-4347-2015 (EGU)

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