TNA User Report

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Project title	SooMount: SOOT mixing state at mountain sites (Monte Cimone/Po Valley and Bolivia experiments)
Name of the accessed calibration center	CCSM
Number of users in the project	2
Project objectives (max 100 words)	SooMount main goal is BC mixing state investigation in mountain sites. The specific goal of the visit at PSI was to evaluate the performance of three different instruments: SP2, SP2-XR. SP2 is based on laser induced incandescence allowing to measure the refractory black carbon (rBC), as well as the non- and less refractory matter coating the rBC core, giving important information on the mixing state of BC-containing particles. Resarchers from CNR-ISAC are interested in being familiar with the SP2 instrument in order to be autonomous in additional field campaigns and evaluate data quality, elaboration and analysis.
Description of work (max 100 words):	The visiting period has been focused on SP2 use. Calibrations in the laboratory, using fullerene, PSL and ammonium sulphate have been performed, as well as data evaluation and back-corrections of data. Moreover, due to the complexity of the SP2, a comprehensive case history of the troubleshooting and procedures for running the instrument has been explored. All the calibrations and alignements have been performed on three instruments: 2 very similar SP2 (LGGE and PSI) and the new compact version, the SP2-XR. We also run the three different instruments for data series intercomparison, after the correct calibration was applied.

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

New user	

Trans-National Access (TNA) Scientific Report

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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 calibration facility
- Method and experimental set-up
- Data description
- Preliminary results and conclusions
- Outcome and future studies
- References

Instructions

Name of the PI: **Angela Marinoni**
Calibration center's name and location: Calibration Centre for Soot Measurements (CCSM), Paul Sherrer Institute, Villigen, Switzerland
Campaign name and period:
Text: SooMount, February, 5th – March 2nd

Text:

Introduction and motivation

The main purpose of the STSM visit to PSI was to improve my experience in using a state of the art instrument for measuring soot, refractory black carbon and its mixing state: the Single Particle Soot Photometer (SP2).

Soot particles are emitted into the atmosphere during incomplete combustion. They contain variable amounts of black carbon (BC), organic carbon (OC), inorganic salts, and trace elements. BC is of particular interest both for air quality issues and because it is a short life climate forcer (SLCF), specifically the most significant aerosol that strongly absorbs solar and infra-red radiation in the atmosphere, directly affecting radiation budget and climate. The aerosol ageing processes may add additional coatings to the particle core via the condensation of low volatile compounds or

coagulation of existing particles; this affects the optical, cloud condensation nuclei, and ice nuclei properties of BC containing particles. To date, the exact measurement of BC remains difficult, with results varying by different methods.
Several filter-based instruments have been used at the GAW Global Station of Monte Cimone (CMN, 44°12' N, 10°42' E, 2165 m asl) during the last 13 years: a PSAP since June 2005 till March 2007, a MAAP since April 2007 (ongoing observations) and an Aethalometer since 2012 (non-continuous, ongoing observations).
A more recent and powerful technique for measuring BC is based on laser induced incandescence, which measures the carbonaceous fraction of particulate matter that is insoluble and vaporizes only at temperatures near 4000 K. This carbonaceous fraction is called refractory black carbon (rBC). The mass of refractory black carbon is indirectly measured in every single particle from the amount of light emitted at the vaporization point of rBC, independent of the amount of non-refractory, internally mixed matter. In addition, the amount of non- and less refractory matter coating the rBC core can also be retrieved, giving important information on the mixing state of BC-containing particles.

