13th International Conference on Carbonaceous Particles in the Atmosphere

July 9–12, 2023 I Berkeley, California, USA

Technical Program

13th International Conference on Carbonaceous Particles in the Atmosphere

July 9–12, 2023 | Berkeley, California, USA

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13th ICCPA

International Conference on Carbonaceous Particles in the Atmosphere

July 9–12, 2023 | Lawrence Berkeley National Laboratory
Berkeley, California, USA

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13th ICCPA

International Conference on Carbonaceous Particles in the Atmosphere

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13th International Conference on Carbonaceous Particles in the Atmosphere

July 9–12, 2023 | Berkeley, California, USA

108 Participants by Affiliate Country for the 13th ICCPA (as of July 6, 2023)

Country	Number	Percentage
Austria	1	1%
Canada	1	1%
Finland	3	3%
France	2	2%
Germany	1	1%
Greece	1	1%
Hungary	2	2%
India	4	4%
Italy	1	1%
Japan	3	3%
Mexico	2	2%
Netherlands	1	1%
New Zealand	1	1%
Slovenia	4	4%
South Korea	2	2%
Sweden	1	1%
Switzerland	3	3%
United States	75	69%

13th International Conference on Carbonaceous Particles in the Atmosphere

July 9–12, 2023 | Berkeley, California, USA

General Schedule of Events

All conference events will take place at the Brower Center (2150 Allston Way, Berkeley, California, USA, 94704) in downtown Berkeley.

Sunday, July 9

16:30–18:30 Registration & Check-In
18:00–20:00 Welcome Reception

Monday, July 10

08:00–09:00 Coffee & Light Breakfast
09:00–09:15 Opening Remarks
09:15–10:40 Biomass Burning I
10:40–11:00 Coffee Break
11:00–12:25 SOA Formation I
12:25–13:45 Lunch
13:45–14:20 Sponsor Lightning Talks
14:20–15:45 Novel Methods & Instrumentation I
15:45–16:05 Coffee Break
16:05–17:30 Optical Properties, Radiative Forcing, & Climate I
17:30–18:00 Poster Lightning Talks I
18:00–20:00 Poster Session & Reception I – Novel Methods & Instrumentation; Optical Properties, Radiative Forcing & Climate; Source Characterization & Apportionment

Tuesday, July 11

08:00–09:00 Coffee & Light Breakfast
09:00–10:45 Source Characterization & Apportionment I
10:45–11:05 Coffee Break

11:05–12:10 Bioaerosols, CCN, & INPs I
12:10–13:30 Lunch
13:30–14:55 Low-Cost Sensors & Community Monitoring
14:55–15:15 Coffee Break
15:15–16:55 Novel Methods & Instrumentation II
16:55–17:15 Break
17:15–18:00 Poster Lightning Talks II
18:00–20:00 Poster Session & Reception II – Bioaerosols; Biomass Burning; CCN & INPs; Health Effects; Low-Cost Sensors & Community Monitoring; SOA

Wednesday, July 12

08:00–09:00 Coffee & Light Breakfast
09:00–10:45 Source Characterization & Apportionment II
10:45–11:05 Coffee Break
11:05–12:10 Bioaerosols, CCN, & INPs II
12:10–13:30 Lunch
13:30–14:55 Biomass Burning II
14:55–15:15 Coffee Break
15:15–16:40 Optical Properties, Radiative Forcing, & Climate II
16:40–16:50 Closing Remarks
End of Conference

13th International Conference on Carbonaceous Particles in the Atmosphere

July 9–12, 2023 | Berkeley, California, USA

Detailed Schedule of Events

Sunday, July 9

16:30	Check-In Begins
18:00	Welcome Reception—Food and refreshments will be provided
20:00	End of Day

Monday, July 10

08:00	Coffee and Light Breakfast
09:00	**Opening Remarks, Tom Kirchstetter**
09:15	**Biomass Burning 1** ***Co-Chairs: Olga Mayol-Bracero, Chandra Venkataraman***
09:20	Maria A. Zawadowicz, Brookhaven National Laboratory—*Laboratory constraints on photochemical processing of biomass burning-derived secondary organic aerosol*
09:40	Kyle Gorkowski, Los Alamos National Laboratory—*Insights into pyrocumulonimbus updrafts: Observations and simulations of secondary organic aerosol formation*
10:00	Chandra Venkataraman, Indian Institute of Technology Bombay—*Carbonaceous aerosol abundances over India and contributions of agricultural residue burning*
10:20	Arthur Sedlacek, Brookhaven National Laboratory—*Using the black carbon particle mixing state to characterize the lifecycle of biomass burn aerosols*
10:40	Break
11:00	**Secondary Organic Aerosol** ***Co-Chairs: Gabriel Isaacman-VanWertz, Hans Moosmüller***

11:05 Gabriel Isaacman-VanWertz, Virginia Tech—*Ecological drivers of emissions impact aerosol formation potential and properties*

11:25 Julian Resch, University of Basel—*Insights into the storage aging effects on dimer esters and other oligomers in beta-pinene secondary organic aerosol samples*

11:45 Pietro Vannucci, University of California, Berkeley—*Temperature dependent model biases in PM2.5 components in the Eastern U.S. summertime*

12:05 Chenyang Bi, Virginia Tech—*Modeled impact of deposition on the oxidation pathways of common reactive precursors*

12:25 Lunch

13:45 **Sponsor Lightning Talks**
Co-Chairs: Tom Kirchstetter, Chelsea Preble

13:50 3-Minute Lightning Talks by Each Sponsor

14:20 **Novel Methods & Instrumentation I**
Co-Chairs: Ann Dilner, Rajan Chakrabarty

14:25 Romain Ceolato, The French Aerospace Lab-ONERA—*Picosecond Short-Range Elastic Backscatter Lidar (PSR-EBL): A novel technique for remote measurement of black carbon emissions*

14:45 Muhammad Naveed Anwar, University of California, Davis—*Quantification of organic aerosol concentration and composition at Pretoria, South Africa employing Fourier-transform infrared spectroscopy (FT-IR)*

15:05 Joshin Kumar, Washington University in St. Louis: *Correcting for biases in filter-based aerosol light absorption measurements at the ARM Southern Great Plains site*

15:25 Samuel Fernandes, University of California, Berkeley—*Indoor smoke monitoring using short range elastic backscatter lidar for air quality in buildings*

15:45 Break

16:05 **Optical Properties, Radiative Forcing, & Climate I**
Co-Chairs: Arthur Sedlacek, András Gelencsér

16:10 Ganesh Chelluboyina, Washington University in St. Louis—*Quantifying snow albedo reducing effects of brown carbon aerosols on the brown-black continuum using SNICAR radiative transfer model*

16:30 Hans Moosmüller, Desert Research Institute—*The 2023 Soot-on-Snow Campaign in Finland: Study design and first results*

16:50 Maegan DeLessio, Columbia University & NASA GISS—*Initial results and evaluation of brown carbon representation in GISS ModelE*

17:10 Thomas Mueller, Leibniz Institute for Tropospheric Research—*Optical properties of black carbon fractal aggregates: Results from laboratory measurements, optical simulations, and machine learning*

17:30 **Poster Lightning Talks I**
Chair: Chelsea Preble

17:35 1-Minute Lightning Talks by Each Poster Presenter

18:00 **Poster Session and Reception I**
Novel Methods & Instrumentation
Optical Properties, Radiative Forcing, & Climate
Source Characterization & Apportionment

20:00 End of Day

Tuesday, July 11

08:00 Coffee and Light Breakfast

09:00 **Source Characterization & Apportionment I**
Co-Chairs: András Gelencsér, Chandra Venkataraman

09:05 Ryan Farley, University of California, Davis—*Diverse sources and atmospheric processing of soot aerosol in Houston: Insights from measurements of black carbon composition and mixing state*

09:25 Drew Hill, AethLabs—*Practical applications of real-time black carbon source apportionment using a portable micro-Aethalometer with various climate control and sample line conditioning configurations*

09:45 András Hoffer, University of Pannonia—*Assessment of the contribution of residential waste burning to PM10 concentrations using novel organic tracers*

10:05 Chandra Venkataraman, Indian Institute of Technology Bombay—*Carbonaceous aerosol emissions from the Speciated Multipollutant Generator (SMoG): India emission inventory*

10:25 Asta Gregorič, Aerosol d.o.o.—*High-time-resolution carbonaceous aerosols fingerprint using an advanced total carbon–black carbon (TC-BC(λ)) method: Los Angeles Basin case study*

10:45 Break

11:05 **Bioaerosols, Cloud Condensation Nuclei, & Ice-Nucleating Particles I**
Co-Chairs: Hinrich Grothe, Olga Mayol-Bracero

11:10 Abu Sayeed Md Shawon, Los Alamos National Laboratory—*Meteorological impacts on the properties of bioaerosol particles during the SAIL Campaign*

11:30 Barbara Bertozzi, Paul Scherrer Institute—*Annual cycle of black carbon-cloud interactions in the high Arctic*

11:50 Hinrich Grothe, Vienna University of Technology—*Biological macro-molecules causing heterogeneous ice nucleation*

12:10 Lunch

13:30 **Low-Cost Sensors & Community Monitoring**
Co-Chairs: Kalpana Balakrishnan, Chelsea Preble

13:35 Lu Liang, University of North Texas—*Integrating low-cost sensor monitoring, satellite mapping, and geospatial artificial intelligence for intra-urban air pollution predictions*

13:55 Charles Scarborough, Sonoma Technology—*Neighborhood-scale air quality mapping in Sacramento communities using a research-grade mobile platform*

14:15 Rebecca Sugrue, University of California, Berkeley—*The use of black carbon sensors to enhance particulate matter monitoring in communities*

14:35 Ajith Kaduwela, University of California, Davis—*Community air quality monitoring in Sri Lanka using home-made low-cost sensor packages*

14:55 Break

15:15 **Novel Methods & Instrumentation II**
Co-Chairs: Griša Močnik, Ann Dillner

15:35 Konstantinos Eleftheriadis, National Centre of Scientific Research "Demokritos"—*Standardisation of black carbon aerosol metrics for air quality and climate modelling: The StanBC project*

15:55 Erkki Lamminen, Dekati Ltd—*Experimental and numerical characterization of a new oxidation flow reactor (DOFR)*

16:15 Griša Močnik, University of Nova Gorica—*A dual-wavelength photothermal aerosol absorption monitor: Design, calibration, performance, and measurements of coated soot*

16:35 Battist Utinger, University of Basel—*Online quantification of oxidative potential from residential wood combustion (RWC) and car exhaust aerosol*

16:55 Break

17:15 **Poster Lightning Talks II**
Chair: Chelsea Preble

17:20 1-Minute Lightning Talks by Each Poster Presenter

18:00 **Poster Session and Reception II**
Bioaerosols
Biomass Burning
Cloud Condensation Nuclei & Ice-Nucleating Particles
Health Effects
Low-Cost Sensors & Community Monitoring
Secondary Organic Aerosol

20:00 End of Day

Wednesday, July 12

08:00 Coffee and Light Breakfast

09:00 **Source Characterization & Apportionment II**
Co-Chairs: Hans Moosmüller, Gabriel Isaacman-VanWertz

09:05 András Gelencsér, University of Pannonia—*Emission factors for PM10 and polycyclic aromatic hydrocarbons (PAHs) from illegal burning of different types of municipal waste in households*

09:25 Hamesh Patel, The University of Auckland—*Utilizing x-ray fluorescence and Raman microscopy to determine the chemical and elemental composition of ambient particulate in a Southern Hemispheric city*

09:45 Chelsea Preble, University of California, Berkeley—*Characterization of in-use heavy-duty diesel truck emission rates and emission control technology performance*

10:05 Minna Aurela, Finnish Meteorological Institute—*Sources of carbonaceous aerosol at the street canyon site over the years 2015–2022 in Helsinki, Finland*

10:25 Kristina Glojek, University of Nova Gorica—*Identification and detailed characterization of PM10 sources in an Alpine valley influenced by a cement plant*

10:45 Break

11:05 **Bioaerosols, Cloud Condensation Nuclei, & Ice-Nucleating Particles II**
Co-Chairs: Hinrich Grothe, Kalpana Balakrishnan

11:10 Ogochukwu Enekwizu, Brookhaven National Laboratory—T*he activation properties of fresh and aged black carbon from biomass burning*

11:30 Susan Mathai, Michigan Technological University—*Light absorbing aerosol-cloud interactions*

11:50 Abu Sayeed Md Shawon, Los Alamos National Laboratory—*Properties of bioaerosol particles emitted from smoldering and flaming burns of evergreens*

12:10 Lunch

13:30 **Biomass Burning II**
Co-Chairs: Griša Močnik, Arthur Sedlacek

13:35 Dongli Wang, Clemson University—C*haracterization of black carbon aerosols from prescribed and laboratory fires in the Southeast U.S.*

13:55 James Butler, University of California, Berkeley—*Comparison of black and brown carbon emission factors, pollutant ratios, and optical properties in prescribed burn and wildland fire smoke in California*

14:15 Jishi Zhang, Lawrence Livermore National Laboratory—*Multiscale convection-permitting wildfire simulation over California*

14:35 Nealan Gerrebos, University of British Columbia—*Liquid-liquid phase separation and viscosity in biomass burning organic aerosols and climatic impacts*

14:55 Break

15:15 **Optical Properties, Radiative Forcing, & Climate II**
Co-Chairs: Hans Moosmüller, Rajan Chakrabarty

15:20 Hans Moosmüller, Desert Research Institute—*Properties of black carbon aerosols needed for remote sensing and radiative forcing applications*

15:40 Arushi Sharma, Indian Institute of Technology Bombay—*Black carbon and dust dominant aerosols intensify heat stress in India*

16:00 Jesús Yus-Díez, University of Nova Gorica—*Airborne in-situ measurements during JATAC/CAVA-AW 2021/2022 Cabo Verde campaigns: First climate-relevant results*

16:20 Rajan Chakrabarty, Washington University in St. Louis—*Dominant contribution to shortwave absorption by dark brown carbon in wildfire smoke*

16:40 **Closing Remarks, Tom Kirchstetter**

16:50 End of Conference

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Poster Presentations

Monday, July 10

Novel Methods & Instrumentation

Poster	Presentation Detail
1	Anahita Amiri-Farahani, University of California, Davis—*Fourier transform infrared (FT-IR) organic and elemental carbon (OC & EC) measurements in the Chemical Speciation Network (CSN)*
2	Fred Brechtel, Brechtel Manufacturing Inc—*Fall 2020 wildfire biomass burning and diesel truck traffic measured by the tricolor absorption photometer*
3	Olivier Durif, KTH Royal Institute of Technology—*From RO2 to HOMs: Investigating the monomolecular reactions of individual unsaturated RO2 with proton transfer mass spectrometry*
4	Hiroyuki Hagino, Japan Automobile Research Institute—*Simultaneous measurement of carbon and trace elements in brake wear particles from passenger car using Inductively Coupled Plasma Time-of-Flight Mass Spectrometer*
5	Tommaso Isolabella, University of Genoa—*BLAnCA: An innovative instrument for full-spectrum light absorption measurements on carbonaceous aerosol*
6	Ann Dillner, University of California, Davis—*Can infrared spectra functional group measurements improve organic aerosol characterization from time of flight-aerosol chemical speciation monitor (TOF-ACSM)?*
7	Andrew Metcalf, Clemson University—*An NSF user facility for measuring black carbon aerosol for research and education*
8	Warren White, University of California, Davis—*Absorption photometry on ringed-PTFE filters: Accounting for pixelated deposits*
9	Xiaolu Zhang, University of California, Davis—*Quantifying residual elemental carbon by thermal-optical analysis using an extended IMPROVE_A protocol with higher maximum temperature*

Optical Properties, Radiative Forcing, & Climate

Poster	Presentation Detail
10	Barbara Bertozzi, Paul Scherrer Institute—*Assessing the potential to improve polarimetric aerosol property retrievals for black carbon aerosol*
11	Kyle Gorkowski, Los Alamos National Laboratory—*Humidity-induced changes in the optical properties of dust particles: Insights from field measurements and simulations*
12	Joshin Kumar, Washington University in St. Louis—A*ggregation-induced enhancements in aerosol absorption and scattering across the black-brown continuum*
13	Susan Mathai, Michigan Technological University—*Optical properties of atmospherically aged tar balls from the free troposphere and their climatic impacts*
14	Hans Moosmüller, Desert Research Institute—*Snow surface albedo sensitivity to black carbon: Radiative transfer modelling*

Source Characterization & Apportionment

Poster	Presentation Detail
15	Abisheg Dhandapani, Birla Institute of Technology, Mesra—*Source identification and characteristics of water-soluble inorganic ions in PM2.5 in Mesra, Ranchi: A COALESCE network site in India*
16	Hinrich Grothe, Vienna University of Technology—*Classification of carbonaceous aerosol particles originating from asphalt pavement*
17	Drew Hill, AethLabs—*micro-Aethalometer-based black carbon measurements and source apportionment at novel long-term monitoring sites in Addis Ababa, Ethiopia as part of the Multi-Angle Imager for Aerosols (MAIA) Investigation*
18	Alena Kubatova, University of North Dakota—*Thermal desorption-pyrolysis-gas chromatography-mass spectrometry tool for analysis of both non-volatile and volatile air particulate matter markers*
19	Ngoc Tran, Osaka Prefecture University—*Source apportionment of one-year observation PM2.5 in Ho Chi Minh City, Vietnam*

Tuesday, July 11

Bioaerosols

Poster	Presentation Detail
1	Kevin Axelrod, Desert Research Institute—*Quantitative chemical analysis of pollen extracts and their volatility behavior in aerosolized form*

2	Palina Bahdanovich, Desert Research Institute—*Chemical characterization of bioaerosols*
3	Hinrich Grothe, Vienna University of Technology—*Biological aerosol particles in the Finnish Sub-Arctic*

Biomass Burning

Poster	Presentation Detail
4	Giovanni Carabalí, National Autonomous University of Mexico—*The influence of carbonaceous aerosols on the reduction of solar irradiance in Mexico City*
5	Yusuke Fujii, Osaka Metropolitan University—*Assessment of carbonaceous ultrafine particles in Kuala Lumpur, Malaysia, influenced by peatland fires*
6	Dagen Hughes, Droplet Measurement Technologies—*Trends in refractory black carbon mass concentration and coating thickness during the 2021 Regional Cumulative Assessment Project (ReCAP)*
7	Timothy Onasch, Aerodyne Research Inc—*Near infrared-absorbing, non-black carbon particulate material from biomass burning*
8	Minhan Park, Gwangju Institute of Science and Technology—*Comparison of physical, chemical, and toxicological properties of fresh and aged fine particles emitted from rice straw and pine stem burning*
9	Chandra Venkataraman, Indian Institute of Technology Bombay—*Agricultural biomass burning in India: Carbonaceous aerosol constituents and optical properties*

Cloud Condensation Nuclei & Ice-Nucleating Particles

Poster	Presentation Detail
10	Saman Aria, West Texas A&M University—*Investigation of atmospheric ice nucleation using nano-liter volume water droplets with a microfluidic device*
11	Darrel Baumgardner, Droplet Measurement Technologies—*Introducing the Droplet Residual Analyzer for Groundbased Observations of Nucleation (DRAGON)*
12	Manuella El haber, University of Lyon—*Surfactants in complex atmospheric aerosols: Mixing effects, synergism, and implications for cloud formation*
13	Matthew Fraund, Sonoma Technology Inc—*Characterization of cloud condensation nuclei over the Eastern North Atlantic*
14	Emmanuel Oko, West Texas A&M University—*Potential impact of the Arctic glacier recession on ice-nucleating particle emission*

Health Effects

Poster	Presentation Detail

Poster	Presentation Detail
15	Rajan Chakrabarty, Washington University in St. Louis—*Oxidative potential and optical properties of biomass burning aerosols: Direct and filter-based measurements*
16	Olga Mayol-Bracero, Brookhaven National Laboratory—*A worldwide carbonaceous aerosol phenomenology*

Low-Cost Sensors & Community Monitoring

Poster	Presentation Detail
17	Mark Campmier, University of California, Berkeley—*Mobile measurements enable identification of multi-pollutant hotspots: Evidence from intensive monitoring in San Francisco and Oakland*
18	Sami Harni, Finnish Meteorological Institution—*Detecting small-scale spatial differences in black carbon concentrations using BC sensor network*
19	Anthony Strawa, Sustainable Silicon Valley—*Engaging youth on air quality issues*

Secondary Organic Aerosol

Poster	Presentation Detail
20	Haofei Zhang, University of California, Riverside—*Reevaluating isoprene oxidation pathways and their influence on secondary organic aerosol formation*

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Abstracts—Platform Presentations

Laboratory constraints on photochemical processing of biomass burning-derived secondary organic aerosol

Maria A. Zawadowicz[1], Yuzhi Chen[2], John E. Shilling[2], Gregory W. Vandergrift[2], Tania Gautam[2], Swarup China[2], Arthur J. Sedlacek III[1]

[1]Brookhaven National Laboratory, Upton, NY, USA
[2]Pacific Northwest National Laboratory, Richland, WA, USA

Biomass burning events, such as wildfires, are a substantial, and potentially increasing, source of primary and secondary aerosol and reactive gas emissions into the free troposphere. As the fire plumes age, biomass burning-derived aerosols and gases undergo photochemical processing, which can result in changes to aerosol organic mass and chemical transformations that impact their optical and hygroscopic properties. Capturing those processes in global climate models is important for constraining organic aerosol mass and correctly predicting both direct and indirect effects of aerosols on climate. Recently Sedlacek et al. have described biomass burning aerosol lifecycle using data from multiple field measurements, showing a fast (first few hours) initial organic coating accumulation through secondary organic aerosol (SOA) formation, followed by a slow (1-10 days) loss of 75% of the organic coating. This presentation reports results of laboratory experiments aimed at constraining the efficiency of SOA production from two biomass burning-derived volatile organic compounds, guaiacol and furfural, and its subsequent loss via direct photolysis. Guaiacol and furfural SOA was produced via OH oxidation in a 10.6 m^3 environmental chamber under low- and high- NO_x conditions, and subsequently aged with UV exposure for ~12 hours. Additionally, changes to the SOA composition following aging were quantified using high-resolution mass spectrometry. Guaiacol- and furfural-derived SOA was found to be non-photolabile compared to biogenically-derived SOA produced from oxidation of isoprene and α-pinene, suggesting longer atmospheric lifetimes of biomass burning-derived SOA, consistent with field campaign data.

Insights into Pyrocumulonimbus Updrafts: Observations and Simulations of Secondary Organic Aerosol Formation

Kyle Gorkowski (1)*, Eunmo Koo (2), Spencer Jordan (1, 2), Jon Reisner (1), Katherine B. Benedict (1), Manvendra Dubey (1)

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1. Earth and Environmental Sciences, Los Alamos National Laboratory, Los Alamos, NM, USA
2. University of California, Davis, Davis, CA, USA

Pyrocumulonimbus clouds (PyroCbs) are formed by large fires due to the interaction between atmospheric conditions (e.g., stability, humidity), hot updrafts, and released aerosol. With the increasing frequency of megafires, the yearly impact of PyroCbs on the climate is now being realized. These smoke plumes inject light-scattering particles into the stratosphere, causing cooling of the climate. When addressing the impact of PyroCbs on the climate, it is essential to quantify the aerosol mass injected into the stratosphere, which can persist for months to years.

In this study, we analyzed aircraft measurements of smoke plumes and developed a parameterization for large eddy simulations to account for the formation of organic aerosols during the lofting of a PyroCb. The measurements provided evidence of additional aerosol mass resulting from condensational growth, consistent with the formation of secondary organic aerosols (SOA). Based on a temperature-dependent volatility basis set for emitted organic gases such as 1-nonene, a simplified parameterization of SOA mass formation was developed and integrated into a large eddy simulation of a PyroCb. The simulation realistically captures the chimney effect, where the intact column of the PyroCb remains until it reaches the tropopause. Our study also reveals that the black carbon (BC) mass fraction of 0.5-3% in the free troposphere, observed in aircraft measurements of wildfire smoke, is consistent and lower than the boundary level mass fraction. These findings provide insights into the mechanisms that govern the vertical distribution of BC mass fraction in wildfire smoke plumes and the role of SOA in modifying the BC mass fraction.

Overall, our insights have implications for climate modeling and the environmental impacts of wildfires. We highlight the need for further research to investigate the aerosol microphysical and chemical processes that govern the vertical distribution of BC mass fraction in different types of biomass burning.

Carbonaceous aerosol abundances over India and contributions of agricultural residue burning

Chandra Venkataraman[1], Sujit Maji[2], Abhinav Anand[1], Kaushik Reddy Mudhuchuru[1], Arushi Sharma[1] Abhilash A. Panicker[2], Abhishek Chakraborty[1], Vikas Singh[3]

[1] Indian Institute of Technology Bombay, Mumbai, India

[2] Indian Institute of Tropical Meteorology Pune, Pune, India

[3] National Atmospheric Research Laboratory, Gadanki, India

Carbonaceous aerosols play important roles in affecting public health, as constituents of fine particulate matter (PM-2.5 or particles with aerodynamic diameters smaller than 2.5 μm) and climate, particularly through radiation absorption by black carbon or BC and the relatively less understood effects of brown carbon (BrC, a radiation absorbing fraction of organic carbon (OC). Here we use a newly developed carbonaceous aerosol emission inventory deployed in chemical transport model simulations and evaluate with pan-India network measurements across 11 stations for the full year of 2019. This work was done through the COALESCE network (CarbOnaceous AerosoL Emissions, Source apportionment and ClimatE impacts).

We use chemistry-coupled model simulations (WRF-Chem, with RADM2-SORGAM chemistry and MADE aerosol microphysics) for 2019, to evaluate seasonal and spatial distributions in carbonaceous aerosol abundances over India. We make a sensitivity simulation, turning off emissions from agricultural residue burning, to evaluate the contribution of this source to carbonaceous aerosol abundance.

Evaluation with daily-mean observations from 11 pan-India sites reveals good agreement of OC (normalized mean bias, NMB = 10%), however, an underestimation of BC (NMB= -40%) concentrations. This implies improved emission estimation of OC, but continued deficiencies in BC emissions in the SMoG-India emission inventory. These occur largely during the winter (DJF) and pre-monsoon (MAM) months, pointing to underestimated residential and agricultural biomass burning emissions in these months. A north-south spatial gradient occurs, with 1.7-2 and 2-3 times larger concentrations of BC and OC, respectively, in north India, during the dry season. Significant contributions to carbonaceous aerosols from agricultural residue burning range 30-50% and 40-70% of BC and OC concentrations, respectively, in parts of northwest and central India, during the post-harvest months, establishing the importance of addressing this emission source.

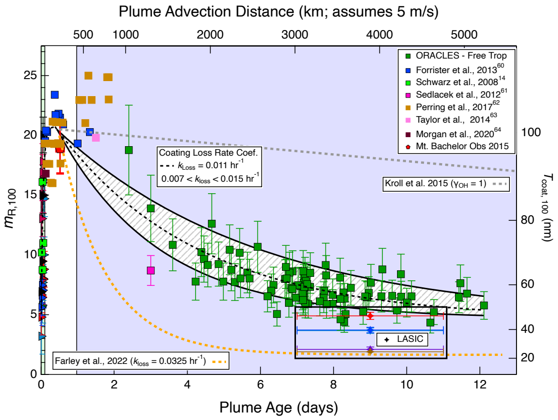
Using the Black Carbon Particle Mixing State to Characterize the Lifecycle of Biomass Burn Aerosols

A. J. Sedlacek[1], Ernie R. Lewis[1], Timothy B. Onasch[2], Paquita Zuidema[3], Jens Redemann[4], Daniel Jaffe[5], and Lawrence I. Kleinman[1]

[1]Brookhaven National Laboratory, Upton, NY, USA
[2]Aerodyne Research Inc, Billerica, MA, USA
[3]University of Miami, Miami, FL, USA
[4]University of Oklahoma, Norman, OK, USA
[5]University of Washington, Bothell, OR, USA

Wildfires are increasing in frequency and intensity because of both climate change and anthropogenic activities. In the mid-latitudes, these events are the primary drivers of year-to-year variability of particulate loading and air quality and they represent an important radiative forcing feedback loop – fires release warming agents that can contribute to further increases in the global temperatures that, in turn, can result in more wildfires.

