clarity AETHLABS

Beyond Mass Concentration

The Synergy of Black Carbon and Particulate Matter Measurements in Air Quality Monitoring

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Black Carbon Module

Meet the panelists!

Jeff Blair

President and CEO
AethLabs

Dr. Drew Hill, PhD, MPH

Data Science & Applied Research Lead
AethLabs

Dr. Daniel Mendoza

Professor, Atmospheric Sciences, Internal Medicine, and City & Metropolitan Planning at University of Utah

Paolo Micalizzi

Co-Founder & CTO
Clarity Movement Co.

Black Carbon

Impacts and Innovations

L. Drew Hill, PhD MPH

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Mar 28, 2024

Acknowledgements *

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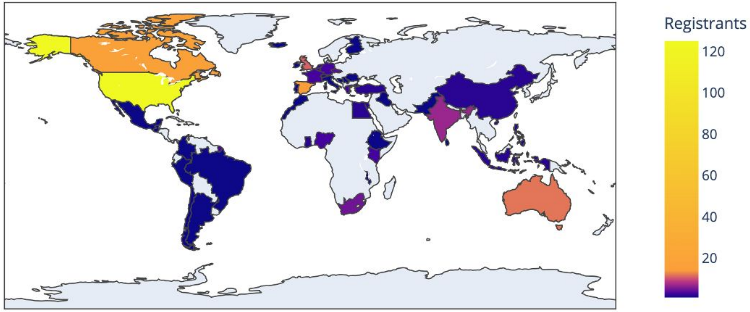
THE UNIVERSITY OF UTAH



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

INERIS
maîtriser le risque
pour un développement durable

votre parten'air
Atmo
AUVERGNE-RHÔNE-ALPES

ADDAIR

COLUMBIA CLIMATE SCHOOL
LAMONT-DOHERTY EARTH OBSERVATORY

NASA
Jet Propulsion Laboratory
California Institute of Technology

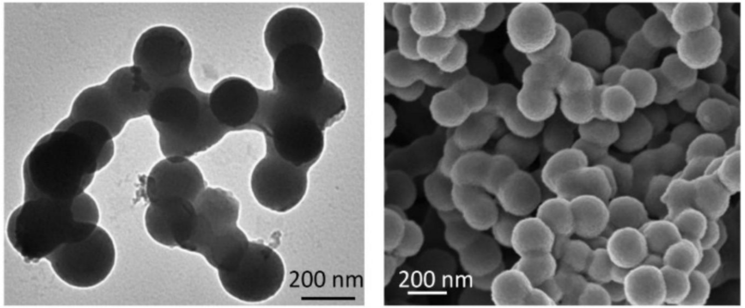
ADDIS ABABA UNIVERSITY

W
UNIVERSITY *of* WASHINGTON

* Not endorsements

Black Carbon (BC)

Salas-Sánchez et al,



Aerosol, component of $PM_{2.5}$

- 5-25% of $PM_{2.5}$ is black carbon
- BC: particulates ~< 1 μm in diameter
  - 100x smaller than human air

Dark, light absorbing

- Soot

Super Pollutant

- Major health & climate impacts

Credit: ECPA

Sources

Produced during incomplete combustion

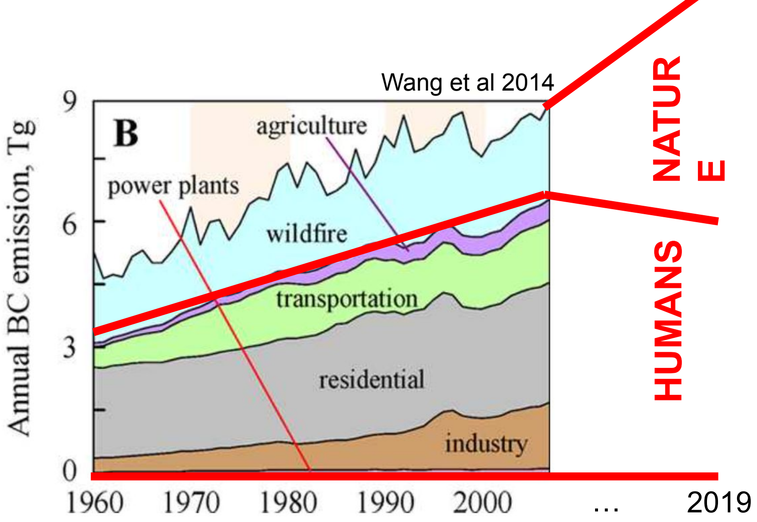
Nature

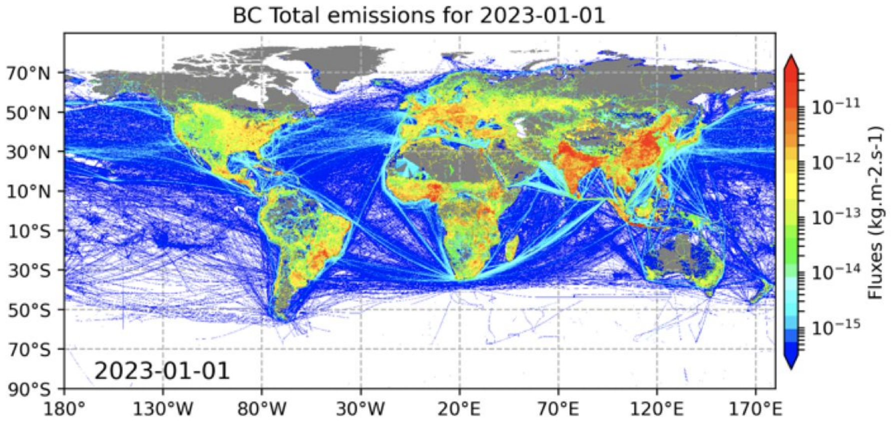
- Wildfires
  - Increasing at twice expected pace due to climate change

Humans (Energy generation/use)

- Fossil fuels (45%)
- Biomass (44%)
- Regional variation
  - Asia & Africa: 60-80% from solid fuels
  - North America & Europe: 70% diesel

Wang et al 2014





CAMS 2023

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Health Effects

Significant driver of $PM_{2.5}$ toxicity

- BC ~ 3 – 28x more toxic per unit mass than total $PM_{2.5}$ (Li et al 2016)

BC comprises ~ 5 – 25% of $PM_{2.5}$

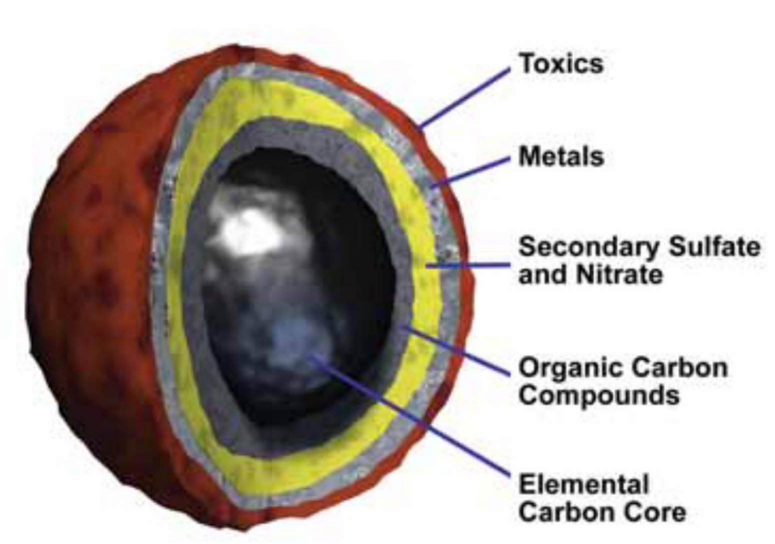
- $PM_{2.5}$ kills ~ 6.4 mil annually

14,000 annual deaths from BC in 2010 in US alone (Li et al 2016)

Attracts nasty surface chemicals to its surface

- Toxics, metals, sulfates, nitrates

Biologically relevant size (< 1μm)



Schneider and Hill, 2005

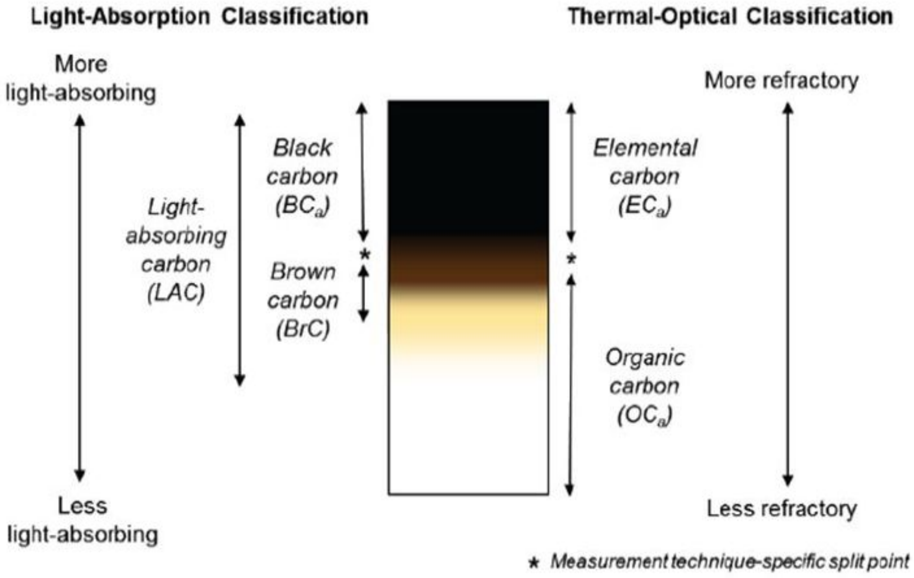
Climate Effects

Black carbon is black

- Absorbs IR light (heat) uniquely well in air
  - Heating air, dimming sunlight
- Settles onto plants, snow, ice
  - Surface heating

#2 most important climate agent

- ~ 65% of the total impact of CO_2
- Despite ~ 1000x less emissions and 4 - 12 day lifetime
- **460 – 1,500x more potent** than CO_2



Lack et al. 2013

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Concerning Trends

North America (and Europe!)

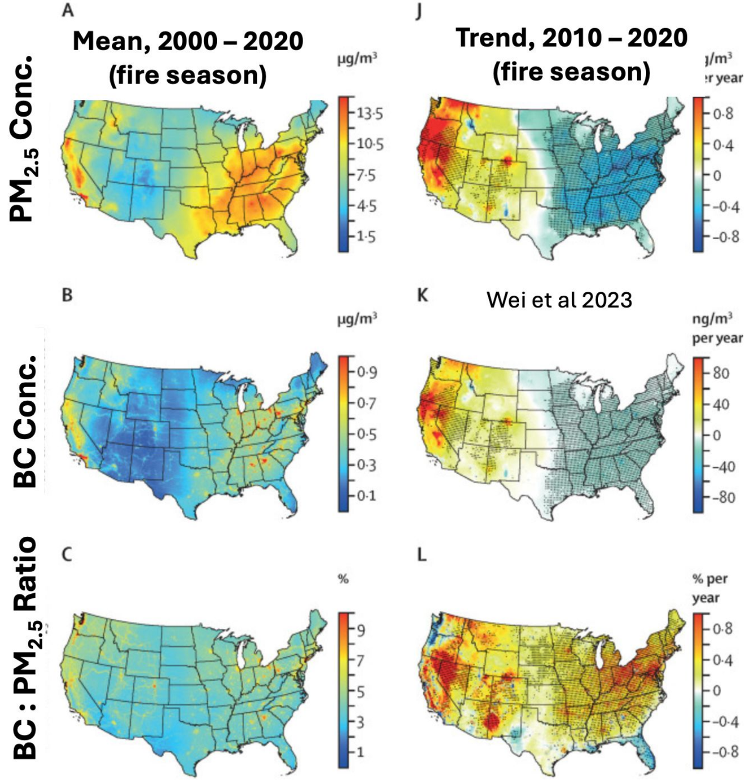
- Increased BC due to wildfires, especially in West
  - Increase in exposures, non-attainment
- 2-4% *per year* increase in BC:$PM_{2.5}$ ratio
  - Increasing $PM_{2.5}$ toxicity
- Transport to Europe

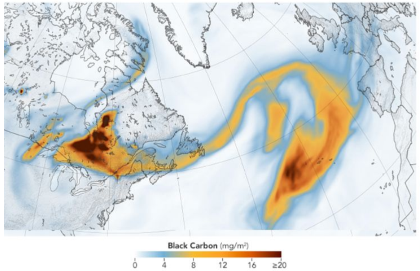
South Asia & Himalayas

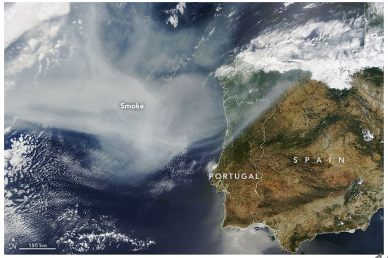
- Increasing BC → Tibetan Plateau (Asia's water tower)
- Darkening glaciers, reducing rain
- Water scarcity for billion+ people

Scarcity of binding regulation and related measurement networks

- Measurement-informed control actions could reduce emissions 80% (UNEP & WMO 2011)







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AethLabs

AethLabs revolutionizes black carbon monitoring with our innovative microAeth® technology, empowering researchers, individuals, communities, and industries alike to proactively manage black carbon emissions and drive global health and sustainability.