Scientific objectives

SooMount main goal is BC mixing state investigation in mountain sites.
The specific goal of the visit at PSI was to evaluate the performance of three different instruments: SP2, SP2-XR. SP2 is based on laser induced incandescence allowing to measure the refractory black carbon (rBC), as well as the non- and less refractory matter coating the rBC core, giving important information on the mixing state of BC-containing particles.
Resarchers from CNR-ISAC are interested in being familiar with the SP2 instrument in order to be autonomous in additional field campaigns and evaluate data quality, elaboration and analysis.
An experiment on BC was carried out in the framework of ACTRIS-2 WP11 (Improving the accuracy of aerosol light absorption determinations) during the Monte Cimone-Po Valley field campaign. For the first time a Single Particle Soot Photometer (SP2) was used at Monte Cimone. The SP2 can contribute to BC characterization by directly measuring the mass of refractory black carbon (rBC; hereafter referred to as BC) in individual particles based on calibrations using Fullarene generated aerosols of known monodisperse sizes. The SP2 can provide the mass and number size distributions of BC cores in the size range (80-550 nm). Additionally, the SP2 provides optical sizing of particles. A secondary data product of the SP2 is a semi-quantitative measurement of the coating thickness of non-refractory material on individual BC cores.
The contribution of SP2 measurements at Monte Cimone for the ACTRIS campaign was a synergy of the interests of researchers: from the Institute of Geoscience of the Environment (Grenoble, France) which provided the SP2 instrument for the campaign, and the expertise of researchers from the Paul Scherrer Institut (CH) on the topic of black carbon and operation of the SP2. The project was aimed to provide a deeper knowledge on the mixing state of BC containing aerosols in the free troposphere in a site influenced during summer by the very polluted Po Valley basin.

Reason for choosing the calibration facility

The highly instrumented and well maintained Calibration Centre for Soot Measurements (CCSM) facility is well suited for investigating rBC concentration. We deployed one instrument from Monte Cimone and the CCSM offers the unique opportunity of simultaneous calibration and intercomparison with two additional instruments.

Method and experimental set-up

The visiting period has been focused on the use of the Single Particle Soot Photometer. Calibrations in the laboratory, using fullerene, PSL and ammonium sulphate have been performed, as well as data evaluation and back-corrections of data. Moreover, due to the complexity of the SP2, a comprehensive case history of the troubleshooting and procedures for running the instrument has been explored. The activity conducted during this STMS at PSI greatly improved my autonomy in managing the SP2 instrument, as well as the data evaluation and analysis. Three instruments were available: 2 very similar SP2 (LGGE and PSI) and the new compact version, the SP2-XR.

First we performed the main adjustments of SP2, in detail:

- Alignment of the mode aperture
- Alignment of the output coupler (both with power meter and with camera)
- Particle beam alignment (moving the cell under a flow of PSL particles)
- Low detection limit (with monodisperse ammonium sulphate in six different bins; the 100% counting efficiency was found at 160 nm)
- Scattering calibration (with mixture of 150 nm and 268 nm PSL)
- Fullerene incandescence calibration

Bothe scattering and incandescence calibrations were performed on 15/16, 22 and 28 February 2018. After the calibrations performed, we checked the consistency with previous calibrations performed in Bologna and Monte Cimone, and we also plan to be performed in Bolivia (not altogether trivial). A comparison of the calibrations is shown in Figure 1.

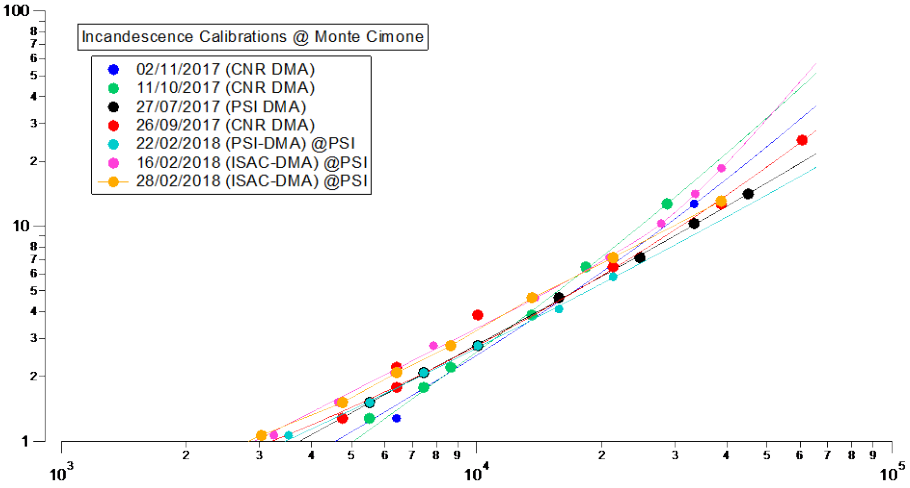


Figure 1. Comparison of broadband incandescence channel during incandescence calibrations performed at Monte Cimone and PSI.