We will discuss the lifecycle of black carbon (BC)-containing particles from biomass burns in the free troposphere using aircraft and surface observations of BC mixing state for plume ages from ~15 minutes to 10 days. Because BC is non-volatile and chemically inert, changes in the mixing state of BC-containing particles are driven solely by changes in particle coating, which is mainly secondary organic aerosol (SOA). The coating mass initially increases rapidly (first order growth rate constant = 0.84 hr^{-1}), then remains relatively constant for 1 to 2 days as plume dilution no longer supports further growth, and then undergoes a slow decrease to an asymptote of ~30 % of the maximum coating mass after 10 days. The derived first order loss rate constant of 0.011 hr^{-1} is nearly two-orders of magnitude slower than the rate constant for the growth. The mass ratio of coating-to-core for a BC-containing particle with a 100 nm mass-equivalent diameter BC core reaches a maximum of ~20 after a few hours and asymptotically approaches ~5 after 10 days of aging. The initial increase in coating mass can be used to determine SOA formation rates. The slow loss of coating material, not captured in global models, comprises the dominant temporal and spatial extents of the lifecycle of these particles. Coat-to-core mass ratios of BC particles in the stratosphere are much greater than those in the free troposphere indicating a different lifecycle.



Sedlacek et al., 2023: Mass ratio of non-refractory coating-to-BC for particles with mass equivalent diameter = 100 nm, $m_{R,100}$, as a function of plume age reveals that the dominate process in the BB-BC mixing state lifecycle is the loss of coating. For comparison, the grey dotted line is the squalene mass loss for γ_{OH} of 1 and the orange dotted line is the mass loss of OA measured at MBO during the 2019 wildfire season and BBOP. Upper axis shows plume advection distance for an assumed 5 m s^{-1} wind speed.

Ecological drivers of emissions impact aerosol formation potential and properties

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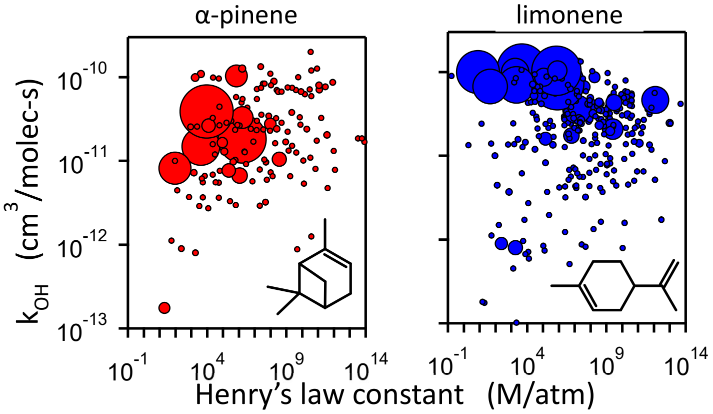
A significant majority of reactive carbon in the atmosphere is biogenic, emitted by plants as a function of biological and ecological characteristics. Each individual gas is emitted under a unique combination of ecological conditions, and has a unique set of physicochemical properties that modulate their atmospheric impacts. Consequently, even small shifts in plant emissions due to seasonal changes in phenology, drought or pest stress, and ecosystem composition can drive significant shifts in atmospheric reactivity and composition. Oftentimes, these changes are not well captured by emissions models, nor are their impacts on atmospheric conditions or aerosols well represented. We examine here multiple years of measurements from the Virginia Forest lab to understand ecological drivers in the concentrations of biogenic reactive gases and how they change between seasons and between years. We study the atmospheric oxidation of these gases in a box model to better understand how these changes in concentration lead to changes in the reactivity and aerosol formation potential of the atmosphere. In particular, summertime concentrations of monoterpenes are observed to have a minor light-dependent component that peaks in the daytime and is comprised of highly reactive compounds. These compounds not only cause a peak in daytime atmospheric reactivity, we show here that they are modeled to yield higher reactivity products that are less likely to be removed than other more dominant compounds before reacting further to realize aerosol formation. We extend this discussion more generally to the potential impact of emissions changes on aerosol formation and properties.



Differences in the physicochemical properties of different reactive gases imply different atmospheric impacts, in particular differences in the likelihood products are removed before reacting to form aerosol.

Insights into the storage aging effects on dimer esters and other oligomers in beta-pinene secondary organic aerosol samples

Julian Resch[1], Kangwei Li[1], Alexandre Barth[1] and Markus Kalberer[1]

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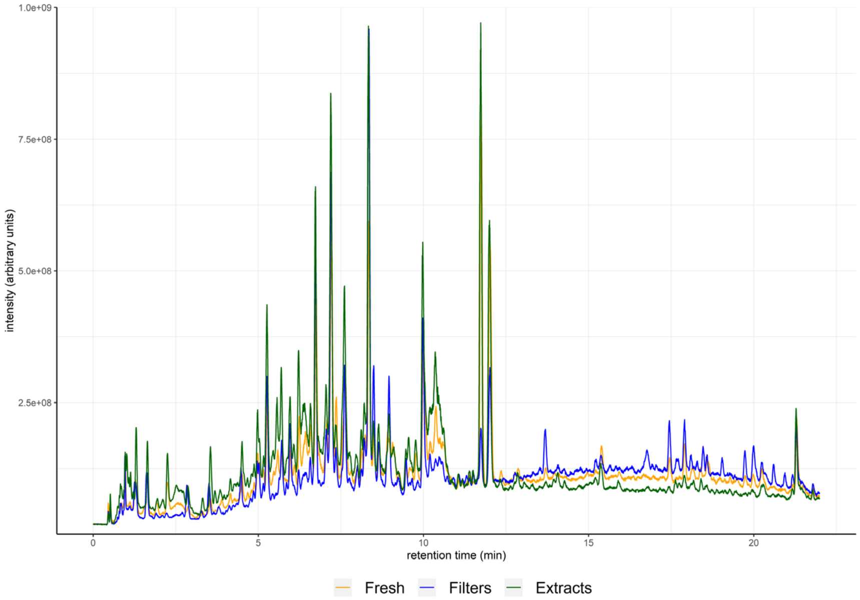
Collection of secondary organic aerosol (SOA) onto filters is often used in combination with LC-MS for detailed chemical characterization. Studies have shown that a large fraction of laboratory-generated SOA can be attributed to high molecular weight oligomeric compounds. Often there is a significant delay between sample collection and analysis which may lead to changes in the chemical profile of the samples.

In this study beta-pinene SOA was generated by O_3 and OH oxidation and collected onto filters, which were either extracted in a mixture of water and acetonitrile or left on the filter, to investigate changes in the overall chemical composition profile over time up to one month. The samples were analyzed by UHPLC-ESI-MS in negative polarity mode.

An untargeted approach led to several thousand detected compounds and principal component analysis indicated a significant difference between the samples stored on filters or as extracts. In order to understand these differences, further focus was put on previously identified carboxylic acids, dimer esters and other oligomers tentatively assigned to the ester class.

The signal intensity for oligomers in the chromatograms decreases over time in extracts, which can be explained by hydrolysis causing decomposition of esters and other components. On the other hand, the signal intensity on filters shows a strong increase for dimers and trimers, which suggests a further chemical aging of the SOA particles (or "film") deposited on the filters which allows further reactions of SOA monomer compounds to form dimers and trimers. The two different storage conditions represent two atmospheric processing conditions: (1) the aging of SOA under dry conditions favoring oligomerization over long time scales of days and (2) the effects occurring when SOA partitions into cloud droplets where water is promoting hydrolysis and decomposition of oligomers back to monomers.



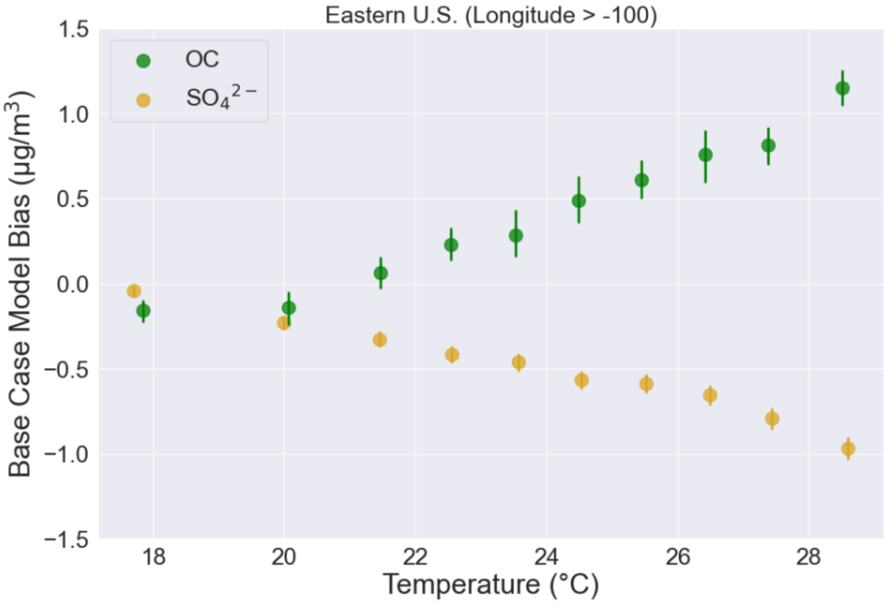
Total Ion Chromatogram representing fresh (orange), 4-week-old filter (blue) and extracts (green). Monomers elute at a retention time between 2-12 minutes and oligomers between 12-22 minutes.

Title: Temperature dependent model biases in $PM_{2.5}$ components in the Eastern U.S. Summertime

Authors:
Pietro F. Vannucci (UC Berkeley), Ronald C. Cohen (UC Berkeley), Havala O.T. Pye (EPA)

Abstract: Across the Eastern United States, summertime $PM_{2.5}$ concentrations exhibit a significant temperature dependence. Decadal reductions in anthropogenic emissions have had considerable success, but there remain public health benefits to exploring additional avenues for abating $PM_{2.5}$. Therefore, we must consider the processes that regulate both sources and sinks of summertime $PM_{2.5}$ in a temperature-dependent manner. Atmospheric models are a useful tool for probing the factors influencing the production and removal of specific $PM_{2.5}$ components. By exploring model biases in $PM_{2.5}$ as a function of temperature, we can better assess the sensitivity of modeled concentrations to specific atmospheric processes. Here, we utilize CMAQ v5.4 running the CRACMM v1.0 chemical mechanism to explore temperature dependent $PM_{2.5}$. We find that model biases of both sulfate and organic carbon $PM_{2.5}$ are strongly temperature dependent. The enhancement of sulfate $PM_{2.5}$ with temperature is widely underestimated in the model, owing both to a lack of sulfur dioxide emissions as well as chemical conversion. Conversely, the enhancement of organic carbon $PM_{2.5}$ with temperature is widely overestimated in the model, due to a combination of overactive temperature dependent BVOC emissions, overactive conversion of VOCs to SOA, or underactive removal mechanisms. We then assess how various alterations to model inputs influence the representation of these $PM_{2.5}$ components with temperature, and how these sensitivities inform our understanding of the drivers of high summertime $PM_{2.5}$. For SO_4^{2-}, we find that our bias is improved significantly by the introduction of an aerosol-phase pathway for SO_2 oxidation and less so by the introduction of additional SO_2 emissions. For OC, we find that our bias is improved by the introduction of a photolysis sink for monoterpene-derived organic aerosols as well as a hydrolysis sink for organic nitrates. These findings help guide our understanding of the processes regulating summertime $PM_{2.5}$ and inform future model design strategies.

Figure: Diverging temperature dependent model biases in the Eastern U.S. for sulfate and organic carbon $PM_{2.5}$. Observations from EPA Air Quality System. Temporal scope of June-August 2019.



Modeled Impact of Deposition on the Oxidation Pathways of Common Reactive Precursors

Chenyang Bi[1], Gabriel Isaacman-VanWertz[1]

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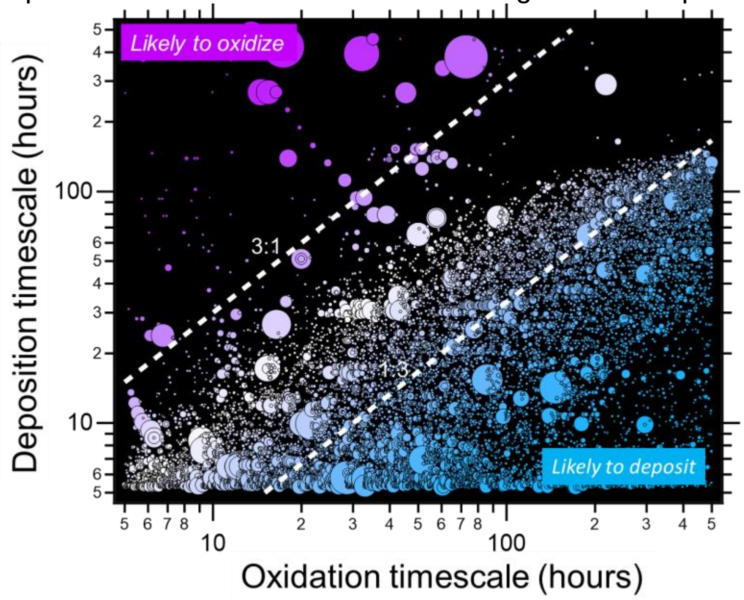
The fate of a compound in the atmosphere can be considered as competition between loss processes, particularly oxidation, which propagates chemistry and may form aerosol, and deposition, which removes reactive carbon from participating in further chemistry. The physicochemical properties of modeled and measured atmospheric oxidation products can be used to estimate timescales for these processes. In this work, we estimated the dry and wet deposition timescales of atmospheric organics as a function of Henry's law constant and calculated the oxidation timescale as a function of OH reaction rate constants. The obtained timescales were used to examine the competition between oxidation and deposition and understand the impacts of deposition on the downstream chemistry in the case of the oxidation of common precursors. Timescales for dry and wet deposition are implemented as first-order processes into a 0-d box model to simulate the oxidation of single reactive precursors, such as isoprene and α-pinene, and a mixture of common reactive precursors found in the Southern Oxidant and Aerosol Study (SOAS) campaign. The simulations enabled the quantification of the fraction of oxidant reactivity and formation potential of secondary organic aerosol (SOA) that is removed or prevented by deposition. We find that first-generation oxidation products, which remain reactive and potentially have high SOA yield, are rapidly removed by deposition and consequently result in a significant loss of aerosol formation potential. We will discuss the implications of this result for local and regional atmospheric composition.



The competition of timescales between deposition and oxidation for atmospheric relevant compounds sized by their relative concentration in the model simulations.

Picosecond Short-Range Elastic Backscatter Lidar (PSR-EBL) : a novel technique for remote measurement of black carbon emissions

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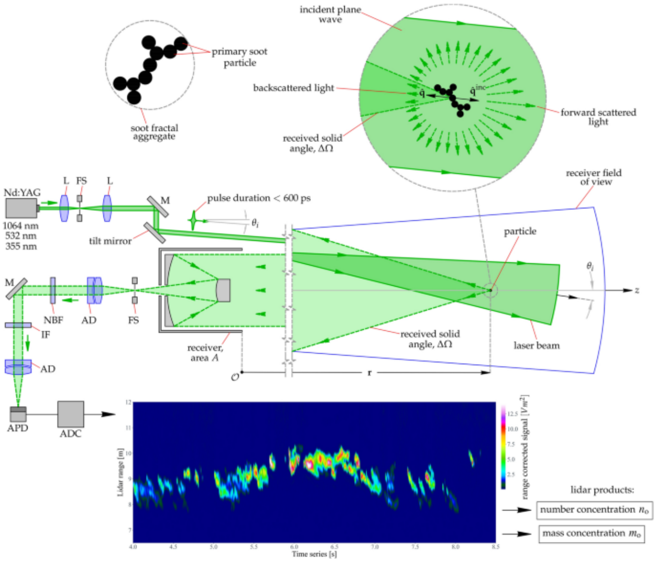
Black carbon aerosol emissions are recognized as contributors to global warming and air pollution. There remains, however, a lack of techniques to remotely measure black carbon aerosol particles with high range and time resolution. This article presents a direct and contact-free remote technique to estimate the black carbon aerosol number and mass concentration at a few meters from the emission source. This is done using the Colibri instrument based on a novel technique, referred to here as Picosecond Short-Range Elastic Backscatter Lidar (PSR-EBL). To address the complexity of retrieving lidar products at short measurement ranges, we apply a forward inversion method featuring radiometric lidar calibration. Our method is based on an extension of a well-established light-scattering model, the Rayleigh–Debye–Gans for Fractal-Aggregates (RDG-FA) theory, which computes an analytical expression of lidar parameters. These parameters are the backscattering cross-sections and the lidar ratio for black carbon fractal aggregates. Using a small-scale Jet A-1 kerosene pool fire, we demonstrate the ability of the technique to quantify the aerosol number and mass concentration with centimetre range-resolution and millisecond time-resolution.



Principle of operation of the Picosecond Short-Range Elastic Backscatter Lidar (PSR-EBL) technique, intended to measure BC aerosol number and mass concentration [1].

[1] - Ceolato, R., Bedoya-Velásquez, A.E., Fossard, F. et al. Black carbon aerosol number and mass concentration measurements by picosecond short-range elastic backscatter lidar. Sci Rep 12, 8443 (2022). https://doi.org/10.1038/s41598-022-11954-7

Quantification of Organic Aerosol concentration and composition at Pretoria, South Africa employing Fourier-transform Infrared Spectroscopy (FT-IR)

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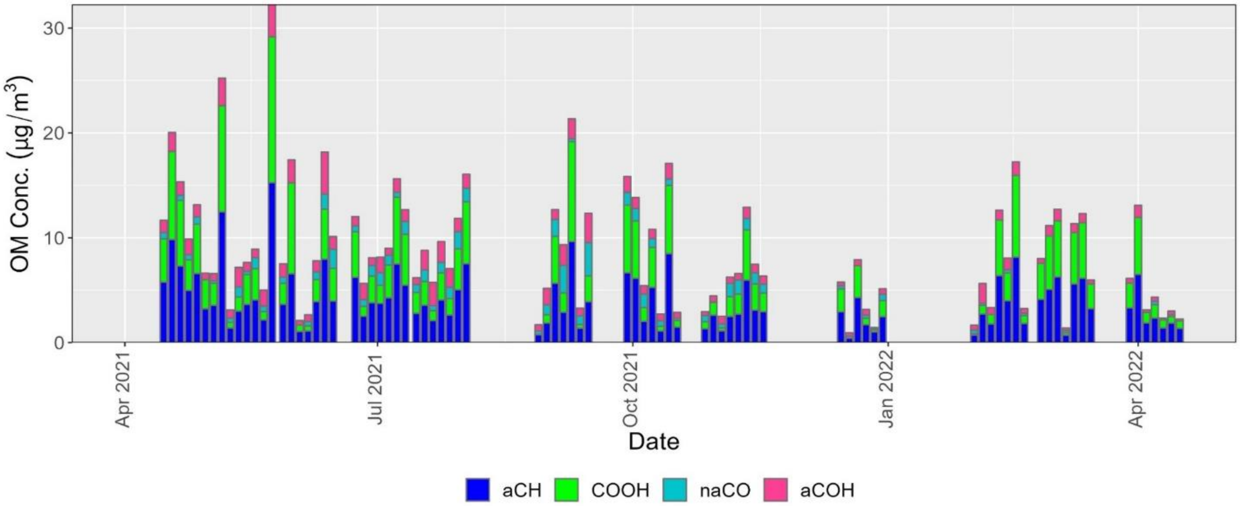
Presenting Author: Muhammad Naveed Anwar

Approximately 7 million premature deaths occur due to air pollution, primarily due to $PM_{2.5}$ exposure, worldwide. Organic matter (OM) often dominates $PM_{2.5}$ mass, sometimes even up to 9/10th of total mass, warranting the need of its quantification particularly in urban areas that have limited PM measurements. However, quantification poses great challenge given its molecular complexity. In this study, Fourier-transform Infrared Spectroscopy (FT-IR) was employed to quantify the composition and concentration of OM on the basis of the following organic functional groups: Alkane (aCH), Alcohol (aCOH), Carboxylic Acid (COOH), and Non-Acid Carbonyl (naCO). This study focuses on Pretoria, South Africa which has a population of 3.3 million and a moderate dry subtropical climate. Sampling was conducted by Surface Particulate Matter Network (SPARTAN) for the period of one year (April 2021 to April 2022) using an AirPhoton SS5i Sampler with PTFE filters (MTL Corp., PT25AN-PF03). $PM_{2.5}$ samples were collected for 24 hrs sampling period every third day starting at 09:00am. 71 samples were collected with an overall mean concentration of $PM_{2.5}$ of 16.08 ug/m^3 and with seasonal variation as follows: Winter (19.34 ug/m^3 > Autumn 16.462 ug/m^3 > Spring 13.70 ug/m^3 > Summer 9.49 ug/m^3). Elemental and ionic speciation was carried out; however, this work will focus on the functional group composition (figure below). A detailed analysis of functional groups composition's daily, seasonal, and overall variation is presented in addition to variation in the OM/ $PM_{2.5}$ fraction. In the future, the organic and inorganic speciation, in conjunction with positive matrix factorization (PMF) results and back trajectories, will be used for source apportionment for $PM_{2.5}$.



Organic Functional Groups concentration in Pretoria $PM_{2.5}$ samples over the study period

Correcting for biases in filter-based aerosol light absorption measurements at the ARM Southern Great Plains site

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Measuring aerosol light absorption is crucial to assess direct radiative forcing that impacts local and global climate. While filter-based instruments like the Particle Soot Absorption Photometer (PSAP) are low-cost and simple to operate, they suffer from unquantifiable artifacts due to the filter medium and complex interactions between filter fibers and deposited aerosols.
Various correction algorithms (Bond et al., 1999; Virkkula et al., 2005; Li et al., 2020) have been introduced to correct for the filter-based absorption coefficient measurements toward predicting the particle-phase absorption coefficient (B_{abs}). Since previously developed correction algorithms have a fixed analytical form, fundamentally, they are unable to predict B_{abs} with a high degree of accuracy universally: different corrections for rural and urban sites across the world.

In this study, we have analyzed three months of high-resolution ambient data collected in parallel using a PSAP and 3-wavelength photoacoustic spectrometer; both instruments were operated at the Department of Energy's Southern Great Plains user facility in Oklahoma. We implemented the following algorithms to predict particle phase B_{abs} values from PSAP data and estimate their accuracy – (1) the Virkkula (2010) correction algorithm, (2) Revised Virkkula algorithm with updated coefficients, and (3) a Random Forest Regression (RFR) machine learning algorithm. The RFR algorithm outperformed predictions by both the Revised Virkkula and Virkkula (2010) algorithms. The wavelength averaged Root Mean Square Error (RMSE) values for predicting B_{abs} using RFR, Revised Virkkula and Virkkula (2010) algorithms were 0.37, 0.67 and 3.18 Mm^{-1}, respectively.

To further test the potential of the proposed machine learning model, we trained and tested the RFR algorithm on dataset of laboratory-generated combustion aerosols. The RFR model used the size distribution, uncorrected Tricolor Absorption Photometer based B_{abs}, and Nephelometer B_{scat} as input variables and predicted particle-phase B_{abs} values within 5% of the reference B_{abs} from photoacoustic spectrometer.

Indoor smoke monitoring using short range elastic backscatter lidar for air quality in buildings

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Wildfires are an increasingly large source of particulate matter (PM2.5) in the western United States and other parts of the world including Europe, South America and Australia. Since people shelter indoors during smoke events, heating ventilation and air conditioning (HVAC) controls in buildings are one control mechanism to minimize occupant exposures and health impacts from smoke during a wildfire. Therefore, characterizing exposure to wildfire smoke particles indoors is important.

We measure fog-oil, which has similarities to smoke particles using a picosecond lidar that provides backscatter data at fine spatial and temporal resolution. From this data, we evaluate the mixing as a room fills with smoke and the mixing as a room empties of smoke with the introduction of clean air. The mixing process is quantified using the variance of backscatter, and we analyze its relation to the variance of concentration after the lidar inversion process. Turbulence and air exchange rates are varied, and their impact on the lidar backscatter data stream are presented. We found that lidar was able to track smoke at a very high spatio-temporal resolution, which could be used to characterize exposure smoke particles indoors and used for developing better indoor building HVAC controls.

Quantifying snow albedo reducing effects of brown carbon aerosols on the brown-black continuum using SNICAR radiative transfer model

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As wildfire frequency and intensity have trended upward in recent years, the deposition of light-absorbing aerosols of biomass-burning origin on snow and ice has gained salience. These impurities, when dispersed in snow and ice, induce a reduction in surface albedo compared to pristine snow. Previous studies have extensively measured the concentrations of black carbon (BC) and mineral dust in snow, and attributed albedo reductions to these constituents. However, the influence of brown carbon (BrC), which is co-emitted with BC in wildfires, on albedo remains poorly constrained, and has not been examined as much on account of the wide variability in its optical properties, as well as its differing solubilities.

In this study, we use the optical classification of BrC proposed by Saleh et al., 2018, referred to as the 'brown-black continuum' of light-absorbing aerosols, to show the response of snow albedo to a broad range of BrC optical properties. Specifically, we apply the brown-black continuum parameterization to generate, through Mie theory calculations, an optical property dataset for BrC. This is used within simulated aerosol dispersal scenarios in snow to calculate spectral and broadband albedos.

Our results show that, at 1 ppm of aerosol in snow, the strongest absorbing BrC can produce a broadband albedo reduction of up to 0.12 between the wavelengths 400-1000 nm. Within the category of strongly absorbing BrC (S-BrC[*], k_{550} in the range 0.1-0.25), for the same concentration of BrC aerosol, the spread in albedo reductions can be as large as 0.11. Further, we show the results of a combined sensitivity analysis that includes snow microphysical properties such as ice grain size along with aerosol optical properties, and develop a parameterization to predict broadband albedo. Finally, we calculate the mean radiative forcing. These results could be consequential in better predicting glacier and snow melt in areas downwind of forest fires.

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[*] S-BrC are insoluble in water and thus remain externally mixed with snow and ice.

The 2023 Soot-on-Snow Campaign in Finland: Study Design and First Results

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Five Soot-on-Snow (SoS) experiments have been organized by the Finnish Meteorological Institute (FMI) since 2011 to study effects of soot deposition on snow optics and melting. Since 2013, SoS experiments were conducted at an abandoned airfield near FMI's Sodankylä observatory in Lapland. In all experiments, soot particles are blown into chambers standing on top of the snow. After deposition, chambers are removed, and snow samples are taken from contaminated and reference snow spots and are analysed for elemental and organic carbon. The albedo of the snowpack is monitored over deposited and reference areas until snow melts out.

