Deliverable D12.2: Documentation of the inter-comparison campaign of the instruments used in tower-based measurements

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The purpose of the WP12 is to standardize the vertical exchange measurements of aerosol particles in the planetary boundary layer using a combination of state-of-the-art in-situ and remote-sensing techniques. Here the in-situ measurements mainly refer to the tower-based eddy covariance (EC) technique which combines a three-dimensional anemometer measuring wind and a particle counter. The EC technique is the most direct method to measure the aerosol flux (or exchange) between the surface and the atmosphere. Within ACTRIS-2 these tower-based particle flux measurements are made at six sites (AGORA in Spain, Auchencorth Moss (AUC) in UK, Cabauw in the Netherlands, Hyytiälä and Pallas in Finland and Kosetice in Czech Rebublic) above different land cover types. At each site, different particle counter models are used as part of the EC systems, which creates challenges for interpretation and comparison of the measurements. One of the main aims of the WP12 was to conduct an inter-comparison campaign where the particle counter models used at the various sites would be run in parallel with the same anemometer in order to better understand the differences originating from the usage of different particle counters.

The campaign took place in Hyytiälä Forestry Field Station in Finland between 24 April and 22 May 2017. A total of seven particle counters were included to the comparison with some of the models used at the actual ACTRIS-2 sites (Table 1). In addition to the condensation particle counter (CPC) models we had one mixing condensation particle counter and one optical particle counter (OPC), covering the particle diameter range from 0.3 to 10 µm, included to the inter-comparison. CPCs measure the total particle number flux, which tends to be dominated by the Aitken mode. By contrast, OPCs explicitly only measure the larger particles which would be subsumed in the CPC measurement, and therefore provides invaluable information for comparisons that will be made between the tower-based in-situ and ground-based lidars. All instruments were connected in parallel to a common sampling inlet leading from close to the anemometer to each of the counters. The measurement height from the ground level was 35 m. Instrument details, their logging and flow rate are given in Table 1.

Table 1. Instrumentation and measurement setup used in the inter-comparison campaign in Hyytiälä, Finland, in 24 April – 22 May 2017.

Instrument type	**Model**	**Loggin rate**	**Logging method**	**Flow rate**	**Site**
Anemometer	Metek USA-1	10 Hz	Serial	-	
OPC	TSI 3330	1 Hz	Serial	1 lpm	-
CPC	TSI 3772	10 Hz	Pulse reading	1 lpm	
	TSI 3775	10 Hz	Pulse reading	1.5 lpm	Kosetice, Cabauw
	TSI 3787	10 Hz	Pulse reading	1.5 lpm	
	TSI 3025	10 Hz	Pulse reading	1.5 lpm	AGORA*, Pallas*
	TSI 3010	1 Hz	Analog voltage	1 lpm	Hyytiälä
	Brechtel MCPC	10 Hz	Pulse reading	0.6 lpm	AUC
Measurement setup					
Measurement height	35 m				
Sensor-inlet horizontal separation	3 cm				
Sensor-inlet vertical separation	20 cm				
Sampling line diameter	4 mm				
Sampling line length	4.5 - 5.5 m (depending on instrument location in sampling line)				
Flow rate	20.1 lpm				
Additional flow rate (after last CPC)	12 lpm				

*Identical 3776 used at the site

The time series of the different CPC's show a good agreement during the measurement campaign (Fig. 1). During presumed nucleation events, the impact of the variable lower detection limits between the CPC's are observed, with the more sensitive particle counters showing larger concentrations. Disagreement between the particle counters became larger around noon, when newly formed particles typically grow up to 4 – 10 nm in diameter, which is around the detection limit of most CPCs (Kulmala et al. 2004).

The instruments with smaller sample flow have greater statistical uncertainty associated with them (Fig. 2). This is to be expected, as the measured concentration is effectively calculated from a smaller subset of measured particles and the amount of counts is directly related to the amount of uncertainty in the data (Kangasluoma and Kontkanen, 2017). For the range of instruments present in the inter-comparison, the uncertainty in the particle concentration ranged from 2 – 9 %. The instruments with faster response times showed higher variance, which is partially explained by them more accurately capturing the rapid fluctuation in particle concentrations and partially by the lower sampling flows used. This means that the improvements in data quality provided by the faster response time are partially masked to by the added random noise in the measurements. The opposite case can be observed with the slowest instruments, such as the TSI 3010. It shows very low statistical uncertainty, but is unable to distinguish the fastest eddies, and in effect buffers them out resulting in an unrealistically low variance. Therefore, neither of the extremes provide ideal data for flux measurements. The deeper data analysis is ongoing and particularly the effect of the CPC to the surface fluxes will be evaluated in the future.