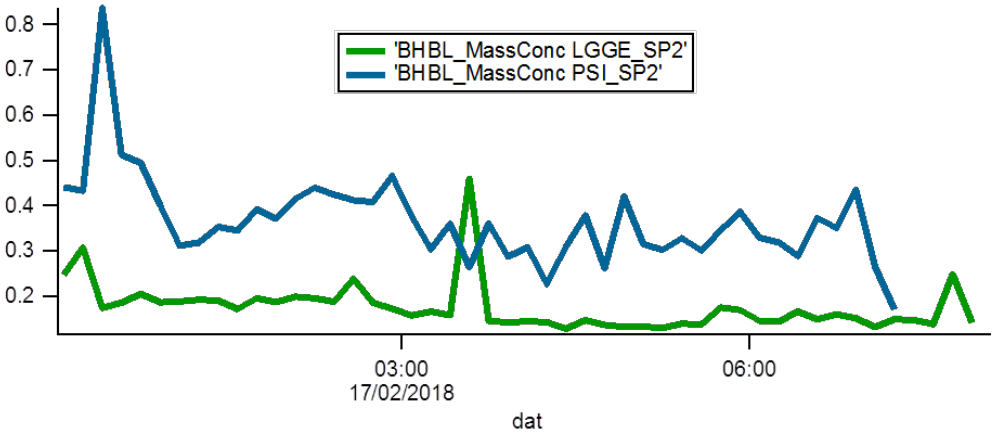
We also run the three different instruments for data series intercomparison, after the correct calibration was applied. In particular these time series has been performed and analysed :

- weekend 17-18 (data available only from 18:00 of 16/02/2018 to 19:00 of 17/02/2018, because acquisition was set at 1 particle every 1)
- night from 20 to 21 /02/2018
- weekend 23-24-25-26 /02/2018
- night 28/02-01/03 (LGGE with manual baseline)

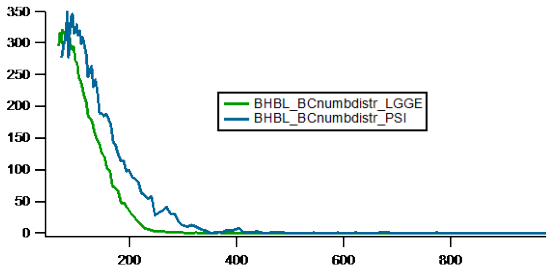
Data description

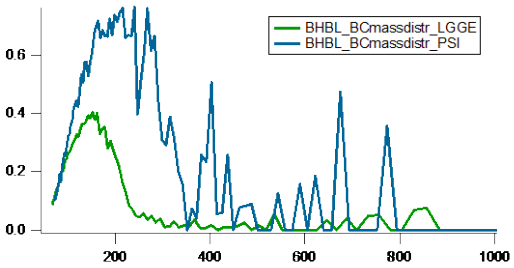
Preliminary results and conclusions

The calibration performed on 15/16 February for each instrument was applied to two data set of 17/02/2018 and night between 20 and 21 February 2018. The data set of 17/02/2018, after calibrations applied, shows significant differences between two SP2, both in size distributions (number and mass) and in total BC mass concentration. In particular the averaged valued for the period 17/02/2018 from 0 to 7 AM showed an average mass concentration of 0.175898 µg m-3 for LGGE and 0.366999 µg m-3 for PSI instrument.
A plot of the rBC conc for both instruments is reported in Fig 2.