For the 2023 SoS experiments, directed by Virkkula, biomass-burning soot from burning real wood and peat and diesel soot from a diesel generator were used. The smoke is diluted and cooled down in large aluminium pipes covered with snow and finally injected into a chamber above the snow. Soot samples are taken both from the air blown into the chamber and from the snow after the deposition. These samples are analysed for UV-NIR absorption spectra of water-soluble organic carbon, methanol-soluble organic carbon, and elemental carbon to obtain the contribution of black and brown carbon to melting. Electron microscopy is utilized to study soot particles' structural changes from fractal to more compact forms and chemical composition is analysed using mass spectrometry. Snow samples are taken several times a week after the initial deposition to observe aging. Snow physics measurements include spectral albedo, reflectance and transmittance spectra, snow grain size and type, density, and temperature.

This work was supported in part by the Academy of Finland project "Black and Brown Carbon in the Atmosphere and the Cryosphere" (No. 341271) and by the Broad Agency Announcement Program and the Cold Regions Research and Engineering Laboratory (ERDC-CRREL) under Contract No. W913E523C0002.

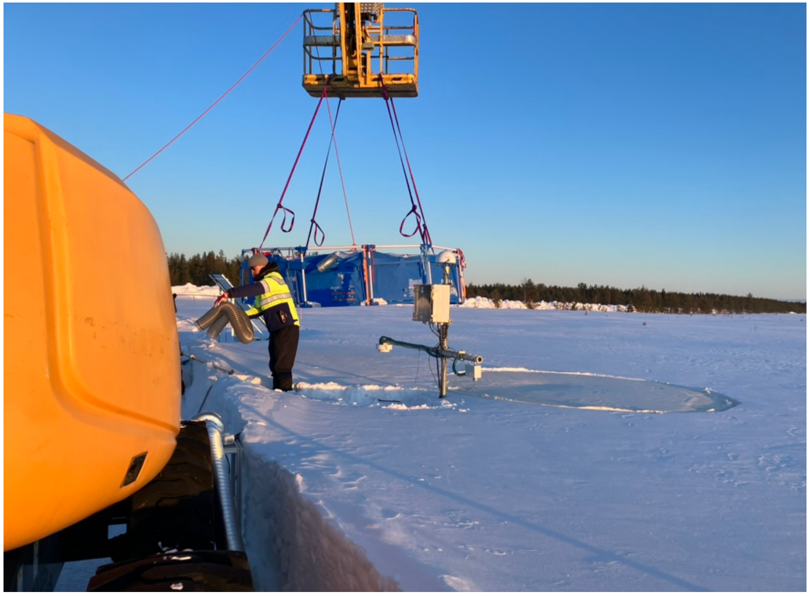

Fig. 1: *Removing deposition chamber from fresh peat smoke deposition spot.*

Initial results and evaluation of brown carbon representation in GISS ModelE

Co-authors: Kostas Tsigaridis (Columbia University/NASA GISS), Susanne Bauer (NASA GISS), Greg Schuster (NASA Langley)

Abstract: Brown carbon (BrC) is an absorbing organic aerosol primarily emitted by the combustion of biomass and biofuel. While field and laboratory studies have shown that BrC exhibits light absorption unique from black carbon (BC) and organic carbon (OC) aerosols, the radiative forcing of BrC is still highly uncertain. We present the implementation of BrC in the One-Moment Aerosol (OMA) module of the GISS ModelE ESM. Primary BrC is emitted from biomass burning with a range of optical properties and is processed through a unique chemical aging scheme. Brown secondary organic aerosols (SOA), formed from biogenic precursors, are also represented. Several simulations with varied emissions, optical properties, and chemistry have been run to assess the sensitivity of this BrC implementation within ModelE. Initial results indicate BrC typically contributes a radiative effect of 0.039 W/m^2, with the inclusion of secondary BrC and a bleaching process having a substantial impact. BrC representation is further evaluated through comparison to an AERONET retrieval dataset with BrC mass and both BrC and total optical depth. This comparison focuses on biomass burning regions, where ModelE shows BrC to be concentrated, during periods of intense burning.

Optical properties of black carbon fractal aggregates: Results from laboratory measurements, optical simulations and machine learning

Thomas Müller[1], Baseerat Romshoo[1], Sascha Pfeifer[1], Jorge Saturno[3], Jaikrishna Patil[2], Tobias Michels[2], Alfred Wiedensohler[1], Andreas Nowak[3], Krzysztof Ciupek[4], Paul Quincey[4], Konstantina Vasilatou[5], Michaela N. Ess[5], Maria Gini[6], Konstantinos Eleftheriadis[6], Chris Robins[4], François Gaie-Levrel[7], Marius Kloft[2] and Mira Pöhlker[1]

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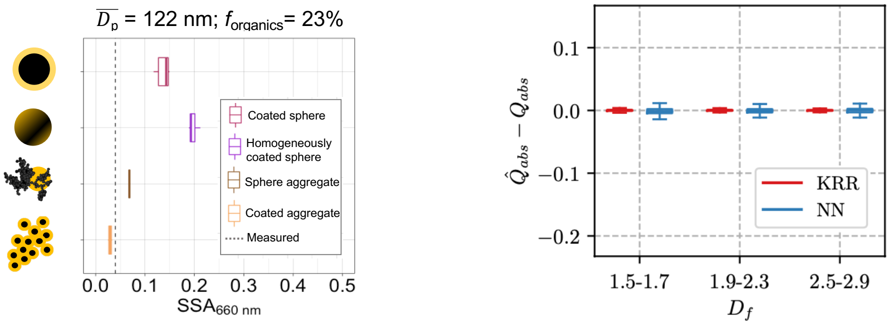
In order to estimate the impact of black carbon (BC) on climate, one needs to know its optical properties. The Lorentz-Mie theory is commonly used to calculate the optical properties of BC assuming a spherical morphology. However, this leads to discrepancies compared to measurements. For this reason, researchers are exploring the possibility of computing the optical properties using a fractal aggregate morphology.

The aim of this study is to compare the different modelling techniques with laboratory measurements. A first experiment focused on uncoated BC particles, while in a second experiment organic containing BC particles were used. Figure 1 shows that an aggregate representation (calculated with Multi Spheres T-Matrix algorithm, MSTM, Mackowski, and Mishchenko, 2011) results in a significant reduction of discrepancies compared to a spherical morphology for the single scattering albedo. Based on the data computed with MSTM, we have developed a machine-learning algorithm (ML) that can calculate the optical properties of fractal aggregates in a fraction of the time compared to the time consuming MSTM algorithm. The ML algorithm generates the optical properties using either kernel ridge regression (KRR) or a neural networks (NN) for a fractal aggregate with desired properties like size, morphology, and fraction of organic coating. Figure 1 shows that the ML algorithms precisely predicts the absorption efficiency (Q_{abs}).



Comparison of modelling techniques: (left) Comparison of modelled single scattering albedo (SSA) with the measurement value (dashed line) and various morphological assumptions of BC with organic coatings. (right) Differences between the with ML predicted value ($\hat{Q}_{abs}$) and the with MSTM calculated values (Q_{abs}) for different fractal dimensions (D_f).

Reference: Mackowski, D. W. and Mishchenko, M. I.: A multiple sphere T-matrix Fortran code for use on parallel computer clusters, Journal of Quantitative Spectroscopy and Radiative Transfer, 112, 2182–2192, 2011.

Diverse Sources and Atmospheric Processing of Soot Aerosol in Houston: Insights from Measurements of Black Carbon Composition and Mixing State

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Black carbon (BC) aerosol plays a significant role in the Earth's climate system, but its effects are highly dependent on its mixing state. To shed light on this relationship, we used a high-resolution soot particle aerosol mass spectrometer (SP-AMS) to measure the bulk chemical composition and the single particle mixing state of submicron soot aerosol in Houston, TX during the TRACER campaign in the summer of 2022. The SP-AMS was operated to selectively measure only refractory black carbon (rBC) and associated coating material. The average rBC concentration was 62 ± 116 ng m^{-3} and the BC coatings primarily consisted of organics (63%) and sulfate (26%). Positive matrix factorization analysis (ensemble particle measurements) and K-means clustering (single particle measurements) were used to understand the sources and atmospheric processing pathways of the rBC containing aerosol. Soot aerosol during TRACER was composed of oxidized organic aerosol (OOA) factor related to processed primary organic aerosol, an inorganic sulfate factor, an oxidized rBC factor and a mixed mineral dust/biomass burning factor with significant contribution from K^+. Additionally, the single particle clustering allows us to differentiate soot aerosol populations mixed with OA of various degrees of oxidation. The single particle measurements further highlight the large variation in BC coating thickness with coating mass to black carbon mass ratios ranging from 0.1 to 100 for individual particles. The average mixing state index (χ) was 47 ± 12% with higher values during the day than at night due to increased photochemical activity or regional transport of atmospherically processed aerosol. Our study provides valuable insights into the mixing state of BC aerosol and its impact on the atmosphere.

Practical applications of real-time black carbon source apportionment using a portable micro-Aethalometer with various climate control and sample line conditioning configurations

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Black carbon (BC) is a carbonaceous aerosol with a long history of measurement in science and academia. The resulting literature has increasingly tied BC to various health effects and climate impacts, which, in turn, have driven communities and regulators toward considering BC as a key component of their monitoring and action plans. Recent developments in aethalometry techniques that facilitate the estimation of BC concentrations from different sources may further increase the actionability and utility of BC measurements for these parties. Our talk discusses one such technique, the "Aethalometer Model," which leverages simultaneous BC measurements at multiple wavelengths to approximate the relative carbon content of a sample in real-time. Because BC emissions from low quality combustion (e.g., residential log wood burning) are typically more-absorbing at shorter wavelengths than BC emissions from high quality fuel combustion (e.g., fossil fuels), a comparison of absorption at short vs. long wavelengths allows for the estimation of the amount of measured BC produced according to source combustion efficiencies. We will provide a brief overview of a multi-year development that resulted in the successful implementation of the Aethalometer Model into the stock firmware of the microAeth® MA series portable micro-Aethalometer. Winter collocations with the Magee Scientific AE33 produced linear regression slopes of 1.11 (r^2 = 0.96) and 0.98 (r^2 = 0.96) for BC concentration and 1.01 (r^2 = 0.87) and 0.67 (r^2 = 0.75) for biomass source-specific BC concentration at two sites in two different years (all assuming intercept = 0; 15-minute mean data aggregation). We describe the Aethalometer Model parametrization now implemented in the microAeth® firmware, discuss best practices and policy implications, and present partner field measurements from geographically disparate environments plagued by wildfires, residential biomass burning, and/or traffic. These notably include the major New York City region wildfire smoke event of June 2023 with peak BC and biomass-specific BC concentrations of nearly 10 µg/m3 and 8.6 µg/m^3, respectively, and a unique year-long set of measurements in Addis Ababa, Ethiopia with hourly mean BC and biomass BC concentrations at one site averaging 8.3 µg/m^3 and 1.1 µg/m^3, respectively, for the study period.

Assessment of the contribution of residential waste burning to PM10 concentrations using novel organic tracers

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Besides biomass burning, the burning of different types of household wastes is a non-negligible source of particulate matter in human settlements. Open waste burning is quite common in many countries, especially where the organized waste collection system is missing or disfunctional, or expensive. Although residential waste burning is illegal in most countries, a sizable part of solid waste ends up in household stoves. Being an illegal activity the assessment of the magnitude of household waste burning and its effect on air quality is a challenging task. This work is the first attempt to assess the potential contribution of solid waste burning in households to ambient PM10 concentrations in different settlements in Hungary and Romania based on laboratory measurements of emission factors of specific tracers of waste burning.

Potential new tracer compounds for waste burning were identified by GC-MS from samples collected in laboratory experiments during which various household wastes (packaging materials made of different plastic types, furniture panels and clothes) as well as firewood was burned separately in a conventional household stove under controlled conditions. Beside the already known waste burning tracer components new and highly specific tracers were identified such as the styrene trimer, PET dimer and the pyrolysis products of the ABS copolymer. The relative amount of the tracer compound to the emitted PM10 was determined. Ambient samples were collected in Romania and Hungary during two heating seasons and were analysed for the identified waste burning tracers. The contributions of residential waste burning to ambient PM10 concentrations were estimated based on the tracer method and typical residential waste burning practices were evaluated in various urban and rural settlements.

This work was supported by project RRF- 2.3.1-21- 2022-00014 of the national Multidisciplinary Laboratory for Climate Change.

Hoffer, A. et al., (2021) Atmos. Chem. Phys. 21(23), 17855-17864.

Carbonaceous aerosol emissions from the Speciated Multipollutant Generator (SMoG) - India emission inventory

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Emission inventories are essential tools to understand the causes and consequences of climate change and air pollution and to develop effective mitigation policies. Black carbon (BC) and organic carbon (OC) have important roles as both air pollutants and short-lived climate pollutants. Global emission inventories are open data sources including a comprehensive list of emission sectors, completeness of pollutant lists and consistent emission estimation methodologies. However, they typically cannot capture region-specific activities and practices, especially those which occur in the informal economy.

India is a region of complex economic contrasts, resulting in the persistence of traditional technologies and fuels, transposed against the burgeoning demand for fossil fuels for industry, energy and transport. In this work, we report on carbonaceous aerosol emissions calculated through an emission management system, developed under the COALESCE network (CarbOnaceous AerosoL Emissions, Source apportionment and ClimatE impacts) in India. Sectoral energy, fuel and emission calculation modules use sector appropriate calculators that account for technology details, fuel type and composition and activity details. Novel sector calculators are developed from pan-India field survey data for emissions from residential biomass, agricultural residue burning, brick production and on-road vehicles. We employ emission factors from extensive field measurements across these sectors and a fine 5km x 5km horizontal resolution.

We estimate annual India-emissions of 1074 Ggy^{-1} BC and 3264 Ggy^{-1} OC. Largest sectoral shares of emissions for BC are residential (48%), informal-industry including brick production (18%), on-road diesel vehicles (15%) and agricultural combustion (8%). Similarly, sectors dominating OC emissions are residential (78%) and agricultural combustion (14%). A large, discontinuous injection of emissions occurs following the harvest seasons of *Kharif* (Oct-Nov) and *Rabi* (Mar-May) which, together, account for 63% of BC and 76% of OC emissions from the agricultural sector. We will discuss implications of these emissions for air quality over India.

High-time-resolution carbonaceous aerosols fingerprint using an advanced total carbon−black carbon (TC-BC(λ)) method: Los Angeles Basin case study

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In recent years, carbonaceous aerosols (CA) have drawn much scientific attention due to their negative impact on public health and contribution to global warming. CA was also recognized as a significant component of fine particulate matter ($PM_{2.5}$). Due to the complex chemical structure of CA, different optical properties of its components, and various possible sources, the apportionment of CA to more components is crucial to prepare efficient future measures for air quality improvement on a local level and implement effective mitigation strategies to limit further warming on a global level.

In this study, we used the Carbonaceous Aerosol Speciation System (CASS, Aerosol Magee Scientific), comprised of two instruments, a Total Carbon Analyzer TCA08 (Rigler et al., 2020) in tandem with an Aethalometer AE33. CASS provides high-time-resolution measurements of total carbon (TC) and black carbon (BC). By integrating different numerical algorithms (i.e., Aethalometer model, EC tracer model, BrC model), we introduce an advanced method to apportion CA into six components based on their optical absorption properties and their primary or secondary origin:

$$\mathrm{CA}=\mathrm{BC}_{\mathrm{ff}}+\mathrm{POA}_{\mathrm{BrC}}+\mathrm{POA}_{\text{non-abs}}+\mathrm{SOA}_{\mathrm{BrC}}+\mathrm{SOA}_{\text{non-abs}},$$

where BC_{ff} and BC_{bb} represent fossil fuel and biomass burning related BC components, POA_{BrC} and SOA_{BrC} are the primary emitted and secondarily formed light-absorbing organic aerosols, and $POA_{\text{non-abs}}$ and $SOA_{\text{non-abs}}$ represent the non-light-absorbing aerosols (Ivančič et al., 2022). In this study, we will provide a detailed step-by-step analysis of such advanced CA apportionment method, as well as the uncertainty in the calculation of each step.

This method was applied to two-year-long CA measurements at two different locations within California's Los Angeles Basin, which enabled to study seasonally specific diurnal pattern of different CA components. Secondary OA represented on average >50% of CA, with dominant contribution especially during summer afternoons. On the other hand, BC and primary emitted OA dominated during the morning rush hour.

References:

Rigler et al. (2020) Atmospheric Meas. Tech. 13, 4333–4351.
Ivančič et al. (2022) Sc. of the tot. Envir., 848:157606.

Meteorological Impacts on the Properties of Bioaerosol Particles during the SAIL Campaign

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Abstract: Primary aerosol particles originating from biological origins, e.g., pollen, fungi, bacteria, are considered bioaerosol particles. Despite their known impacts to our climate system, ecosystem, and human health, the abundance, lifecycle and properties of bioaerosol particles are still not well understood. In particular, long-term real-time data is scarce. Here, we elucidate diurnal and seasonal trends in the mountainous terrain of Colorado that are coupled with collocated online and offline measurements, such as meteorology, biological activity and ice nucleating particles.

The Surface Atmosphere Integrated Field Laboratory (SAIL) is a U.S. DOE Atmospheric Radiation Measurement campaign focused on the mountain hydrometeorology of the East River Watershed. During SAIL, we deployed the Wideband Integrated Bioaerosol Sensor (WIBS-Neo, Droplet Measurement Technologies) at Crested Butte Mountain (elevation 9500 ft). The WIBS measured the fluorescence excitation at two wavelengths (280 nm and 370 nm) to identify biogenic activity based on the fluorescence profiles of tryptophan and NADH. Using the WIBS, we collected real-time data from June 15 - September 13, 2022, and March 22 - June 15, 2023. Our analyses of the first campaign show that different types of bioaerosol particles present distinct diurnal variability indicating different regional processes for bioaerosol production and transport. We also find that meteorological conditions such as temperature, relative humidity, wind, precipitation etc., impact the contribution of different types of bioaerosol particles. Moreover, further investigation of approximately 54 precipitation events suggests that some of these events may instigate the production of bioaerosol particles.

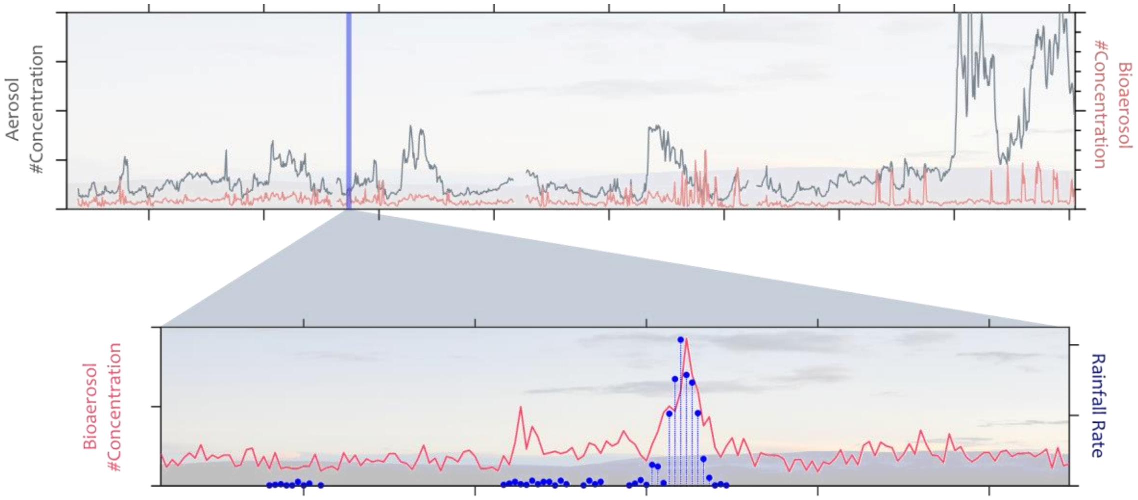

Fig: Do raindrops instigate bioaerosol production?

Annual cycle of black carbon-cloud interactions in the high Arctic

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Black carbon (BC) particles impact the Arctic due to their ability to absorb sunlight and affect snow and ice albedo. However, our understanding of BC's microphysical properties (e.g., size and mixing state) and cloud activation potential is poor, making it challenging to accurately model their concentration, deposition, and interaction with clouds.
To address this gap, we measured refractory BC (rBC) particles' mass concentration and size distribution using a Single Particle Soot Photometer Extended Range (SP2-XR) instrument. Measurements were taken over 18 months (April 2019 - September 2020) at the Zeppelin Observatory (Svalbard). The Zeppelin Observatory is ideal for this study because frequently engulfed in persistent clouds, influenced by several different types of long-range transported air masses and largely unaffected by local sources.
In this work, we present measurements of rBC cloud residuals to understand the mechanisms behind BC cloud droplet activation. During clear skies, particles were sampled from a total inlet, while during cloudy periods, cloud droplets and aerosol particles were sampled alternatingly from the total inlet and a counterflow virtual impactor (CVI) inlet. This study includes data from 58 cloud events with a mean duration of about 10 hours each. Cloud events were classified according to ambient thermodynamic conditions, total rBC mass concentration, and rBC particle activation behavior. The figure below shows the rBC mass size distributions measured behind the total and CVI inlets (see Fig. 1 a) and the corresponding size-resolved scavenged fractions (panel b) for two cloud events. During the cloud event shown in green, all detected rBC particles are activated as cloud droplets, indicating a CCN-limited cloud regime. During the event shown in orange, instead, the scavenged fraction decreases with decreasing rBC core size, suggesting a partially updraft-limited cloud formation. The impact of source regions and atmospheric processing on rBC cloud activation properties will be presented.

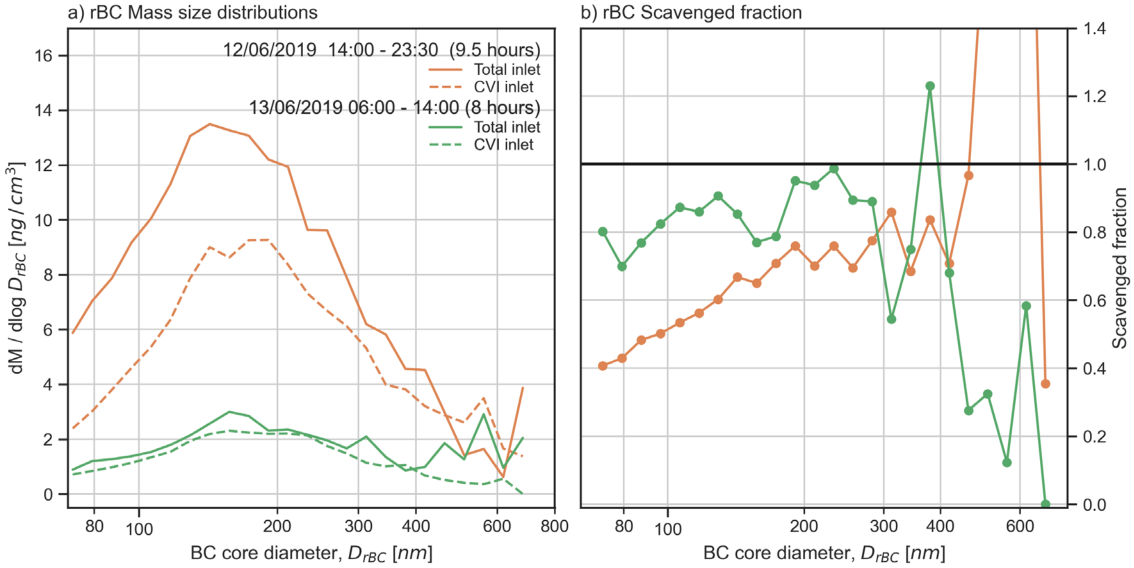

Figure 1: Comparison of two cloud events for a) the mass size distributions of rBC and b) the ratio of cloud residuals to total rBC particles (i.e., scavenged fraction).

Biological Macro-molecules causing Heterogeneous Ice Nucleation

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Biological materials from plants, bacteria and fungi are dispersed in the environment. This can be whole organisms or just fragments. When these particles get airborne, they are termed bioaerosols and are in the size range between hundred nanometers and a few micrometers. Here we present the particularity that macromolecules from these bioaerosols can be washed off in aqueous solution and that these macromolecules can exist independently from the mother grain, e.g. in water droplets or on the surface of dust particles.

In general, ice nucleation of bioaerosols is a topic of growing interest, since their impact on ice cloud formation and thus on radiative forcing, an important parameter in global climate, is not yet fully understood. We have focused on birch and pine trees, which exhibit an elevated ice nucleation activity and we proof the size of these molecules, their stability against oxidation and their chemical origin. Further we find evidence that these macromolecules can be detected on the whole surface of many parts of the tree (pollen, leaves, primary and secondary wood) but with different concentrations.

An interesting point remains the mechanisms of heterogeneous ice nucleation, in which the biomaterials play a crucial role. Spectroscopy and microscopy have been applied to solve these processes and get a fundamental understanding of how ice nucleation in trees is prevented or triggered, respectively. Obviously, this is a survival mechanism on molecular level.

Integrating Low-Cost Sensor Monitoring, Satellite Mapping, and Geospatial Artificial Intelligence for Intra-Urban Air Pollution Predictions

Abstract

There are emerging needs for applying geospatial artificial intelligence analysis of seemingly disparate environmental datasets to offer solutions that have explicit benefits to frontline communities. Prediction of health-relevant ambient ground-level air pollution concentrations is one of the critical issues. Questions remain, however, regarding the size and representativeness of limited ground reference stations for model development, reconciliation of multi-source data, and the interpretability of deep learning models. This research leverages an extensive, strategically deployed low-cost sensor (LCS) network, of which sensor data was rigorously calibrated through an optimized neural network. A set of raster predictors with varying data quality and spatial scales was retrieved and processed, including gap-filled satellite aerosol optical depth products and airborne LiDAR-derived 3D urban form. A multi-scale, attention-enhanced convolutional neural network model was developed to reconcile the LCS measurements and multi-source predictors for estimating daily pollution levels at the block scale (30 m resolution). This model is advanced in using the geostatistical Kriging method to generate a baseline pollution pattern and a multi-scale residual method to identify both regional patterns and localized events for high-frequency feature retention. We further used permutation tests to quantify the feature importance, which has rarely been done in DL applications in environmental science. Finally, we demonstrated one application

of the model by investigating the air pollution inequality issue across and within various urbanization levels at the block group scale.

Neighborhood-scale Air Quality Mapping in Sacramento Communities Using a Research-Grade Mobile Platform

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Urban air pollution is complex and poses risks to human health. Mobile air monitoring is an emerging research tool that can help build understanding of the spatial patterns and variability of urban air pollution at resolutions that are not practical with traditional stationary monitoring. While mobile monitoring provides a broad spatial view of air pollution, it can also be used to identify highly localized areas of elevated pollution within communities. In this study, we deployed a mobile monitoring platform, equipped with research-grade instrumentation, to monitor air quality in disproportionately impacted communities in Sacramento, California. The campaign culminated in multiple days of observations in February and March 2023, and measured concentrations of criteria air pollutants ($PM_{2.5}$, NO_2, O_3, and CO), greenhouse gases (methane, CO_2, and black carbon), and air toxics (aromatics, dienes, alkanes, and chlorinated VOCs). The resulting data were corrected for rolling background concentrations to remove regional influences and mapped onto 30-, 60-, and 90-meter resolution grid cells. We produced maps displaying the mean and median concentrations per grid cell. We also used an integrated statistical analysis approach to identify localized high pollution zones (HPZs) to discern which areas are being disproportionately impacted by air quality burdens. We used HPZs to target areas in communities and collected subsequent stationary pollution measurements to comprehensively characterize the localized high pollution areas. Our results demonstrate that mobile monitoring is an effective tool to identify localized high pollution areas within a community.

