TNA User Report

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Project title	Characterization and calibration of a new instrument for filter-based measurement of aerosol absorption coefficient at 5 wavelengths" (CESAM-003-2018)
Name of the accessed chamber	Cesam (LISA)
Number of users in the project	1
Project objectives (max 100 words)	The main scientific objective of the experiments in CESAM was the evaluation of DBAP performances. To achieve this goal we investigated detection limit and possible zero offset using clean air and non-absorption aerosols (ammonium sulphate particles), the behavior under strong absorbing aerosol (fullerene and Aquadag) and the spectral response using low-absorbing mineral dust. All the experiments were conducted with concurrent optical measurements (2-wavelength CAPS-Pmex, TSI integrating 3-wavelength nephelometer, 1-wavelength MAAP, 7-wavelength aethalometer). According to the recommendation by the TNA evaluation, the MAAP was taken as master instrument for comparison as usually assumed as artefact-free reference instrument for aerosol absorption.
Description of work (max 100 words):	The DBAP characterization was carried on by 5 days of experiments. Experiments on day 1 targeted the characterization of the detection limit and possible zero offset using particle-free air and non-absorbing ammonium sulfate. Experiments on day 2-4 targeted the possible non-linear magnification of absorption by filter media when the filter is loaded with analogs for black carbon aerosol (liquid solutions of calibration material such as Fullerene soot and Aquadag). Experiments on day 5 studied the response of DBAP to low-absorbing aerosols (mineral dust). The response to urban ambient air by sampling air from the laboratory was also studied.

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[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 ENG= Engineer; ACA= Academic; TEC= Technician.
[4] Reproduce the table for each user who accessed the infrastructure

Trans-National Access (TNA) Scientific Report

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Instructions

Please limit the report to max 5 pages, you can include tables and figures. Please make sure to address any comments made by the reviewers at the moment of the project evaluation (if applicable, in this case you were informed beforehand). Please do not alter the layout of the document and keep it in Word version.
The report will be made available on the eurochamp.org website. Should any information be confidential or not be made public, please inform us accordingly (in this case it will only be accessible by the European Commission, the EUROCHAMP-2020 project partners, and the reviewers). Please include:

- Introduction and motivation
- Scientific objectives
- Reason for choosing the simulation chamber/ calibration facility
- Method and experimental set-up
- Data description
- Preliminary results and conclusions
- Outcome and future studies
- References

Name of the PI: Maurizio BUSETTO
Chamber name and location: CESAM (CNRS-LISA), Créteil - France
Campaign name and period: September 2018
Text:

Introduction and motivation

Atmospheric aerosols, both of anthropogenic and natural origin, regulate the global temperature of the Earth by forcing the regional radiative budget.

Observations and climate models indicate that the effect of aerosols on climate has great sensitivity to their shortwave absorption properties (e.g., Loeb and Su, 2010). However, light absorption by aerosol particles is a difficult property to be measured because 1/ it is small with respect to the competing scattering; 2/ it varies strongly with wavelength depending on their chemical composition and size distribution. Unfortunately, existing data are often limited to a single wavelength, often not the same.

A new instrument, called Dual Beam Absorption Photometer (DBAP), has been developed by LEN scientific lab (Chiavari – GE) to advance this science question. DBAP is a filter based instrument for the measurements of aerosol absorption coefficients at 5 different wavelengths (405, 465, 522, 634 and 870 nm), characterized by dual beam technology and automatic filter changes in function of the filter transmittance. Dual beam technology allows to take into account possible changes in the filter characteristics (due to changes in atmospheric conditions) and variation in light intensity. It is therefore fundamental when the same portion of the filter is exposed to the air flow for long periods, as in remote areas, but also in polluted areas where the particle concentration is very high. The automatic advancement of the fiber glass tape filter is also very useful to supply the impossibility of the manual intervention of an operator.