AethLabs

Founded in 2011, AethLabs is the manufacturer of microAeth® Aerosol Black Carbon (BC) monitors, based in San Francisco, CA

AethLabs makes portable, network connected instruments

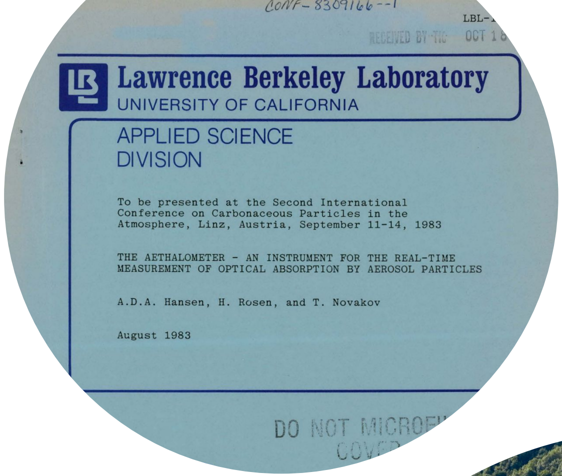
Our devices allow users to quantify BC by its sources (fossil fuel vs. biomass burning)

We often work with regulators, scientists, and community groups

An Introduction to Aethalometer Technology

- The aethalometer was first described in 1980 and later presented at the Second International Conference on Carbonaceous Particles in the Atmosphere, Linz, Austria, September 11-14, 1983 by A.D.A. Hansen, H. Rosen, and T. Novakov. L. Gundel's work made the aethalometer a quantitative instrument.

- Technology and instrumentation was developed by Magee Scientific which produced numerous versions of the Rack Mount Aethalometer. In 2007 at


Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

APPLIED SCIENCE
DIVISION

To be presented at the Second International Conference on Carbonaceous Particles in the Atmosphere, Linz, Austria, September 11-14, 1983

THE AETHALOMETER - AN INSTRUMENT FOR THE REAL-TIME MEASUREMENT OF OPTICAL ABSORPTION BY AEROSOL PARTICLES

A.D.A. Hansen, H. Rosen, and T. Novakov

August 1983

microAeth® AE51

- Released 2008
- Personal Monitoring
- Health studies
- Ultra-portable Aethalometer®
- Made new science possible
- Manufactured by AethLabs after 2011

Dimensions: 11.7cm x 6.6cm x 3.8cm

Collects particulates on filterstrip with single sampling spot

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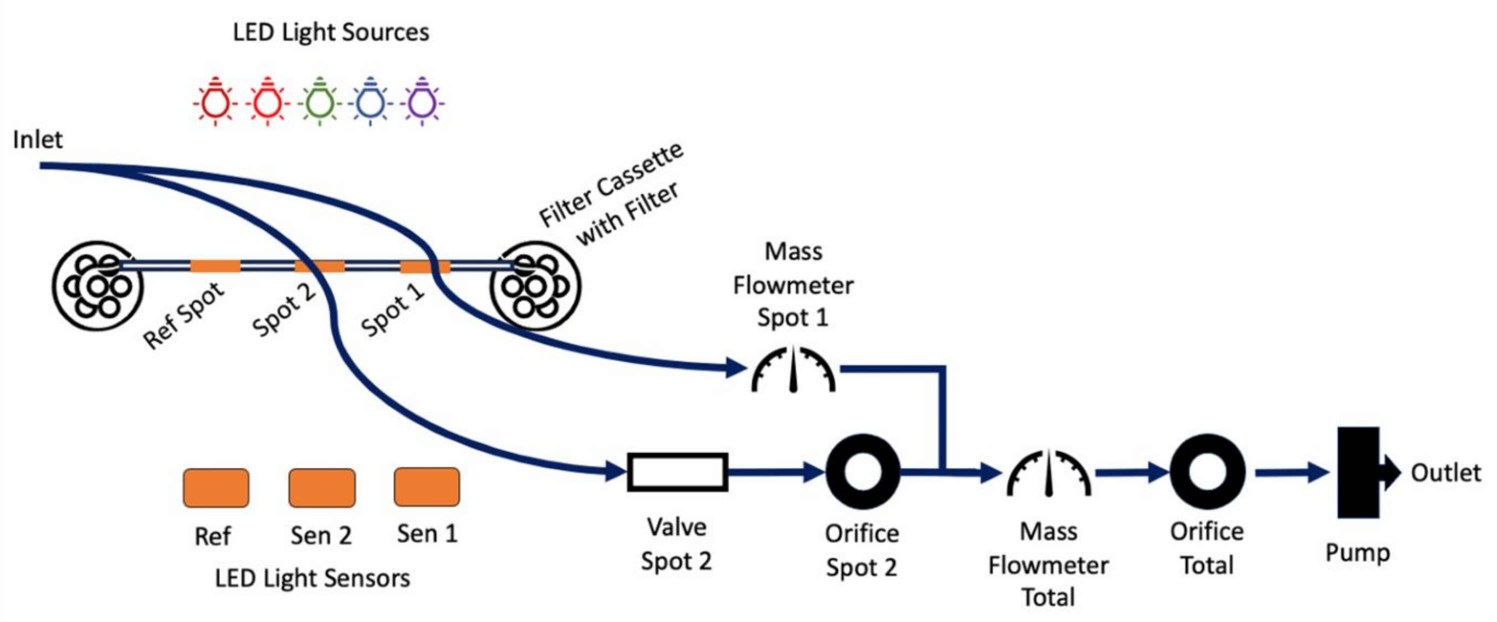
Principle of Operation: DualSpot™

Figure 1. Diagrammatic representation of the path that sample air takes through the MA350, showing high-level components.



Mendoza et al 2024

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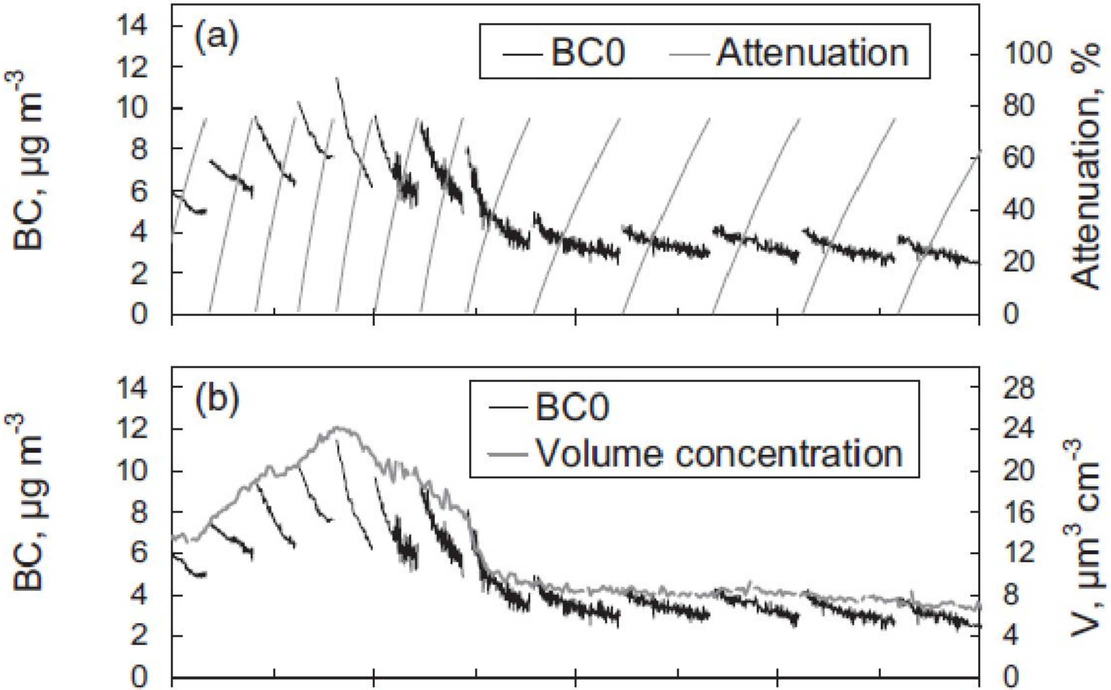
Principle of Operation: DualSpot™



Virkkula et al. JA&WMA 2007 57:10, 1214-1222

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AethLabs microAeth® MA350 vs. Magee Scientific AE33

	MA350	AE33®
λ	5 λ (**375 – 880 nm**)	7 λ (370 – 950 nm)
Size	**7 x 10 x 20 cm, 1 kg**	28 x 43 x 33 cm, 21 kg
Power Use	< 1 W typical; **built-in battery** (~ 56 hours)	25 W typical
Flow	**0.050 – 0.170 L/min**	2 – 5 L/min
Resolution	**0.001 µg/m3**	0.001 µg/m3
Detection Limit	**0.030 µg/m3** *5 minutes*, 150 mL/min SingleSpot™	< 0.005 µg/m3 *60 minutes*
Operating Conditions	5 ~ 40 C non-condensing	10 – 40 C non-condensing
Tech	• DualSpot® or SingleSpot™ • Filter cassette (months to year+) • **Source apportionment** • **Serial data output**, onboard storage • GPS & accelerometer • **WiFi & online data management** • Outputs **raw optical data** (S, R, ATN) • Battery (~ 56 hours) • Timebase: 1s, 5s, 60s, 300s	• DualSpot® • Filter tape • Source apportionment • Serial data output, onboard storage • Timebase: 1s, 60s

Magee Scientific

Pictures approximately to relative scale

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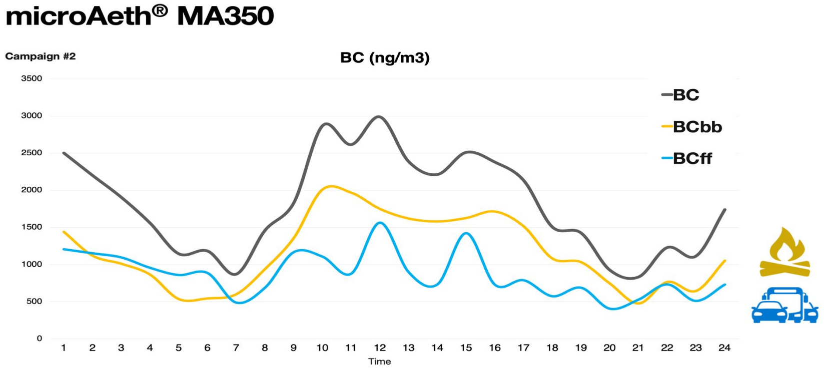
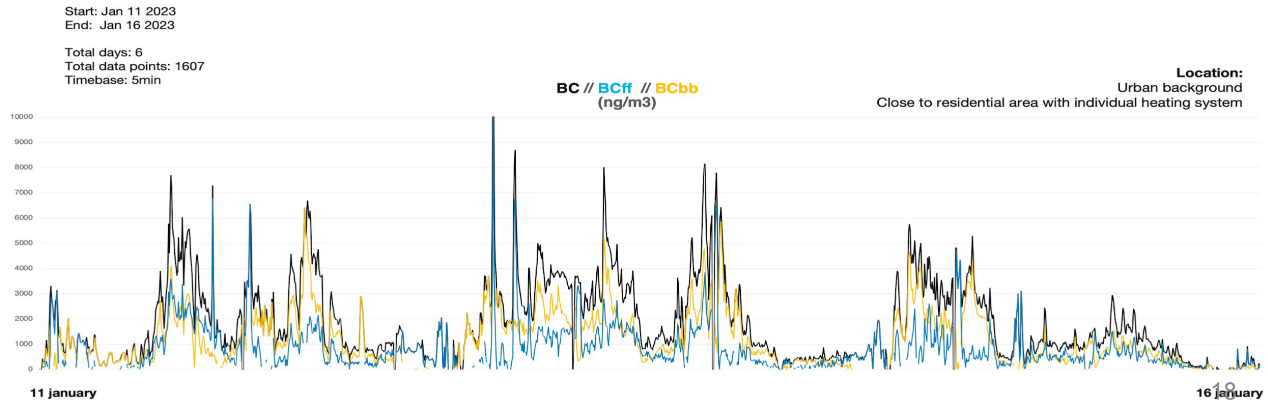
microAeth® MA350 with Source Apportionment

MA350





MA350 Early Validation

- Experiments Conducted:
- Evaluation of BC emissions from wood stove and crude oil burn.
- Assessment of ambient monitoring at the AIRS site in RTP, NC.
- Comparison of MA350 and AE33 measurements across multiple wavelengths.
- Testing for correlation with PASS 3 instrument.
-

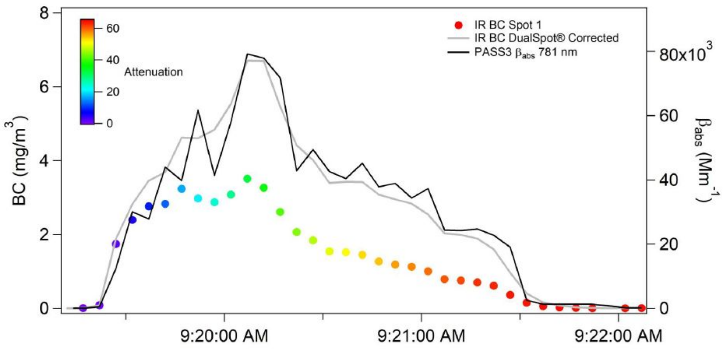
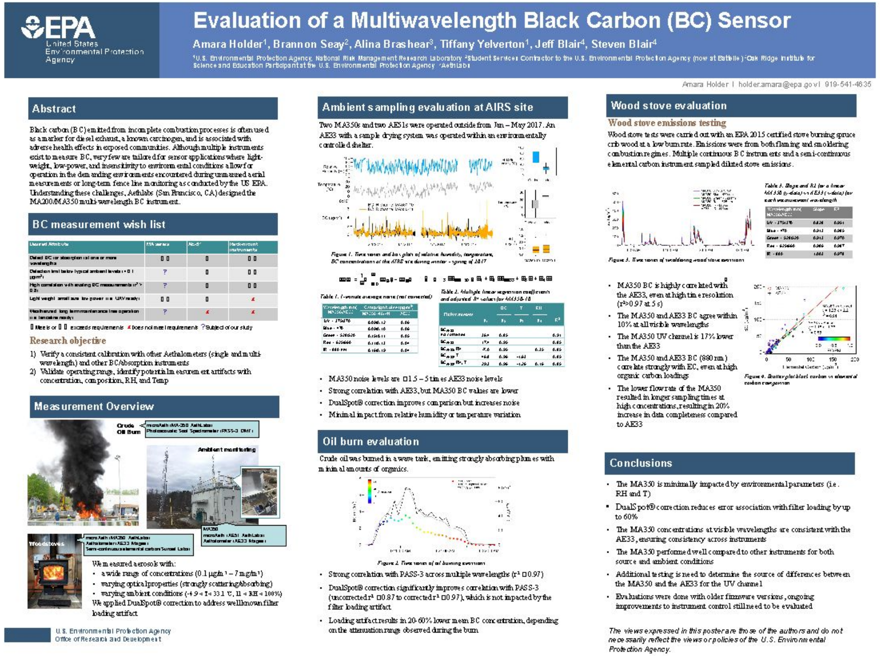


Figure 2. Time series of oil burning emissions



Holder, A., B. Seay, A. Brashear, T. Yelverton, J. Blair, AND S. Blair. Evaluation of a multi-wavelength black carbon sensor. 10th International Aerosol Conference, St. Louis,MO, September 02 - 07, 2018.