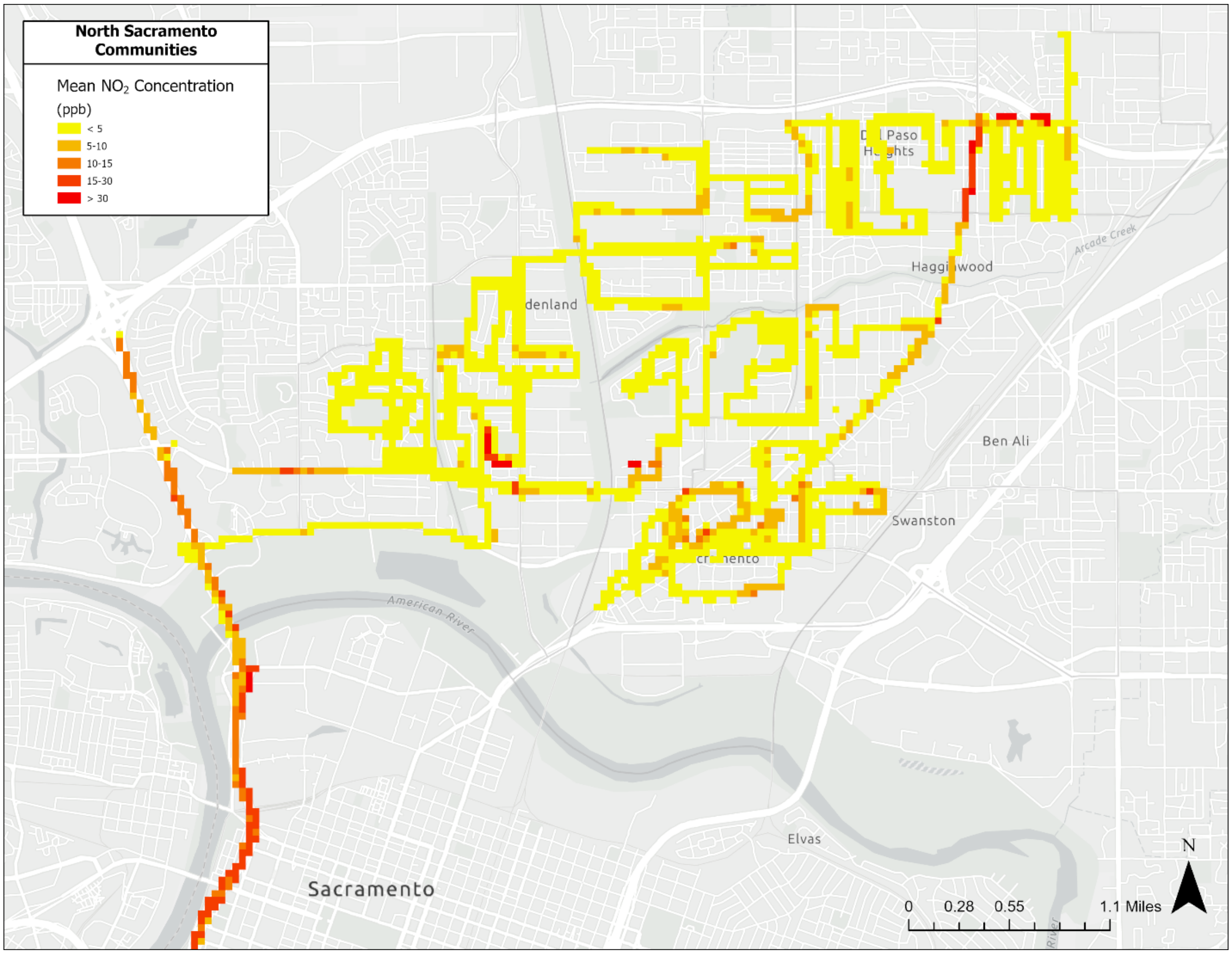

Figure 1. Mean NO_2 concentrations at 60 m grid cell resolution over north Sacramento communities.

The Use of Black Carbon Sensors to Enhance Particulate Matter Monitoring in Communities

Rebecca A. Sugrue, Chelsea V. Preble, James D.A. Butler, Alaia J. Redon-Gabel, Pietro Marconi, Karan D. Shetty, Lee Ann L. Hill, Audrey M. Smith, Boris R. Lukanov, Thomas W. Kirchstetter

Low-cost air pollution sensors are increasingly deployed to understand community exposures and determine local emission sources. Fine particulate matter ($PM_{2.5}$) is commonly measured, due in part to the affordability of commercial sensors. However, a significant portion of ambient $PM_{2.5}$ may be attributable to pollution sources beyond the community boundaries. This study measured concentrations of $PM_{2.5}$ and black carbon (BC), a component of $PM_{2.5}$ emitted primarily from diesel engines and biomass burning, using low-cost monitors that employed laser scattering and filter-based absorption photometry methods, respectively. Over four weeks in two seasons, a monitoring network with 50 locations in Richmond, California, was established to evaluate the information gained from measuring both pollutants. Concentrations of BC varied more than $PM_{2.5}$ both temporally and spatially. Monthly network-average BC was 3× higher in winter than late spring, while $PM_{2.5}$ was instead 10% lower. In both seasons, average $PM_{2.5}$ concentrations at two-thirds of sites were within ±10% of the network average, whereas only one-third of sites were within ±10% of the network-average BC concentration. The most and least polluted locations were more persistent across seasons for BC than $PM_{2.5}$, and there was little commonality in the sites that experienced the highest concentrations of BC and $PM_{2.5}$. While the five most polluted sites in the winter had an average BC concentration 2.2× the average concentration of the five least polluted sites, the temporal dynamics of the BC pollution at each of the sites were similar. Together, these spatiotemporal trends show that BC, a carbonaceous primary aerosol, is a better indicator for local pollution sources than $PM_{2.5}$.

ICCAP Abstract 2023; **Session:** Low-cost sensors and community monitoring; **Prefer** Oral Presentation. **Presenting Author**: A.P. Kaduwela

Community Air Quality Monitoring in Sri Lanka using Home-Made Low-Cost Sensor Packages

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Sri Lanka is a low income country in South Asia (an Island located just below India) and we have deployed 20 homemade real-time proof-of-concept low-cost Air Quality (AQ) monitoring sensor packages in urban areas. We plan to expand this network by adding more sensors and packages. This sensor package consists of a Raspberry Pi microprocessor controlling sensors measuring particulate matter, carbon monoxide and will also include ozone, methane, sulfur dioxide, nitrogen oxides, total VOCs, and noise in the future. It also measures meteorological parameters such as temperature, relative humidity, and barometric pressure. Most of these quantities are also measured with a mobile automated regulatory measuring station Sri Lanka owns. In addition there are several other data validation opportunities in Sri Lanka, especially the beta attenuation monitor (BAM) at the American Consulate and two fixed automated standard reference monitoring stations at Colombo and Kandy. During this presentation we will discuss the makeup of this low-cost air sensor package and the use of it to measure air pollution in various communities and environmental conditions.

Standardisation of Black Carbon aerosol metrics for air quality and climate modelling. The StanBC project

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Black carbon (BC) is an air pollutant that contributes to climate forcing and impacts on our health. It is produced by incomplete combustion of transport and other fossil fuels and legally binding procedures are in place to identify and treat emission sources. Measurements of equivalent Black Carbon (eBC) mass concentrations in real time are becoming widely available by means of light absorption photometers, but traceability is incomplete, uncertainties are poorly understood, and robust documentary standards are lacking. The StanBC project will address these needs and aims to generate greater reliability for measurements of this important air pollutant via input into normative standards. The specific objectives of the project are: First, to develop traceable in situ reference methods for aerosol light absorption coefficient (extinction minus scattering and photo-thermal interferometry) with a robust uncertainty budget estimation as a function of the light wavelength and ambient aerosol properties (e.g. single scattering albedo, SSA) suitable for use in generating a calibration chain to monitoring BC instruments. This is aimed for field deployment of in situ reference methods and a series of well-defined synthetic aerosols generated in the laboratory. Target measurement uncertainties for the reference methods are ≤ 10 %.

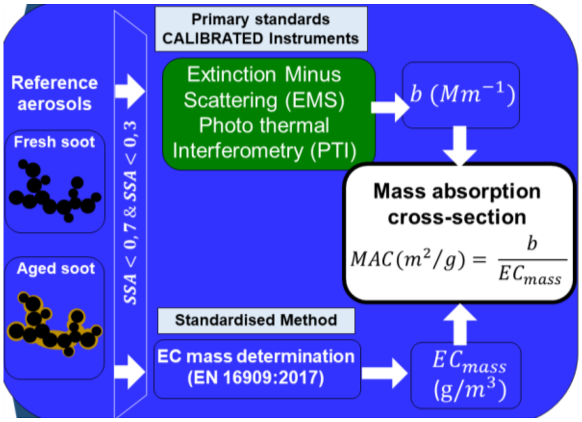

Fig.1 Schematic framework for standardizing methods for the measurement of mass absorption cross-section (MAC)

Secondly, to determine traceable methods for the measurement of the aerosol mass absorption cross-section with a robust uncertainty budget estimation at various wavelengths based on traceable measurements of light absorption and EC mass (Fig. 1). In addition, to establish the relationship between eBC mass, rBC mass and EC mass (EN 16909:2017) via inter-comparisons. Finally, to contribute to the development of a new CEN standard on i) traceable reference methods for determining aerosol light absorption coefficients (i.e. at multiple wavelengths) and ii) materials and methods for calibrating filter-based photometers against the reference method(s).

The STANBC project is supported by the European Partnership on Metrology Work Programme, EURAMET

Experimental and numerical characterization of a new oxidation flow reactor (DOFR)

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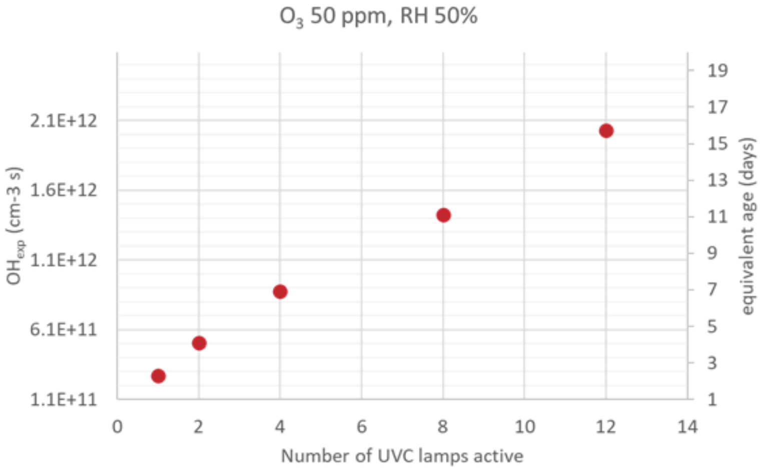
Oxidation flow reactors have become increasingly important tools for investigating secondary aerosol formation. OFR's are useful in studying the photochemical aging of transient emissions sources due to high time resolution compared to environmental chambers and compact physical size. The high time resolution stems from the short aerosol residence time (~1 min) compared to environmental chambers (~hours). Despite the short residence time in OFRs, the equivalent photochemical aging time can be in the order of several days accomplished by the high concentration of oxidants compared to atmospheric conditions. Despite that accelerated photochemistry of OFRs have some limitations on how accurately they simulate atmospheric aging, OFRs provide joint metrics to compare the potential of precursor emission sources to produce secondary aerosols.

In this study, we characterized a new commercial OFR called Dekati Oxidation Flow Reactor (DOFR). Main oxidizer in the DOFR is OH-radical that is formed by UV-C (254 nm) photolysis of externally injected O3 and H2O. The characterizations include the determination of the photochemical ageing range, the particle residence time distributions (RTD), and the SOA yield from toluene precursor. In addition, the DOFR was used to measure secondary aerosol formed by several passenger cars. Particle size distributions were measured with ELPI+ (Dekati Ltd.) and SMPS (TSI Inc.) instruments. The photochemical age was determined with CO-trace gas method.

The photochemical age was determined for several relative humidities (RH) and UV-light intensities as a function of O3 concentration. The ageing range was found to be in 1 – 17 days with the CO tracer and was varied by switching the no. of UV lamps on. The toluene precursor oxidation experiments showed comparable results to previous studies. The emission measurements suggested that gasoline vehicles could produce 1 to 4 orders of magnitude more SA mass compared to primary mass with a cold engine.



The determined OH-exposure and the photochemical age as a function of active UV lamps of the DOFR.

A dual-wavelength photothermal aerosol absorption monitor: design, calibration, performance and measurements of coated soot

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The direct measurement of aerosol light absorption coefficient is preferrable over indirect methods. A photothermal interferometer probes the change of the refractive index caused by light absorption in the sample – the detection is linear and can be traced to first principles. Measurement at two wavelengths allows the determination of its wavelength dependence and the Ångström exponent (AAE). The photothermal aerosol absorption monitor (PTAAM) uses a folded Mach-Zender interferometer (similar to Moosmüller & Arnott, 1996; Sedlacek, 2006, Visser et al., 2020). Two pump lasers at 532 and 1064 nm are modulated at different frequencies and focused in the sample chamber using an axicon (patent granted) for simultaneous measurement. The interferometer signal is detected by photodiodes and lock-in amplifiers at the two respective frequencies. The green channel is calibrated traceably to primary standards using ~1 µmol/mol NO_2. The calibration is transferred to the IR using aerosolized nigrosin (Drinovec et al., 2022). The uncertainties for absorption coefficients at 532 and 1064 nm and AAE were 4%, 6% and 9%, respectively. We calibrated filter photometers in green and IR. A winter ambient campaign has shown similar multiple scattering parameter values for ambient aerosols and laboratory experiments. We have also determined the absorption enhancement by coatings of BC with non-absorbing secondary organic matter (SOM), see Fig 1 (Kalbermatter et al., 2022).

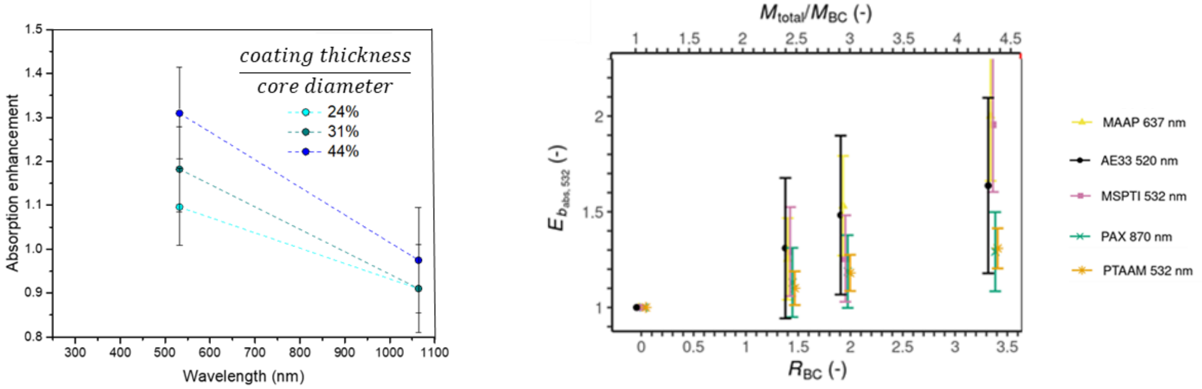

Figure 1. Absorption enhancement due to coating of BC with SOM vs. wavelength using PTAAM (left); vs. relative coating mass (right). Filter photometers overestimate the enhancement factor (E_{babs}).

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We thank SNSF (200021_172649), EUROSTARS (11386), ARRS (P1-0385, P1-0099, I-0033), and EMPIR (Black Carbon, AeroTox).

Online Quantification of Oxidative Potential from and Residential Wood Combustion (RWC) and Car Exhaust Aerosol

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Air pollution particles are the single highest environmental health risk and have adverse effects on human health with over 7 million premature deaths per year. Despite these negative effects, many physical and chemical properties of particulate matter (PM) and their effect on human health still remain unclear. The oxidative potential (OP) has widely been suggested as proxy to measure toxicity in PM. Different assays have been developed to quantify OP over the recent years. Most of them measure the OP offline from aerosol that is collected on a filter and analyzed with a time delay from days to month.

We could show for a biogenic secondary organic aerosol using α-pinene as precursor, that the OP-active compounds decay with a half-life from seconds to hours, leading to the assumption that the OP in filter samples, is potentially highly underestimated. Therefore, we built an online instrument that can quantify OP with a high time resolution using a physiological relevant assay. With this online instrument and the corresponding offline assay, we characterized several aerosol types, where we could show that there is not only an OP decay during the offline analysis, but that this decay is also highly variable for different aerosol systems.

With the online instrument we also measured primary (fresh) and secondary (aged) emissions from RWC and car exhaust to investigate the differences in aging times and compositional toxicity of the different aerosol systems. We could show a highly time resolved signal as well as that for RWC high photochemical ages lead to a lower mass-normalized OP, compared to car exhaust emissions where a higher aging leads to a slightly higher OP. Aged RWC gives, compared to aged car exhaust, an order of magnitude higher OP showing that aged RWC is potentially more toxic.

Emission factors for PM_{10} and polycyclic aromatic hydrocarbons (PAHs) from illegal burning of different types of municipal waste in households

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It is a common practice in the developing countries and in some regions of Europe that solid wastes generated in the households (e.g. plastic beverage packaging and other plastic wastes, textile wastes, fibreboards, furniture, tyres, and coloured paper waste) are burned in wood- or coal-fired stoves during the winter months. Even though particulate emissions from illegal waste burning pose significant hazard to human health due to the combination of excessive emission factors (EFs) and uncontrolled chemical composition, there is scarce information on the specific EFs for PM_{10} and polycyclic aromatic hydrocarbons (PAHs) in the scientific literature.

In this work, controlled combustion tests were performed with 12 different types of municipal solid waste and particulate emissions were measured and collected for chemical analysis. Absolute EFs for PM_{10} and PAHs as well as the benzo(a)pyrene toxicity equivalent of the latter are reported for the first time for the indoor combustion of 12 common types of municipal solid waste that are frequently burned in households worldwide.

It was found that the PM_{10} emission factors from the combustion of wood-based waste samples were about twice that of firewood, whereas EFs in the range of 11–82 mg g^{-1} (a factor of 5–40 times higher than that of dry firewood under the same conditions) were obtained for different types of plastic waste. The latter were also found to emit exceptionally high amounts of PAHs, by a factor of 50–750 more than upon the combustion of dry firewood under the same conditions. Since the more toxic 4–6 ring PAHs were predominant in the particulate emission from plastic waste burning, BaP equivalent toxicity was up to 4100 times higher than that from wood combustion.

Utilizing X-ray Fluorescence and Raman Microscopy to Determine the Chemical and Elemental Composition of Ambient Particulate in a Southern Hemispheric City

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Particulate matter (PM) is one of the greatest risks to human health and the environment. PM is emitted into the atmosphere via a series of different emission pathways, both anthropogenic and natural and is comprised of different elements and compounds varying in size, morphology and chemistry. Components of PM are most commonly quantified using gravimetric mass estimates and other spectroscopic techniques. However, many fail to identify the composition of black carbon (BC). Data collected from fixed site monitors is commonly used to estimate personal exposure. These methods are therefore limiting in providing an accurate assessment of personal exposure to PM, impacting contributions to policy initiatives like traffic calming measures to mitigate this hazardous air pollutant. A sampling campaign was devised to collected samples across Central Auckland, New Zealand, covering roads of differing traffic intensities. Using a FilterMote, samples were collected onto PTFE filters. Samples were then analyzed using a combination of techniques including gravimetric, Raman spectroscopy (RS), x-ray fluorescence (XRF) and light reflectance. Mass reconstruction from the XRF analyses indicated the presence of soil components (Al, Si, Fe), sea salt (Na, Cl) whilst trace levels of heavy metals (Cr, Fe, Co, Ni, As, Mo, Cd, Sn, Sb, Ba) were also detected. XRF, gravimetric and reflectance data yielded similar results across the sites. RS identified carbon black and diesel soot, along with the presence of other chemicals. Peak fitting of soot particles exhibited differing intensities within the D and G bands, revealing the presence of particles of different crystallinities; significant differences were detected between sites. RS proved powerful in complimenting other commonly used techniques to identify ambient particulate's elemental and chemical composition from sites in Auckland. Such studies allow for the continued characterization of ambient particulate to contribute to toxicology studies and policy initiatives to mitigate the impacts of air pollution.

Characterization of in-use heavy-duty diesel truck pollutant emission rates and emission control technology performance

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Diesel particle filter (DPF) and selective catalytic reduction (SCR) emission control systems are standard equipment on new heavy-duty diesel trucks (HDDTs) in the United States to reduce emitted particulate matter (PM) and nitrogen oxides ($NO_x = NO + NO_2$), respectively. In California, statewide regulations have accelerated fleet turnover and the adoption of these emission controls over the last decade, such that all HDDTs must now be equipped with 2010 and newer engines that are DPF- and SCR-equipped. Prior work has shown that on-road emissions have decreased over the last decade as DPFs and SCR became widely used, but that a majority of pollution is now emitted by a minority of trucks (Preble et al., *ES&T* 2015; 2018; 2019).

To evaluate the impact of DPF and SCR systems on HDDTs under real-world conditions and compare in-use emissions to corresponding emission standards and mobile source emission model predictions, tailpipe exhaust emissions from thousands of in-use trucks were measured at three California locations between 2019–2023. Each location captured a different driving mode: (1) entering a port terminal entrance, (2) traveling along an urban arterial street, and (3) driving up a 4% gradient on a highway. Fuel-based emission factors ($g\ kg^{-1}$) of black carbon (BC) and key nitrogenous species (NO_x, NO_2, nitrous oxide (N_2O), ammonia (NH_3)) were calculated via a carbon balance method on a truck-by-truck basis, using an exhaust plume capture approach that related pollutant concentrations measured at high time resolution (≥1 Hz) to above-background carbon dioxide (CO_2) concentrations. Emission profiles for each truck were linked to engine model year and installed after-treatment controls by matching recorded license plates to state-managed truck databases.

A majority of HDDTs are now equipped with DPFs and SCR, which has driven down fleet-average BC and NO_x emission factors by ~80% between 2010 (pre-regulation) and 2021. Across all sites, trucks equipped with 2010+ engines that include both SCR and DPF had lower BC emissions than those 2007–2009 MY trucks with only a DPF, even though all 2007+ engines must meet the same emission standard. This difference by technology seems to be impacted by driving mode, increasing with assumed engine load: on average, BC emissions by 2010 and newer engines are 35% lower at the terminal entrance, 61% lower at the arterial road site, and 90% lower on the highway, compared to 2007–2009 engines with a DPF alone. Notable increases in BC from trucks with pre-2010 engines without SCR indicate reduced DPF performance as systems age. A substantial fraction of the on-road fleet has emissions that exceed federally allowable exhaust standards, and in-use emissions can be higher than predicted by mobile source emission models. This comparison of on-road measurements of real-world emission trends and assumed emission rates based on exhaust standards and models is key for refining existing and developing new emission inventories

Sources of carbonaceous aerosol at the street canyon site over the years 2015-2022 in Helsinki, Finland

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Atmospheric aerosols cause adverse health effects, reduce visibility, and interact with climate. The main chemical components are organic aerosol (OA) and black carbon (BC) which may together contribute up to 90% of the submicron particle (PM1) mass. Typical primary sources of OA and BC in urban areas are e.g. traffic and biomass burning (including e.g. residential heating, wild fires, prescribed burning), whereas secondary OA are produced from volatile organic carbon compounds or from oxidation processes of primary OA.

In this study, sources of OA and BC are investigated at the street canyon site in Helsinki, Finland using a multi-linear engine algorithm (ME2) coupled with a source finder tool (SoFi) and an aethalometer model which separate BC from biomass combustion (BC_{wb}) and fossil fuel burning (BC_{ff}), respectively. Chemical composition of PM_1 was measured using an aerosol chemical speciation monitor (ACSM: OA, SO_4, NO_3, NH_4, Cl) and an aethalometer (AE33) and/or a multiangle absorption photometer (MAAP) for analyzing BC. This long-term OA dataset is analyzed using so called rolling PMF-analysis (14 days window) to account the temporal variation of factor profiles. Changes in chemical composition and sources of carbonaceous compounds over the years are studied. Preliminary results of specific organic marker ions and their contribution to OA over the years 2015-2022 (Figure 1) and an earlier investigation of the OA sources over the time June 2017-May 2018 showed 2-3 primary factors and 1-2 oxidized OA at the site.

Financial support from European Union Horizon 2020 research and innovation programme under Grant agreement No 101036245 (RI-URBANS), Urban Air Quality 2.0 project funded by Technology Industries of Finland Centennial Foundation and the Academy of Finland (BBrCAC, decision nr. 341271) is gratefully acknowledged.

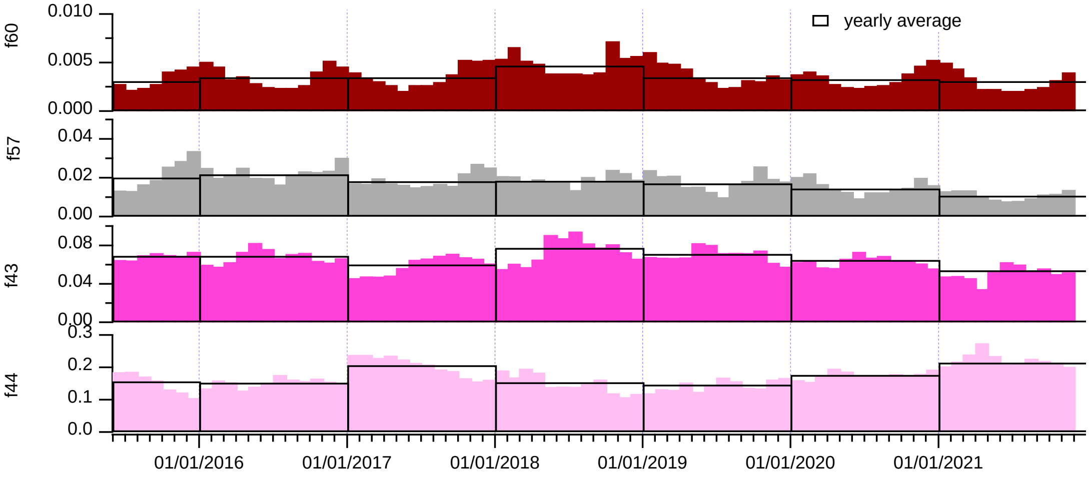

Figure 1. Monthly and yearly contribution of special organic ions to total OA. f60 (m/z60/OA), is a marker for biomass combustion OA, f57 for hydrocarbon-like OA, f43 and f44 for oxidized OA.

Identification and detailed characterization of PM_{10} sources in an Alpine valley influenced by a cement plant

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[2] University of Grenoble Alpes, CNRS, INRAE, IRD, Grenoble INP, IGE, Grenoble, France
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The contribution of traffic and wood burning to particulate matter (PM) across the Alps is widely recognized and studied (Herich et al., 2014 and references therein; Glojek et al., 2020). However, studies on valleys with cement production are scarce (Kim et al., 2003; Rovira et al., 2018) despite its large PM emissions and potential toxic properties (Erik et al., 2022; Weinbruch et al., 2023). We aim to identify and characterize sources' contribution to the complex mixture of carbonaceous and mineral PM_{10} in a representative Alpine valley.

Quartz filter samples of PM_{10} were collected daily from December 2020 to December 2021 and analyzed using different chemical techniques. In the same period equivalent black carbon (eBC) measurements were taken with the Aethalometer AE43. The measured species were analyzed using Positive Matrix Factorization (PMF) model (EPA PMF 5.0) with newly added tracers, i. e. source-specific eBC (Sandradewi et al., 2008) and organic species (2-MT, 3-MBTCA, phtalic acid, MSA and oxalate). The final PMF results were compared to online PMF-factors (SoFi Pro) derived from PM_{10} and $PM_{2.5}$ elemental measurements (Cooper Xact 625i).