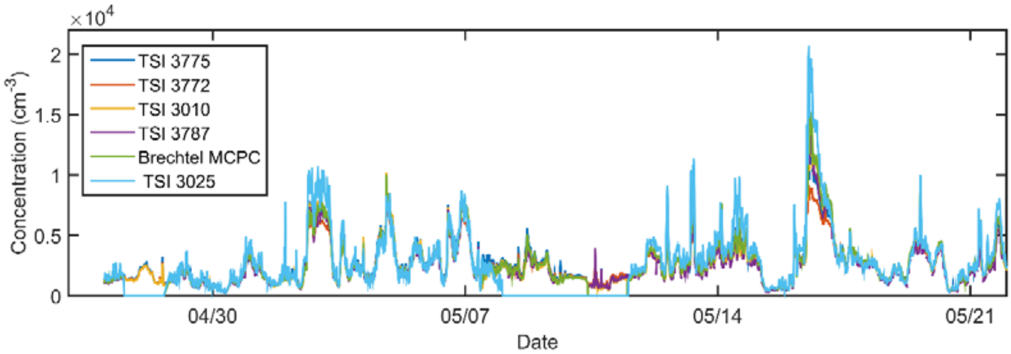

Figure 1. Time series of particle number concentration measured with the different CPCs over the measurement campaign 24 April – 22 May 2017 at the Hyytiälä Forestry field station.

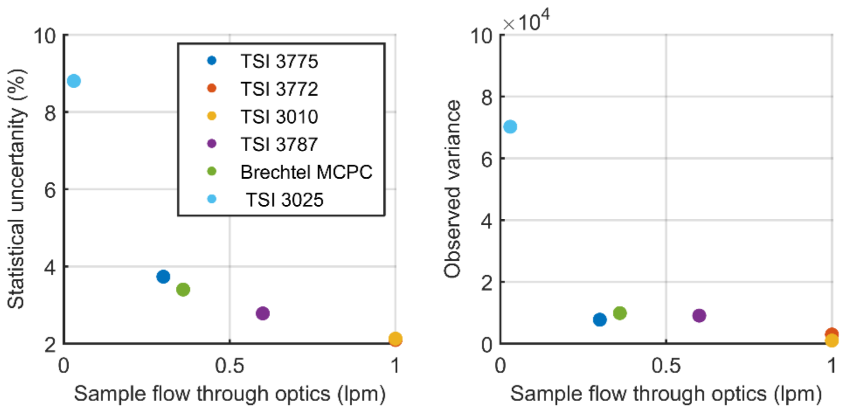

Figure 2. Mean statistical uncertainty of the recorded concentration and observed variance as a function of sampled aerosol flow.

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In order to get better understanding on the variation of the concentrations higher in the boundary layer at the same time with the surface flux measurements, vertical profiling of aerosol particles, temperature, pressure and relative humidity was done by the Finnish Meteorological Institute - Remotely Piloted Aircraft System (FMI-RPAS, tailored hexa-copter with ground station). During the campaign, the FMI-RPAS measurements were conducted in two periods from 26th to 28th April and from 10th to 12th May, respectively. In the first period, the particle concentration measurements were made with one CPC (TSI 3007), humidity and temperature were measured with Vaisala HMP110 probe, and temperature, relative humidity and pressure with lightweight BME280 sensor for Arduino. For the second period the same setup was used, but two CPCs with two different cut-off diameters (7 and 14 nm) to separate the freshly nucleated particles from the CPC total particle count. The FMI-RPAS operated within the reserved airspace, the dangerous area EFD409 in Hyytiälä, to its maximum aviation authority (Trafi) allowed height of 1400 m.s.l. During the whole campaign 29 vertical profiles were obtained with ceiling heights dependent on day to day weather conditions.

References

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Kulmala, M., Vehkamäki, H., Petäjä, T., Dal Maso, M., Lauri, A., Kerminen, V. M., Birmili, W., and McMurry, P. H. (2004). Formation and growth rates of ultrafine atmospheric particles: a review of observations. *Journal of Aerosol Science* 35, 143-176.

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