The principle of measurement is similar to all filter-based instruments commercially-available. The spectral absorption coefficient is obtained by monitoring the changes in filter transmittance as the filter is loaded by particles. Because of the dual beam technology the transmittance (τ) is defined as the ratio between the light intensity detected in the measurement cell (I_m) and in the reference cell (I_r) and it has been normalized to 1 at the beginning of the measurement cycle (*t=0*)

$$\tau^{\lambda}(t) = \frac{I_m^{\lambda}(t)/I_r^{\lambda}(t)}{I_m^{\lambda}(0)/I_r^{\lambda}(0)} \qquad \text{(Eq. 1)}$$

From this definition of transmittance the absorption coefficient (σ_{ab}) is given by

$$\sigma_{ab}^{\lambda} = \frac{A}{Qdt} ln\left(\frac{\tau^{\lambda}(t-dt)}{\tau^{\lambda}(t)}\right) \qquad \text{(Eq. 2)}$$

where A is the area of the sample (spot area), Q is the flux of the air passing through the filter and *dt* the time interval, which is set to 60 seconds for DBAP.

Scientific objectives

The main scientific objective of the experiments in CESAM was the evaluation of DBAP performances. To achieve this goal we investigated detection limit and possible zero offset using clean air and non-absorption aerosols (ammonium sulphate particles), the behavior under strong absorbing aerosol (fullerene and aquadag) and the spectral response using low-absorbing mineral dust.

All the experiments were conducted with concurrent optical measurements (2-wavelength CAPS-Pmex, TSI integrating 3-wavelength nephelometer, 1-wavelength MAAP, 7-wavelength aethalometer).

According to the recommendation by Collaud-Coen et al. (2010), and recommendations of the TNA evaluation, the MAAP was taken as master instrument for comparison as usually assumed as artefact-free reference instrument for aerosol absorption.

Reason for choosing the simulation chamber/ calibration facility

CESAM is a multi-instrumented simulation chamber with capability of generating different types of aerosols of known optical properties. The concentrations and the environmental conditions can be controlled. CESAM is also the only chamber with capabilities of generating mineral dust in a realistic way with respect to the natural process and mineralogy of the parent soil (Di Biagio et al. (2017).

Method and experimental set-up

The instrumental configuration of CESAM during the experiments, shown in Figure 1, is listed in the Table here below.

Picture label	Instrument	Measurement	Wavelengths [nm]	Time resolution
1	Aethalometer (Magee Sci, model AE31)	Absorption coeff.	370, 470, 520, 590, 660, 880, 950	2 minutes
2- 3	CAPS-Pmex (Aerodyne Inc)	Extinction coeff.	450, 630	1 sec
4	DBAP	Absorption coeff.	405, 465, 522, 634, 870	1 minute
5	MAAP (Thermo Sci., model 5012)	Absorption coeff.	670	1 minute
6	Nephelometer (model 3563, TSI Inc.)	Scattering coeffi.	450, 550, 700	1 sec

The DBAP characterization was carried by 5 days of experiments in the CESAM chamber.

Experiments on day 1 targeted the characterization of the detection limit and possible zero offset using particle-free air and non-absorbing aerosols such as ammonium sulfate (Sigma-Aldrich 99.999 % purity, 0.01 M solution in ultrapure water).

Experiments on day 2-4 targeted the possible non-linear magnification of absorption by filter media when the filter is loaded. To do so, the concentrations of a strong absorbing aerosol was injected in the chamber and the temporal dynamics of the measured was followed to investigate non-linearity. Two analogous were used for black carbon aerosol: was generated as liquid solution of calibration material such as Fullerene soot (Alfa Aesar) and Aquadag, (Aqueous Deflocculated Acheson Graphite, Acheson Inc., USA), a colloidal dispersion of aggregates of irregular flakes of graphite (Moteki et al., 2009) in water (~80 % H_2O).

Experiments on day 5 studied the response of DBAP to low-absorbing aerosols such mineral dust. This was generated by a natural soil from Niger, previously characterized at LISA (Di Biagio et al., 2017), as rich in iron oxides, the main light-absorber in mineral dust.