Ten factors were identified at the site, including commonly detected biomass burning, traffic, nitrate- and sulfate-rich, aged sea salt and mineral dust. With the added additional organic traces, primary biogenic and secondary oxidation were recognized as well. In addition, two unusual factors were disclosed, contributing 10% to annual PM_{10}. Namely, Cl-rich and a mineral dust-rich factor, which we name the cement kiln factor. We associate these two factors to different processes in the cement plant.

The outputs of the study provide vital information about the influence of cement production on PM_{10} concentrations in complex environments and are useful for PM control strategies and actions.

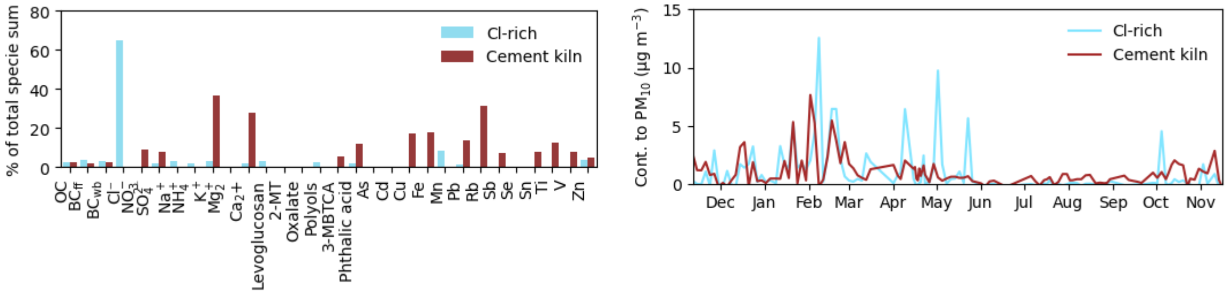

Figure: Cl-rich and Cement kiln factor associated with the cement production.

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The Activation Properties of Fresh and Aged Black Carbon Particles from Biomass Burning

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Black carbon (BC) particles affect climate directly through the absorption of solar radiation and indirectly by changing cloud properties such as cloud amount and lifetime. An abundant source of BC is biomass burn (BB) events (i.e., wildfires), which concurrently release copious amounts of condensable organic vapors that form thick coatings that encapsulate the BC. The coatings increase the hydrophilicity of the otherwise hydrophobic BC particles while at the same time increase the particle size, both of which enhance the ability of these particles to act as cloud condensation nuclei (CCN) and affect their optical properties. Due to the complex interplay between hydrophilic properties of the coating and the hydrophobic properties of the BC "core", along with the particle size, better quantification of the hygroscopic properties for this important class of particle will improve our understanding and representation of the direct and indirect climatic forcing contributions by these particles. In this study, we report on the CCN activity of pure and thickly coated BC surrogate particles determined by laboratory measurements under typical atmospheric supersaturations using levoglucosan, a known tracer for BB, as a proxy for fresh organic coating and oleic acid as a surrogate for aged organic coating, as a function of coating thickness for different core (i.e., BC) diameters. Additionally, we use our experimental results to derive the hygroscopicity parameter (κ) of the BC core and coatings. The limiting cases of fresh and aged organic coatings, which span the range of coating ages, are used to investigate the activation behavior of an ensemble BC particle population consisting of particles with different core diameters and different coating thicknesses and how activation, in turn, affects the aerosol optical properties. Our findings provide a critical fundamental-level understanding of aerosol-cloud interactions for this important class of particles.

- **Light-absorbing aerosol-cloud interactions**

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Atmospheric light-absorbing aerosols, such as Black Carbon containing particles (BC), have a significant impact on the Earth's radiation budget. These particles interact with solar radiation, scattering, and absorbing light, as well as with clouds. However, changes in the morphology of BC particles and their internal mixing with other materials, like organic coatings, can affect their ability to scatter and absorb light and interact with clouds. While previous studies have explored these processes, the effects of these interactions of BC with clouds have received less attention, and important questions remain open. Light-absorbing aerosol-cloud interactions is a project designed to investigate these processes in the Michigan Tech cloud chamber (the Pi-Chamber). We used BC and BC surrogates and coating surrogates to understand better the effects of aging on aerosol-cloud interactions. Cloud experiments employed a Pumped Counterflow Virtual Impactor to investigate changes in the morphology, optical and chemical properties of the BC particle aggregates and coated BC upon cloud activation and evaporation in the PI chamber. During these experiments, we study the changes in optical and cloud condensation nuclei properties of interstitial and residual particles compared to the aerosols before they are injected into the Pi chamber. We also studied the changes in the properties of liquid smoke upon activation, which was used as a surrogate for BC coating. We also developed a coating method to coat surrogate BC. We will provide an overview of the project and some preliminary results.

Properties of Bioaerosol Particles Emitted from Smoldering and Flaming Burns of Evergreens

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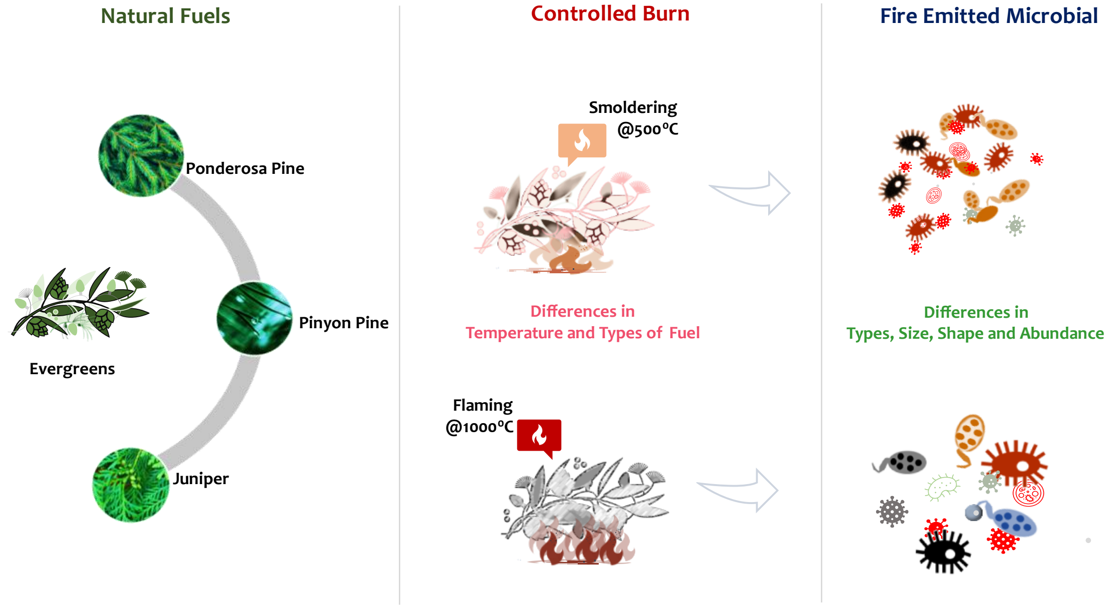
Abstract: Aerosol from biogenic sources or bioaerosol are not well characterized in the atmosphere. However, they appear to have wide ranging impacts from climate to ecosystems to human health. Contrary to one's expectation, some bioaerosol particles tend to survive high temperatures, and biomass burning events such as wildfires may act as the source of bioaerosol particles. In laboratory settings, we performed several controlled burns using evergreen fuels (Pinyon Pine, Ponderosa Pine and Juniper). Two temperatures, 500° C and 1000° C, were chosen to understand the effect of smoldering and flaming temperatures, respectively, on the amount and properties of bioaerosol particles. Bioaerosol particles emitted from these burns were measured using Wideband Integrated Bioaerosol Sensor-NEO (WIBS-Neo, DMT). WIBS uses fluorescence excitations to identify aerosol particles as biogenic. The WIBS-Neo measured the fluorescence from excitation at two different wavelengths, 280 and 370 nm. The detected particles were then categorized based on where they fluoresce between 310-400 nm and 420-650 nm. Our preliminary analyses suggest that smoldering and flaming temperatures contribute to emitting different types and shapes of bioaerosol particles. Different biofuels also affect the properties of these bioaerosol particles.



Characterizations of Black Carbon Aerosols from Prescribed and Laboratory Fires in the Southeast US

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Biomass burning from prescribed fires and wildfires is one of the important sources of carbonaceous aerosol in the atmosphere. The southeastern U.S. has far more prescribed fires as compared to the western U.S. region, and such fires can have significant impact on air quality and local visibility (see Figure 1). However, direct field measurements of aerosol emissions from small, prescribed fires are relatively sparse. Black carbon (BC) is one of the important aerosol emissions from open biomass burning, affecting air quality and human health on a regional scale. BC is also an efficient light-absorbing aerosol component and thus affects radiative transfer in the atmosphere. Optical properties are critical parameters determining the impacts of aerosol emissions on climate and are highly dependent on aerosol composition.

In this presentation, BC aerosol emissions from prescribed fires in the southeast U.S. are compared to emissions from simulated fires in a laboratory study. A scanning mobility particle sizer (SMPS) is used to measure the total submicron aerosol size distributions, and a Single Particle Soot Photometer (SP2) is employed as the primary measurement of BC aerosol number and mass mixing ratios, mass and size distributions, and number fractions of coated and uncoated BC-containing aerosol particles. Where available, optical property measurements are used to calculate absorption enhancement of BC aerosol for different fire conditions. Measurements are performed for both fresh emissions and after photochemically aging emissions in an oxidation flow reactor to investigate the effect of aging on BC mixing state. A comprehensive investigation of BC aerosol leads to advances in predicting aerosol optical properties from its composition and provides information for emission inventories to better predict its impact on air quality and the climate system.

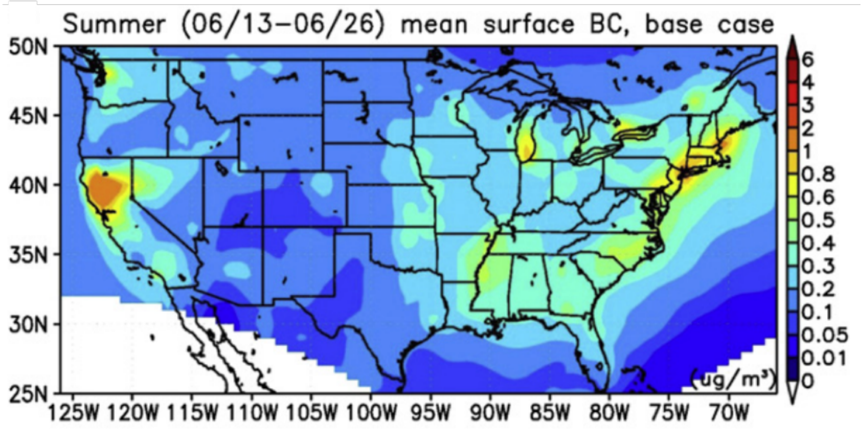

Figure 1: Surface BC concentrations (µg m^{-3}) (Huang, M. et al. https://doi.org/10.1016/j.atmosenv.2012.01.021, 2012.)

Comparison of black and brown carbon emission factors, pollutant ratios and optical properties in prescribed burn and wildland fire smoke in California

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Climate change and a build-up of excess fuel loads over the previous century are contributing to an increase the frequency and intensity of wildland fires in the western United States. Prescribed burns are a low-cost and effective fuels management practice to ensure healthy and climate resilient forests long employed by indigenous peoples. Wildland fires and prescribed burns alike generate fine particulate matter ($PM_{2.5}$) and other toxic air pollutants that are climate pollutants and degrade air quality in downwind communities. Black carbon (BC), a component of $PM_{2.5}$ and a short-lived climate pollutant, was measured on a ground-based utility vehicle platform with a multi-wavelength dual-spot aethalometer and on an aerial-based drone platform with the UC Berkeley low-cost aerosol black carbon detector (ABCD). CO and CO_2 were measured alongside BC to calculate fuel-based emission factors during four prescribed burns in a productive mixed conifer forest at the Blodget Forest Research Station. We also measured BC and $PM_{2.5}$ from aged wildland fire smoke with a distributed network of 24 ABCDs in Richmond, CA during August 2020 and obtained BC, $PM_{2.5}$ and CO measurements at regulatory sites in the SF Bay Area and Los Angeles for 2018-2020. Brown carbon (BrC) concentrations and the absorption Angstrom exponent (AAE) were determined from BC data measured with a multi-wavelength aethalometer and informed when regulatory sites were impacted by wildfire smoke. For the low-cost distributed network and regulatory sites, the black carbon to fine particulate matter ratio ($BC/PM_{2.5}$) and BC to CO enhancement ratio ($\Delta BC/\Delta CO$) attributable to wildland fire smoke were calculated. Emission factors and pollutant ratios measured at the prescribed burns, by the low-cost distributed network, and at regulatory sites will provide more accurate emissions estimates to constrain California's BC emissions inventory and as inputs to a first-order fire effects model (FOFEM).

Multiscale Convection-Permitting Wildfire Simulation over California

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Wildfires are a significant and increasingly frequent natural disaster in California, and the importance of high-resolution wildfire simulation to California's climate extends beyond immediate concerns about human safety and property damage. Once wildfire-induced smoke plumes enter the stratosphere and spread rapidly throughout the hemisphere, it could remain in the stratosphere for months or even years, causing significant radiative impacts. Although the hemispheric-scale radiative effects can be appropriately assessed at an O(100km) resolution, high-resolution simulations over the ignition zone are crucial to providing a detailed view of how smoke plumes are pumped up and a better description of wildfire-induced aerosol transport within the most critical first days.

However, the current global Earth system models (ESMs) used for wildfire simulations are plagued by significant uncertainties. First, the general low-resolution (LR, >=100km) ESM is too coarse for critical wildfire local processes. Moreover, some important physical processes (e.g., chemical-aerosol interactions) are often missing in the global high-res version. In this study, we attempt to further develop a framework suitable for large wildfires based on the recently released Energy Exascale Earth System Model Version 2 (E3SMv2) (Golaz et al., 2022). Here we will 1) push the resolution of the E3SMv2 Regional Refinement Model (RRM) (Tang et al., 2022) to the convective permit scale (3km) in California, 2) use the next generation of E3SM development conducted by our group to improve the chemistry and aerosol treatments for the stratospheric fire smoke, and 3) implement more realistic fire emissions using WRF-SFIRE-CHEM. We conducted a case study focusing on the 2020 Creek fire. The wildfire impacts on surface temperature, winds, cloud radiative effects, soil water and runoff in RRM simulations will be compared to the default E3SMv2-LR and observations. The smoke transport and dissipation will be evaluated against satellite observational data, for example, aerosol optical depth retrieved from the NASA GOES-R Series Advanced Baseline Imager (ABI) measurements.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. It is supported by the LLNL LDRD 22-ERD-008. LLNL IM release: LLNL-ABS-846451.

Biomass burning organic aerosol: phase separation and viscosity

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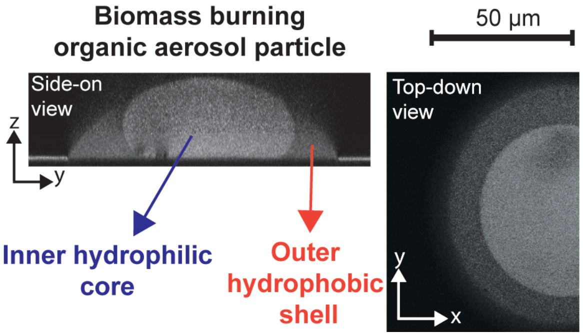
Smoke emissions produced through biomass burning are among the largest contributors to worldwide organic aerosol, having significant impacts on the climate and human health. Biomass burning organic aerosol (BBOA) contain organic compounds known as brown carbon that can absorb UV/Vis radiation, contributing to warming of the earth-atmospheric system. An improved understanding of the physicochemical properties of BBOA, such as the phase behavior and viscosity, is needed to understand its environmental impact. The viscosity can affect aerosol growth rates and heterogeneous reaction rates, including the whitening rate of brown carbon in BBOA that affects the Earth's radiative budget. The phase behavior (how many phases coexist in particles and the morphology) is important for equilibrium partitioning of semi-volatile organic compounds, reaction rates and the cloud nucleation ability of BBOA. However, there is still limited understanding about the phase behavior and viscosity of BBOA particles.

In this work, we generated BBOA from wood smoldering in a controlled furnace flow-tube. Using fluorescence microscopy, we identified that BBOA from pine smoldering undergoes liquid-liquid phase separation to form core-shell particles. We used a photobleaching method to measure the viscosity of the different BBOA phases, showing that the two non-crystalline phases in BBOA particles exhibit different viscosities. Under some conditions the viscosity of the hydrophobic organic shell can be several orders of magnitude greater than the hydrophilic core, which has important implications for reaction kinetics. Using a multi-layer kinetic model (KM-GAP), we demonstrated how the presence of phase separation in BBOA particles can significantly decrease the reaction rate of brown carbon whitening by atmospheric ozone. Thus, liquid-liquid phase separation can lengthen the lifetime of brown carbon in the atmosphere and increase its warming effect.



Laser scanning confocal fluorescence microscopy images of a BBOA particle exhibiting liquid-liquid phase separation.

Properties of Black Carbon Aerosols Needed for Remote Sensing and Radiative Forcing Applications

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Material and morphological properties of light absorbing particles in the atmosphere determine their single scattering albedo, asymmetry parameter, and direct radiative forcing, thereby affecting climate change predictions and mitigation. A quantitative understanding of aerosol optical properties is also needed for their global quantification through satellite and ground-based remote sensing. The dominant light absorbing aerosol is black carbon (BC) that has non-spherical, fractal-like shapes that complicate the determination of its optical properties. Here we discuss the basic material and morphological properties of BC aerosols as needed to understand, measure, and calculate their optical properties with a focus on recent progress and remaining gaps in obtaining and using these properties.

For BC aerosols, the complex refractive index outside of the visible spectrum is still poorly constrained, probability distribution functions for parameters of fractal-like shape models and their evolution during atmospheric aging are inadequately defined, and complex refractive indices of atmospheric BC coatings are also insufficiently known. In addition, DDA calculations for coated fractal-like chain aggregates, as needed for modeling the optical properties of atmospheric BC aerosols, are computationally very costly. While such calculations for coated BC particles have made great progress (Liu et al., 2022), extension to size-averaged ensemble calculations with more random realization of morphology types are still needed. These knowledge gaps greatly limit BC radiative transfer evaluation and satellite retrievals. Here, we further outline these knowledge gaps and discuss research efforts needed to fill them.

This work has been supported in part by NSF grant No. OIA-2148788 and NASA ROSES grant 80NSSC20M0205 (PACE SAT Project: PACE UV ROAD).

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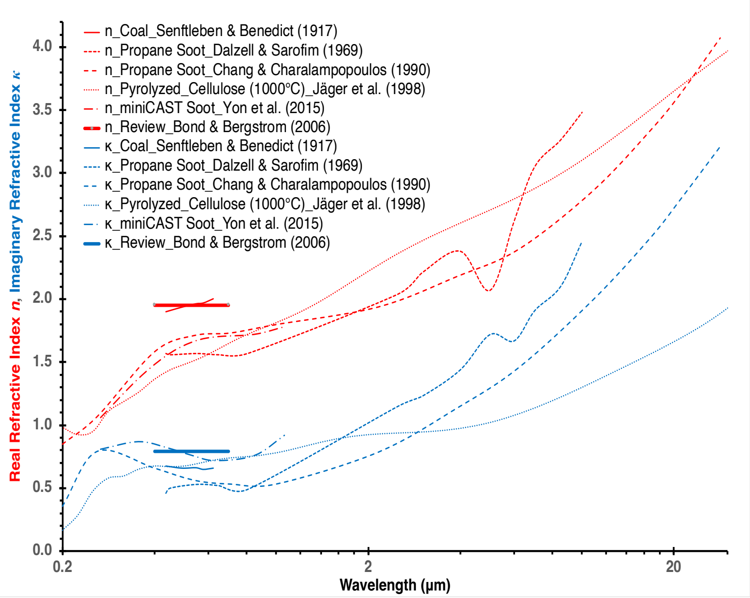

Fig. 1: Real (*n*) and imaginary (*κ*) refractive indices of black carbon as function of wavelength.

Black carbon and dust dominant aerosols intensify heat stress in India

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Extreme weather events associated with climate change are increasingly concerning in many world regions. Heat waves are widely linked to meteorological conditions like north-Atlantic blocking or anomalous cooling in the Pacific and greenhouse gas increases. Anthropogenic aerosols are implicated in atmospheric cooling in most world regions, where they predominantly contain radiation-scattering inorganic (sulfate, nitrate) or organic constituents. However, in a less understood effect, absorbing aerosol (black carbon, dust) enhancements at low altitudes, which drive surface temperature increases through diabatic heating, correlate with temperature maxima enhancements in India.

In this work, we use chemistry-coupled model simulations (WRF-Chem, with RADM2-SORGAM chemistry and MADE aerosol microphysics) to evaluate the impact of aerosol radiative feedback to dry heat stress (maximum dry bulb temperature) and moist heat stress (maximum wet bulb temperature or WBT) during a heat wave event in 2015, which claimed 2500 lives in India and 1500 lives in Pakistan. We made two one-year WRF-Chem simulations: the first with both aerosol direct and indirect radiative effects (BASE) and the second without the aerosol direct effect (NoARI), with the difference between them analyzed to understand aerosol-induced effects.

During the period May 22-Jun 5, 2015, aerosol radiative feedback led to an enhancement of dry heat stress (increased 2-m maximum temperature or TX2m) over the affected region (15°N-27.5°N; 71°E-85°E) by 1-3 °K. Further, increases in moist heat stress (WBT from increases in relative humidity), occurred during May 1-21 and Jun 5-30, 2015. There were collocated enhancements in surface layer black carbon concentrations by 0.5-1.5 μg m^{-3} during the dry heat stress period. We will discuss the underlying mechanism, which includes absorbing aerosol induced atmospheric stabilization and changes in surface energy fluxes, leading to enhanced surface shortwave heating rates.

Airborne In-situ Measurements during JATAC/CAVA-AW 2021/2022 Cabo Verde campaigns - First Climate-Relevant Results

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During September 2021 and 2022 the JATAC/CAVA-AW campaign took place on and above the Cabo Verde Islands. It provided a complete dataset of in-situ and remote measurements with the aim to be used for calibration and validation activities of the ESA's Aeolus ALADIN lidar products as well as additional studies related to the effects of the aerosol particles on climate. We performed a series of instrumented flights over the Atlantic Ocean near the Cabo Verde Islands, where some of the flights under the Aeolus ALADIN orbit path. These airborne measurements enable the in-situ characterization of the aerosol particles up to a heigh of 3000 m a.s.l. The light absorption properties of aerosols were determined at multiple wavelengths with a filter-based photometer (CLAP). The aerosol light scattering and backscattering coefficients were measured with a polar integrating multi-wavelength nephelometer Aurora 4000. The particle size distributions were measured for diameters above 0.3 µm with two Grimm 11-D Optical Particle Size Spectrometers (OPSS) for the fine aerosol fraction and the enriched coarse fraction. Complementary measurements of solar irradiance, CO2 concentration, temperature, aircraft GPS position, and air and ground speed were also performed by additional instrumentation onboard the aircraft. During the instrumented flights, additional remote sensing measurements were performed with two ground-based lidars which provided profiles of the optical properties of aerosols. The in-situ single-scattering albedo Angstrom exponent (SSAAE) and the lidar depolarization ratio were used to determine the presence of Saharan dust particles. Spatial and temporal differences will be shown for different events featuring strong gradients of composition and concentration of aerosols, as well as the presence of the Saharan dust along multiple layers. We will show the in-situ atmospheric heating/cooling rates and provide insights into the regional and local effects of this heating on the dust layers.

Dominant contribution to shortwave absorption by dark brown carbon in wildfire smoke

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Wildfires emit large amounts of black carbon (BC) and light-absorbing organic carbon, dubbed brown carbon (BrC), into the atmosphere. These particles perturb Earth's radiation budget through absorption of incoming shortwave radiation. The established understanding is BrC loses its absorptivity post-emission in the atmosphere because of sunlight-driven photochemical bleaching. Consequently, these aerosols exert a net atmospheric cooling effect and help offset the warming effects of BC. In this talk, we will present measurements of ensemble- and particle-scale shortwave absorption in smoke plumes of western United States wildfires from the ground to the troposphere. This study was part of the 2019 NASA/NOAA sponsored Fire Influence on Regional to Global Environments and Air Quality (FIREX-AQ) field campaign to investigate the plume composition of western wildfires.

We find a hitherto unrecognized category of dark BrC (d-BrC) contributing to three-fourths and half of the total absorption in short and long visible wavelengths, respectively. This strongly absorbing organic aerosol species is water insoluble, resists daytime photo bleaching, and increases in absorptivity with nighttime atmospheric processing. By leveraging recent developments in electron microscopy and spectroscopy, we measured the complex refractive indices of d-BrC aerosols with sub-nanometer spatial resolution across the ultraviolet–visible–near-infrared spectral region. We calculate a single scattering albedo of 0.38 for these organic particles in the visible–near-infrared spectral region. With the predicted increase in wildfires globally in the coming decades, our findings underscore the need for revised BrC parameterizations in climate models toward improved estimation of smoke aerosol radiative forcing and associated warming.

13th International Conference on Carbonaceous Particles in the Atmosphere

July 9–12, 2023 I Berkeley, California, USA

Abstracts—Poster Presentations

Fourier transform infrared (FT-IR) organic and elemental carbon (OC & EC) measurements in the Chemical Speciation Network (CSN)

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The CSN is a U.S. national $PM_{2.5}$ monitoring network, whose data is used for characterizing composition and trends, identify sources and assess health impacts. Representing OC and EC using FT-IR method at CSN sites improves cost and efficiency, minimizes sample handling and eliminates the quartz sampler and thermal optical analysis (TOA) from most sites. TOA on quartz filters would be retained a select group of sites for calibration.

Previous work suggests that CSN sites may require partitioning into two groups of for accurate calibration.

In this work, our first objective is to identify and separate atypical and typical sites. Using a global calibration we designate a site as atypical if, FT-IR predictions errors are large. Our second objective is to select representative typical and atypical sites to use for calibration. Atypical sites are partitioned using hierarchical cluster analysis (HCA) using median relative percent bias as well as the ratio of the median pyrolysis (char) artifact measured during thermal analysis (i.e., OP) to EC ratio and median OP/OC. One or two sites per cluster are selected for calibration. Typical sites are selected for calibration following the application of HCA to samples on six speciation measurements OC/ NH_4^+, EC/ NH_4^+, OP, NH_4, NO_3^-, and SO_4^{2-} and one site per cluster is selected for calibration Our third objective is to measure FT-IR OC and EC for all samples. As typical sites are reasonably similar in terms of carbon composition one model for OC and one for EC is developed, while individual models are developed for each atypical cluster. Overall, only 15 (8 atypical + 7 typical) sites appear to represent, to a reasonable degree, the composition of aerosol carbon in the 140 sites in CSN. The impact of COVID on identifying typical versus atypical sites and on prediction capabilities will be investigated.