MA350 Early Validation: Conclusions

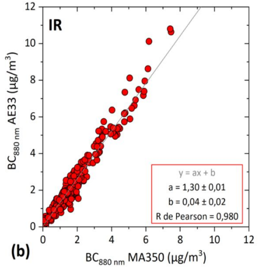
1. Through DualSpot® correction technology, the MA350 effectively mitigates errors associated with filter loading, resulting in a significant reduction of up to 60%.
2. Concentrations measured by the MA350 at visible wavelengths exhibit consistency with those of the AE33, ensuring uniformity and reliability across instruments.
3. The MA350 consistently demonstrates strong performance in both source and ambient conditions, outperforming other instruments in comparative evaluations.

7 Years of microAeth MA_x Deployments

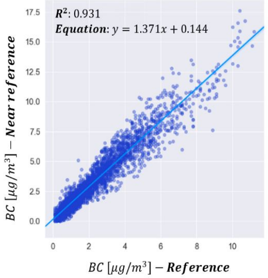
131 Google Scholar results

- "AethLabs" AND "MA300" | "AethLabs" AND "MA350" | "AethLabs" AND "MA200", excluding citations
- 593 results if you add "| AethLabs" AND "microAeth"

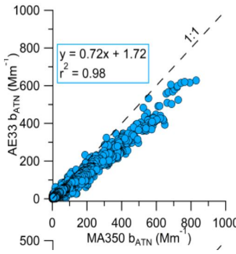
Numerous performance evaluations



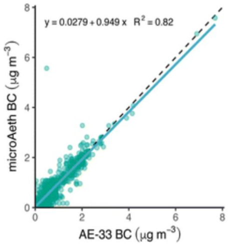
Atmo Nouvelle-Aquitaine 2019



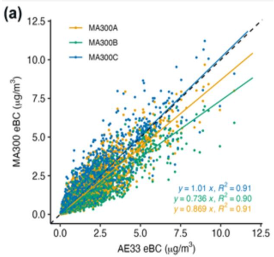
Moroni et al 2022



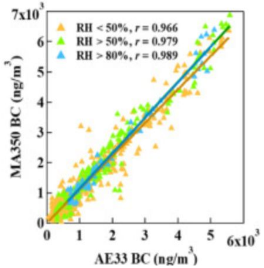
Stavroulas et al 2022



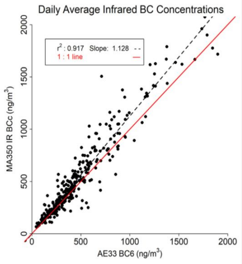
Robinson et al 2023



Chakraborty et al 2023



Wu et al 2023



Mendoza et al 2024

7 Years of microAeth MA_x Deployments

Identify BC exposures from trans-continental transport (Chillrud et al 2018, Hill et al 2023a)

Quantify bicycle commuter exposures in urban areas (Quo et al 2022)

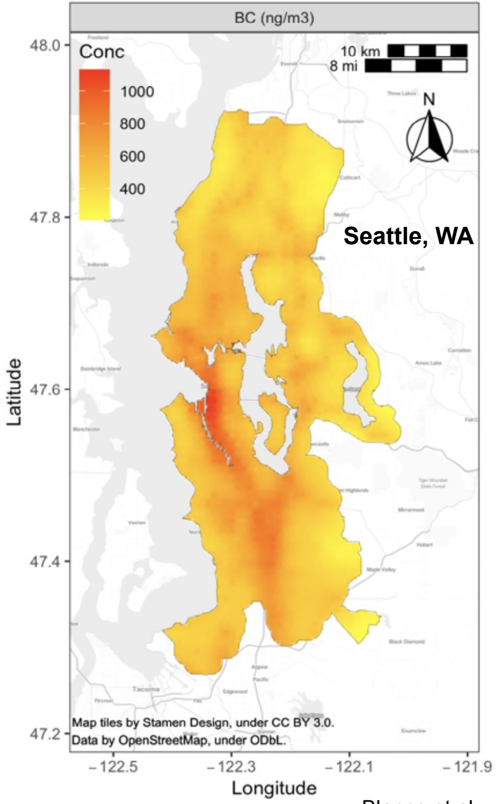
Measure long-term $BC/PM_{2.5}$ ratios as high as 30% in Addis Ababa, Ethiopia (Hill et al 2023c)

Characterize exposures in major US metropolitan areas (Blanco et al 2022) and tribal areas (Stampfer et al 2020)

Assess effectiveness of air purifiers in schools (Carmona et al 2022)

Quantify accelerated cognitive aging due to BC exposures (Carmona et al 2023)

Safely assess concentrations near dangerous roadways via drone (Lee et al 2022)



Blanco et al 2022

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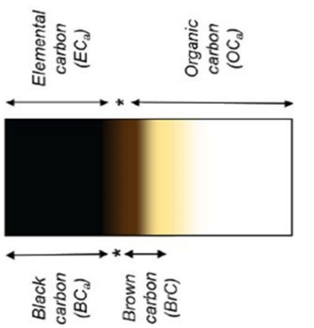
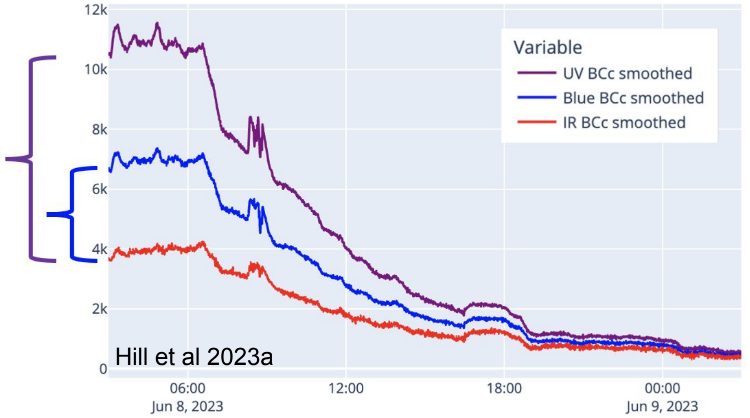
Source Apportionment

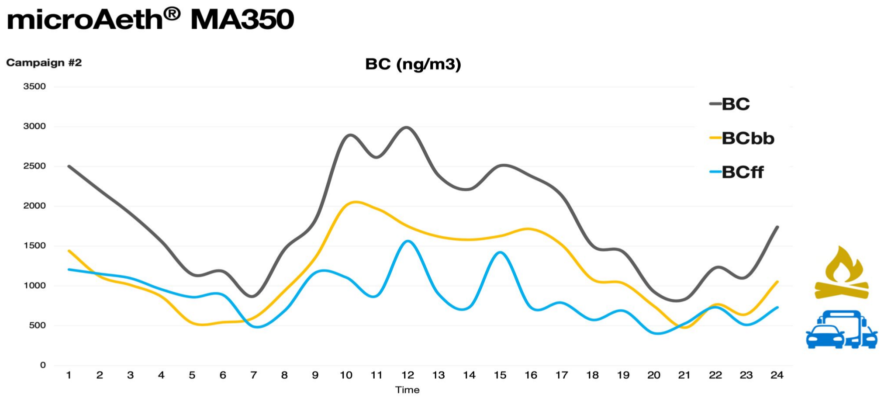
- Biomass vs Fossil Fuel
  - Fossil fuel combustion → more-purely BC
  - Biomass combustion → stronger OC presence
- As OC content increases, aerosols will absorb more-strongly in Blue & UV wavelengths than in IR wavelength (Sandradewi et al 2008)



Lack et al. 2013

UV BCc, Blue BCc, and IR BCc during a diminishing biomass smoke event





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INERIS, ATMO in France

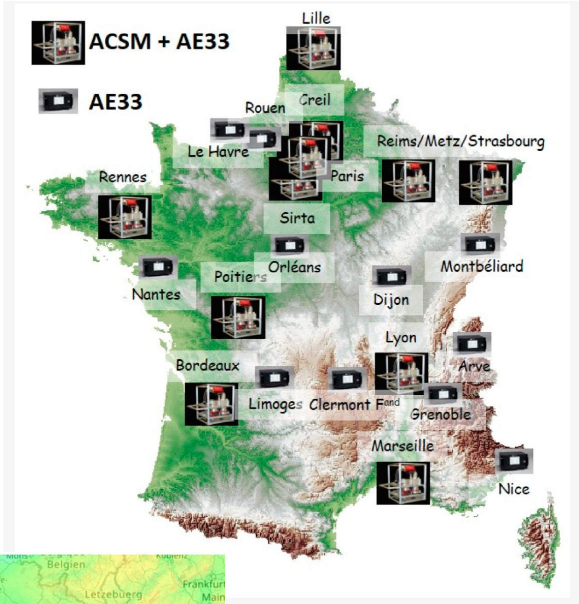
Complex aerosol landscape

- Residential wood heating, traffic
- Regional transport, orography

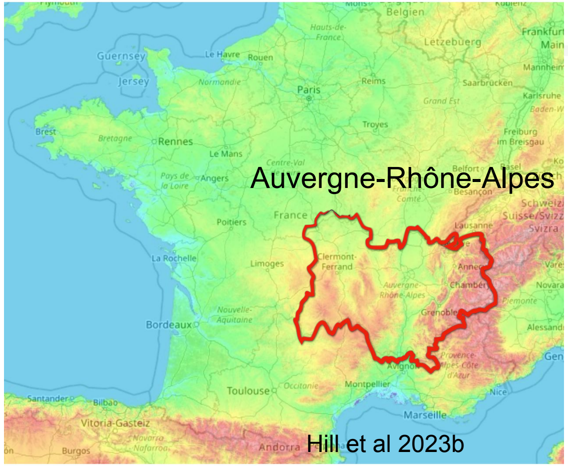
Understanding source contributions is key to effectively reducing concentrations

Can MA350's Source Apportionment assist French agencies in this goal?

- Collocate MA350 & AE33 in Lyon
- Mar – Feb, 2022



Favez et al 2021



Hill et al 2023b

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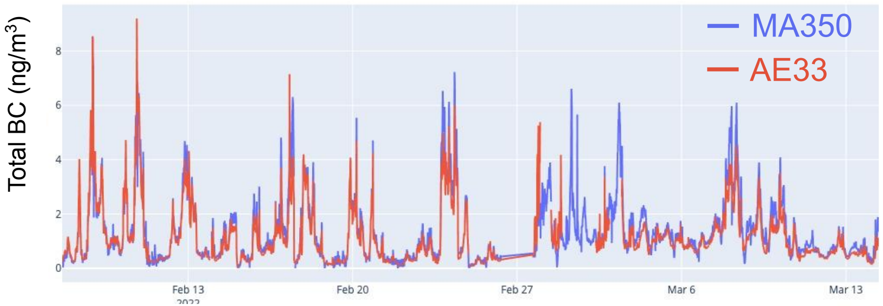
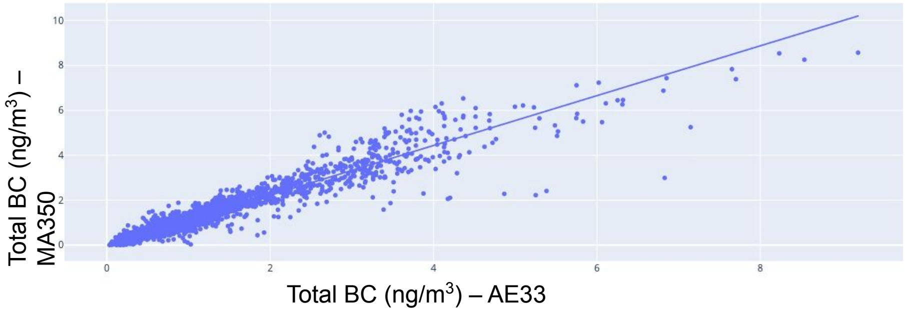
Lyon Results

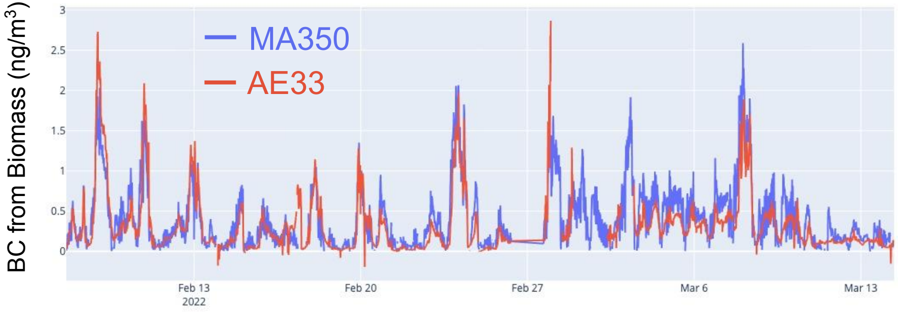
Black Carbon (Total)



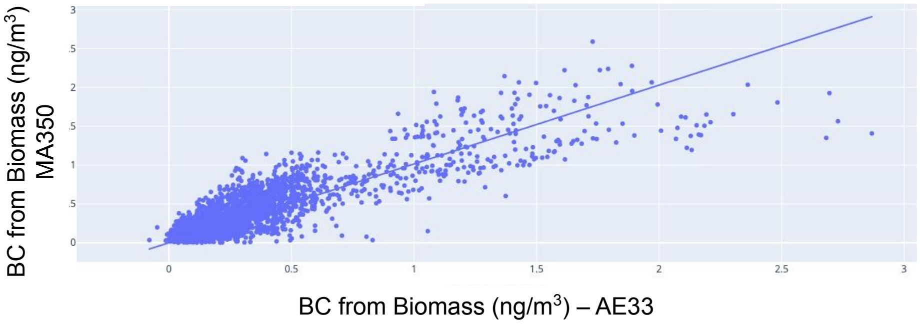
Slope = 1.11
Adjusted r^2 = 0.96



Black Carbon from Biomass Burning



Slope = 1.01
Adjusted r^2 = 0.87



Hill et al 2023b

Conclusions

Black carbon is:

- soot
- a major component of $PM_{2.5}$
- responsible for a great deal of illness and death
- the 2^{nd} leading cause of climate change
- lacking direct regulation

AethLabs:

- has worked to inform action through BC measurement for over 15 years
- specializes in small, flexible, best-in-class BC monitors

Works Cited

Carmona, Nancy, Edmund Seto, Timothy Gould, Jeffry H. Shirai, B.J. Cummings, Lisa Hayward, Timothy Larson, and Elena Austin. "Indoor Air Quality Intervention in Schools; Effectiveness of a Portable HEPA Filter Deployment in Five Schools Impacted by Roadway and Aircraft Pollution Sources." Preprint. Public and Global Health, January 13, 2022. https://doi.org/10.1101/2022.01.12.22269175.

