TNA User Report

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Project title	LOW-weight Aerosol Monitoring Evaluation CHAMber exPeriment (LOWAMECHAMP)
Name of the accessed chamber	LEAK (Leipzig Aerosolkammer)
Number of users in the project	2
Project objectives (max 100 words)	Compare low-weight instruments for I) particle concentration and II) equivalent black carbon concentration to reference instruments to gain confidence for future field measurements.
Description of work (max 100 words):	Combustion products of 3 different fuel types (wood logs, wood chips, and hay) were measured separately and mostly online during roughly 4 days. The fires took place on the roof of the LEAK Chamber and the smoke was diluted with dried and compressed before reaching the instruments. Main focus was on measuring particle concentration and absorption. Several auxiliary measurements have been conducted, but are not further discussed within this report. Overall results were positive and showed a good correlation for particle concentration measurements.

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Trans-National Access (TNA) Scientific Report

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Name of the PI: Patrik Winiger
Chamber name and location: LEAK (Leipzig Aerosolkammer), Leipzig
Campaign name and period: LOW-weight Aerosol Monitoring Evaluation CHAMber exPeriment (LOWAMECHAMP) 08/04/2019 - 12/04/2019

[1] Physics; Chemistry, Earth Sciences & Environment; Engineering & Technology; Mathematics; Information & Communication Technologies; Material Sciences; Energy; Social sciences; Humanities.
[2] UNI= University and Other Higher Education Organisation;
RES= Public Research Organisation (including international research organisations and private research organisations controlled by public authority);
SME= Small and Medium Enterprise;
PRV= Other Industrial and/or Profit Private Organisation;
OTH= Other type of organization.
[3] UND= Undergraduate; PGR= Post graduate; PDOC= Post-doctoral researcher; RES= Researcher EXP= Engineer; ACA= Academic; TEC= Technician.
[4] Reproduce the table for each user who accessed the infrastructure

Introduction and motivation

Ground and UAV observations of wildfire emissions require high mobility of the used scientific equipment. Measurements have to be conducted at several different locations within a timeframe of few hours. Therefore, reliable and highly mobile equipment is of outmost importance. It is well known that the disadvantage of such equipment, compared to standardized and well calibrated laboratory equipment, is the relatively higher uncertainty of the received data. Our mobile equipment has been calibrated for ambient concentrations and 'dust' type particles. Additional calibration is needed for biomass burning particles and the relatively high concentrations encountered in a fire plume. To increase confidence in wildfire aerosol observations, a set of two different mobile samplers were compared to high-fidelity laboratory instruments in an aerosol chamber. These mobile samplers are also known as personal samplers, because they can be carried on person, and as such are indicators for personal safety of the carrier. Therefore, our experiment will also be to the benefit of e.g., industrial workers (in mines or chemical plants), or fire fighters.

Scientific objectives

The objective of the action was to compare the two aerosol measurements (equivalent black carbon and particle mass concentration) of the two portable samplers with reference instruments, to gain confidence in the low-weight sampler data from future measurements during wildfire events.

Reason for choosing the simulation chamber/ calibration facility

LEAK-LACIS provided the necessary instrumentation and expertise needed. Having access to the Leipzig Biomass Burning Facility (LBBF) as part of LEAK, was especially important for successful implementation of this project and allowed to test real biomass burning emissions for comparison of our instruments to reference instruments.

Method and experimental set-up

Instrumentation

A list with applied instruments is contained in Table 1. An APS to measure particles >800nm (for reference) was unfortunately not available during the period of the TNA project.

Table 1 Equipment

Equipment	Measurement	Unit	Temporal resolution
Low weight instruments			
[5]SidePak™ AM520, TSI	PM mass concentration (0.1 –10 µm); inferred from 90° light scattering (650 nm)	µg/ m^3	1/s
[6]microAeth® AE51, AethLabs	Equivalent Black carbon (880 nm)	ng / m^3	1/s
Reference instruments			
Filter/ Sunset analyzer	OC/EC	g/cm^3	1/fire
MAAP type 5012, TSI	Equivalent Black carbon (670 nm)	ng / m^3	1/s
Aethelometer AE33, AethLabs	Equivalent Black carbon (370 nm, 470 nm, 520 nm, 590 nm, 660 nm, 880 nm, 950 nm)	ng / m^3	1/s

