Measurements of Black Carbon Aerosol in DC3 and SEAC^{4}RS

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Black carbon (BC) in the atmosphere plays an important role in global climate change, affecting climate radiative forcing directly through its absorption of solar radiation and indirectly by affecting cloud processes. Measurements of BC as proposed during DC3/SEAC^{4}RS will help elucidate not only its direct impact on climate, but also will bear on both its possible indirect (as CCN/IN) and semi-direct effects. These measurements will be carried out with a pair of Single-Particle Soot Photometers (SP2; Droplet Measurement Technologies, Boulder, Colorado).

The SP2 is a laser-induced incandescence instrument primarily used for measuring the BC mass content of individual particles. It is able to provide this data product independently of the total particle morphology and mixing state, and thus delivers detailed information not only about BC loadings, but also size distributions, even in exceptionally clean air. The instrument can also provide the optical size of individual particles containing BC, and identify the presence of coatings associated with the BC fraction (i.e. identify the BC's mixing state). Since its introduction in 2003, the SP2 has been substantially improved, and now can be considered a highly competent instrument for assessing BC loadings and mixing state in situ.

A single SP2 system is shown schematically to the right. Ambient air is drawn through an intense intracavity laser (a diode-pumped Nd:YAG laser operating in a Gaussian TEM-00 mode at 1.064 μm wavelength). Aerosol particles in the air enter the laser singly, and there scatter laser light according to their size and composition. The quantity of scattered light, and its evolution in time, is recorded. When BC enters the laser, it is heated to vaporization (~3500K), emitting blackbody radiation (incandescent light) in quantities directly related to its mass, regardless of particle morphology or mixing state. The color of this radiation is detected and used to deduce the vaporization temperature of the particle as a constraint on its composition. A detector system developed by NOAA is used to optically size BC-containing particles, before they are perturbed by laser heating.

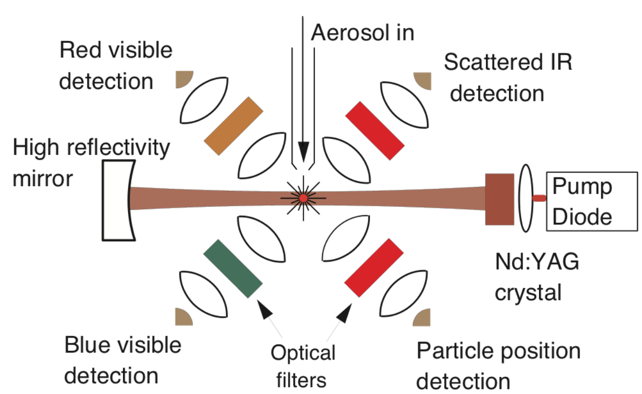

Figure 3. Schematic diagram of the SP2 photometer showing the basic optics and laser-induced incandescence and scattering detectors.

This allows quantification of the amount of non-BC material (interpreted as coating thickness via shell-core Mie theory) associated with each BC core, and its impact on the optical properties (including absorption cross-section) of the BC-component

The thickness of coatings on a BC core is related to the core's history and source; freshly emitted BC tends to be relatively bare and then accrues additional coating materials with time. Coatings increase BC's absorption of sunlight, and their hygroscopicity is a microphysical parameter that dramatically affects the likelihood of BC's removal through wet deposition. Hence coating thickness and hygroscopicity (κ_{BC}) affect BC's concentration and ultimate impact on climate. κ_{BC} has not been measured from an airborne platform before.

In DC3/SEAC^{4}RS two SP2s operating in parallel at different RHs will quantify κ_{BC}. This composite instrument, called the "Humidified Dual-SP2" (HD-SP2) draws upon the individual-particle detection of the SP2 to maximize sensitivity, and provides continuous dry and humidified sampling of all accumulation mode particles containing BC. Note that the κ_{BC} information extracted is not merely that of the bulk-material internally mixed with BC because the HD-SP2 can differentiate different classes of BC-containing particles within the whole distribution. For example, if fresh fossil-fuel emissions are mixed with aged air, a bimodal shift in optical size with humidification occurs, due to the different amounts and κ_{BC} of the coating materials associated with the different types of BC aerosol.

The NOAA HD-SP2 will be fully autonomous, hence team members are not needed onboard the DC8 during flight. With the NASA Real Time Mission Monitor (RTMM) system and aircraft communication using the Research Environment for Vehicle-Embedded Analysis on Linux (REVEAL) live quick-look data can be provided to the ground or aircraft mission science team. With the communication link, we can monitor, control, and optimize the instrument performance from the ground during flights. The performance characteristics of the HD-SP2 configuration proposed for DC3 and SEAC4RS are listed in Table 1.

Table 1: Performance characteristics of the HD-SP2.

Operational altitude	Ground - 21 km (1013 hPa – 50 hPa)
Flight duration	12 hours
Weight	210 lbs for the two SP2s and the humidifier forming the HD-SP2
BC Aerosol data products	1. Black carbon mass and size distributions 2. Black carbon mixing state 3. Total optical size of BC-containing particles 4. Average κ_{BC} of materials internally mixed with BC
Maximum particle event rate	20,000 s^{-1}
BC mass detection range	0.5 – 680 fg (corresponding to 0.08 – 0.9 μm mass-equivalent diameter assuming a 2 g/cc density)