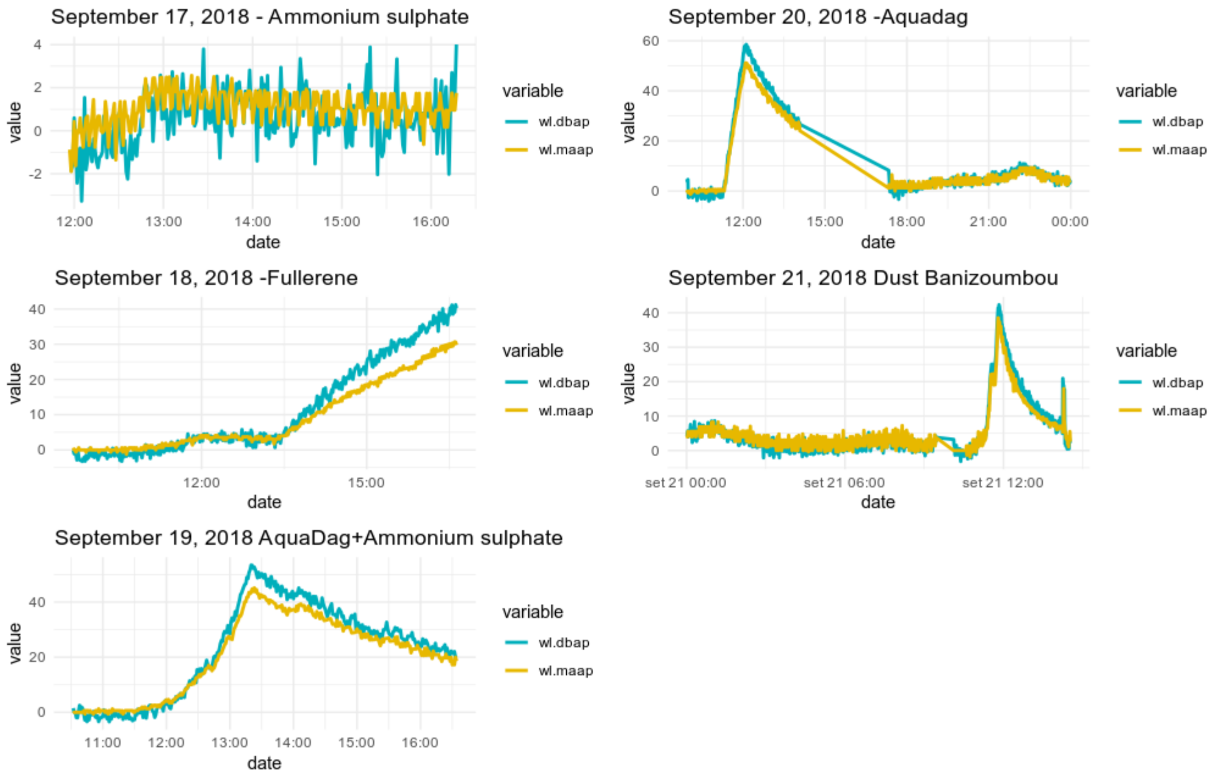
Ammonium sulfate, fullerene and Aquadag aerosols were injected as solutions using a commercial TSI atomizer (TSI, model 3075) operated at 3 L min^{-1} and coupled with a diffusion drier (TSI, model 3062). Mineral dust was generated by mechanical shaking of about 10 g of parent soil. The generated aerosol was in the chamber by a constant output nitrogen flux.

During night between days 4-5 we studied the response to ambient air by sampling air from the laboratory. CESAM is located is in the suburbs of Paris, at the ground floor of the University Paris-Est Creteil building, which is close to a main local road (~ 20 m) and to the A86 highway (~200 m).

Preliminary results and conclusions

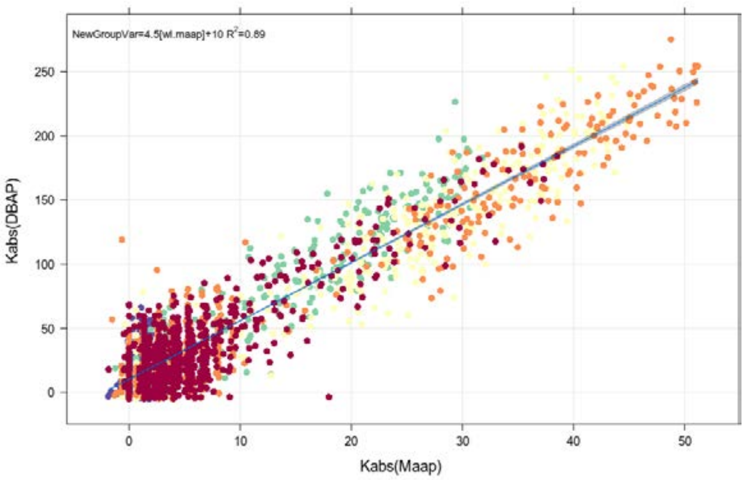
The preliminary analysis presented in this report concerns the comparison between the measurements of the DBAP at 634 nm and those of the MAAP measurement at 670 nm.