[5] Personal Aerosol Monitor (light-scattering laser photometer) that provides real-time aerosol mass concentration. Weight: 680g

[6] Aethalometer that provides real-time equivalent black carbon analysis by measuring the rate of change in absorption of transmitted light due to continuous collection of aerosol deposit on filter. Weight: 280g

APS	Not available	No. particles / aerodynamic size fraction	1 series / 5'
SMPS	Particle number size distribution (10 – 800 nm mobility); 71 bins	No. particles / mobility fraction	1 series / 5'
Multigas analyzer	CO_2, CO, SO_2, NO	Vol%; ppmv	1/s
Picarro G2401	CO_2, CO, CH_4, NO, H_2O	Vol%; ppmv	1/s
HR-ToF-AMS, Aerodyne	Mass spectrum of chemicals	m/z	
PILS	Imidazole via MS		1 vial/10'

Flow calibration

The flow rate of the SidePak™ AM520 is set to 1.7 L/min by default and recommended by the producer if the instrument is used together with one of the provided four impactor inlets (cuts at 1.0 µm, 2.5 µm, 5 µm, and 10 µm). The flowrate was calibrated using the Sensidyne Gilian gilibrator (primary flow calibrator 20cc-6 LPM adapter). The flow was calibrated to 1.7 L/min, the average of 10 measurements was 1.699 L/min.

The flow rate of the microAeth® AE51 can be adjusted according to the expected conditions encountered during the experiments (low to high BC concentrations) and was calibrated using a Sensidyne Gilian gilibrator (primary flow calibrator 1-250 cc). Each 25 mL/s flow rate step was calibrated separately. The averaged differences of 5 measurements per flow rate gave deviations of measurement and expected flow of 1% or less.

Operation settings

Fires

Experiments were performed with wood logs (beech), wood logs of unknown origin, wood chips (mixed origin) and hay; to generate biomass burning particles at different combustion efficiencies. If not stated otherwise, the smoke dilution with dried and compressed air was set to the maximum concentration (that the reference instruments can handle), a factor of 16.

microAeth® AE51, MAAP and AE33 (equivalent Black carbon)

All instruments receive diluted air. The micro aethalometer was set to a flowrate of 50 mL/min for the first experiment and 100 mL/min for all others. Filters were changed after each full experimental fire. The measurement frequency is set to 1 Hz. The MAAP was operated at a flowrate of 6 L/min. MAAP and AE33 changed 'filters' automatically, as usual.

SidePak™ AM520 (PM_1) and SMPS (particle size distribution)

The inlet was located in the diluted and dried airstream, prior to measurements, and was the same for both instruments. PM_1 cut-off size was chosen to aid comparison with the SMPS data. A sub-set of experiments were made with a $PM_{2.5}$ inlet (field conditions).

OC/EC (quartz-fiber filters)

The quartz fiber filters were connected to a 3 L/min flow on an in-line filter set-up using the flow calibration adapter. $PM_{2.5}$ samples are collected on 47mm Whatman quartz fiber filters. Filters were collected from the smoldering and flaming phase of each fire. Samples are transported under sealed and cool conditions and analyzed in the Centre for Isotope Research (CIO), Energy and Sustainability Research Institute Groningen (ESRIG), University of Groningen, the Netherlands. The OC/EC ratio is measured using a thermo-optical analyzer (Sunset laboratories). One filter blank was taken per day.

Gasses before dilution (CO_2, CO, NO and SO_2)

Before dilution: Gas concentrations were measured directly from an undiluted stream using a Dr. Fodisch AG MGA12 multi-gas analyzer. After dilution: measured using a cavity ring-down spectroscopy (Picarro G2401).

Imidazole

Water soluble particles were captured using a particle into liquid sampler (PILS). Imidazole molecules are later detected using an orbitrap mass spectrometer. This data will be analysed by Mechthild Schmidtpott for her master thesis.

AMS (quantitative size and chemical mass loading)

Quantitative size and chemical mass loading during the aging experiments were analysed using an aerodyne High-Resolution Time of Flight aerosol mass spectrometer.

Fresh biomass burning experiments (Online)

During 4 of the 5 days fresh biomass burning of different fuel types was measured with the above operation settings.