Carmona, Nancy. "Air Pollution in the Puget Sound: Environmental Health Disparities and Brain Health." Doctoral Dissertation, University of Washington, 2023.

CAMS: O'Rourke, Patrick R, Steven J Smith, Andrea Mott, Hamza Ahsan, Erin E McDuffie, Monica Crippa, Zbigniew Klimont, et al. "CEDS V_2021_04_21 Release Emission Data." Zenodo, April 6, 2021. https://doi.org/10.5281/zenodo.4741285.

Chakraborty, Mrinmoy, Amanda Giang, and Naomi Zimmerman. "Performance Evaluation of Portable Dual-Spot Micro-Aethalometers for Source Identification of Black Carbon Aerosols: Application to Wildfire Smoke and Traffic Emissions in the Pacific Northwest." Atmospheric Measurement Techniques 16, no. 9 (May 5, 2023): 2333–52. https://doi.org/10.5194/amt-16-2333-2023.

UNEP and WMO. "Integrated Assessment of Black Carbon and Tropospheric Ozone." 2011. https://www.ccacoalition.org/resources/integrated-assessment-black-carbon-and-tropospheric-ozone.

Hill, L. Drew, Mark Arend, Jeff Blair, Steven Blair, Steven Chillrud, Vincent Crenn, David Diner, et al. "Practical Applications of Real-Time Black Carbon Source Apportionment Using a Portable Micro-Aethalometer with Various Climate Control and Sample Line Conditioning Configurations." In 13th International Conference on Carbonaceous Particles in the Atmosphere, 2023a.

Hill, L. Drew, Vincent Crenn, Mario Duval, Didier Grenier, Alexandre Marpillat, Ivan Iskra, Olivier Favez, and Jeff Blair. "Results from Winter Field Collocations of the AethLabs MA350 microAeth and AE33 Rack Mount Aethalometer in Lyon and Clermont-Ferrand, France: An Analysis of Filter Loading Compensated Black Carbon and Source Apportionment Measurements." In ACTRIS: Innovation in Atmospheric Measurement Techniques. Paris, France, 2023b.

Hill, L. Drew, Sina Hasheminassab, Jeffrey Blair, Steven Blair, Ivan Iskra, Tesfaye Mamo, Araya Asfaw, and David J. Diner. "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." In 13th International Conference on Carbonaceous Particles in the Atmosphere, 2023c.

Janssen, Nicole A.H., Gerard Hoek, Milena Simic-Lawson, Paul Fischer, Leendert van Bree, Harry ten Brink, Menno Keuken, et al. "Black Carbon as an Additional Indicator of the Adverse Health Effects of Airborne Particles Compared with PM 10 and PM 2.5." Environmental Health Perspectives 119, no. 12 (December 2011): 1691–99. https://doi.org/10.1289/ehp.1003369.

Lack et al. 2013 Characterizing elemental, equivalent black, and refractory black carbon aerosol particles: a review of techniques, their limitations and uncertainties

Lee, Suhyeon, Hyemin Hwang, and Jae Young Lee. "Vertical Measurements of Roadside Air Pollutants Using a Drone." Atmospheric Pollution Research 13, no. 12 (December 2022): 101609. https://doi.org/10.1016/j.apr.2022.101609.

Li, Ying, Daven K. Henze, Darby Jack, Barron H. Henderson, and Patrick L. Kinney. "Assessing Public Health Burden Associated with Exposure to Ambient Black Carbon in the United States." Science of The Total Environment 539 (January 1, 2016): 515–25. https://doi.org/10.1016/j.scitotenv.2015.08.129.

Mendoza, Daniel L., L. Drew Hill, Jeffrey Blair, and Erik T. Crosman. "A Long-Term Comparison between the AethLabs MA350 and Aerosol Magee Scientific AE33 Black Carbon Monitors in the Greater Salt Lake City Metropolitan Area." Sensors 24, no. 3 (February 1, 2024): 965. https://doi.org/10.3390/s24030965.

Moroni, Silvia, Francesco Cruz Torres, Paolo Palomba, Umberto Dal Santo, and Cristina Colombi. "Near-Reference Air Quality Sensors Can Support Local Planning: A Performance Assessment in Milan, Italy." In ECAS 2022, 36. MDPI, 2022. https://doi.org/10.3390/ecas2022-12814.

S. Robinson, Ellis, Meeta Cesler-Maloney, Xinxiu Tan, Jingqiu Mao, William Simpson, and Peter F. DeCarlo. "Wintertime Spatial Patterns of Particulate Matter in Fairbanks, AK during ALPACA 2022." Environmental Science: Atmospheres 3, no. 3 (2023): 568–80. https://doi.org/10.1039/D2EA00140C.

Works Cited (continued)

Qiu, Zhaowen, Xin Wang, Zhen Liu, and Jianhao Luo. “Quantitative Assessment of Cyclists’ Exposure to PM and BC on Different Bike Lanes.” Atmospheric Pollution Research, November 2022, 101588. https://doi.org/10.1016/j.apr.2022.101588.

Rönkkö, Topi, Sanna Saarikoski, Niina Kuittinen, Panu Karjalainen, Helmi Keskinen, Anssi Järvinen, Fanni Mylläri, Päivi Aakko-Saksa, and Hilkka Timonen. “Review of Black Carbon Emission Factors from Different Anthropogenic Sources.” Environmental Research Letters 18, no. 3 (March 1, 2023): 033004. https://doi.org/10.1088/1748-9326/acbb1b.

Salas-Sánchez, Aarón A., Julian Rauch, M. Elena López-Martín, J. Antonio Rodríguez-González, Giorgio Franceschetti, and Francisco J. Ares-Pena. “Feasibility Study on Measuring the Particulate Matter Level in the Atmosphere by Means of Yagi–Uda-Like Antennas.” Sensors 20, no. 11 (January 2020): 3225. https://doi.org/10.3390/s20113225.

Schneider, Conrad, and L. Bruce Hill. “Diesel and Health in America: The Lingering Threat.” Clean Air Task Force, 2005

Stavroulas, I, M Pikridas, G Grivas, S Bezantakos, E Liakakou, P Kalkavouras, A Bigi, E Gerasopoulos, J Sciare, and N Mihalopoulos. “Field Evaluation of Miniature Absorption Photometers in an Eastern Mediterranean Urban Environment,” 2022, 1.

Stampfer, Orly, Elena Austin, Terry Ganuelas, Tremain Fiander, Edmund Seto, and Catherine J. Karr. “Use of Low-Cost PM Monitors and a Multi-Wavelength Aethalometer to Characterize PM2.5 in the Yakama Nation Reservation.” Atmospheric Environment 224 (March 2020): 117292. https://doi.org/10.1016/j.atmosenv.2020.117292.

US EPA, OAR. “Climate Change Indicators: Wildfires.” Reports and Assessments, July 1, 2016. https://www.epa.gov/climate-indicators/climate-change-indicators-wildfires.

Wang, Rong, Shu Tao, Huizhong Shen, Ye Huang, Han Chen, Yves Balkanski, Olivier Boucher, et al. “Trend in Global Black Carbon Emissions from 1960 to 2007.” Environmental Science & Technology 48, no. 12 (June 17, 2014): 6780–87. https://doi.org/10.1021/es5021422.

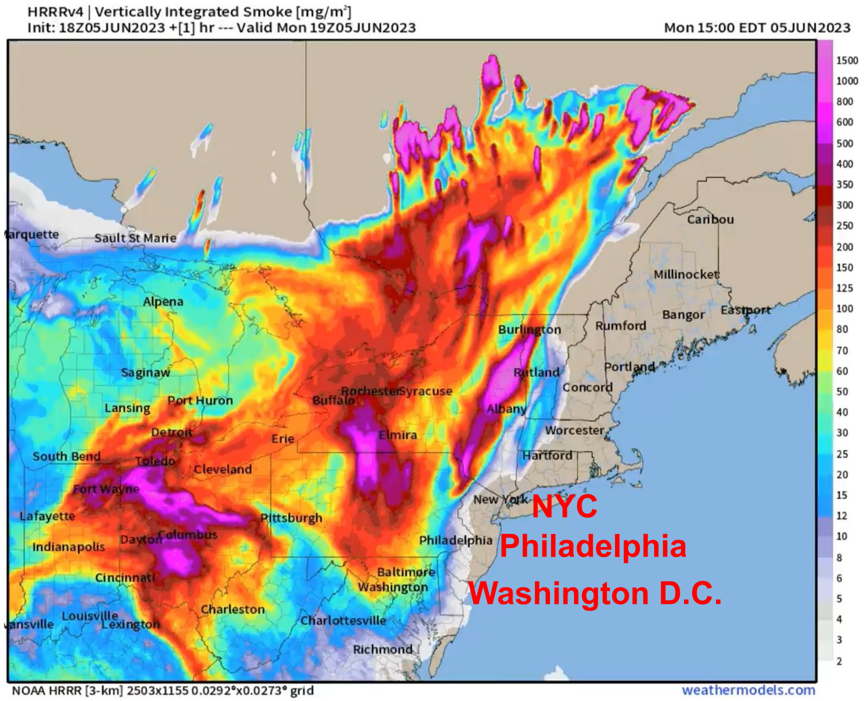
Wei, Jing, Jun Wang, Zhanqing Li, Shobha Kondragunta, Susan Anenberg, Yi Wang, Huanxin Zhang, et al. “Long-Term Mortality Burden Trends Attributed to Black Carbon and PM2·5 from Wildfire Emissions across the Continental USA from 2000 to 2020: A Deep Learning Modelling Study.” The Lancet Planetary Health 7, no. 12 (December 1, 2023): e963–75. https://doi.org/10.1016/S2542-5196(23)00235-8.

Winiger, Patrik. “Atmospheric Sciences | Black Carbon: The Dark Side of Warming in the Arctic.” Accessed March 27, 2024. https://blogs.egu.eu/divisions/as/2016/11/02/black-carbon-the-dark-side-of-warming-in-the-arctic/.

Wu, Liqing, Yicheng Shen, Fei Che, Yuzhe Zhang, Jian Gao, and Chong Wang. “Evaluating the Performance and Influencing Factors of Three Portable Black Carbon Monitors for Field Measurement.” Journal of Environmental Sciences 139 (May 1, 2024): 320–33. https://doi.org/10.1016/j.jes.2023.05.044.

Yang, Junhua, Shichang Kang, Deliang Chen, Lin Zhao, Zhenming Ji, Keqin Duan, Haijun Deng, et al. “South Asian Black Carbon Is Threatening the Water Sustainability of the Asian Water Tower.” Nature Communications 13, no. 1 (November 30, 2022): 7360. https://doi.org/10.1038/s41467-022-35128-1.

Smoke from 2022 Ontario Wildfires



Thank you!