Fall 2020 Wildfire Biomass Burning and Diesel Truck Traffic Measured by the Tricolor Absorption Photometer

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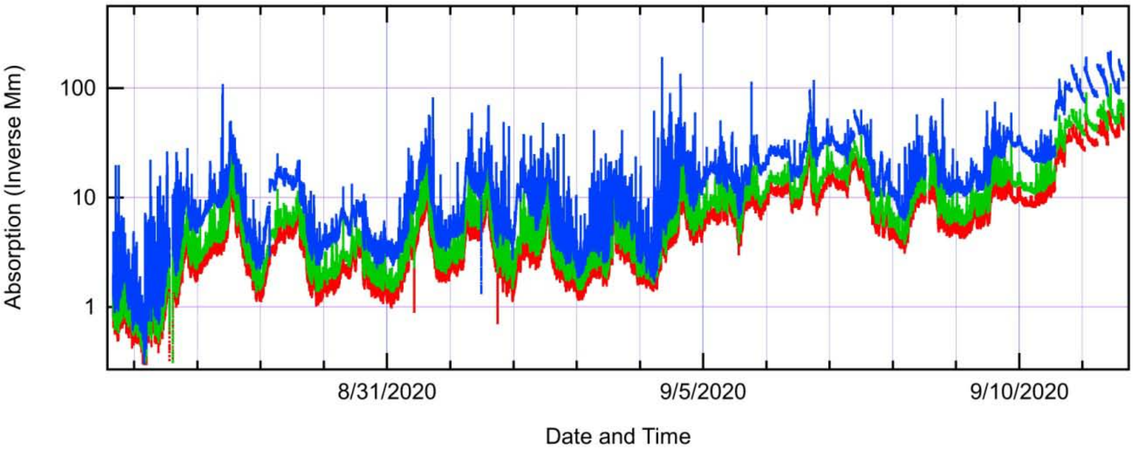
A Tricolor Absorption Photometer (TAP Model 2901, Brechtel) was used over a 3 week period to continuously monitor the dry ambient aerosol light absorption coefficient during the fall of 2020 when intense wildfires were burning in California. Sampling was performed in Hayward, CA at Brechtel's factory location using an inlet sampling at 30 ft agl. A major 4-lane industrial road is located only 40 ft from the inlet and a 10-lane interstate freeway is located 1600 ft away from the inlet. On-road sources provided numerous transient plumes, mainly from large diesel trucks. The results from wildfire and diesel truck monitoring are presented here. We will present representative days before the fire and during the fire to illustrate daily black carbon exposure, its increase during the fire, and diurnal loading patterns.



Wildfire light absorption data from August to September 2020.

From RO_2 to HOMs: Investigating the monomolecular reactions of individual unsaturated RO_2 with Proton transfer Mass Spectrometry

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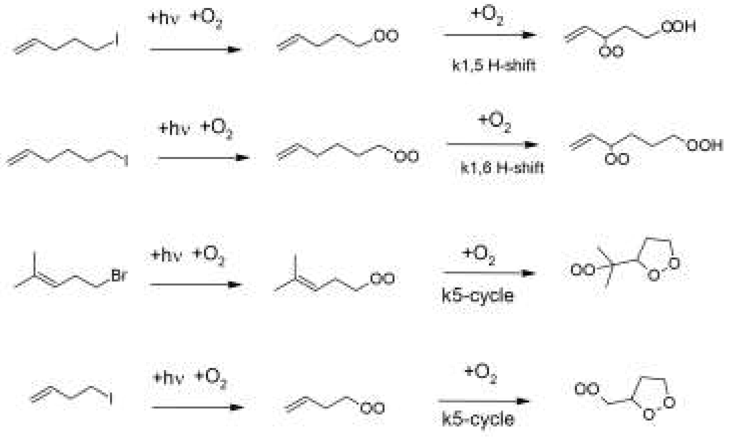
Over the last 10 years the importance of the monomolecular reactions (autoxidation) of organic peroxy radicals (RO_2) in the formation of Highly Oxygenated Molecules (HOMs) and, ultimately, secondary organic particles, has become increasingly evident.[1] Recent structure-activity relationships (SARs) based on quantum calculations of the rate coefficients for these reactions [2,3] have already helped to reduce the discrepancies between kinetic models and observations.[1,4] But such theoretical studies are still identifying new monomolecular pathways for the RO_2, making their chemistry complex. Most of the experimental studies of HOMs involve complex systems, usually starting with the oxidation of a biogenic compound (isoprene, terpene…) and including hundreds of reactions. But experimental kinetic data is still lacking for many individual monomolecular reactions.

In this work, we report an experimental study of various monomolecular reactions of unsaturated RO_2 (H-shift, cyclisation) to determine their rate coefficients. The reactions were performed in flow reactor where the RO_2 were produced by the direct photolysis of iodinated and brominated precursors[5,6], and the RO_2 and $HOOQO_2$ (resulting from the monomolecular reactions) were observed individually by proton transfer mass spectrometry.[6] The rate coefficients for the monomolecular reactions were then determined by the ratio of their concentrations.



Examples of unsaturated RO_2 investigated in this study and their main monomolecular reaction pathways.

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Simultaneous measurement of carbon and trace elements in brake wear particles using Inductively Coupled Plasma Time-of-Flight Mass Spectrometer.

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Automobile emission controls have been in place around the world since the 1960s and have been tightened year after year. Exhaust particles mainly composed of carbon emitted by internal combustion engines in automobiles are on the decreasing trend, however, with the increasing importance of powertrain alternatives, non-exhaust emissions containing brake wear particles are becoming more significant. Brake wear particles are mainly metal particles, but also contain carbon components such as phenolic resin and aramid fibers as binders and reinforcement materials. Inductively coupled plasma mass spectrometry has been widely used to measure trace elements, which allows for the measurement of metals derived from brake wear. Recently, ICP-TOFMS, which is equipped with a time-of-flight mass spectrometer, has developed and is possible to measure multiple elements simultaneously. Simultaneous measurement of carbon and metal elements by ICP-TOFMS was examined for the purpose of understanding the transient characteristics of the emission mechanism of brake wear particles originating from brake friction materials.

BLAnCA: an innovative instrument for full-spectrum light absorption measurements on carbonaceous aerosol

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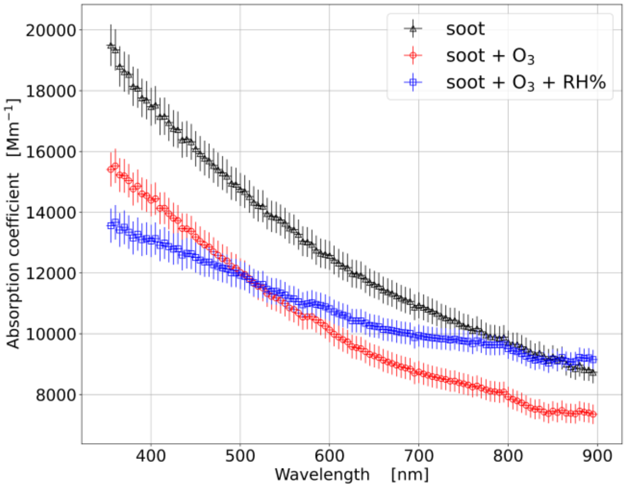
Atmospheric particulate matter (PM), and especially carbonaceous aerosol, plays a fundamental role in the Earth's energy balance and climate due to its light absorption and scattering properties. It is crucial to be able to study these properties in detail to obtain meaningful insights on its climate impact and – as they are related to aerosol sources and composition – to develop efficient abatement strategies. In this context, a new instrument for light absorption measurements has been developed at the Physics department of the University of Genoa, in the framework of the ISPIRA project of the Italian National Institute for Nuclear Physics (I.N.F.N). BLAnCA (Broadband Light Analyzer of Carbonaceous Aerosol) [1] is equipped with a wide spectrum light source and a high-resolution spectrometer. It can perform measurements of the light absorption coefficient (b_{abs}) of aerosol collected on a filter, on the spectral range [350, 900] nm with a resolution of 5 nm. At each wavelength, the phase-function of the light scattered by the sample is measured by placing the detector element on a movable arm that spans the scattering half-plane with an angular resolution up to 1°. To determine the wavelength-resolved absorption coefficient of the sample from the measured phase functions, a modified version of the Multi-Angle Absorption Photometer scheme [2] is used. The figure shows example $b_{abs}(\lambda)$ measurements obtained with BLAnCA on synthetic soot samples in different ageing conditions. The three plots have different spectral behavior, and furthermore present subtle absorption enhancement in some bands. As can be seen in the red squares plot, BLAnCA allows the reconstruction of this fine structure of the light absorption coefficient, highlighting, in this case, the narrow absorption enhancement at 580 nm and 800 nm, and a flattening of the absorption curve after 840 nm. Existing devices can only measure light absorption at a limited number of wavelengths (<10), whereas BLAnCA makes it possible to distinguish such features. This information allows to obtain crucial information about the aerosol type, composition, ageing-induced optical modifications and source apportionment.



A plot of the spectral behavior of synthetic carbonaceous aerosol in different ageing conditions.

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Can infrared spectra functional group measurements improve organic aerosol characterization from time of flight-aerosol chemical speciation monitor (TOF-ACSM)?

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Aerosols affect climate, ecosystems, and human health. Characterizing organic matter (OM) in aerosol particulates is crucial in understanding atmospheric processes in different locations, such as urban and remote areas. The Aerodyne Aerosol Chemical Speciation Monitor (ACSM) has been used to quantify inorganic and organic aerosol with high time resolution for a decade, however, the significant fragmentation of organic molecules by the electron impact ionization source creates uncertainties in analyzing organic aerosol compositions. Fourier transform-infrared (FT-IR) spectra are used to measure functional groups in bulk aerosol but is limited by its low temporal resolution compared to ACSM. In this study, we explore the relationships between fragment ions from several individual compounds, including carboxylic acids and alcohols, and multi-functional compounds and their measured functional groups. The fragment ions and functional groups are obtained using ACSM and FTIR, respectively. First, a PTFE filter-based OM functional group calibration was established using a wide range of chemicals with multiple functional groups such as carbonyl (CO), non-acid carbonyl (naCO), carboxylic acid (COOH), alcohol OH (aOH), alkane (CH), and unsaturated hydrocarbon (UnsCH), using partial least square (PLS) regression. Second, mass spectra of fragment ions are collected for the same chemical species. Third, the correlation of ACSM fragment ions with functional groups is explored using correlations to assess how functional group measurement can enhance ACSM organic characterization.

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

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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 or 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.

In this talk, I will present how 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. I will describe the request process for the instrument, example use cases, and the support that users receive from the Clemson team. For research, our SP2 has been used for ground-based ambient monitoring of BC aerosol near small, prescribed fire sources, aircraft-based field campaigns studying wildfire emissions and aerosol-cloud interactions, and laboratory studies of controlled combustion of common biomass burning sources.

I will also present how our SP2 is requestable for educational and outreach activities and will give a few examples. 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. I will share some of the work our group is doing using the SP2 to promote interest in STEM fields among K-12 and undergraduate student populations.

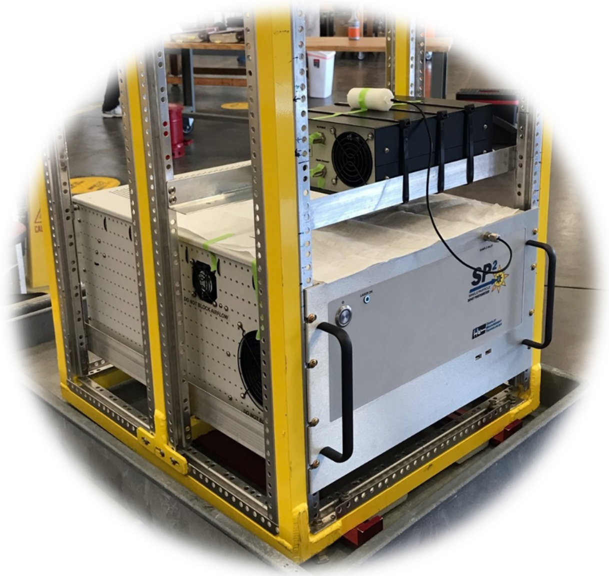

Figure 1: The Clemson University SP2 instrument preparing for field deployment on a research aircraft for measurements of black carbon aerosol from biomass burning and anthropogenic sources.

Absorption photometry on ringed-PTFE filters:
Accounting for pixelated deposits

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In-situ measurements of aerosol light absorption are commonly carried out by real-time photometry of filter samples, typically collected on quartz fiber media for this specific purpose. (This approach goes back to the origins of this ICCPA series!) Optical interpretation of such samples is facilitated by the deposit's even distribution across an illuminating beam, while being complicated by scattering from the optically thick substrate. Thinner and more transparent PTFE membranes are now preferred as substrates for most off-line gravimetric and elemental analyses, and ringed PTFE membranes have established themselves as a workhorse of large-scale networks for chemical and air quality monitoring. Piggybacking on this additional pool of PTFE samples offers an attractive opportunity to increase the coverage of data from absorption photometry. For the last two decades, the IMPROVE network (Interagency Monitoring of PROtected Visual Environments) has demonstrated the viability of such an approach (White et al., 2016, AS&T 50, 984-1002). The present work characterizes the photometric nonlinearity introduced by pixelation typically observed in a PTFE deposit, which reflects the pattern imposed on sample flow through the membrane by the filter holder's support screen.

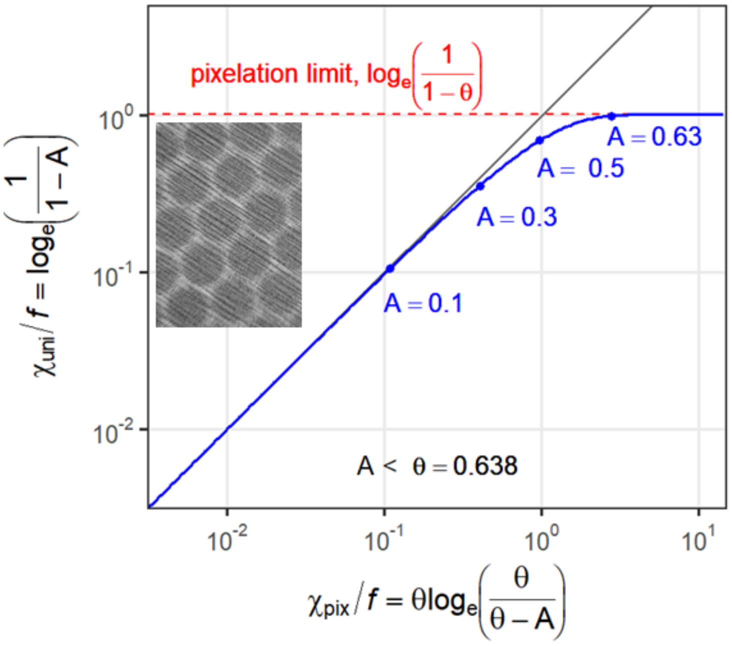

Figure. *Alternative inferences for the mean areal density χ/f of absorbing cross-sections in a maximally pixelated IMPROVE filter sample, where $\chi = \sum_p \sigma_p$ is the sum of absorbing particle cross sections collected in the sample and f is the filter area exposed for their collection. The fixed parameter θ, determined by the design of the filter support screen, is the fraction of the exposed filter area covered by deposited aerosol. The variable $A = 1 - \frac{t}{1-r}$ is the sample absorptance determined from scaled measurements of overall transmittance and reflectance. The cross section $\chi_{pix} > \chi_{uni}$ implied by measured absorptance of a pixelated sample is always greater than that calculated assuming the sample to be uniform. Inset photomicrograph shows detail from a representative pixelated sample with θ = 0.64 and A = 0.29.*

Quantifying residual elemental carbon by thermal-optical analysis using an extended IMPROVE_A protocol with higher maximum temperature

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Thermal-optical analysis (TOA) has long been used to quantify organic carbon (OC) and elemental carbon (EC) on quartz-fiber filter samples collected in national ambient air monitoring networks. In the routine analysis of samples from the Chemical Speciation Network (CSN), we observed a considerable fraction of filter punches that remain gray or black in color after TOA was completed, suggesting the presence of EC that was not fully evolved at the highest temperature specified by the IMPROVE_A protocol (840 °C). We explored the operational conditions necessary to evolve and quantify such residual EC by analyzing four heavily loaded CSN samples with a modified IMPROVE_A-type protocol. We found that adding a higher temperature step at 930 °C more effectively evolved the residual EC than did lengthening the duration of the 840 °C step. Compared with the standard IMPROVE_A results, the modified protocol evolved additional EC of 0.12 to 0.50 μg m^{-3}. This excess EC accounts for 27.1% to 45.3% of the total EC and 7.6% to 25.1% of the total carbon by the standard IMPROVE_A protocol. We then analyzed over 2600 samples from CSN using the extended IMPROVE_A protocol with higher maximum temperature (930 °C). A total of 168 samples (6.4% of the total samples analyzed) contained measurable EC at the added higher temperature step. Among these samples, the average fraction of the evolvable residual EC mass in total EC is 5.7%, and up to 28% for samples with high total EC mass loading (i.e., 95th percentile and above).

Our results suggest that EC measured from urban CSN sites using the standard IMPROVE_A protocol should be considered a lower limit, and that a modified maximum heating temperature of 930 °C or above can be used to better quantify EC from sites impacted by fresh emissions.

Assessing the potential to improve polarimetric aerosol property retrievals for black carbon aerosol

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Philippe Giaccari[2], and Martin Gysel-Beer[1]

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Angular distribution and polarization dependence of light scattered by aerosols allow the retrieval of their microphysical properties using inversion algorithms. However, systematic bias in retrieved properties is known for light-absorbing aerosol (e.g., black carbon, BC) owing to simplified aerosol representation. Therefore, evaluating if using an aerosol model tailored towards combustion aerosol improves BC retrieval quality is worthwhile.

This study explores this using the uNeph, a new prototype of laser imaging polar nephelometer. The uNeph is designed to perform in situ measurements of the phase and polarized phase functions of aerosols at 532nm. We probed homogeneous spherical (PSL, nigrosin) and non-spherical (fullerene soot, Aquadag) aerosols with different optical properties. An algorithm based on least square minimization and assuming spherical particles, i.e., using Mie theory, was applied to infer the size distribution parameters and the complex refractive index. A good agreement between Mie curves and the uNeph measurement is achieved for PSL spheres and light-absorbing spherical nigrosin particles. The retrieved complex refractive index was independent of probed particle diameter and in agreement with literature data (Fig. 1b). Good agreement was also achieved for aerosol number and volume concentration. By contrast, it is not possible to fit Mie curves that match both phase function and polarized phase function measured by the uNeph for non-spherical Aquadag and fullerene soot samples. Consequently, the retrieved geometric mean diameter is highly biased compared to independent data (Fig. 1a).

Future work will focus on i) measurement of more realistic soot generated under well-constrained conditions, ii) a better forward model that can match uNeph observations hence providing more accurate retrievals. Insights from lab experiments shall later be applied to ambient aerosol to assess the potential for improved retrieval of light absorption from polarimetric data.

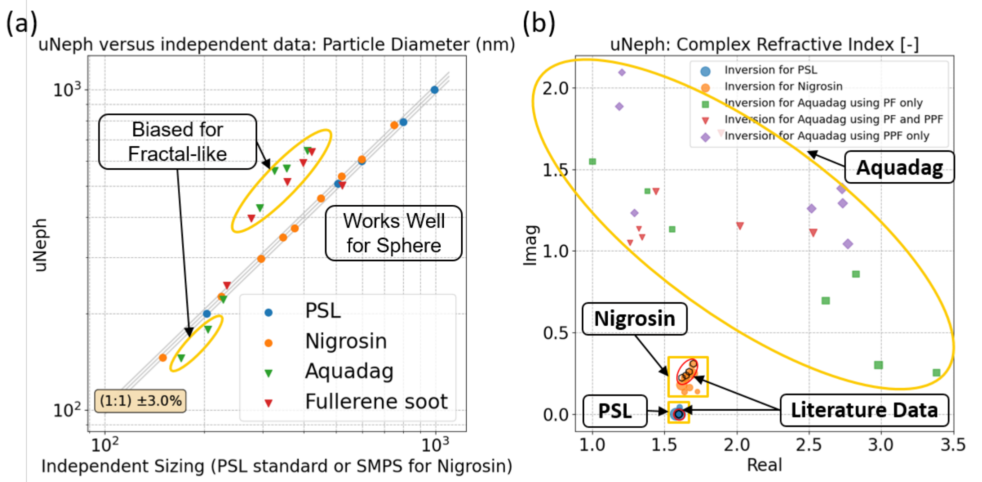

Figure 1. uNeph retrieval vs. independent data.

Humidity-Induced Changes in the Optical Properties of Dust Particles: Insights from Field Measurements and Simulations

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Dust is a ubiquitous atmospheric particle that has significant impacts on climate, air quality, and human health. While the optical properties of dust, such as absorption coefficients, have been studied extensively, the influence of humidity on these properties is poorly measured despite dust particles often encountering varying levels of atmospheric moisture.

In this study, we report on new field measurements taken in Houston during the DOE ARM's TRACER-CAT campaign in July 2022. We investigated the effects of humidity on the optical properties of submicron dust using a combination of field measurements and numerical simulations. We used a custom-built instrument, the dual-channel Humidified-Cavity-Attenuated Phase Shift-Single Scattering Albedo Particulate Matter Monitor (H-CAPS-PM), to measure the optical properties of dust particles under controlled levels of relative humidity. Our results show an increase in aerosol scattering and extinction, as well as an increase in single scatter albedo, with increasing humidity. However, the absorption increase with humidity was found to be variable.

To assess our measurements, we conducted simulations using the Mie theory with modified effective refractive indexes to include the effect of water uptake by dust particles. The simulations confirmed the changes in the optical properties of dust particles due to humidity and showed the importance of incorporating these effects into atmospheric models.

Our findings have important implications for understanding the role of dust in atmospheric processes and climate change. By incorporating the effects of humidity on dust optical properties into atmospheric models, we can improve our predictions of dust radiative forcing and the resulting impacts on regional and global climate.

Aggregation-induced enhancements in aerosol absorption and scattering across the black-brown continuum

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The global radiative forcing of carbonaceous aerosols is one of the largest sources of uncertainty in current climate models. BrC is an amorphous organic aerosol formed in biomass burning events, such as wildfires, and its radiative impact remains poorly understood. Aggregates of BrC primary spheres (monomers) have been recently observed in abundance in wildfire smoke. Aggregation could alter their optical properties and direct radiative forcing, yet very little is known about this phenomenon. This study could improve the representation of BrC aerosols in climate models by enhancing the current understanding of their optical properties.

In this study, we utilize the framework presented by Saleh et al. (2020) for the optical classification of particles in the black-brown continuum but focus on two sub-classes of BrC: dark brown carbon (d-BrC) and weakly-absorbing brown carbon (w-BrC). We calculate and compare the mass absorption coefficient (MAC), mass scattering coefficient (MSC), single scattering albedo (SSA), asymmetry parameter of dark brown carbon (d-BrC) and weakly-absorbing brown carbon (w-BrC), and determine their absorption and scattering enhancements due to aggregation. We use polydisperse diffusion limited cluster-cluster aggregation simulations to generate 90 aggregates of varying monomer diameters, and discrete dipole approximation to calculate optical properties of aggregates at different refractive indices, monomer diameters, and incident wavelengths.

BrC aggregate's optical properties are more sensitive to the number and mean diameter of monomers than their polydispersity. d-BrC has almost twice the MAC of w-BrC at 350 nm, but w-BrC has MSC values almost double that of d-BrC. Both MAC and MSC decrease with wavelength. Aggregation enhances optical properties, with smaller size parameters and lower imaginary part of the complex refractive index of aggregates resulting in stronger absorption and scattering.

Reference: Saleh, R.: From measurements to models: toward accurate representation of brown carbon in climate calculations, Current Pollution Reports, 6, 90-104, 2020.

Optical properties of atmospherically aged tar balls from the free troposphere and their climatic impacts

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Tar balls are particles formed in biomass combustion plumes which exhibit wavelength dependent light absorption and are amorphous as well as highly viscous in nature. These spherical particles, transported in the troposphere, have a potentially significant impact on the Earth's radiative balance. However, their climatic impacts are highly uncertain due to poorly constrained optical properties. In this study, we analyzed aerosol samples collected from the ACTRIS/GAW global station of Mt. Cimone, Italy at an altitude of 2165 m above sea level during the summer of 2017. We found an abundance of tar balls in several of the samples. These samples were used to study the optical properties of tar balls in the free troposphere. We determined the refractive index of single tar balls using electron energy loss spectroscopy for a broad wavelength range, from 200 to 1200 nm. From transmission electron microscopy coupled with energy dispersive x-ray spectroscopy we found particles with different mixing states such as tar balls mixed with soot, coated soot, externally mixed tar balls, tar balls mixed with potassium and sulfur and low viscosity secondary organic aerosols. Hence, we classified the tar balls into two groups, as inhomogeneously and homogeneously mixed, to study potential variations of the refractive indices with the mixing state. We found that the average refractive index of inhomogeneously mixed tar balls is 1.40 ± 0.05 and that of homogeneously mixed tar balls is 1.36 ± 0.07. Furthermore, we used a radiative transfer model (SBDART) to calculate the top of the atmosphere radiative forcing of tar balls. We found that a hypothetical layer of tar balls with an optical depth of 0.1 above vegetation can have radiative forcing of 2.8 ± 0.8 Wm^{-2}. We also compared the TOA RF values from our study with those calculated using the refractive indices from previous studies.

Snow Surface Albedo Sensitivity to Black Carbon: Radiative Transfer Modelling

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The broadband surface albedo of snow can greatly be reduced by the deposition of light-absorbing impurities, such as black carbon on or near its surface. Such a reduction increases the absorption of solar radiation and may initiate or accelerate snowmelt and snow albedo feedback. Coincident measurements of both black carbon concentration and broadband snow albedo may be difficult to obtain in field studies; however, using the relationship developed in this simple model sensitivity study, black carbon mass densities deposited can be estimated from changes in measured broadband snow albedo, and vice versa. Here, the relationship between the areal mass density of black carbon found near the snow surface to the amount of albedo reduction was investigated using the popular snow radiative transfer model Snow, Ice, and Aerosol Radiation (SNICAR). We found this relationship to be linear for realistic amounts of black carbon mass concentrations, such as those found in snow at remote locations. We applied this relationship to measurements of broadband albedo in the Chilean Andes to estimate how vehicular emissions contributed to black carbon (BC) deposition that was previously unquantified.

This work has been supported in part by the Broad Agency Announcement Program and the Cold Regions Research and Engineering Laboratory (ERDC-CRREL) under Contract No. W913E523C0002 and by ANID Project Anillo ACONCAGUA No. ACT210021, Ministry of Science, Technology, Knowledge and Innovation of Chile.