Experiemt	Fueltype	Start	End	SidePak PM-inlet
Online	wood	16:56	18:02	2.5
Online	wood	09:30	10:51	1
Online	wood	11:00	12:16	1
Online	wood chips	12:37	13:49	1
Online	hay	14:24	15:22	1
Online	hay	09:50	10:50	1
Online	wood	11:00	12:15	2.5
Online	wood	12:20	13:21	2.5
Online	wood	13:36	14:27	2.5
Online	wood chips	14:35	15:35	1
Online	wood chips	15:54	16:52	1
Chamber	wood/hay	10:46	15:15	1

Aerosol aging experiment (Chamber)

To test how well the analyzers, respond to secondary organic aerosol (SOA) formation, we performed one aging experiment in the LEAK chamber. Fresh smoke was aged with help of UV lamps and Ozone injection. Ozone and humidity conditions were chosen based on expected field conditions. Boundary layer ozone conditions in the savanna fluctuate between 10-40 ppbv depending on the time of the season (Kgabi and Sehloho 2012, Sanhueza *et al* 1999). As the majority of biomass emissions and our measurements take place in the dry season, we used an initial O_3 concentration of 30 ppb in the chamber experiment. The instruments continuously monitored O_3 and NO_x in the chamber. The experiment had a total duration of 7 hours, during which continuous measurements were done with the low-weight and reference equipment. A ToF-AMS was added to assess chemical changes in the particles. One Quartz-fiber filter was taken of the fresh smoke entering the chamber and one of the aged smoke, during the last 45 minutes of the experiment.

Data description

The chamber was operated for 5 days. 16 measurements of direct (fresh) biomass burning and one of aged biomass burning were made. The available data consists of aerosol (absorption, chemical, scattering, size and number distribution) and gas (concentration) characteristics.

Preliminary results and conclusions (particle concentration and eBC only)

We measure the diluted smoke simultaneously with the SMPS and the SidePak™ AM520 using the existing calibration factor for ambient air SCF_{old} = 0.38 (default ambient setting by producer).

$$SCF_{new} = \frac{PM_{0.8}\ SMPS\ (\frac{mg}{m^3})}{PM_1\ TSI\ AM520\ (\frac{mg}{m^3})} \times SCF_{old}$$

$PM_{0.8}\ SMPS\ \left(\frac{mg}{m^3}\right)$ is calculated using the SMPS. The densities are dependent on the type of particles. Organic particles have lower densities. (Zhai *et al* 2017) calculated the effective density of biomass burning particles in the particles in the size range of 50–400 nm. They used an aerosol particle mass analyzer (APM) to measure the mass of particles that had been classified according to electrical mobility by a DMA . They found dominant modes in the effective density distributions of 200 and 400 nm mobility-selected particles of 1.40 and 1.35 g cm^{-3} respectively, others use higher densities for the calculation of mass concentration from Mobility Particle Size Spectrometer (Costabile *et al* 2017). We converted the total volume of particles for each size class to mg/m^3 assuming (the higher end of) an effective density of ρ_{eff} = 1.40 g/cm^3. The sum of all masses for classes up to 0.8 µm is then compared to the measured < 1µm fraction from the SidePak™ AM520. Particles of < 1 µm generally make up between 80-90% of all the aerosols emitted in biomass burning (Alonso-Blanco *et al* 2014).