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Jeff Blair (CEO, Head of Engineering)
Jeff.blair@aethlabs.com

AETHLABS

Department of CITY & METROPOLITAN PLANNING THE UNIVERSITY OF UTAH

Dept. of Atmospheric Sciences

Global Change & Sustainability Center THE UNIVERSITY OF UTAH

The Consortium for Dark Sky Studies

UNIVERSITY OF UTAH SCHOOL OF MEDICINE

THE UNIVERSITY OF UTAH NEXUS Interdisciplinary Exchange for Utah Science

Beyond Mass Concentration

Daniel Mendoza, PhD, *University of Utah*

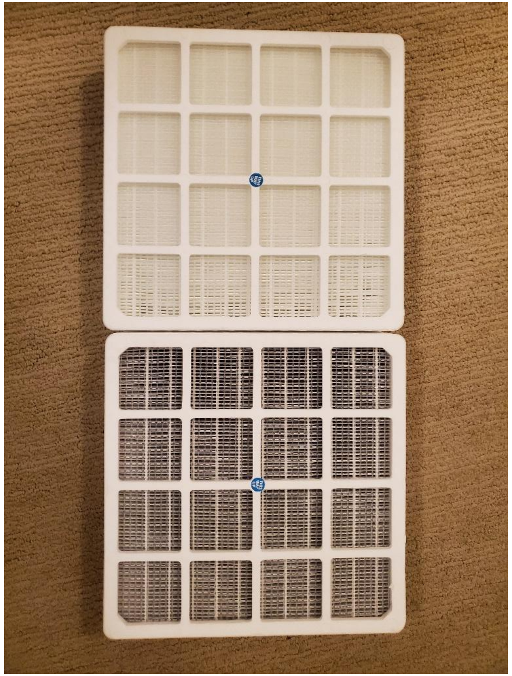
The Synergy of Black Carbon and Particulate Matter Measurements in Air Quality Monitoring

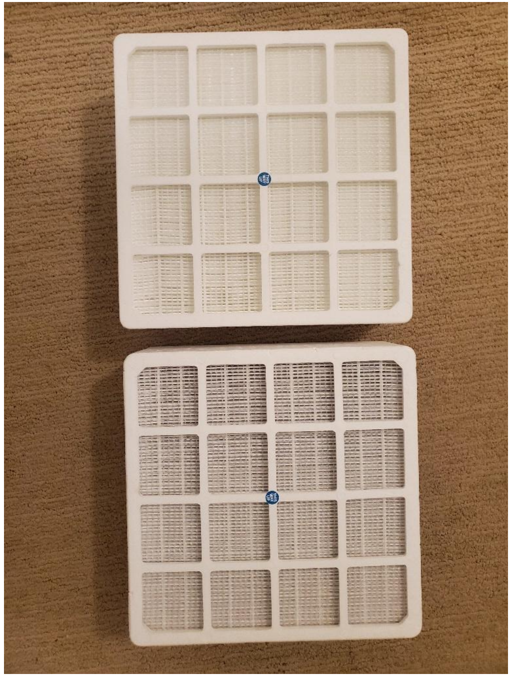
March 28th, 2024

Background

- Health Related Pollutant
- Climate Change Driver
- Sparse Observations
- Involved Maintenance
- Traditionally Costly
- Environmental and Social Justice Implications

Air Filter Change Day (01/18/22)





Open Access Article

A Long-Term Comparison between the AethLabs MA350 and Aerosol Magee Scientific AE33 Black Carbon Monitors in the Greater Salt Lake City Metropolitan Area

by Daniel L. Mendoza [1,2,3,*], L. Drew Hill [4], Jeffrey Blair [4] and Erik T. Crosman [5]

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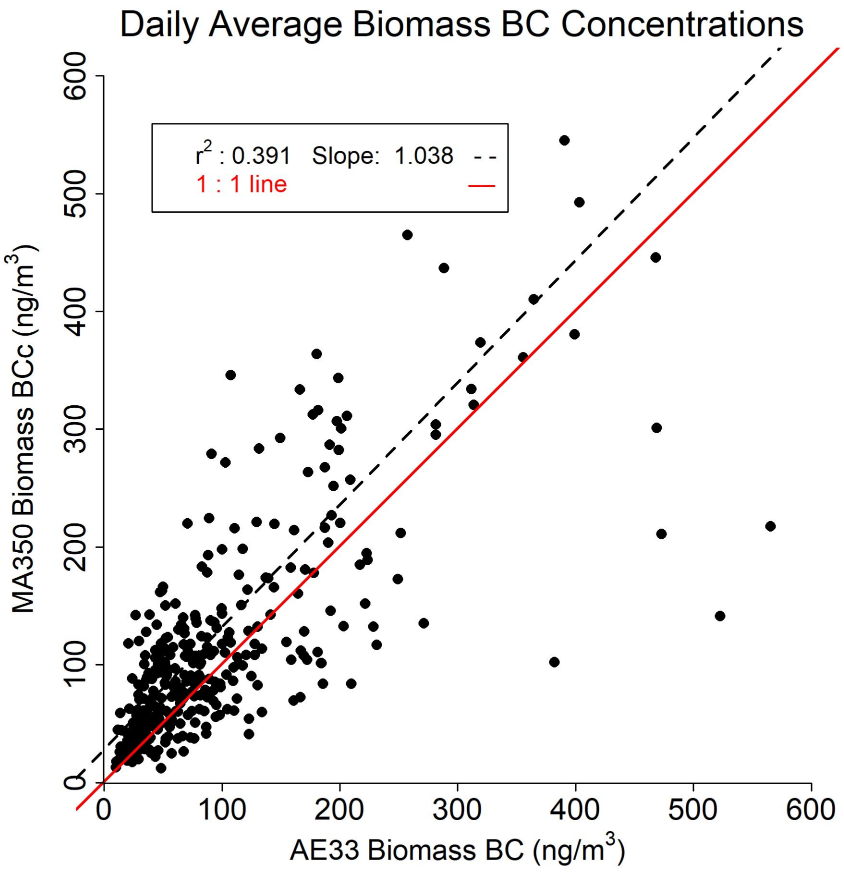
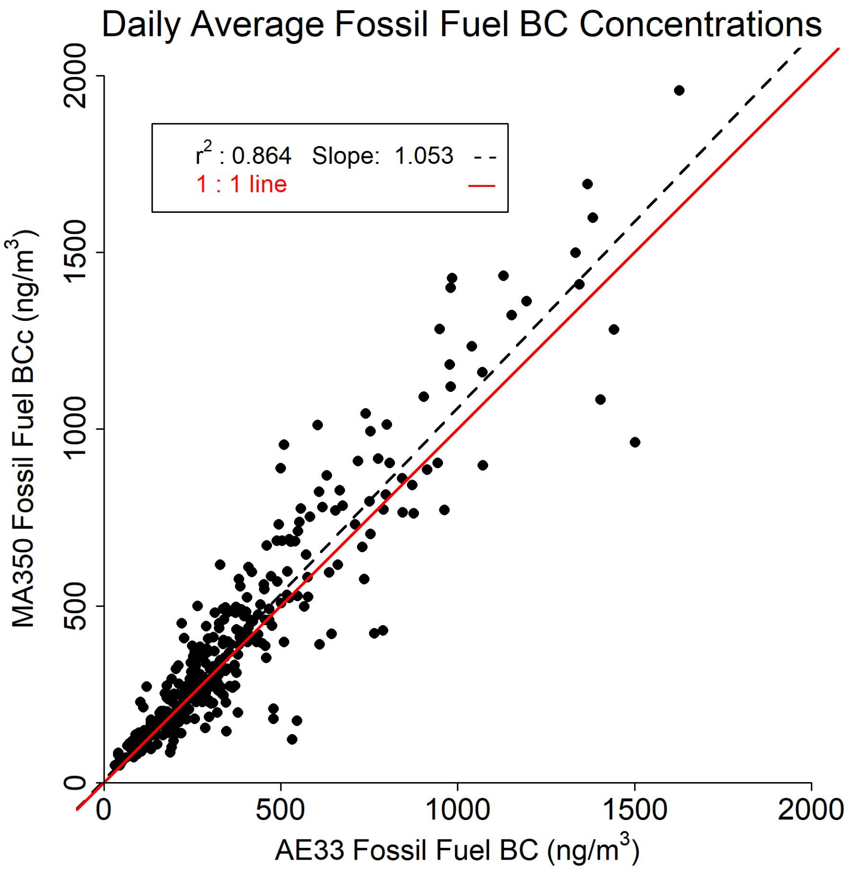
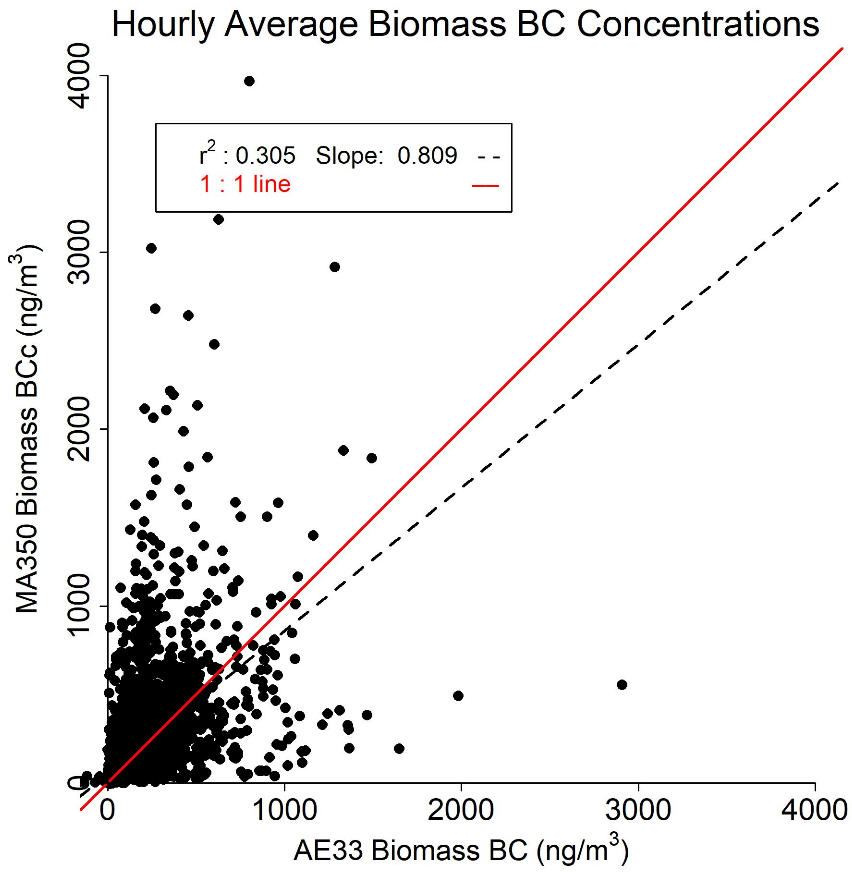
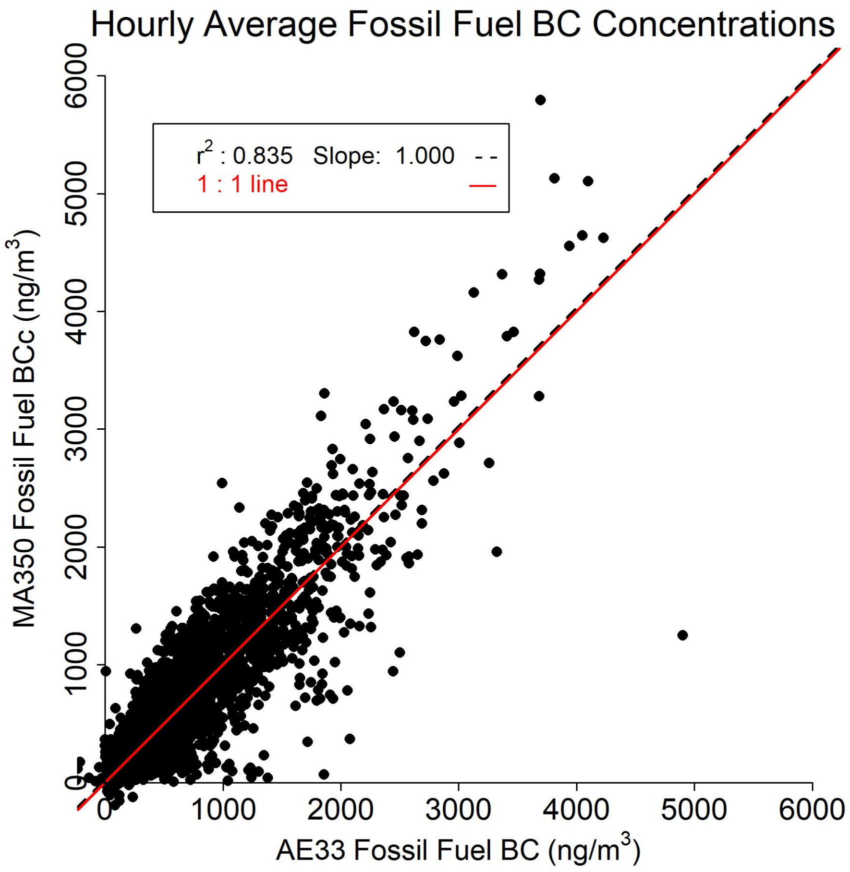

Daily Average Biomass BC Concentrations
r^2 : 0.391 Slope: 1.038 - -
1 : 1 line
MA350 Biomass BCc (ng/m^3)
AE33 Biomass BC (ng/m^3)
0
100
200
300
400
500
600

