BOSTON COLLEGE / AERODYNE SOOT PROJECT 2

Exit Report

The three-week (July 7 to 26, 2008) Boston College/Aerodyne Soot Project 2 has been completed. The Project utilized the Boston College laboratory flame apparatus and aerosol conditioning and characterization equipment which is a well-tested soot aerosol generation system for producing and modifying soot particles over a wide range of sizes, shapes, and coatings. A pre-mixed flat flame burner operating at controlled, premixed fuel–to-air ratios, produced stable and reproducible concentrations of soot particles with known morphologies and chemical compositions. Using the suite of instruments listed in Appendix 2, particles were fully characterized as a function of particle mass, shape, chemistry, and optical properties.

The science goals for the project as outlined in the in the original announcement of April 3, 2008 are shown in Appendix 1. While the final project evaluation will not be available until the data analysis is completed, it appears that the goals have been met and more. By all measures the project has been successful. Highlights from the study will include:

#	Highlights	Science Goals Addressed
1	Particle shape determination as a function of fuel-to-air ratio and collapse observed due to coatings	1
2	Characterization of several new instruments currently under development	2, 3, 4
3	Characterization of the physical and chemical properties of various types of black carbon particles (including incandescence, fullerene content, surface-bound PAH, etc.)	3, 4
4	Mass specific absorption measurements as a function of fuel-to-air ratio and carbon particle type	5
5	Optical absorption enhancement measurements as a function of coatings	5
6	Wavelength-dependent measurements of absorption, scattering, and extinction as a function of fuel-to-air ratio, particle coating, and relative humidity	6, 7, 8

Altogether 19 instruments participated in the studies; 9 mass-based, 8 optically-based and 2 filter samples. Twenty-six people representing 12 institutions participated in the project. (See Appendix 2). Experiments were conducted six days a week beginning typically at 9 a.m. and often continuing past midnight. The group held a breakfast meeting each Wednesday morning to discuss and plan the studies. Each Thursday a group dinner was hosted by Boston College and Aerodyne Research at a near-by Legal Sea Food restaurant.

In the course of the three weeks, 318 runs were performed covering a matrix that systematically tested instruments' performance over a range of relevant parameters. A detailed Run List of these experimental runs will accompany this report. Opportunity was provided for each instrument to sample soot particles as a function of the following measured (directly or indirectly) and controlled parameters: particle mobility size (in the range 30 to 300 nm), particle number concentration, particle shape (dynamic shape factor and fractal dimension), particle chemistry and density (changed via coatings), black carbon mass, and relative humidity in the range 5 to 90%. In selected runs, particles were coated with a measured thickness (few nm to

~150 nm) of sulfuric acid or dioctyl sebacate (DOS). In addition to flame-generated soot, black carbon (BC) particles were also obtained by atomizing fullerene soot, glassy carbon spheres, oxidized flame soot, Regal black toner, and Aquadag paint.

The final tasks are to process the data and publish the relevant results. Preliminary results are to be submitted to Eben Cross (crosse@bc.edu or via ftp server) by September 1, 2008. The preliminary data will consist of averages (with deviations) for relevant measured and calculated observables from each instrument for each of the 318 experimental runs. (Refer to attached Run List). An email list and a ftp site have been established at Aerodyne to help facilitate collaboration and sharing of data. The email address is 'soot_project2@aerodyne.com' and currently includes 36 people (all of whom will receive this exit report). Addresses can be readily added or removed if so inclined (please contact Tim Onasch at onasch@aerodyne.com). The ftp site address is 'ftp://soot:project2@ftp.aerodyne.com/projects/soot_project2/' where the login is 'soot' and password is 'project2' (single quotes not included in any entry).

Our goal is to publish an overview paper (or two) about the Boston College/Aerodyne Research Soot Project 2 that summarizes the project and the main results. We will work hard to facilitate the publishing of detailed work by all interested participating groups. We anticipate all related publications to be completed within the coming year.

APPENDIX 1 SCIENCE GOALS:

Mass-based Measurement Goals:

1. Include an APM/CPMA instrument (in combination with DMA) for accurate particle mass, density, and fractal dimension measurements. These measurements will verify our SMPS-AMS measurements of particle mass, density, and fractal dimension as well as provide a reference for other elemental carbon mass measurements.
2. Quantify SP2AMS carbon ion cluster measurements as a function of black carbon particle mass. Investigate how coatings (liquid/solid, organic/inorganic/water) affect carbon ion cluster measurements? How well can the SP2AMS characterize the chemistry and mass of the soot particle coatings?
3. Verify the quantification of SP2 incandescence measurements as a function of black carbon particle mass. Continue to investigate how coatings (liquid/solid, organic/inorganic/water) affect the SP2 measurements?
4. How do DMA-APM, SP2AMS, and SP2 BC mass measurements compare with OC/EC mass measurements? Investigate how coatings (liquid/solid, organic/inorganic/water) affect the OC/EC measurement? In particular, how well can the OC/EC instrument separate elemental carbon from organic carbon?

