An NSF User Facility for Measuring Black Carbon Aerosol for Research and Education

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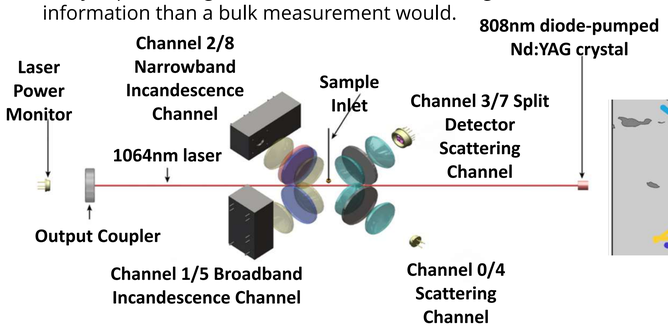
Abstract

As the science and technology of air pollution advances, it is becoming increasingly important that studies of air quality include a complete picture of the chemical and physical properties of aerosols. One important aerosol type found in the atmosphere is that of soot, or black carbon, which comes from nearly every combustion process, including vehicle engines, factories, and forest and agricultural fires. Black carbon (BC) is highly absorbing of sunlight, which makes it an important component to understanding local heating, micrometeorology, and long-range, long-term climate. BC aerosol also can affect human and ecosystem health.

The Clemson University Single-Particle Soot Photometer (SP2) is available as an NSF user facility for measurements of black carbon aerosol. The SP2 is a state-of-the-art instrument that combines incandescence and light scattering to simultaneously determine BC mass and optical size, which allows for analysis of the aerosol mixing state. As a user facility, the instrument can be requested for research projects and education and outreach events through the NSF FARE program. The goal of this program is to lower the barrier that scientists face in accessing the highly specialized measurements by the SP2.

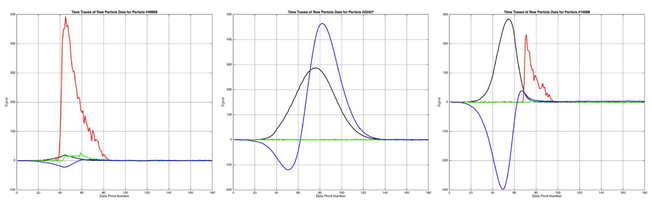
The Single-Particle Soot Photometer (SP2)

The Single-Particle Soot Photometer (SP2) is an instrument primarily used to detect refractory particles, such as black carbon, in an air sample. The SP2 uses a high-powered intra-cavity laser to heat particles to the point of incandescence, allowing for the determination of the mass concentration of single particles present in the sample. The SP2 raw data are saved for each particle 'event' detected, offering the chance to analyze particle signals on an individual basis to glean more information than a bulk measurement would.



In addition to incandescence, the SP2 contains two scattering detectors which measure single-particle scattering at a wavelength of 1064 nm. Scattering signals are then used to determine the presence of non-refractory materials on single particles. When combined, both signal types help determine the mixing state of BC-containing particles; that is, whether the particle is bare or coated.

The plots below show 3 single-particle data events in the SP2.



Requesting the Facility

Step 1: Talk to me! Email or fill out the form on our website (link below) or Google search "Clemson Air Quality Lab".

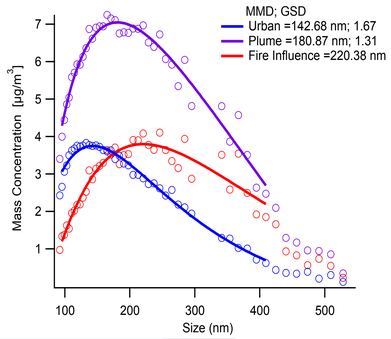
Step 2: Look up the NSF FIRP solicitation #NSF 23-602 (see QR code).

Proposals accepted any time.

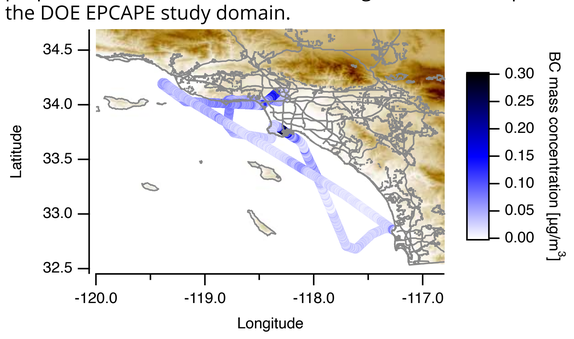
Research in the Air

In 2018, the Clemson SP2 was deployed on the Naval Postgraduate School (NPS) Twin Otter aircraft during the Marine Aerosol, Cloud, and Wildfire Study (MACAWS) near Monterey, CA. The data was used to quantify the impact of ship exhaust and wildfires on the marine atmospheric boundary layer and on local air quality.