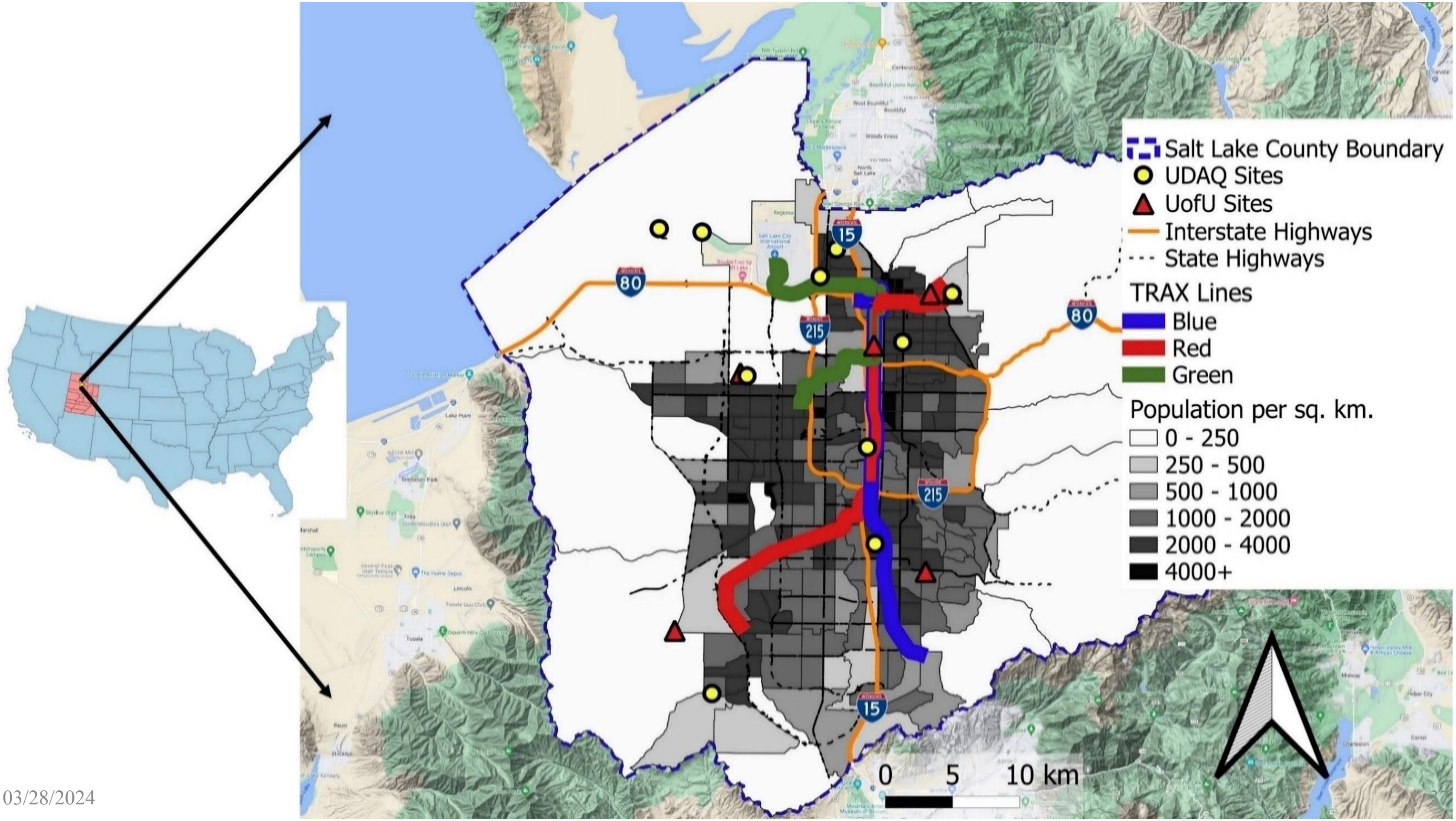

Daily Average Fossil Fuel BC Concentrations
r^2 : 0.864 Slope: 1.053 - -
1 : 1 line
MA350 Fossil Fuel BCc (ng/m^3)
AE33 Fossil Fuel BC (ng/m^3)
0
500
1000
1500
2000


Hourly Average Biomass BC Concentrations
r² : 0.305 Slope: 0.809 - -
1 : 1 line
MA350 Biomass BCc (ng/m³)
AE33 Biomass BC (ng/m³)
0
1000
2000
3000
4000


Hourly Average Fossil Fuel BC Concentrations
r² : 0.835 Slope: 1.000 - -
1 : 1 line
MA350 Fossil Fuel BCc (ng/m³)
AE33 Fossil Fuel BC (ng/m³)
0
1000
2000
3000
4000
5000
6000

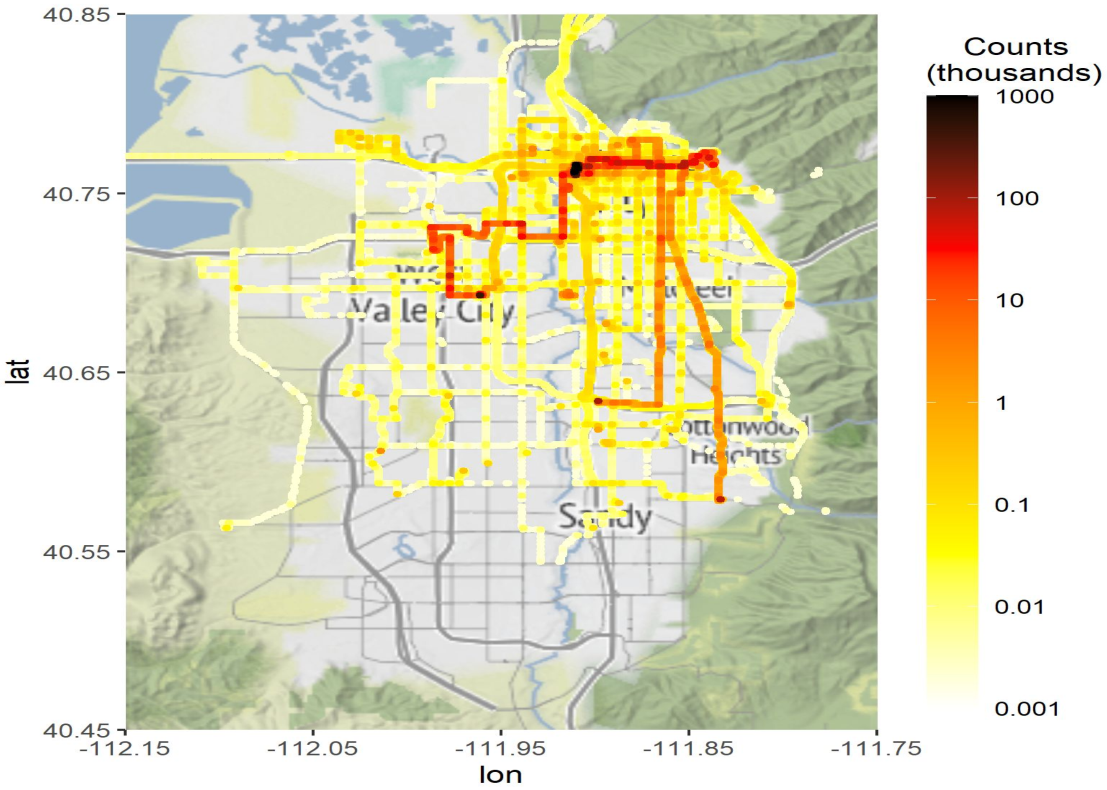
Implications

- Data Democratization
- Network Development
- Diurnal Pattern Analysis
- Public Health Applications
- Potential Early Warning System
- Environmental Refuge


Salt Lake County Boundary
UDAQ Sites
UofU Sites
Interstate Highways
State Highways
TRAX Lines
Blue
Red
Green
Population per sq. km.
0 - 250
250 - 500
500 - 1000
1000 - 2000
2000 - 4000
4000+
80
15
215
0 5 10 km

eBUS Data Point Counts

October 2021 - February 2024



Soon to Be Released Studies

- University of Utah Indoor and Outdoor
- Salt Lake City School District Schools Indoor and Outdoor
- Rural Schools Indoor
- Fireworks Events
- 2023 Canadian Wildfire
- 2021-2022 Wildfire Season

Thank you!

Questions?

daniel.mendoza@utah.edu

clarity

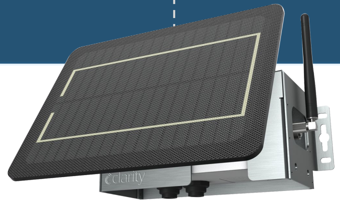
Empowering the world to reduce air pollution

We are on a **mission** to empower the world to **reduce air pollution**

Paolo Micalizzi
Co-Founder & CTO

A fully integrated air quality monitoring service

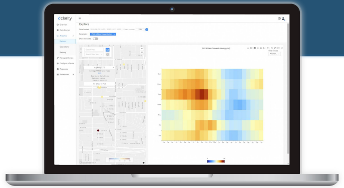
Sensing-as-a-Service℠



Clarity Node Platform

Measures all key air pollutants

- Solar-powered
- Cellular-connected
- Easily installed within 5 minutes



Clarity Cloud

Cloud-based data analysis

- Natively-integrated IoT dashboard
- Secure data pipeline & storage
- Powerful APIs, analytics and visualization

Clarity Expert Support

Scalable project support

- Highly qualified air quality experts
- Accurate and reliable data through Remote Calibration
- Responsive project management enabled by modern software stack

Clarity Node-S

A resilient, independently powered, and cellular-connected air monitor

Weather/UV resistant (IPX3 Rated)

Solar panel

Global cellular connectivity (3G/4G)

Internal battery

Easy installation in 10 minutes or less

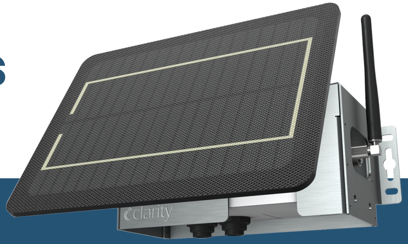
MCERTS
CSA MC230425/00

Measures **PM** and **NO2**.

FCC + CE certified and designed for **easy deployment** everywhere, and **reliable operation** in adverse weather conditions.

Clarity Add-On Modules

clarity



Wind Module

Determine where air pollution is coming from.

Ozone Module

Confirm ozone attainment with this FEM-capable device.

Black Carbon Module

Understand the composition and sources of particulates.

What makes the Black Carbon Module unique?

AethLabs & Clarity Black Carbon Module

1 **Ease of deployment**

2 Seamless data access

3 Best-in-class data quality

4 Collocated PM2.5 and BC

Deploy anywhere

AethLabs & Clarity Black Carbon Module

- Field deployment takes few minutes
- Solar operation requires only 40 minutes of direct sunlight per day
- 14-day autonomy without any sunlight
- Integrates seamlessly with the Clarity Cloud through companion Node-S via cellular
- Low maintenance with long filter tape life

What makes the Black Carbon Module unique?

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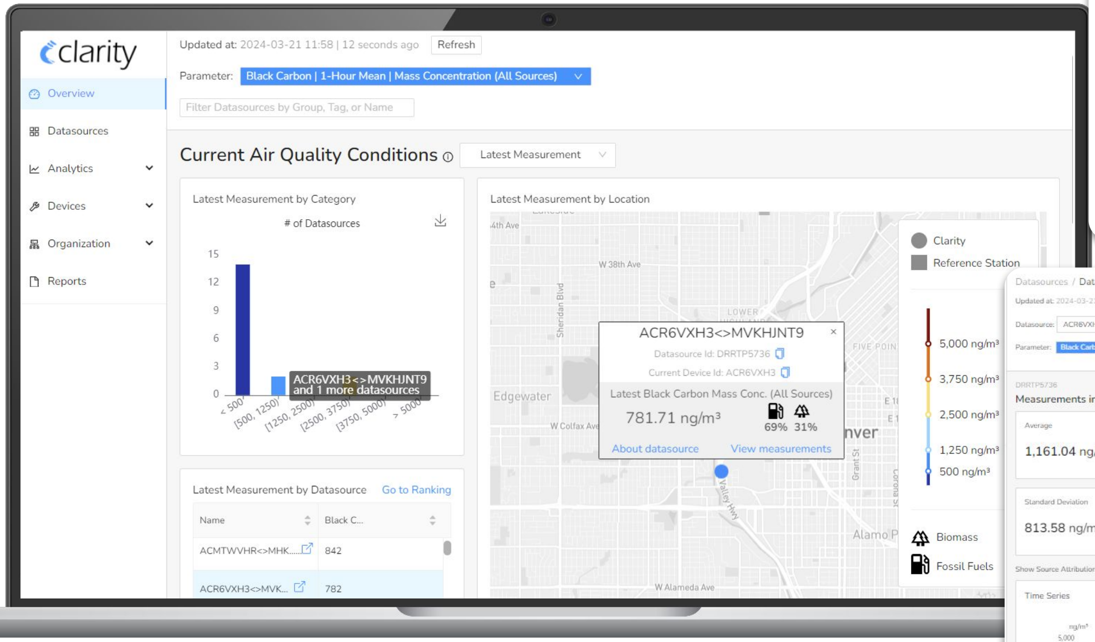
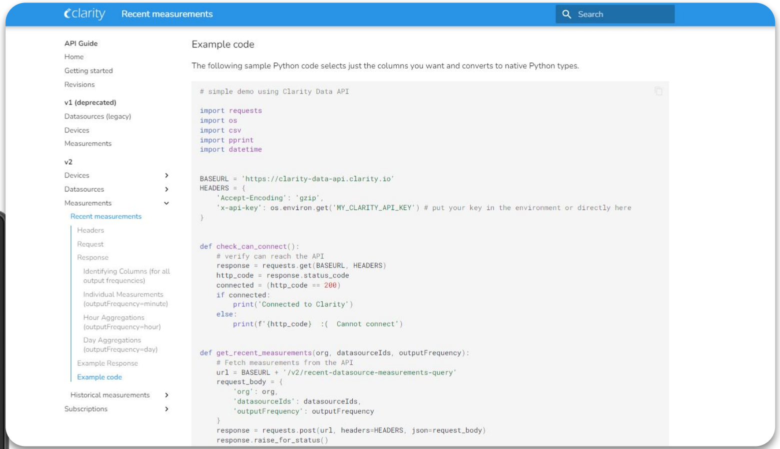
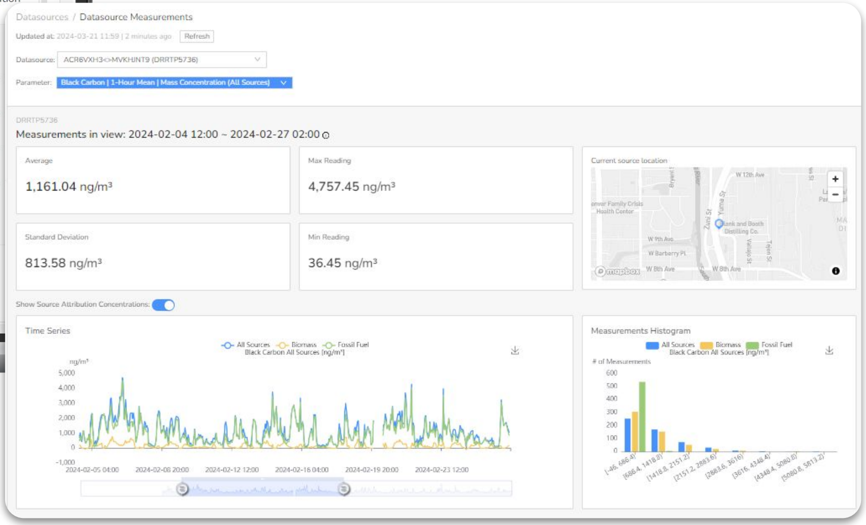
Seamless data access