Figure 2 shows the time series of the absorption coefficients obtained by DBAP (634 nm) and the MAAP (670 nm) using all the 1-minute data.



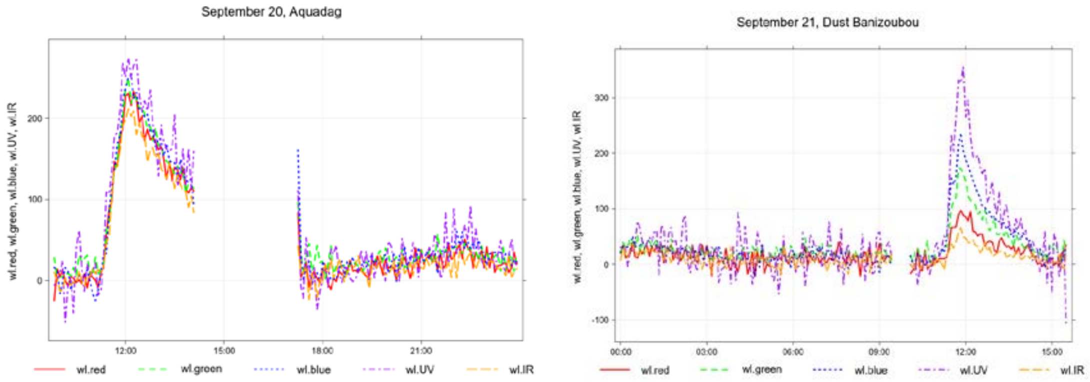
The comparison shows that there is a general good agreement in the observations by the two instruments. The DBAP and the MAAP agree in representing the temporal changes of absorption among experiments. However, the noise on the DBAP measurements for zero-absorption aerosols (ammonium sulfate, left top panel) is higher than in the MAAP measurements, affecting the limit of detection of the measurements.

There is also a significant difference in the magnitude of the calculated absorption coefficient. This can be seen in Figure 3 showing the same values in the form of scatter plot.



The different days are represented by varying colors. A linear fit between the two dataset can be done. Despite an evident dispersion, especially in data close to zero, the correlation is very good (R^2=0.88). However, the DPAB data overestimate by about a factor 5 the absorption measured by the MAAP. The best fit line is represented by a slope of 5.1 and an intercept of 4.4

To illustrate the spectral response of DBAP, Figure 4 shows the DBAP absorption coefficient at 5 wavelengths for the experiments with Aquadag (left) and mineral dust (right).



As expected, there is very little wavelength-dependence in the measurements with the Aquadag, a solution of black material. On the contrary, the spectral response of DBAP is well evident during the dust experiment (right apnel, from 11h50 on), when the absorption decreases with wavelength. Always on the right panel, but prior to the dust injection, Figure 4 shows also data collected during the experiment of ambient air, showing a prevalence of black-carbon dominated pollution aerosol again characterized by a very low spectral dependence. Finally, Figure 4 allows to evaluate the spectral dependence of the noise level, indicating that the greater noise in the UV component needs to be addressed.

Outcome and future studies

The experimental campaign conducted in the CESAM chamber has provided with the first characterization of the performances of the prototype DBAP instrument, which is needed to envisage its commercial use.

Although, to date, only a subset of observations performed during the experiments has been analyzed, we already can count on a very first important set of indications for improvement and further work:

- the need to decrease the measurements noise especially for what concern the UV wavelength;

- the need for understanding the scaling factor between the DBAP and MAAP absorption coefficients at wavelengths close to 634 nm. This will require the full analysis of all observations, including CAPS, aethalometer and nephelometer measurements, also to extend the comparisons to other wavelengths. This will also require a very strict characterization of the air flowrate, hotspot area, playing a role in calculating the absorption coefficient from the attenuation measurement;

- the spectral response of the instrument is very realistic and well represents what expected for known light absorber such as graphitic solutions and mineral dust.

Finally, the need for future experiments cannot be fully anticipated as it is an outcome of the full data analysis. However, future experimental characterization might address the role of ambient relative humidity in affecting the filter properties and apparent absorption.

References

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