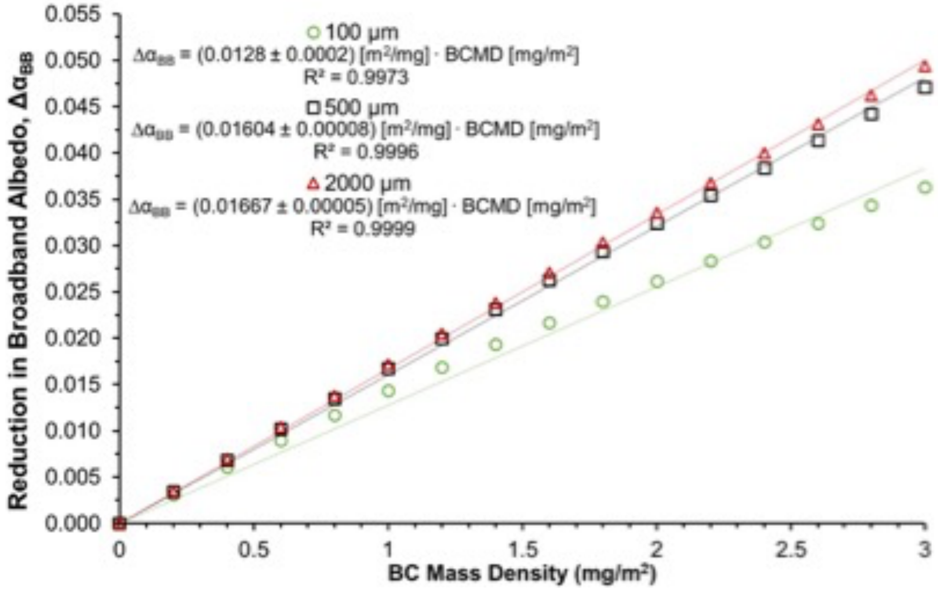

Fig. 1. *Reduction of snow surface albedo* $\Delta\alpha_{BB}$ *as function of* $BCMD$ *for three grain radii (i.e., 100, 500, and 2000 µm) and the resulting slopes* m *for* $BCMD \leq 3$ *mg/m*^{2} *from a linear regression, where the error of* m *is the standard error value of the regression slope.*

Source identification and characteristics of water-soluble inorganic ions in $PM_{2.5}$ in Mesra, Ranchi: A COALESCE network site in India

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Abstract

The present study focused on fine PM and its water-soluble inorganic ions (WSII) characteristics and sources in Mesra, Ranchi, India. The selected site is part of India's COALESCE (CarbOnaceous AerosoL Emissions, Source apportionment, and ClimatE impacts) network. It is also a lesser-studied region lying in the Indo-Gangetic Plain (IGP). The seasonal characteristics of $PM_{2.5}$ and its WSII were investigated based on alternate day 24-h integrated bulk measurements during 2019. Aerosol pH and Aerosol Water Content (AWC) were calculated using ISORROPIA-II, a thermodynamic model in reverse mode and metastable state. The annual mean $PM_{2.5}$ mass concentration over Mesra was 67±46 $\mu g\ m^{-3}$, the third most polluted region among the COALESCE network sites. WSII accounted for 50.5% of the annual mean $PM_{2.5}$ concentration. Ammonia (7.92%), sulfate (16.24%), and nitrate (7.39%) were the major secondary inorganic species in $PM_{2.5}$, constituting 91.06% of the annual mean WSII. As expected, the winter-high and monsoon-low patterns were the seasonal variation observed in mass concentration and WSII. Moreover, cooler temperatures during winter and post-monsoon, along with a shallow boundary layer, favoured the particle phase partitioning predominantly in the form of $(NH_4)_2SO_4$ and NH_4HSO_4 along with NH_4NO_3 of semi-volatile nature. The annual average ratio of (NO_3^-/SO_4^{2-}) was 0.41, indicating the influence of stationary sources compared to mobile sources. Aerosol pH varied seasonally from 3.54 to 7.02, with an annual mean of 5.77. Similarly, the AWC varied seasonally depending on the Relative Humidity (RH). Further, a multivariate technique was used to identify the sources using Principal Component Analysis (PCA). The possible sources determined using PCA indicated a combination of secondary aerosol formation, biomass burning, and coal combustion (45%), dust sources (21%) and aged sea salt (10%). However, a detailed view of different sources can be obtained based on further studies on metallic tracers and carbonaceous aerosols.

Classification of carbonaceous aerosol particles originating from asphalt pavement

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Asphalt related emissions act as non-traditional source of secondary organic aerosol precursors. We have evaluated emissions generated during asphalt pavement construction and compared it to background and laboratory measurements. Particle size distribution during construction, background and laboratory measurements were performed with an Optical Particle Counter (OPC) and correlated with a Wideband Integrated Bioaerosol Sensor (WIBS). Fluorescence intensity and size of aerosol particles of both background measurements (ambient conditions) and during the pavement construction process is used to differentiate between asphalt emissions and background aerosol. This provides information on the concentration and chemistry of asphalt aerosol particles. Laboratory studies on the same asphalt mixture were set up to provide particle size and fluorescence information on the asphalt emission without the influence of environmental impacts. We found that the maximum of the size distribution of the emitted aerosol lies between 150 and 200 nm. Fluorescence excitation and emission spectra of the applied asphalt mixture support the assignment of aerosol particles registered by the WIBS to asphalt origin.

micro-Aethalometer-based black carbon measurements and source apportionment at novel long-term monitoring sites in Addis Ababa, Ethiopia as part of the Multi-Angle Imager for Aerosols (MAIA) Investigation

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Exposure to particulate matter smaller than 2.5 microns in diameter ($PM_{2.5}$) is responsible for millions of premature deaths annually. In recent years, the black carbon (BC) component of carbonaceous aerosols has been identified as one of the key contributors to the toxicity of $PM_{2.5}$. One study currently in development to better characterize the relative toxicity of major chemical components of $PM_{2.5}$, including BC, is the Multi-Angle Imager for Aerosols (MAIA) investigation, a joint mission of NASA and the Italian Space Agency. The MAIA satellite instrument will collect observations that will be integrated with ground-based PM measurements in a geostatistical regression model to map total $PM_{2.5}$ and PM_{10}, as well as speciated $PM_{2.5}$ (sulfate, nitrate, organic carbon, black carbon, and dust) at 1-km spatial resolution in 11 Primary Target Areas (PTAs) around the world. While the satellite is not expected to launch until 2024, investigators have already begun deploying surface monitors at the PTAs. Of particular interest is a PTA in Ethiopia (Addis Ababa), which covers an airshed with diverse aerosol sources like traffic, household heating, and household cooking. Due to the prior lack of $PM_{2.5}$ measurements in Ethiopia, the MAIA project has deployed and is operating a variety of in-situ PM sensors in Addis Ababa, including two custom AethLabs BC monitors based on the optical microAeth® MA series and network PurpleAir sensors, two of which are collocated with existing MetOne BAM 1020 reference $PM_{2.5}$ monitors placed at US Embassy locations in Addis Ababa Central and Jacros. BC data have now been collected for over a year at both sites and represent the first ever year-long continuous BC measurements in Addis Ababa. Data were analyzed for the period Apr 2022 – May 2023. BC levels approximately follow overall $PM_{2.5}$ trends throughout the day, with peaks between 5-7 AM and 6-8 PM. Hourly average BC levels for the study period are 3.8 $\mu g/m^3$ and 8.3 $\mu g/m^3$ at Central and Jacros, respectively, and represent 15% and 30% of $PM_{2.5}$, respectively. $BC/PM_{2.5}$ fractions are substantially higher than values observed in other PTAs such as Beijing and Los Angeles during extended measurement periods. Outputs from the Aethalometer Model for source apportionment indicate that BC in Addis Ababa is dominated by fossil fuel sources, which contribute an average 3.2 $\mu g/m^3$ and 7.2 $\mu g/m^3$ of BC to the air at Central and Jacros, respectively. Biomass burning sources contribute 0.6 $\mu g/m^3$ and 1.1 $\mu g/m^3$ at Central and Jacros, respectively, and appear to play a more important role at night. Local biomass sources may dominate the biomass BC signal between Aug – Sep and Jan – Feb and subside during the rest of the year. Weather data obtained from Bole International Airport ~ 4km from the Jacros site suggest downtown traffic emissions may contribute heavily to fossil fuel related BC – and thus overall BC – at Jacros, while Western biomass burning sources (e.g., residential cooking or heating with biomass) likely dominate its biomass BC signals.

Thermal Desorption-Pyrolysis-Gas Chromatography-Mass Spectrometry Tool for Analysis of both Non-volatile and Volatile Air Particulate Matter Markers

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ABSTRACT

The impact of agriculturally active regions on the composition of atmospheric organic PM was investigated based on profiles of organic tracers during the Polarimetric Cloud Analysis and Seeding Test (POLCAST) in Grand Forks, ND. Thermal optical analysis (TOA) showed that 73 – 87 % of the organic carbon (OC) in the collected PM evolved above 400 °C, i.e., being non-volatile. Thermal desorption – pyrolysis with gas chromatography-mass spectrometry (TD-Pyr-GC-MS) enabled the characterization of both volatile and nonvolatile atmospheric markers in particulate matter (PM). The analysis of non-volatile markers is novel, as solvent extraction cannot provide this information. Based on the composition of thermal desorption fractions evolving below 400 °C, harvesting activities appeared to be related to an increased abundance of longer chain alkanes (waxes). The thermal desorption fractions also contained biogenic fatty acids and their methyl esters, along with other biogenic OC tracers including levoglucosan and 6,10,14-trimethyl-2-pentadecanone. By contrast, long homologous series of *n*-alkenes, *n*-alkylbenzenes, PAHs, *n*-alkanes, and substituted phenols were observed in several pyrolytic fractions, which were differentiated by temperature. We were able to interpret and ascribe the observed hydrocarbon profiles to lipid pyrolysis. Novel pyrolytic indicators were developed reflecting the breakdown of biogenic plant lipids, providing a more representative and comprehensive characterization of PM. According to these new indicators, the biogenic portion of PM appeared to be most abundant, although some sampling periods showed anthropogenic contributions.

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Source apportionment of one-year observation PM$_{2.5}$ in Ho Chi Minh City, Vietnam

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One-year observation on ambient PM$_{2.5}$ in Ho Chi Minh City (HCMC) has been carried out from September 2019 to August 2020. We determined PM$_{2.5}$ mass, water-soluble ions, organic carbon (OC), elemental carbon (EC), and metals. In this study, eleven metals (As, V, Pb, Ni, Mn, Cu, Zn, Mg, Fe, Ca, and Al) were analyzed by inductively coupled plasma mass spectroscopy (PerkinElmer ELAN 9000, USA). Detailed information of others has been provided in our former report (Tran et al., 2023). Based on our concentration data, positive matrix factorization model (PMF) was applied to identify PM$_{2.5}$ sources in HCMC.

OC and EC contributed approximately 41% of PM$_{2.5}$ mass. K$^+$ also showed high correlation with OC and EC ($r > 0.9$, $p < 0.01$) during the sampling period. This suggests the high influence of biomass burning to ambient PM$_{2.5}$ in HCMC. OC/EC ranged from 1.98 to 5.85 (3.28 ± 0.61 (average ± standard deviation)), suggesting that OC and EC sources were derived from transportation, biomass burning, barbecue cooking, and coal combustion. Based on PMF modeling, nine factors were extracted in this study. We determined five main factors of the mixed sources of biomass burning, transportation, and crustal origin (29%), secondary ammonium sulfate (19%), road dust (15%), sea salt (14%), and soil dust (7%) as main sources in HCMC (Fig. 1).

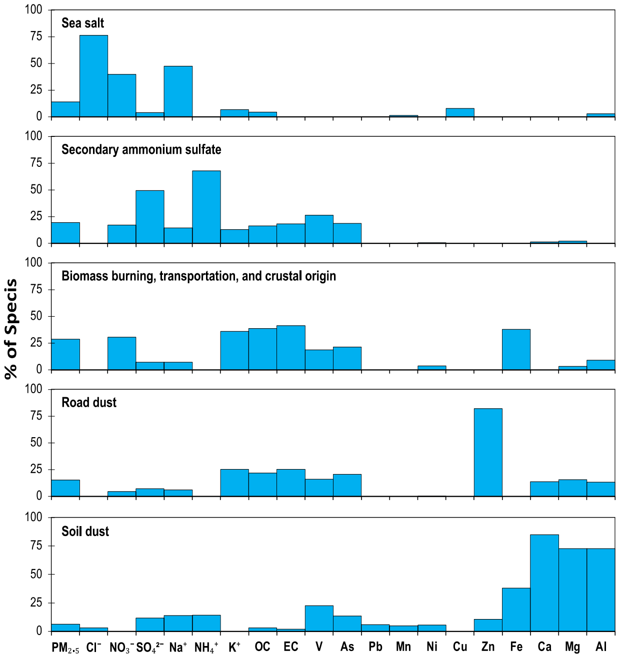

Fig.1. PM$_{2.5}$ source profiles by PMF model

This work was partially supported by the JSPS Kakenhi (grant number: 21K7896), the Japan Science and Technology Agency 6 (JST)-SPRING Program (JPMJSP2139), the Environment Research and Technology Development Fund (5-2013) of the Environmental Restoration and Conservation Agency of Japan.

Tran et al. (2023). *Aerosol Air Qual. Res.* (in press).

Quantitative Chemical Analysis of Pollen Extracts and their Volatility Behavior in Aerosolized Form

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Biological aerosols, or bioaerosols, are defined as any aerosol in the atmosphere that is biological in origin. While bioaerosol studies have increased in frequency significantly in the past decade, overall knowledge of how they play a role in atmospheric chemistry remains unknown. Very few specifics are known about the overall chemical composition of bioaerosols. Additionally, bioaerosol release and concentrations, especially pollen, correlate with rising global temperatures over the past several decades, indicating that they may continue to rise in the coming decades as the global temperature increases (Anderegg et al., 2021). As such, it is very important that we characterize their chemical composition, and also determine their volatility properties in the atmosphere. In this research, quantitative analysis of the water-soluble extracts of several pollen species (focusing on saccharides and free amino acids) are was performed using gas- and liquid chromatography mass spectrometry, in order to identify unique chemical signatures for each species. For instance, Figure 1 depicts varying concentrations of proline and asparagine across multiple pollen species.

Additionally, a method to measure the saturation vapor concentrations and latent heats of vaporization of pure aerosol compounds was employed (Saleh et al., 2008) to determine the volatility behavior of individual compounds found in pollen. Results will be presented, with implications on source tracing and potential to exist in gaseous form in the atmosphere discussed.

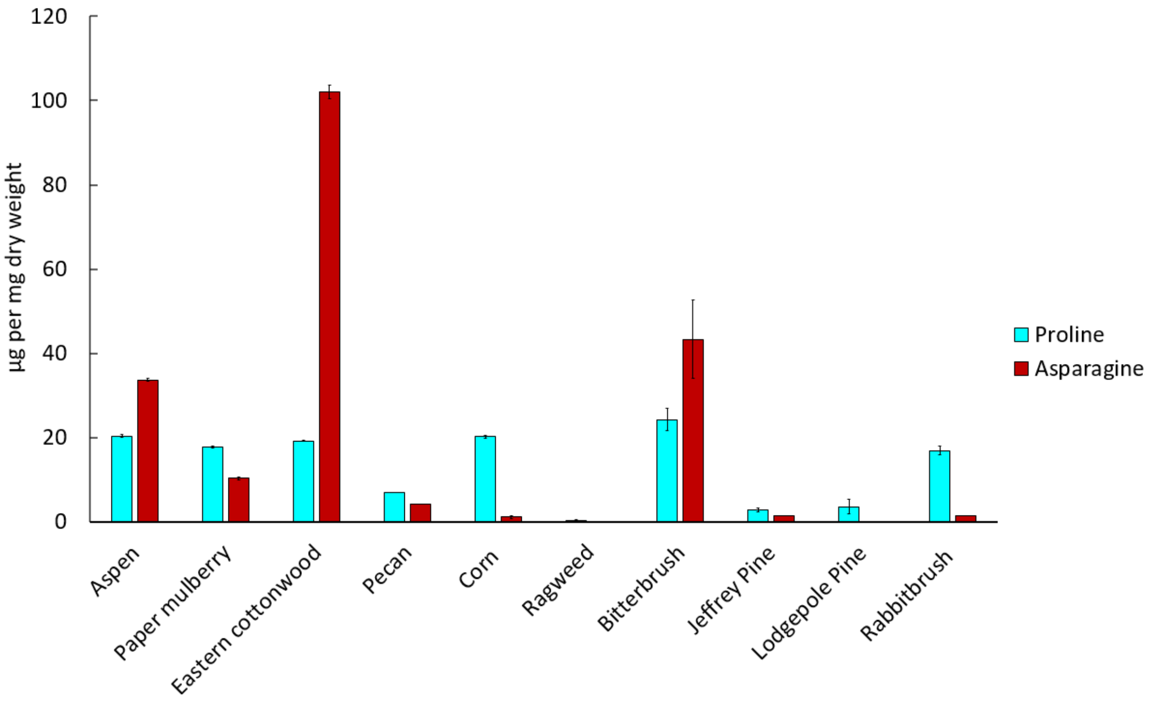

Figure 1. Comparison of the amino acid profiles (in µg of compound per mg dry pollen weight) of several different pollen species that span a wide range of the globe.

Chemical Characterization of Bioaerosols

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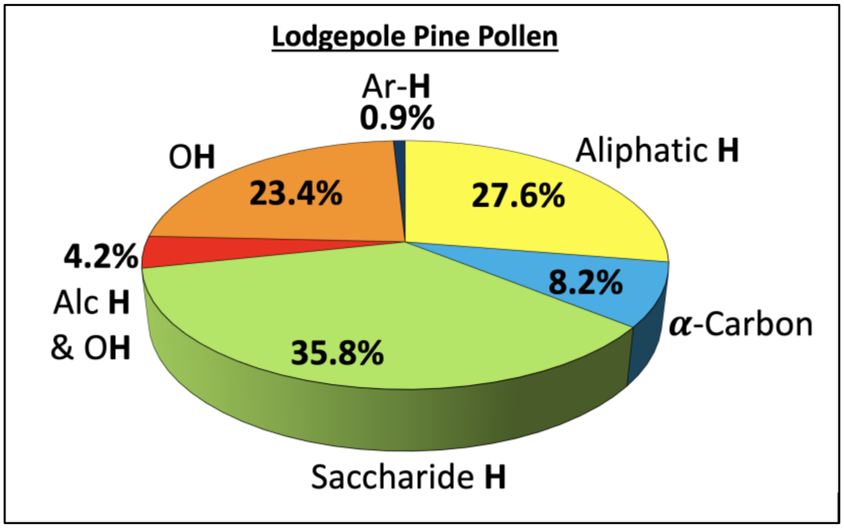
Bioaerosols, or aerosol particles containing biological material, have been found to represent a significant mass fraction of atmospheric particulate matter (PM) and organic carbon (OC). These particles are larger in size (up to 100 µm) than most anthropogenically-generated aerosols but are lighter and thus can be transported over large distances, affecting atmospheric processes and cloud physics (i.e., act as cloud condensation nuclei). Moreover, climate change has increased pollen number concentrations (~21%) as well as pollen season length (+21 days) across North America. So far, only few studies have been conducted on bioaerosols and their behavior under atmospheric conditions. The goal of this research is characterizing the chemical composition of bioaerosols using multiple analytical techniques, such as Proton Nuclear Magnetic Resonance Spectroscopy (^{1}HNMR), Gas Chromatography-Mass Spectrometry (GC-MS), and Ultra-High Performance Liquid Chromatography-Mass Spectrometry (UPLC-MS), thereby advancing atmospheric aerosol chemistry. Various common bioaerosols, including pollen, algae, fungi, and bacteria, are analyzed, and characterized under controlled laboratory conditions. This blueprint is also used for characterizing bioaerosols collected on ambient filter samples in Northern Nevada and California. All samples (laboratory-controlled and ambient) are analyzed for their chemical composition: saccharides with GC-MS, amino acids and fatty acids with UPLC-MS, and functional groups with ^{1}HNMR spectroscopy. The present research is one of the first studies on detailed chemical characterization of bioaerosols with ^{1}HNMR technique, where the ^{1}HNMR results will be also compared with GC- and UPLC-MS quantitative analyses of individual bioaerosol species.



The figure shows the fractional distribution of major *function groups identified in one of the* ^{1}*HNMR spectra of a lodgepole pine pollen extract (Pinus contorta) prepared in dimethyl sulfoxide-d6 (DMSO-*d_6*).*

Biological Aerosol Particles in the Finnish Sub-Arctic

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This study investigates primary biological aerosol particles (PBAPs) at the Pallas supersite, a pristine site in Finnish Lapland 170 km north of the Arctic circle. A Wideband Integrating Bioaerosol Sensor (WIBS 5/NEO – Droplet Measurement Technologies, Longmont, USA) has been used to measure the concentration and size distribution of fluorescent aerosol particles (FAPs). The WIBS detects and sizes particles from 0.5 to 30 µm and measures the autofluorescence of single particles using two excitation wavelengths (280 nm and 370 nm) and two emission bands (310 – 400 nm and 420 – 650 nm), resulting in three fluorescence channels which can further be combined to define 7 types of fluorescent particles. ABC particles for example show fluorescence in all three channels and are therefore a subset of all FAPs (fluorescence detected in at least one channel).

The average total FAP concentration has been found in the range 0.05 cm^{-3}, which contributes 11 % of the total aerosol concentration measured by the WIBS. The fraction of FAPs increases with particles size and in the coarse fraction approximately 50 % of all particles fluoresce. From late October the surrounding land is covered in snow. Snow coverage has a strong influence on ABC-particles: The average concentration of ABC-particles drops from 0.01 cm^{-3} during snow-free time to 0.002 cm^{-3} during snow coverage, suggesting that most ABC-particles are emitted from local vegetation. The general FAP concentration does not follow this trend, as the concentration increases again in December, in a similar manner to the concentration of all particles.

The influence of carbonaceous aerosols on the reduction of solar irradiance in Mexico City

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In this work, we studied the main factors that cause a reduction in the Global Horizontal Irradiance (GHI) values measured in Mexico City (MC) during a high atmospheric pollution event. The primary components driving trends in incoming solar radiation over MC are variations in cloudiness and the concentration of aerosols. During the spring in MC (March to May), skies are mostly clear and solar irradiation reaches maximum values. Additionally, high ambient temperatures favor the initiation of wildfires that emit particulate matter (PM) and gaseous compounds that negatively impact the city's air quality. The dense smoke plumes contribute to increased aerosol concentrations within the Mexico basin and introduce a high amount of carbonaceous particles that cause severe degradation in visibility and a 17% reduction in GHI values. CIMEL sun photometer measurements show that fine aerosols are the main cause of the high aerosol optical depth (τ) values under high pollution conditions, which can reach values ~ 3 times higher than the annual mean (τ_{am}= 0.32 ± 0.12). Furthermore, these photometric measurements show an increase in the imaginary refractive index of aerosols (ki), which is evidence of the presence of absorbing material in the atmosphere. Light-absorbent particles, such as soot and tarballs, were revealed through electron microscopy and X-ray fluorescence (XRF) analysis.

Assessment of Carbonaceous Ultrafine Particles in Kuala Lumpur, Malaysia Influenced by Peatland Fires

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Transboundary haze pollution by peatland fires particularly in Sumatra and Kalimantan Islands has been recognized as a serious environmental issue in Southeast Asia such as Indonesia, Malaysia, and Singapore. In the past, we performed field observations of fine particles ($PM_{2.5}$) in Malaysia to chemically characterize $PM_{2.5}$ related to haze induced by peatland fires (e.g., Fujii *et al.*, 2015a; Sulong *et al.*, 2019). Compared to $PM_{2.5}$, ultrafine particles ($PM_{0.1}$) are considered to cause more pulmonary inflammation and are retained longer in the lung (Schraufnagel, 2020). In this study, we characterized $PM_{0.1}$, particularly focused on carbonaceous species during the haze periods based on ground-based sampling in Kuala Lumpur, Malaysia.

A field study was performed on the roof at Universiti Malaya located in Kuala Lumpur, Malaysia. $PM_{0.1}$ were collected with a Nano Sampler II (Model 3182, KANOMAX) on a quartz fiber filter for 3 days/sample at a flow rate of 40 L min^{-1}. After sampling, we quantified organic carbon (OC), elemental carbon (EC), water-soluble OC (WSOC), water-soluble ions, and biomass burning (BB) markers (organic compounds derived from BB).

In Kuala Lumpur, peatland fires-induced haze was occurred during the sampling periods from August to September 2019. Severe haze events were observed in September. At those time, the average concentrations of OC (5.0 μgC m^{-3}), WSOC (2.5 μgC m^{-3}), sulfate (0.93 μg m^{-3}), ammonium (0.36 μg m^{-3}), and potassium (86 ng m^{-3}) in September were over 4 times higher than those in June, July, and October, 2019. In contrast, the differences in EC concentrations between samples in September and others were not significant. This is because peatland fires are in a smoldering combustion with a slow and low-temperature from of burning (Fujii *et al.*, 2015b, 2019). Further discussion especially on BB markers will be conducted in our presentation.

Acknowledgements

This work was supported by Japan Society for the Promotion of Science (JSPS) Kakenhi Grant Number 21K17896. We also appreciate the financial support by Leading Initiative for Excellent Young Researcher, MEXT, Japan.

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Trends in Refractory Black Carbon Mass Concentration and Coating Thickness During the 2021 Regional Cumulative Assessment Project (ReCAP) Project

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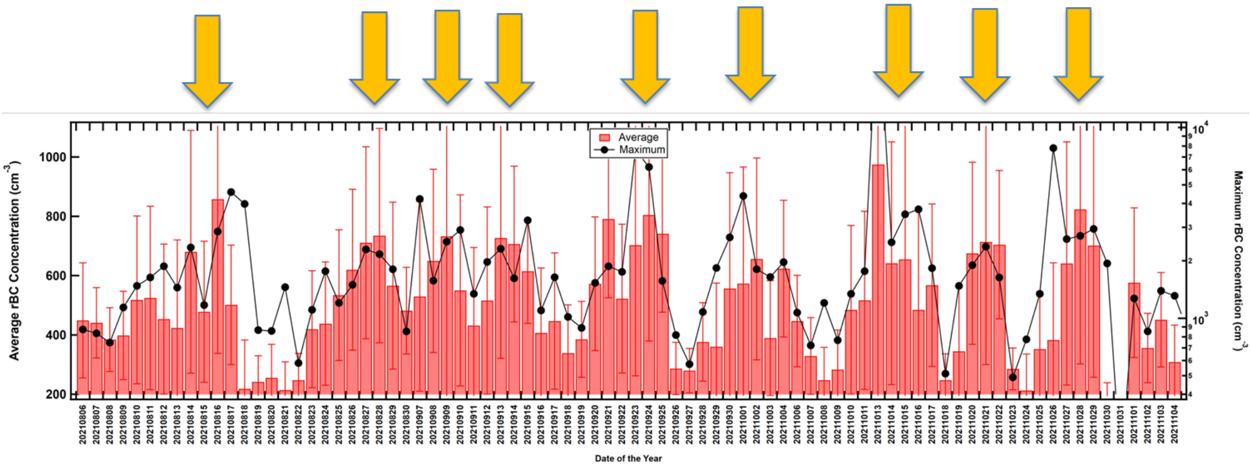
An extended range, single particle soot photometer (SP2XR) measured the mass concentrations of refractory black carbon (rBC) from August through October 2021 in Pasadena, California as part of the RECAP-CA project. In addition to the mass concentration, the coating thickness on individual particles containing rBC was derived over the size range from 100 – 500 nm. The thickness ranged from 30 to 200 nm and fluctuated according to time of day, day of the week and air mass history, i.e. depending on upwind aerosol sources and the proximity of wildfires. This presentation gives a brief description of the methodology used to derive the coating thickness and summarizes the preliminary findings.



The daily average and maximum number concentrations of rBC show the influence of the wildfire's emissions, at least 9 incursions in 3 months, as shown here in the time series of rBC number concentration. The yellow arrows indicate where smoke from the wildfires impacted the local region.

Near Infrared-Absorbing, Non-Black Carbon Particulate Material from Biomass Burning

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Biomass burning produces two classes of light absorbing particles: black carbon (BC) and light-absorbing organic commonly referred to as brown carbon (BrC). BC particles absorb throughout UV, visible, and near-IR wavelengths, whereas BrC particles absorb mainly in the UV-VIS. Recent field and laboratory studies have identified, and begun to quantify, BrC that absorbs light from the UV-VIS out to the near infrared (NIR), which we call NIR-BrC. Examples of such particles are tar balls and BrC strongly associated with BC. NIR absorption by organic material from biomass burning represents a positive *longwave* radiative forcing. For example, while BC has an approximately 10x greater mass absorption cross-section than tar balls at 950 nm, tar balls can be present in near-source biomass burning plumes at 5-10x greater mass concentrations than BC, resulting in roughly the same absorption by both types of particles at 950 nm.