AethLabs & Clarity Black Carbon Module







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AethLabs & Clarity Black Carbon Module

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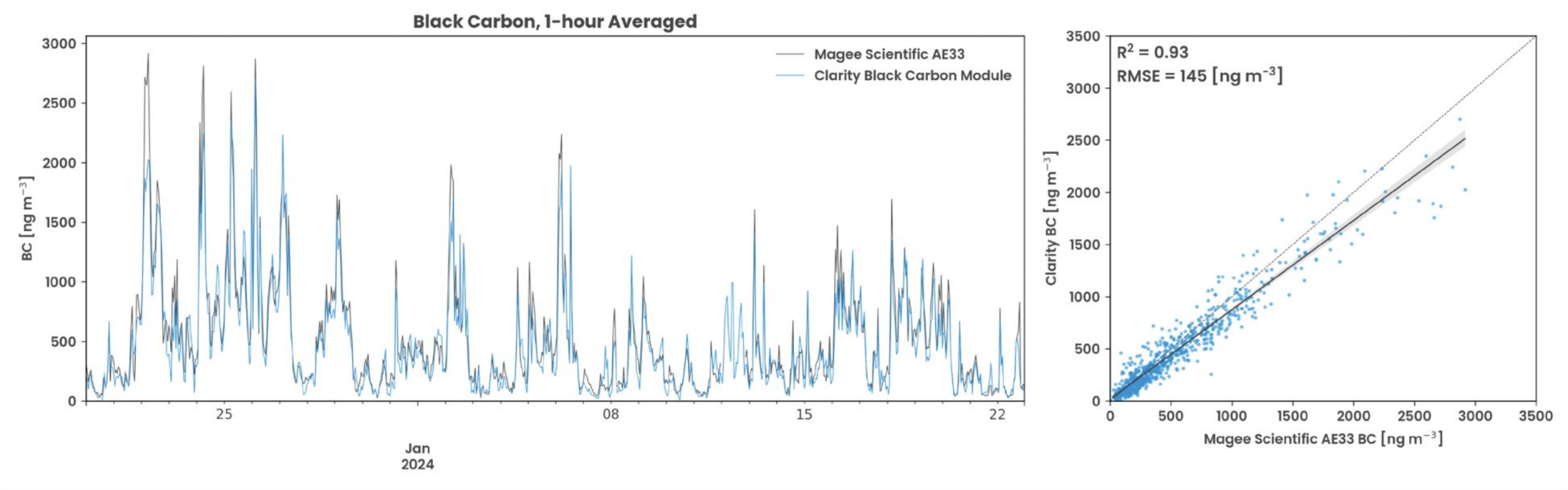
Collocated PM2.5 and BC

Best in class data quality

AethLabs & Clarity Black Carbon Module

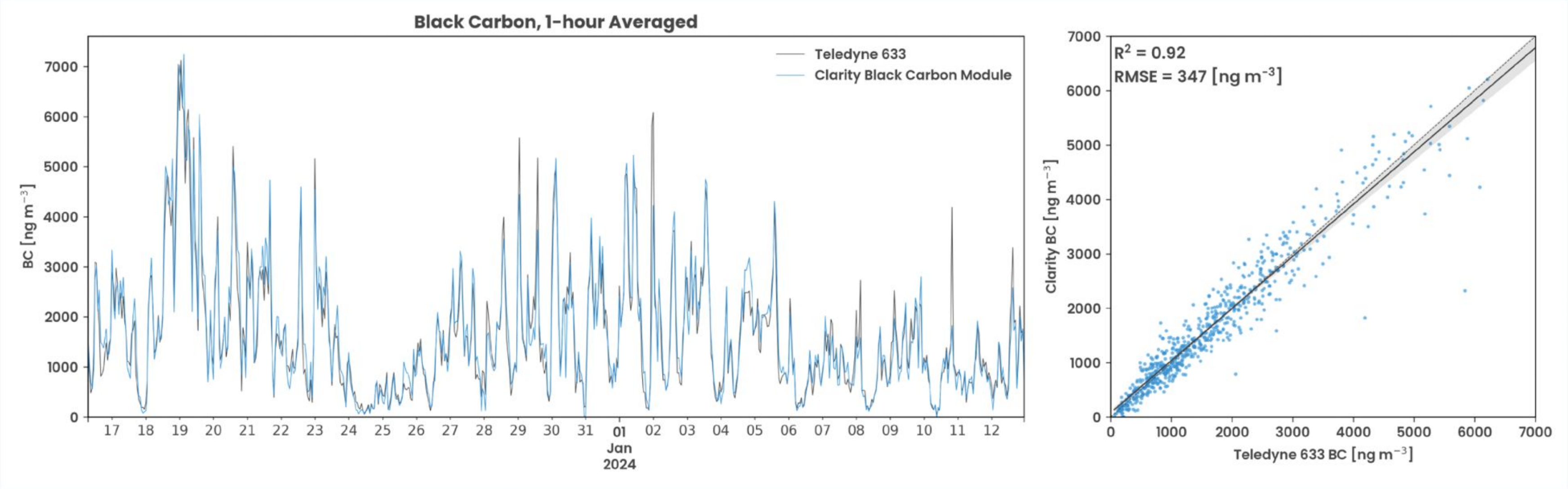
BERKELEY, CA, USA



Best in class data quality

AethLabs & Clarity Black Carbon Module

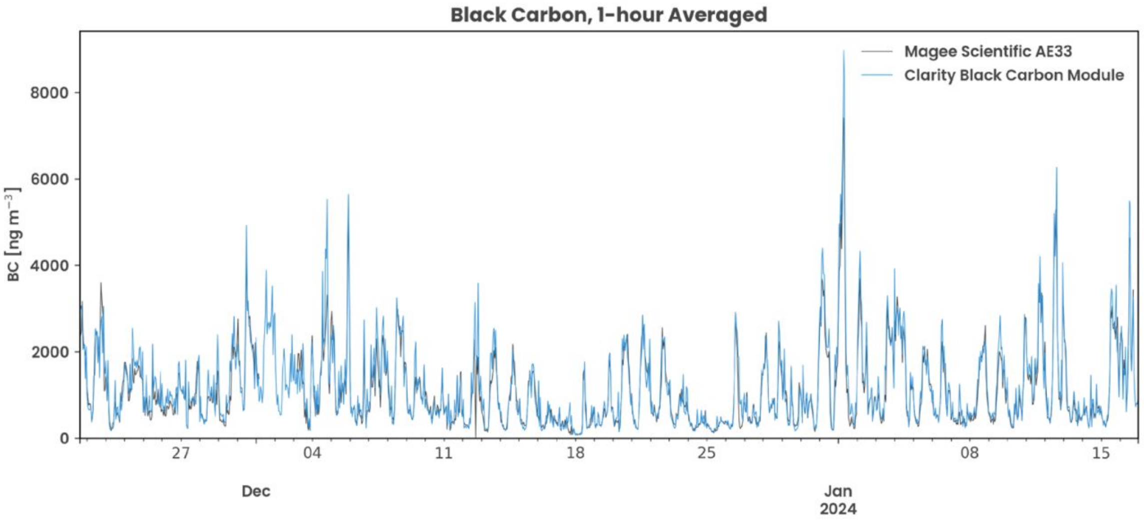
DENVER, CO, USA

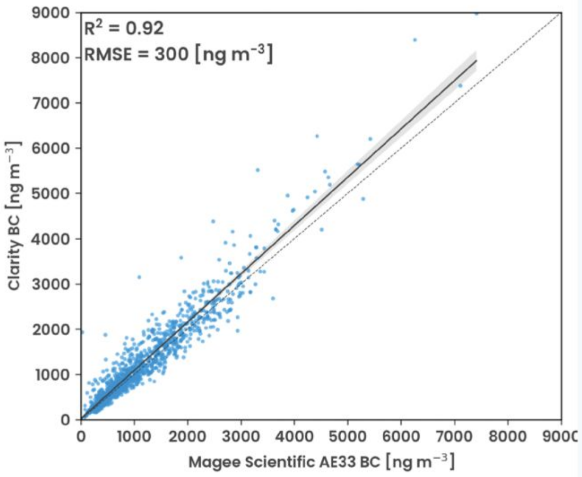


Best in class data quality

AethLabs & Clarity Black Carbon Module

BROWARD COUNTY, FL, USA





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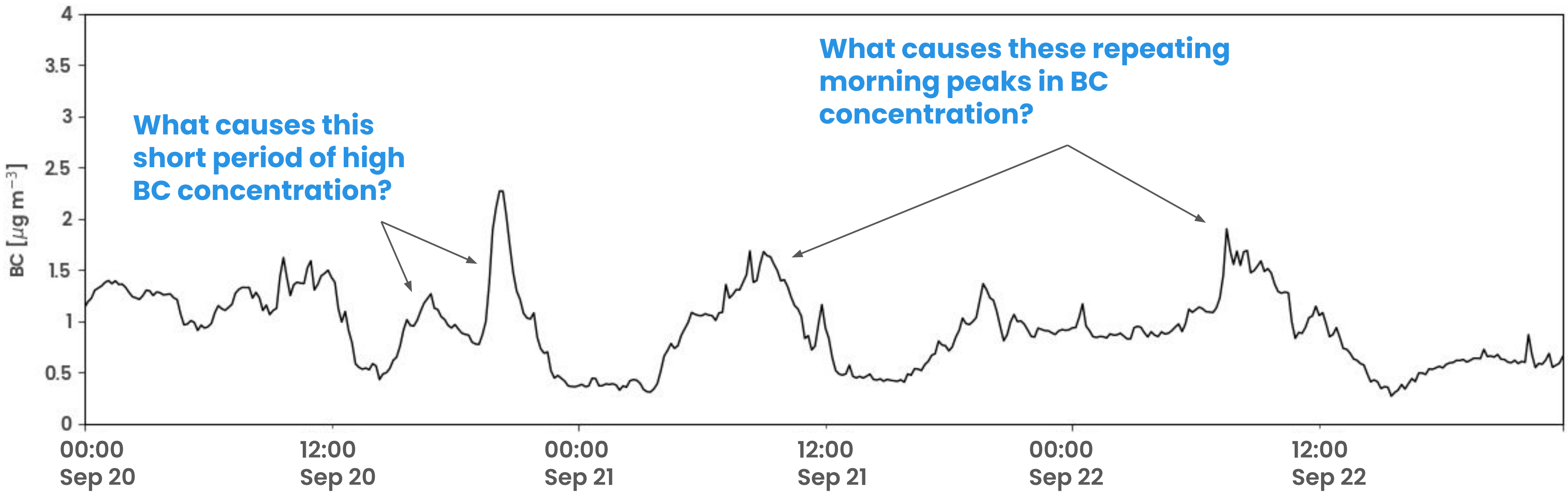
What's driving $PM_{2.5}$ air pollution in Berkeley, California?

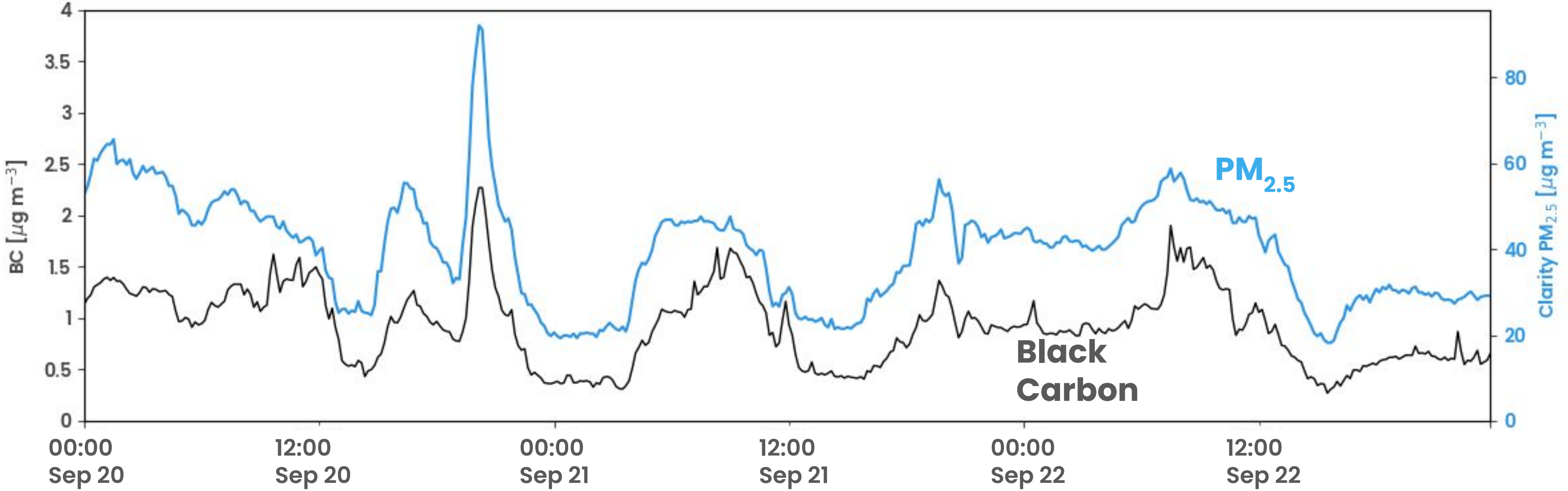
Case Study



Berkeley experiences several episodes of high black carbon concentrations which could increase the risk of negative health impacts. What sources drive this high variability in BC?

What's driving $PM_{2.5}$ air pollution in Berkeley, California?