The plot (right) shows average size distributions of BC aerosol for three different regions during a flight to characterize the emissions from the Country Fire. Differences in BC aerosol on a single-particle level can be used to understand how airmasses mix and the nature of BC sources.



In 2023, the Clemson SP2 was deployed on the NPS Twin Otter aircraft during the Southern California Interactions of Low cloud and Land Aerosol (SCILLA) campaign near San Diego, CA. The data will be used to quantify the impacts of aerosol from different sources on cloud properties in the Southern California Bight and on transport to the DOE EPCAPE study domain.



Facility Advantages

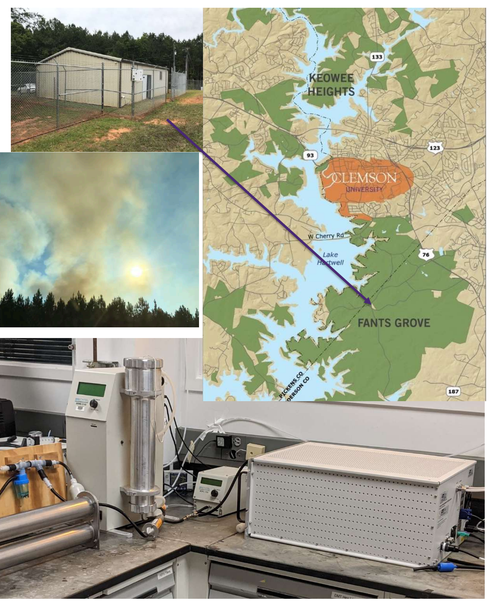
Facility Advantages

- Access high-quality, single-particle black carbon aerosol measurements for your experiment without the significant investment of purchasing your own SP2 instrument.
- The Clemson SP2 is maintained in a ready-state, with frequent calibrations to ensure highest data quality.
- The user fee is about $975 per week, pro-rated and customized to your use-case.
- The SP2 can be hand-delivered (if local) or easily shipped.
- In-person or virtual training to operate the instrument is available.
- Basic and advanced data analysis options are available.

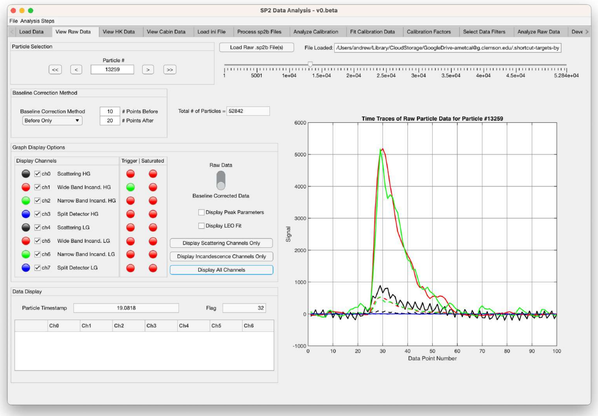
Research on the Ground

In October and November of 2022, the Clemson SP2 was deployed to the Georgia Wildland-fire Simulation Experiment (G-WISE) at the University of Georgia. The data will be used to characterize BC aerosol from different fuel sources relevant to the Southeast U.S. and under different fire conditions (prescribed vs. wild). Data will be combined with a large suite of other measurements available on aerosol chemical and optical properties.

The Clemson Air Quality Lab has been measuring ground-level air quality in the Clemson Experimental Forest (CEF). The SP2 station is located inside of a shelter at the Clemson Atmospheric Research Lab (CARL) within the CEF such that data can be collected near local biomass burning (i.e., prescribed fires used to maintain the forest). Together with a Scanning Electrical Mobility Sizing (SEMS) System, consisting of a DMA and CPC operating in tandem, our ground station quantifies the number and size of nearly all aerosol particles <1 micron in diameter and differentiates the BC aerosol from other aerosol types. We have also deployed low-cost particulate matter sensors for their validation and have plans to expand sampling capabilities at the site.



SP2 Data Analysis App



In an effort to make analysis of SP2 data more accessible, we are developing an SP2 Data Analysis app that is available to facility users. Our app is built with Matlab's App Designer to link an intuitive user interface to the underlying analysis code. For users who do not have access to Matlab, a standalone executable will be distributed for either Windows or Mac operating systems. The goals for the app are to:

1) provide easy visualization of both raw and analyzed data for the user to gain intuition as to what the data mean;

2) to standardize the analysis methods employed to turn raw SP2 data into the final data products.

Education and Outreach

A common challenge faced by scientists is how do we appropriately communicate with a non-scientific audience how our high-tech instruments work and why they are important. One approach is to design simple, hands-on experiments that demonstrate complex physics and chemistry and then relate that experience to the principles on which the instrument operates. Here, we have a simple, hands-on light-scattering experiment to explain how the SP2 "sees" particles suspended in the air. The audience (particularly K-12 students) is especially engaged when they have some control over the experiments, such as turning the fan on and off.

Acknowledgements

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