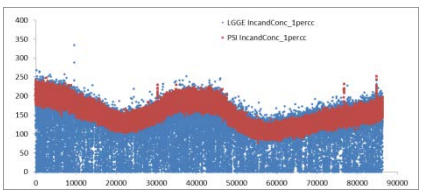
LGGE SP2 measured 48% less mass with respect to PSI SP2, excluding the peak at the beginning of time series, the difference remains still at 25% (averages 0.175925 and 0.234708 µg m-3). Comparison between mass and number size distributions shows that a slightly different SD between two instruments, peaking around 200 nm for PSI and 170 for LGGE SP2. The intensity of the peak also shows a lower value for LGGE, by a factor of 2. The number size distribution of BC cores is much more similar, peaking at 90 nm with PSI SP2 and between 80 and 90 nm for LGGE with comparable intensity.

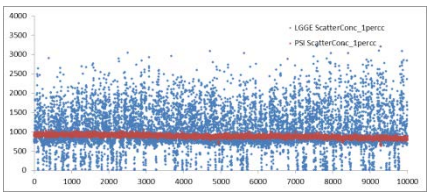




Similar discrepancies were also found in the night from 20 to 21 /02/2018 and during weekend 24-25-26 /02/2018, with LGGE counting around half than PSI.

Looking at the single counts of incandescence and scattering, it appears that the LGGE instruments is much more noisy with respect to the PSI one, in both directions for the scattering counts, while only lower values than PSI are shown for incandescence (See Figures below).



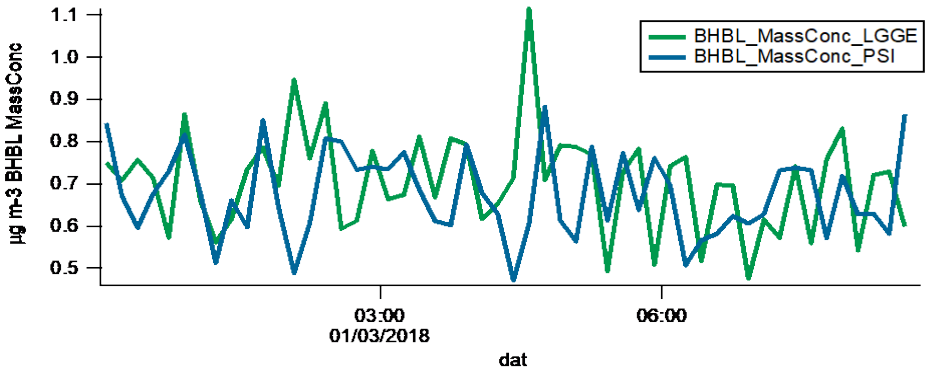


The noise of one instrument with respect to the other suggests that the incandescence detector is not sensitive enough and counts fewer particles than the PSI SP2, even if the trend for the maximum values shows a similar behaviour as the other SP2. Concerning the scattering detector, the noise is much higher, and on average LGGE SP2 counts more than the other. On average the N incandescence detected by LGGE was 85% of PSI and Nscattering was 130% than PSI instrument. We tried a filter based on the variation of Primary threshold, with significant impact on the number of scattering particle (all particle below the PSI averaged values were cut off when deleting the Primary threshold value exceeding the range of 1 σ on a running mean of 100 sec) but no clear influence on the incandescence particle number. A filtering on the Secondary Threshold does not affect in clear way the incandescence or scattering counts.

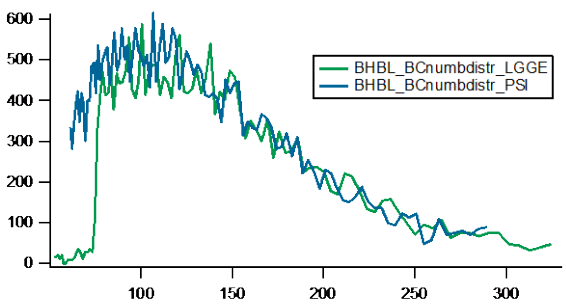
The split detector of LGGE SP2 is inverted with respect to PSI instrument, we hypothesized that a problem was linked to the hysteresis of the LGGE split detector. In fact, by using the split detector as primary channel, if the hysteresis is too high, the split detector trace do not recover to its baseline and it happens that detection of particles is loosen both for incandescent particles and scattering particles.