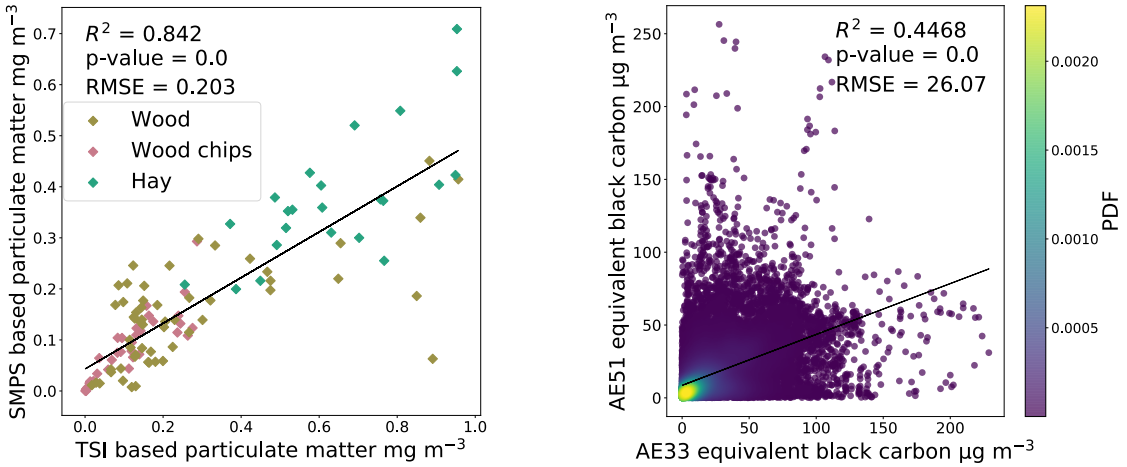

Figure 1 Comparison of reference to low-weight instruments. LEFT: particle concentrations. ; RIGHT: equivalent black carbon measurements (no difference observed between fuels). For the AE33 only the 880nm measurements were used . The linear R^2, p-value (for both figures well below 0.000), and RMSE (root mean square error) is given.

A good linear correlation (R^2=0.842) was achieved for particulate matter concentrations based on the SMPS and the TSI AM520 (Figure 1). Surprisingly, the correlation was far from optimal for the eBC measurements. The AE51 should achieve much better values when compared to an AE33, with R^2-values of up to ~0.95 (Alas *et al* 2019). It is unclear what caused this offset. The analysis comparing the two reference eBC instruments for all experiments (similar to Figure 1 R.) did not result in a more favorable outcome (R^2= 0.419). The example of one of the wood experiments (with the highest R^2 between AE51 and AE33) shows that there were some issues with the signals of the AE33 and MAAP (Figure 2). It is possible, that the concentrations were too high to handle for the filter-based instruments, and a too low dilution factor was applied.

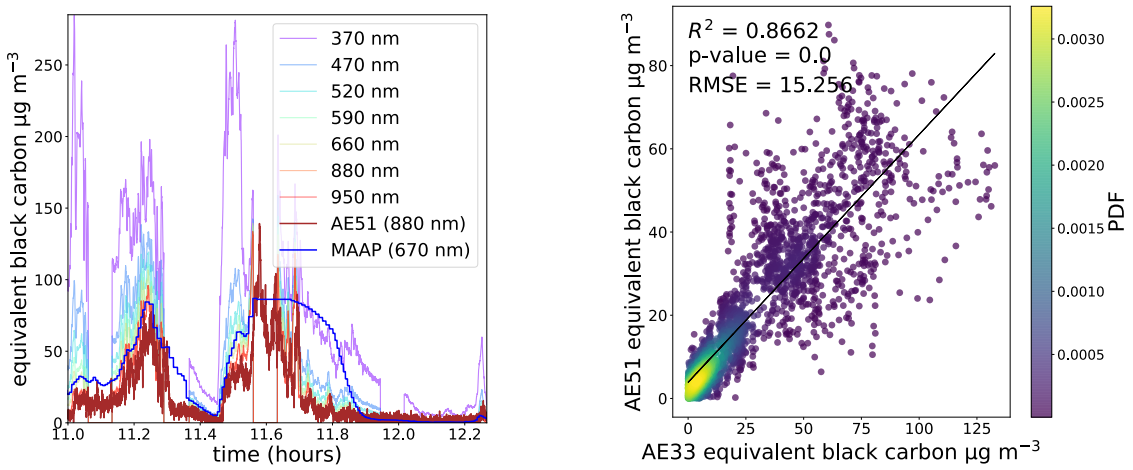

Figure 2 eBC discussion on example of wood experiment 6. LEFT: All wavelengths for the AE55 shown, in addition to the other two instruments (AE51 and MAAP). RIGHT: eBC at 880nm for both AE51 and AE33.

Outcome and future studies

Overall, the results of this experiment were very positive (see PM measurements), despite some issues with the eBC measurements. We could show that the TSI AM520 gives reliable first results when compared to a SMPS. It is important to repeat a similar comparison with different reference instrumentation (e.g., SMPS-APS, TEOM, BAM) and ideally an additional AM520. To gain more confidence in the AE51 we would have to repeat the tests under different conditions (e.g., lower smoke concentration) against reference instruments and against a well-tested instrument of the same type (AE51).

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