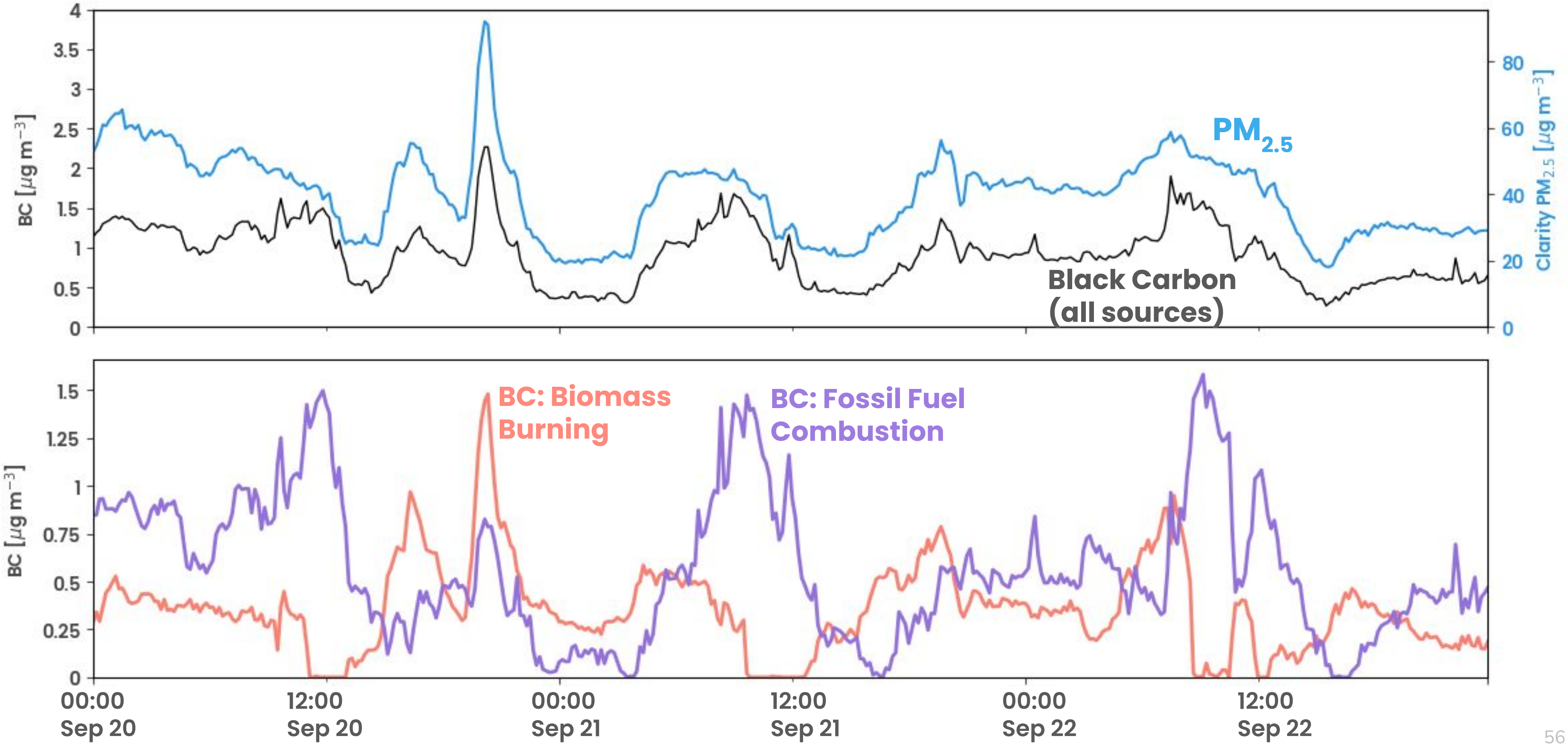
Case Study



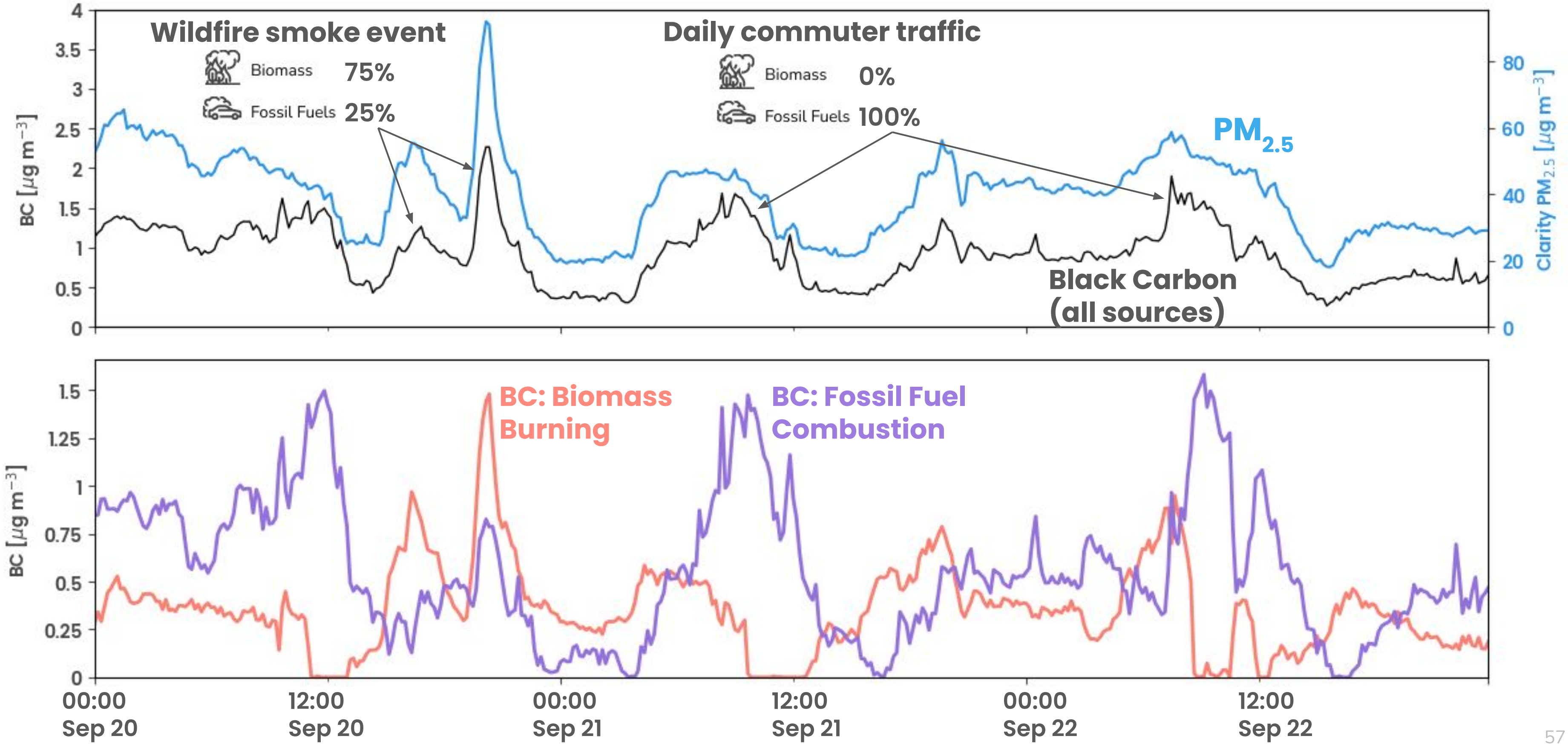
$PM_{2.5}$ and BC are strongly correlated (R^2 = 0.8), suggesting that combustion emissions played a major role in air quality in Berkeley over these several days.

What's driving $PM_{2.5}$ air pollution in Berkeley, California?

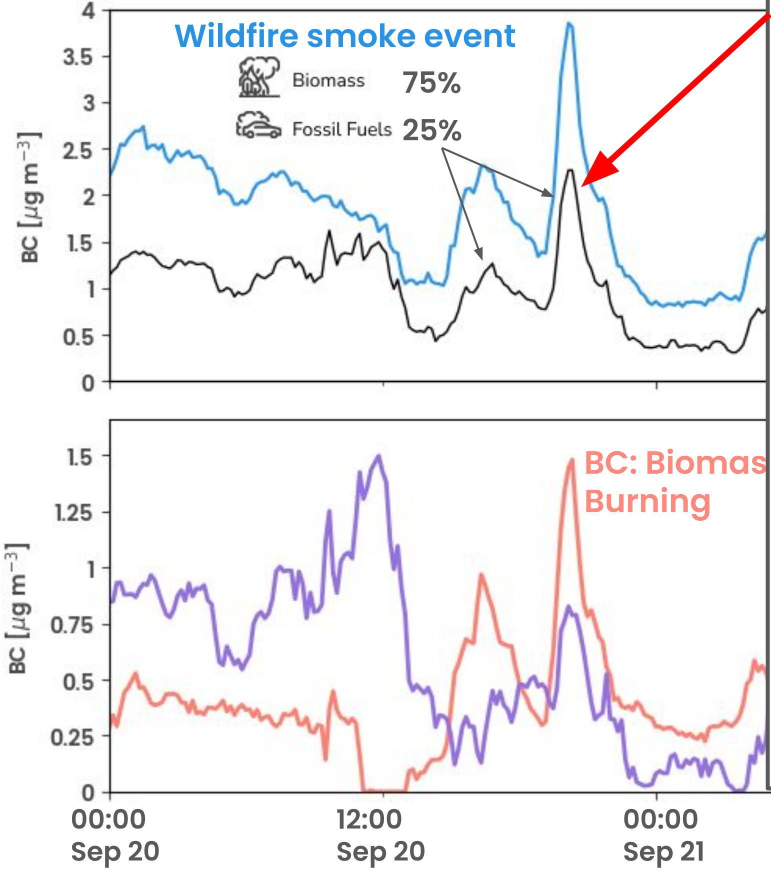
Case Study

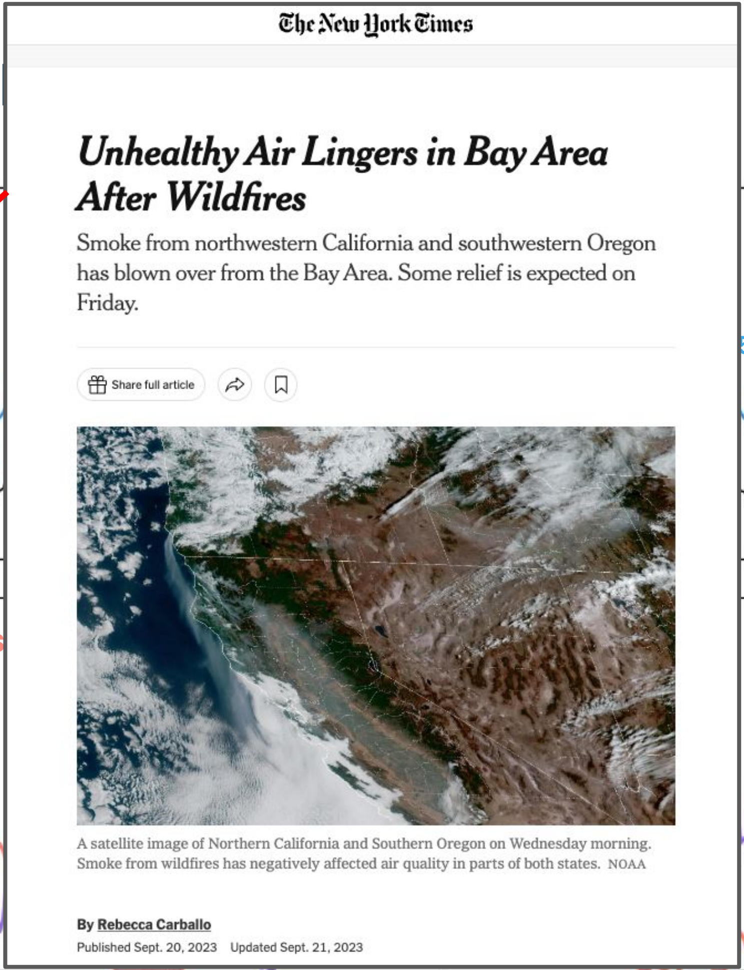


We can further separate the combustion sources



We can further separate t





The New York Times

Unhealthy Air Lingers in Bay Area After Wildfires

Smoke from northwestern California and southwestern Oregon has blown over from the Bay Area. Some relief is expected on Friday.

Share full article

A satellite image of Northern California and Southern Oregon on Wednesday morning. Smoke from wildfires has negatively affected air quality in parts of both states. NOAA

By Rebecca Carballo

Published Sept. 20, 2023 Updated Sept. 21, 2023

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Additional questions?
Contact us or visit the Clarity website

We're here to answer any questions!

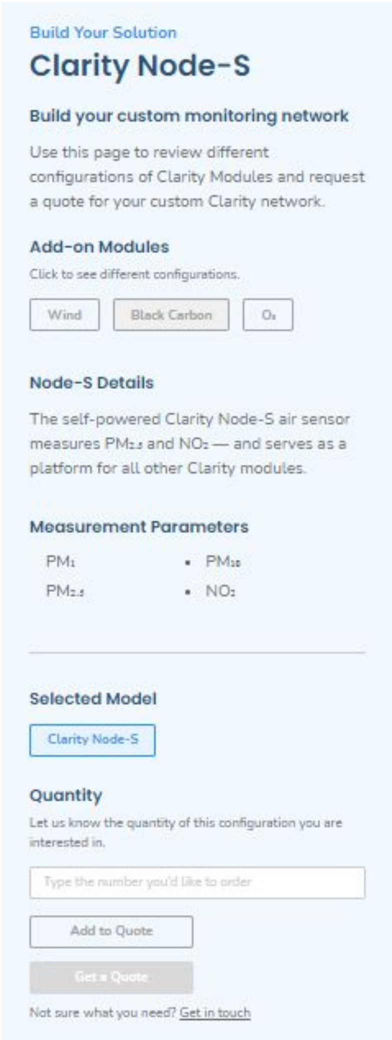
hello@clarity.io

Learn more on the Clarity website

clarity.io

Get a quote for your desired configuration

clarity.io/build-your-solution



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Thank you!

Questions?