Optical-based Measurement Goals:

5. Make measurements of mass specific absorption coefficients as a function of black carbon particle type (e.g. as function of fuel, fuel-to-air ratio, size) and coatings (liquid/solid, organic/inorganic/water)
6. How does water coatings (e.g. RH) affect optical signals (e.g. photoacoustic, maap)? Particle may rearrange or collapse during denuding of coating material, how might morphology changes affect measure optical signals?
7. Effects of absorbing organics on black carbon particles with respect to optical instruments?

8. Optical closure study (Extinction, Scattering, and Absorption) utilizing the extinction and scattering measurements by the new Aerodyne CAPS-based instrument, the NOAA CRD extinction system, and the various absorption and scattering instruments.

APPENDIX 2

INSTRUMENTS USED IN THE STUDY

A. Particle Generation and Conditioning Equipment

Premixed flat flame burner

Coating and humidity conditioners

Thermal Denuder (TD; Aerodyne Research)

Differential Mobility Analyzers (DMA; TSI model 3076 and 3080) - two in number

Assorted flow meters, flow controllers and humidity monitors

B. Mass-Based Instruments

a. Scanning Mobility Particle Sizer (SMPS; TSI)
b. Condensation Particle Counters (CPC; TSI model 3022a) - two in no.
c. Time of Flight Aerosol Mass Spectrometer (TOF-AMS; Aerodyne Research)
d. Soot Particle Aerosol Mass Spectrometer (SP2-AMS; Aerodyne Research)
e. Single Particle Soot Photometer (SP2; Droplet Measurement Technology) - three in number
f. Couette Centrifugal Particle Mass Analyzer (CPMA) and CPC (TSI model 3025)
g. Particle-Bound Polycyclic Aromatic Hydrocarbons (PAH) Monitor (PAS2000CE; EcoChem)
h. Diffusion Charger (DC2000CE; EcoChem)
i. Cloud Condensation Nuclei Counter (CCN; DMT)

C. Optically Based Instruments

j. Photo-acoustic Spectrometer (PAS; NOAA)	λ = 532 nm
k. Photo-acoustic Soot Spectrometer (PASS-3; DMT)	λ = 405, 532 and 781 nm
l. Photo-Thermal Interferometer (PTI)	λ = 532 nm
m. Cavity-Ring Down (CRD) Extinction Spectrometer	λ = 355, 532 and 1064 nm
n. Cavity Attenuated Phase Shift (CAPS) Extinction monitor	λ = 440 nm
o. Particle Soot Absorption Photometer (PSAP; Radiance Res.)	λ = 450, 550 and 700 nm
p. Nephelometer (TSI model 3563)	λ = 450, 550 and 700 nm
q. Multi-Angle Absorption Photometer (MAAP; Thermoelectron)	λ = 670 nm

D. Filter Samples

r. Organic Carbon-Elemental Carbon Analyzer (OCEC; Sunset Labs) filter samples
s. Scanning Electron Microscope (SEM) filter samples

PARTICIPATING INSTITUTIONS

Aerodyne Research Inc. (ARI)

Boston College (BC)

Brookhaven National Laboratory (BNL)
Droplet Measurement Technologies (DMT)
Los Alamos National Laboratory (LANL)
NOAA CIRES
NOAA ESRL
University of California Davis
University of Hawaii
University of Illinois
University of Toronto
Virginia Tech

LIST OF PARTICIPANTS

(Bracketed letters refer to the instruments operated by the person.)

Ahern, Adam	Boston College (BC)	(A, r, s)
Brem, Benjamin	University of Illinois (Tami Bond group)	(r)
Cappa, Christopher	UC Davis	(j)
Cross, Eben	BC	(A, a, b, c)
Davidovits, Paul	BC	(A)
Dubey, Mavendra	Los Alamos National Laboratory (LANL)	(k, s)
Freedman, Andy	Aerodyne Research Inc. (ARI)	(n)
Freitag, Steffen	University of Hawaii (Tony Clarke group)	(e, o, p)
Jayne, John	ARI	(A, d)
Kok, Greg	Droplet Measurement Technologies (DMT)	(e)
Lack, Daniel	NOAA ESRL	(j, m, o)
Massoli, Paola	NOAA ESRL	(m)
Mazzoleni, Claudio	LANL	(k, s)
Ng, Sally	ARI	(d)
Olfert, Jason	Brookhaven National Laboratory (BNL)	(f)
Onasch, Tim	ARI	(A, d)
Schwarz, Joshua (Shuka)	NOAA CIRES	(e)
Sedlacek, Arthur	BNL	(l)
Slowik, Jay	University of Toronto	(a, c)
Spackman, Ryan	NOAA CIRES	(e)
Subramanian, R. (Subu)	DMT	(e)
Thornhill, Dwight	Virginia Tech (Linsey Marr group)	(g, h)
Trimborn, Achim	ARI	(d)
Williams, Leah	ARI	(d)
Worsnop, Doug	ARI	(d)
Wrobel, Billy	BC	(A, i)