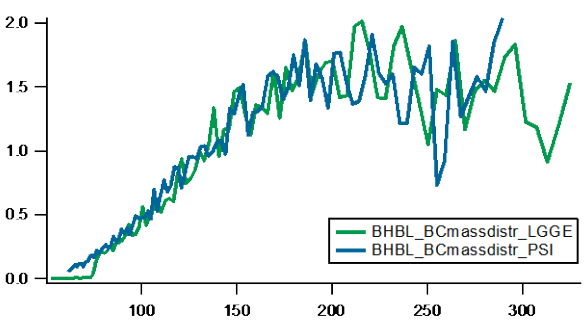
We than selected the HG scatter channel as Primary Channel and a manual baseline set at the averaged value of last 10 minutes for both channels (500 as PT and -29000 for ST). We selected only only the primary channel as fixed at -29000, but the secondary was also constant during the whole night.

Nevertheless the counting of particle were significantly different (Incandescence: 199.976 for LGGE vs 244.155 for PSI; Scattering: 583.331 for LGGE vs 1249.87 for PSI), the mass concentration was extremely similar (0.704648 for LGGE vs 0.674549 for PSI).

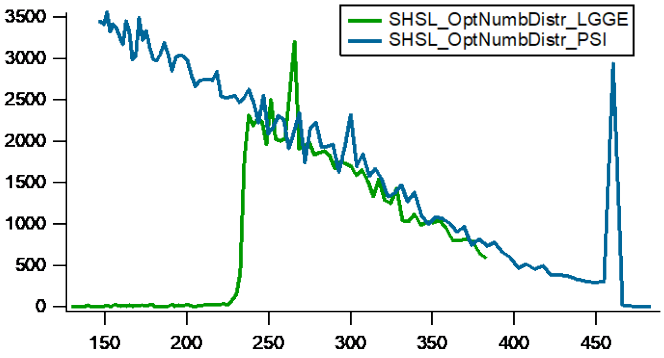


Both Number and Mass BC size distributions fitted very well between two instruments, as shown in the following graphs.





The scattering size distribution is consistent only in diameter range from 250 to 400 nm, that could be due because of the different detector used (HG in LGGE vs Split in PSI).



Outcome and future studies

Next experiment in Bolivian field campaign, taking place from April 1st to May 31st will see the joint participation of Angela Marinoni (CNR-ISAC) and Robin Modini (PSI) on the field. The campaign has a specific goal on improving knowledge on the processes driving the formation of new particles at the High altitude of Andean mountain range.

The LGGE SP2 and the PSI SP2-XR will be deployed at Chacaltaya (5200 m asl) and El Alto (4000 m asl, with the aim to quantitatively segregate between precursors associated to the traffic source and the biomass burning source when air masses arrive from the La Paz area. The SP2 brings additional information as respect to more conventional Aethalometer/MAAP instruments used for the long-term monitoring at CHC allowing for a differentiating emission sources based on 1) size distribution and 2) degree of mixing. Air masses originating from long-range transport of biomass burning are expected to have size distribution peaking in the accumulation range and a high degree of coating while those originating from La Paz – La Paz area will have smaller sizes and limited degree of coating. We plan to deploy the SP2 during the campaign and to perform, for the first time in South America, measurement at high altitude using this instrument. It will then be used to derive an indicator of biomass burning aerosol characteristics that can be used for air mass classification.

A specific work on Monte Cimone data analysis is also foreseen and a common paper based on the data taken on Monte Cimone last year, the results of which will be integrated with time series data from Jungfraujoch, including other BC measurement techniques (MAAP and PSAP). Data analysis and elaboration of data collected at Monte Cimone during and after the July 2017 experiment will be analysed in order to derive the first information on the mixing state of BC-containing particles at Monte Cimone. This elaboration will add an important knowledge to the BC time series data that has a 12 year history, previously only measured by filter-based techniques.