The Soot Particle Soot Photometer (SP2) can be utilized to detect NIR absorption by NIR-BrC particles. Here we are working to extend the novel SP2 analysis technique described by Corbin and Gysel (2019), which uses the time series of the scattering signal of non-BC-containing particles to determine if absorption of the 1064 nm laser energy results in particle shrinkage. We are applying this technique to ground-based SP2 measurements of smoke plumes collected as part of the 2019 FIREx campaign. This technique offers the unique potential for providing particle-resolved measurements of NIR-BrC, an estimate of the fraction of OA that absorbs in the NIR, and a basis for delineating the NIR absorption contributions between BC and NIR-BrC. These observations may provide an important quantitative assessment of NIR-BrC particles and their importance to radiative forcing.

Comparison of physical, chemical, and toxicological properties of fresh and aged fine particles emitted from rice straw and pine stem burning

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Agricultural burning and forest fires in Northeast Asia contribute significantly to the elevated levels of $PM_{2.5}$, impacting radiative balance, cloud formation, air quality and human health. Atmospheric aging processes can change physical, chemical, and toxicological properties of $PM_{2.5}$. This study aims to assess variability in toxicity of $PM_{2.5}$ produced from rice straw and pine stem burning. Additionally, atmospheric aging of biomass burning particles was simulated using a potential aerosol mass-oxidation flow reactor (PAM-OFR) to determine change in $PM_{2.5}$ toxicity by atmospheric aging. Chemical characteristics of biomass burning particles before and after aging were determined by measuring ions, metals, organic carbon (OC) and elemental carbon (EC) using ion chromatography (IC), inductively coupled plasma mass spectrometry (ICP-MS), and thermal-optical transmittance (TOT) methods, respectively. The hygroscopicity of biomass burning particles was determined by using a hygroscopic tandem differential mobility analyser (HTDMA). For chemical response, oxidative potential (OP) was measured using dithiothreitol (DTT) assay. For biological responses, cytotoxicity and oxidative stress were determined using neutral red uptake (NRU) assay and water soluble tetrazolium salt (WST-1), and 2',7'-dichlorofluorescein diacetate (DCF-DA) assay, respectively. The results showed that the fractions of OC and nitrate increased by ~1.6 times and ~5 times, respectively, in biomass burning particles after aging. The fraction of water-soluble organic carbon (WSOC) in OC also increased by ~1.5 times, which could be due to the formation of secondary organic aerosols during the aging process. The cloud formation potential (κ) of aged biomass burning particles increased, consistent with the chemical data. The mass-normalized OP of biomass burning particles also increases by ~1.7 times after aging, which was consistent with cell-based oxidative stress results. An increase in cell toxicity was observed in rice straw burning particles. The changes of toxicity of biomass burning particles could be related with increase in solubility of transition metals and water soluble organic compound in $PM_{2.5}$ after atmospheric aging.

Agricultural biomass burning in India: Carbonaceous aerosol constituents and optical properties

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Among various biomass fires in the Indian region, agricultural residue burning leads to a large, discontinuous injection of pollutants to the atmosphere, following harvest seasons in Oct-Nov and Mar-May. In northern south Asia, this source contributes significantly very poor air quality episodes. However, in-situ measurements of aerosol emissions from this source in the region are limited, with uncertainty in the understanding of aerosol chemical and optical properties.

In this study, in-situ emission measurements were conducted of commonly burned agricultural residues in western India. Emissions measurements were made from 15 fires from the burning of three types of residues: straws, stalks, and stems. A custom-built field dilution sampler was employed, with a multi-arm inlet to aspirate plume-wide aerosol for aerosol and gaseous property measurements. These include real-time concentrations of CO_2 and CO, and multi-wavelength aerosol absorption coefficients ($b_{abs,\lambda}$), time-integrated, quartz fiber filter derived organic (OC) and elemental carbon (EC) concentrations and PTFE filter-derived $PM_{2.5}$. These measurements are used to study the relationships between chemical and optical properties and combustion efficiency. These include the modified combustion efficiency (MCE), the mass absorption cross section (MAC_{520}) – a measure of the strength of aerosol absorption, and the absorption Angstrom exponent ($AAE_{370/660}$) – a measure of the wavelength dependence of the absorption.

The measured MCE, OC/EC, and EC/PM are range(median) of 0.73–0.97(0.92), 0.24v32.77 (1.14), and 0.01–0.71 (0.4) respectively, implying significantly larger elemental carbon content than previously reported for biomass burning fires. The MAC_{520}, and $AAE_{370/660}$ are in the range(median) 0.03–29.43 (4.55) and 1.25–4.01 (1.67), respectively, implying strongly absorbing aerosol, and possible contributions by organic (brown) carbon. An increase in combustion efficiency leads to an increase an increase in the EC/PM ratio, an increase in MAC_{520}, and a decrease in $AAE_{370/660}$, i.e., more efficient combustion leads to the emission of more strongly absorbing aerosol with a weaker wavelength dependence. Further analysis of the interdependence of aerosol chemical and optical properties will be presented.

Investigation of Atmospheric Ice Nucleation Using Nano-Liter Volume Water Droplets with a Microfluidic Device

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Atmospheric ice-nucleating particles (INPs) modulate the properties of clouds, precipitation, and climate, especially in the Arctic due to predominant mixed-phase clouds. However, our understanding in INPs is still insufficient in part because ambient ice nucleation in clouds is a complex process via multiple freezing mechanisms.

As a step to fill our understanding gap, we developed a low-cost microfluidic device that can mimic the atmospherically relevant volume of water droplets (1-60 nL) for simulating and replicating atmospheric immersion freezing (i.e., freezing of INPs immersed in a water droplet). The device holds hundreds of nanoliter volume droplets and performs the nucleation using a temperature-controlled stage at constant cooling rates with 1 °C min^{-1} to -50°C. The freezing efficiency is determined from the acquired images of the nucleation process as a function of observed freezing temperature of droplets. The device performance is verified with well-characterized bulk powder INP proxies, such as illite NX, Snomax, and cellulose.

The ice nucleation in Microfluidic device is further compared with that in a Differential Scanning Calorimetry (DSC) for the same set of samples. A 3 μL single droplet of water is placed in a petroleum jelly-coated DSC pan. The droplet is then cooled at constant cooling rates with 1 °C min^{-1} to -45°C. The exothermic energy release during the phase transition of the water droplet is observed in the DSC. The onset and endset of the freezing point are determined from phase transition curve.

Our studies with the microfluidic device and DSC demonstrate that (1) the results from two devices are comparable and (2) these instruments are affordable and useful tools to study ice nucleation in clouds.

Introducing the Droplet Residual Analyzer for Groundbased Observations of Nucleation (DRAGON)

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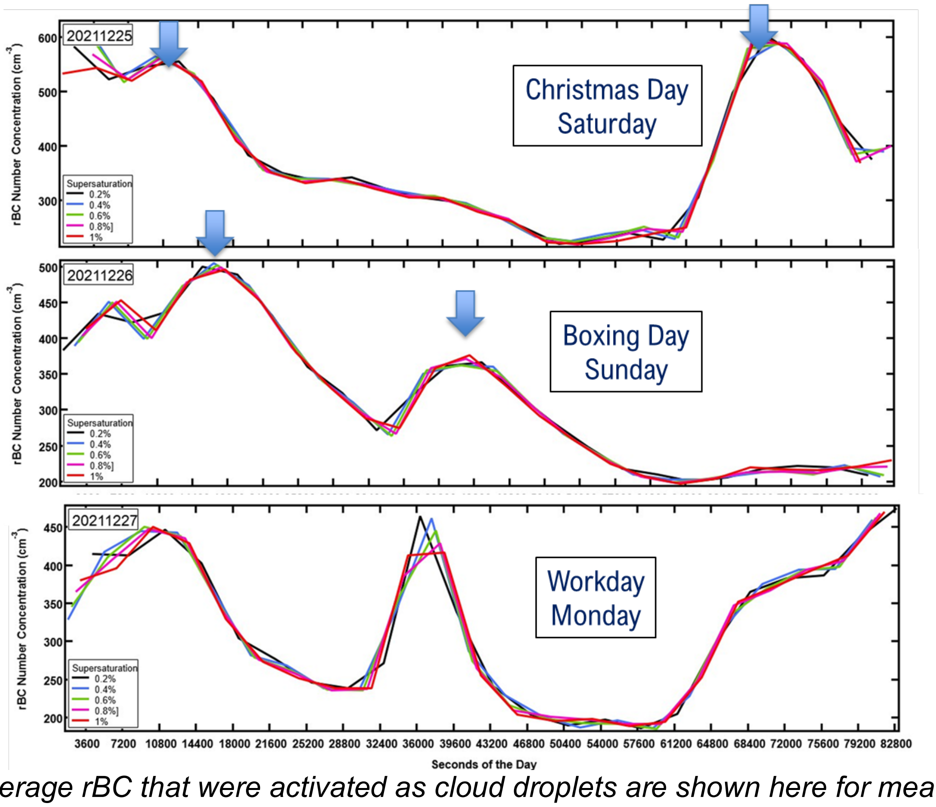
Droplet Measurement Technologies (Droplet) has developed a system for evaluating the properties of cloud droplet residuals using Droplet's Cloud Condensation Spectrometer (CCN-100) as a cloud chamber coupled with a Brechtel Engineering pumped counterflow impactor (PCVI) to introduce the residuals of activated droplets to an extended range Single Particle Soot Photometer (SP2XR) and Wideband Integrated Bioaerosol Spectrometer (WIBS). The DRAGON system provides a particle by particle analysis of refractory black carbon (rBC) and fluorescing aerosol particles (FAP) found in residuals of activated CCN that form on ambient aerosols. Preliminary results during the Christmas holidays in Solapur, India show distinctive trends in rBC activated as CCN that depend on the time of day and day of celebration, as shown in the figure below.



The daily average rBC that were activated as cloud droplets are shown here for measurements on Christmas Day, Boxing Day and the first work day following the holidays.

Surfactants in complex atmospheric aerosols: mixing effects, synergism, and implications for cloud formation

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Over the last decades the role of surfactants in the activation of atmospheric aerosols into cloud droplets has received a growing interest. Most of the investigations, however, have focused on simple mixtures containing only one surfactant, while the composition of atmospheric aerosol is complex and might modulate the surfactant efficiency. The present work investigates the properties of surfactants in different types of mixtures in order to understand and predict their efficiency in atmospheric aerosols. For this, the adsorption isotherm and, where relevant, critical micelle concentration (CMC) were determined by drop-shape analysis for the following mixtures of model compounds: (1) two different amphiphiles with different CMC, (2) amphiphiles + semi-soluble organics, (3) two different semi-soluble organics and (4) amphiphiles or semi-soluble organics + inorganic salts. In addition, the mixing properties of surfactant fractions extracted from atmospheric aerosols in the presence of semi-soluble organics (oxalic acid, glutaric acid) and inorganic salts were also studied.

Some mixtures of surfactants (amphiphile or semi-soluble) did not display any molecular interaction and resulted in a surface tension, σ, and/or a CMC for the mixture varying proportionally with those of each surfactant (Fig. 1, left). Other mixtures, however, clearly displayed some synergistic effects (Fig. 1, right), i.e. a surface tension or CMC lower than that resulting from the individual contributions, and due to molecular interactions between the surfactants. Finally, for all types of surfactants, inorganic salts were found to lower the surface tension and CMC (if any) of the mixtures due to salting out effect. The efficiency of surfactants in atmospheric aerosols is thus more complex than expected from the simple systems studied in laboratory. Many of the mixture effects observed in this study contribute to a lower surface tension than expected.

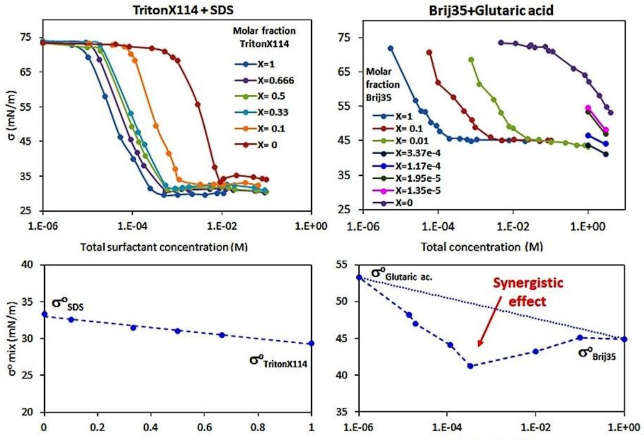

Figure 1: Some surfactant mixtures display independent contributions to the surface tension (left) while others (right) display synergistic effects (surface tension of mixture lower than the sum of the individual contributions).

Characterization of Cloud Condensation Nuclei over the Eastern North Atlantic

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Over the course of two intensive operation periods (IOP1 in Summer 2017 and IOP2 in Winter of 2018), aerosol particle samples were collected by impaction as part of the Aerosol and Cloud Experiments in the Eastern North Atlantic (ACE-ENA) field campaign supported by the DOE ARM program. Scanning transmission X-ray microscopy coupled with near-edge X-ray absorption fine structure spectroscopy was used to collect spatially-resolved, elementally-specific molecular information about particles impacted onto the size-segregated samples. The ENA field site on the Azores Island of Graciosa is located in the mid-Atlantic, far off the coast of Portugal, and is likely to be heavily influenced by biogenic sea spray aerosol particles.

The spectromicroscopy data collected was used in tandem with the many complementary measurements made at the ARM field site to characterize the conditions (local and long-range) that contribute to aerosol composition. Inorganic sea spray aerosol particles coated with organic compounds represented a large majority of the particles; however, aged particles that contain black carbon were also found during a few sampling periods. Airmass back trajectories are used to help determine the possible sources for these distinct aerosol populations and define the impact they have on the ENA particle population that can serve as cloud condensation nuclei.

Potential impact of the Arctic glacier recession on ice-nucleating particle emission

Emmanuel Oko, Francesca Pittino, Erika Bruno, Beatrice Moroni, Adam Nawrot, Yang Shi, Xiaohong, Liu, Isabella Gandolfi, David Cappelletti, and Naruki Hiranuma

The Arctic is warming more rapidly than the rest of the globe, and this phenomenon is known as Arctic amplification. While the role of aerosol-cloud interactions and cloud feedback remains obscure in the Arctic, it is hypothesized that the increase in ice-nucleating particles (INPs) can accelerate the current warming trend. To understand the climate impact of INPs from de-glaciated soils, we characterized the immersion freezing efficiency of surface soil samples collected in 2019 from Southern Spitsbergen. Eight samples were collected along a latitudinal transect of the Ariebreen catchment (ARB) in the Hornsund fiord area. Half of the samples were from the inner ARB (north; most recently de-glaciated soil samples), and another half was sampled in the outer ARB de-glaciated spots (south; oldest de-glaciated soil samples). Our preliminary immersion freezing results of the ARB samples indicate a gradual increase in freezing efficiency from north to south ARB. From the heat treatment analysis, we see the inclusion of heat-sensitive biogenic INPs in most samples. Likewise, for the bulk samples, the analyses of trace elements, inductively coupled plasma mass spectrometry data, and next-generation sequencing data describing microbial communities along the sequence suggest a gradual increase in Pseudomonas content as well as several bio-tracer elements (e.g., P and K) from north ARB to south ARB. Thus far, our results overall imply the glacier recession can increase local INP emission and modulate other inherent particle properties from ARB soils, which can potentially accelerate the warming. Ultimately, we will use a global climate model (i.e., E3SM) constrained by our observations to predict the de-glaciated dust emissions and impact on INPs burden, Arctic clouds, and radiation budgets in historical and future periods (1850, 2010, and 2100).

Oxidative potential and optical properties of biomass burning aerosols: Direct and filter-based measurements

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Carbonaceous aerosols emitted from wildfires and biomass-burning (BB) activities significantly influence the earth's radiation budget and are major sources of particulate matter (PM) air pollution globally. These particles, when inhaled, can generate excess reactive oxygen species (ROS), leading to oxidative stress and respiratory diseases. This ability of PM to induce oxidative stress is termed “oxidative potential (OP).”

The conventional approach of OP and optical properties (light absorption) measurements of BB aerosols involves collecting BB-derived PM onto a filter and measuring the light attenuation across the filter or extracting the PM from the filters using a solvent and determining its OP and light absorption properties. Filter-based light absorption measurements can be subject to measurement artifacts such as multiple scattering, filter overloading, and other unquantifiable biases. Whereas measurements from filter extracts are dependent on the extraction efficiency of the solvent, which will vary based on the source and composition of the BB aerosols.

In this study, we used a combustion chamber to generate BB aerosols using four biofuels: peat, sage, grass, and pine. The bulk optical properties were measured using integrated photoacoustic nephelometers (IPN) operated at 405, 721, and 1047 nm. The BB-generated PM was collected on filters and extracted using water and methanol. We used a “particle into liquid sampler” to directly collect the BB aerosols in water and measured their OP. OP of the samples collected using the PILS were compared with filter-based OP measurements to study potential filter extraction biases. Based on our preliminary experiments, the average BC fractions (based on IPN 1047 nm) for peat, sage, and grass were 0.4%, 4%, and 12%, respectively. The ratio of particle phase to methanol soluble mass absorption coefficients at 405 nm were 0.68, 2.0, and 1.99 for peat, sage, and grass, respectively. We are currently conducting the OP measurements, which will provide new information on filter extraction biases and a link between PM solubility and its potential health effects.

A worldwide carbonaceous aerosol phenomenology

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On the initiative of the World Meteorological Organisation – Global Atmosphere Watch Scientific Advisory Group on Aerosols, Elemental Carbon (EC) and Organic Carbon (OC) data obtained from thermal-optical analyses of more than 130,000 $PM_{2.5}$ filter samples collected between 2015 and 2020 across the world were analysed together with particulate matter mass ($PM_{2.5}$) concentrations measured simultaneously at the same sites. The objective of this study is to compare the aerosol carbonaceous contribution (OC/PM, EC/PM) and composition (OC/EC) at sites experiencing different particulate pollution levels. Beyond concentrations, which depend on emission fluxes but also on pollution dispersion, such ratios inform on emission sources and atmospheric processes. Long-term (≥ 1year) data sets were selected so that statistics are representative of a whole year and seasonal variations can be studied. Thus, about 330 sites in Africa (5), Latin America and the Caribbean (2), North America (172), Asia (130, of which 110 in Japan), and Europe (21) were included. Preliminary analyses suggest a positive worldwide correlation between site median concentrations of OC and $PM_{2.5}$ on the one hand, and EC and $PM_{2.5}$ on the other hand. However, both ratios are generally lower in Asia, Japan excepted. The correlation between OC and EC median concentrations is even clearer, and further improves if differences in thermal protocols used for thermal-optical analyses are taken into account. However, site-specific OC/EC ratios still differ by a factor of about 10 across the sites. EC, OC, and total mass concentration data in the PM_{10} size fraction were also collected, in a much smaller amount than in the $PM_{2.5}$ fraction though (about 1/10). Collocated measurement in both fractions suggest that the $PM_{2.5}$ fraction is enriched in carbonaceous aerosol compared to the PM_{10} fraction, and that the OC/EC ratio is generally lower in the $PM_{2.5}$ fraction than in the PM_{10} fraction.

Mobile Measurements Enable Identification of Multi-Pollutant Hotspots: Evidence from Intensive Monitoring in San Francisco & Oakland

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Spatial variation of primary urban air pollutants is strongly influenced by local sources. Regulatory monitoring, satellite measurements, and land-use regression (LUR) successfully represent intraurban pollution variation but do not fully characterize distributional extremes. Previous work in the Bay Area from an intensive mobile monitoring campaign demonstrated concentrations of black carbon (BC), and ultrafine particles (UFP), can vary by a factor of 2 – 5 among neighboring city blocks. From 2015 – 2019 we conducted mobile monitoring of BC, UFP, and other pollutants with reference-grade 1-Hz instruments on Google Street View vehicles. Data were gridded with 0.01 km^2 hexagons to allow consistent nearest-neighbor comparisons. This study adapts a methodology of identifying hot spots by establishing confidence intervals (CI) for the median (p_{50}) and 90th percentile (p_{90}) concentrations and scoring cells based on the total number of metrics that can be classified as outliers within a moving window.

Multiple non-highway clusters of cells in Oakland were identified as containing at least one type of hotspot. Hotspot cells exceeded the moving window baseline by as much as 1.4 – 2x. Non-highway hotspots contained recycling facilities and exhibited especially high UFP ($p_{50} > 40{,}000$ cm^{-3}) and BC concentrations ($p_{90} > 2$ $\mu g/m^3$). Two other non-highway hotspots were associated with residential heavy-duty truck routing, and with a concrete facility. Mobile sources, especially heavy-duty vehicles, clearly influence hotspot designation. However, focusing on local roads shows that p_{50} and p_{90} values near industrial sites and truck off-ramps can exceed or match highway levels. Specifically, recycling, and concrete facilities should be additionally investigated as local sources of high air pollution exposure. Future work will expand to other mobile monitoring datasets within California.

Detecting small-scale spatial differences in black carbon concentrations using BC sensor network

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Laboratory-grade instruments for black carbon (BC) measurements are expensive and require well-controlled environments. Therefore performing measurement with good spatial coverage using laboratory scale instruments is often impossible. To answer the demand several different commercial BC sensors have been developed.

In this study, four ObservAir (Distributed Sensing Technologies, USA) and two AE 51 BC sensors (AETHLABS, USA) were deployed in pairs around the Kumpula area in Helsinki, Finland, between 1.7.2022 and 15.9.2022, with Multi-Angle Absorption Photometer (MAAP) at SMEAR III as a reference instrument. The locations formed a line in the SW-NE direction with the Botanical garden (BG) being the SW location and with the greatest distance to roads. The middle station was a parking area (PA) entrance parking lot and the most Northeastern spot was situated on the third floor over a bus stop (BS). The distance between the BG and PA is 350 m and 170 m between PA and BS. SMEARIII is located at the opposite corner of the same parking area as PA.

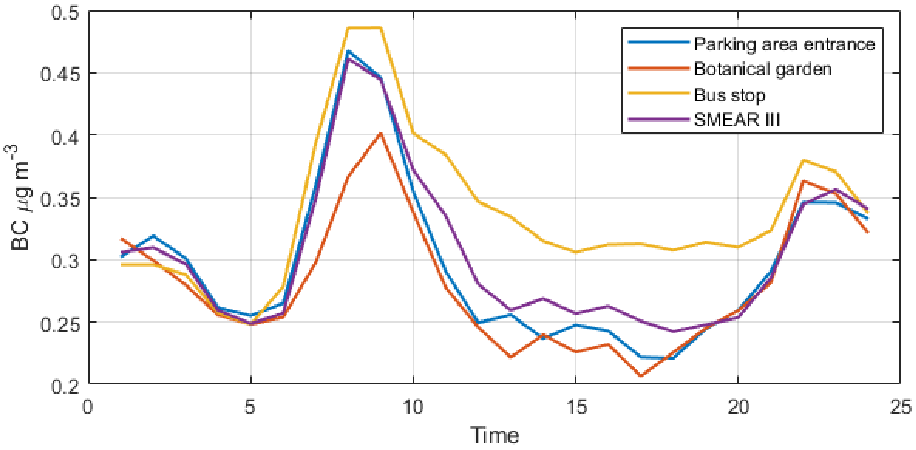

Figure 1: Diurnal profiles BC at PA (average of two ObservAir sensors), BG (average of two ObservAir sensors), and BS (average of two AE51 sensors).

The average BC concentrations at the PA, BG, BS, and SMEAR III were 2.97, 2.83, 3.37, and 3.03 µg m^{-3}, respectively. Figure 1 shows that the diurnal profiles were noticeably different for the three sensor locations despite the short distance between the locations. All the locations had a peak during the morning rush hour at 8-9 am and a second peak in the evening at around 10-11 pm which is likely to be related to biomass burning.

The BS had elevated contractions during the whole day likely because of frequent bus stops and the BG had the lowest concentrations because of the long distance to the roads. The evening peak however is similar between all four locations as the BC from biomass combustion is regionally transported.

Financial support from Technology Industries of Finland Centennial Foundation (Urban Air Quality 2.0 project), European Union Horizon 2020 research and innovation programme (GA no 101036245, RI-URBANS), and the Academy of Finland (BBrCAC, no 341271) is gratefully acknowledged.

ICCPA abstract

Engaging Youth on Air Quality Issues

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In 2022 Sustainable Silicon Valley (SSV), in partnership with TD Environmental Services, LLC, was awarded a CARB Community Air Grant to fund the Youth Air Quality Advocates (YAQA) program in San Jose. YAQA will demonstrate local community advocacy, advance environmental justice initiatives, and engage students in challenging STEM-based activities geared toward air pollution, citizen science, and civic action. Successful environmental education programs rely not only on classroom learning but also developing personal connections to the subject matter, helping students understand the issue's relevance to their lives as well as their agency to address current environmental issues through action.

The two-year YAQA project will target high school students who attend schools in San Jose districts, serving disadvantaged and low-income communities as designated by the CARB California Climate Investments Priority Populations tool. Initially, this project is focusing on the largest district, East Side Union High School District. Teachers and students will utilize the SSV-developed BackpAQ mobile air quality monitor, which features particulate, CO2, temperature and humidity sensors.

The YAQA project trains teachers and engages students in a hands-on curriculum designed to educate participants about pollution, enable them to build their own BackpAQ low-cost air sensors, and then guide them to understand how local conditions and policies affect air pollution and empower them to affect changes in their communities. The suggested air quality curriculum and associated experiments use particulate matter and CO2 sensors in activity-based learning to make air quality more concrete for students.

The BackpAQ sensors are also participating in a colocation comparison with BAAQMD. Students collect and analyze data using cutting-edge data science and analytics tools, present their findings to the greater San Jose community at community meetings, libraries, houses of worship, City Council meetings, etc., and propose solutions to the observed problem. The program started in the summer of 2022. This paper will present progress, preliminary results, and lessons learned.

Reevaluating Isoprene Oxidation Pathways and Their Influence on Secondary Organic Aerosol Formation

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Abstract:

Isoprene is the largest global non-methane hydrocarbon emission, and the chemical reactions of isoprene with atmospheric oxidants play a crucial role in the formation of secondary organic aerosols (SOA), particularly under low-NO$_x$ conditions. Two primary pathways contribute to SOA formation from isoprene low-NO$_x$ OH oxidation: (1) the production of low-volatility compounds through OH oxidation of intermediates such as ISOPOOH (LV pathway) and (2) the reactive uptake of isoprene epoxidiol (IEPOX) on acidic or aqueous particle surfaces, resulting in the formation of 2-methyltetrols and organosulfates (IEPOX pathway). In this study, we develop a condensed gas-phase chemical mechanism for isoprene oxidation based on the most recent observation-constrained chemistry, and update the zero-dimensional F0AM-WAM model to predict SOA formation from both pathways under chamber and field conditions. We applied our revised isoprene mechanism in simulating chamber studies to evaluate its performance against existing mechanisms by comparing simulations to the observed SOA data. Modeling of the Southern Oxidant and Aerosol Studies (SOAS) field measurements using F0AM-WAM indicate that low-volatility compounds contribute to isoprene SOA more significantly than previously thought, with the modeled SOA mass ratio from the LV pathway of 15-20%, with the rest from the IEPOX pathway. Our findings emphasize that the mass yield from the LV pathway should be considered to enhance the accuracy of model estimations for isoprene SOA formation. The new condensed isoprene chemical mechanism will be further incorporated into regional-scale air quality models, such as the Community Multiscale Air Quality Modelling System (CMAQ), to assess the influence of the LV pathway on a larger scale.