Black Carbon Measurement in the European Union

Navigating the New Air Quality Directive

clarity

UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

AETHLABS

Meet the panelists!

Jeff Blair

President and CEO,
AethLabs

Dr. Stig Hellebust

Lecturer in Physical Chemistry,
University College Cork

Ivan Iskra

Business Development Lead,
AethLabs

Lee Swanson

Regional Account Manager,
Clarity Movement

Black Carbon Module

Black Carbon

Impacts and Innovations

Jeff Blair (CEO, Head of Engineering)

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Acknowledgements*

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UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

CRAC
Centre for Research into Atmospheric Chemistry

NASA
Jet Propulsion Laboratory
California Institute of Technology

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

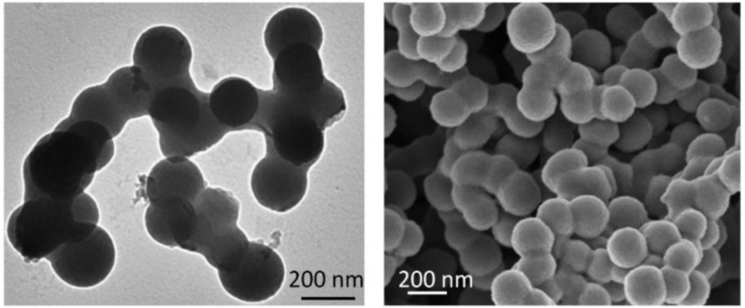
Addis Ababa University

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

Credit: ECPA

Dark, light absorbing

- Soot

Super Pollutant

- Major health & climate impacts

Sources

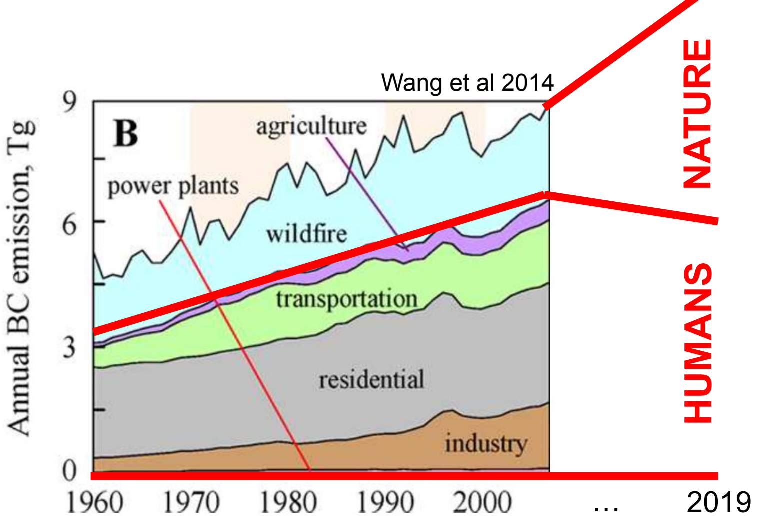
Produced during incomplete combustion

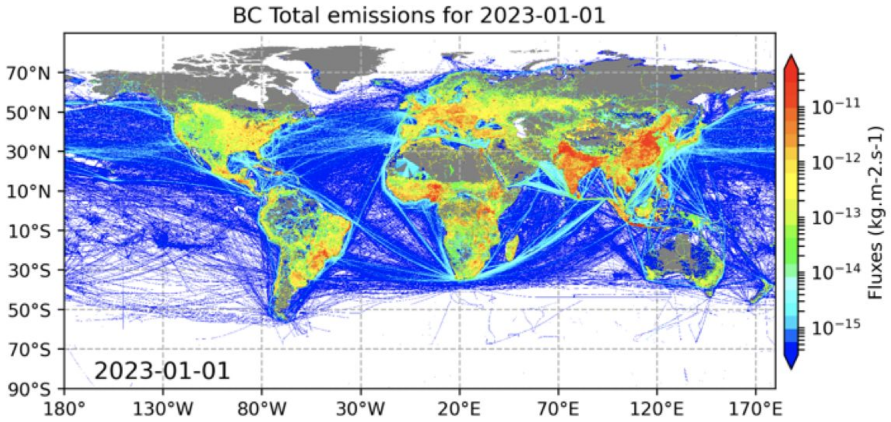
Nature

- 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





CAMS 2023

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BC Health Effects

In 2020, exposure to concentrations of fine particulate matter above the 2021 World Health Organization guideline level resulted in **238,000 premature deaths** in the EU-27.(European Environment Agency 2021)

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 $PM_{2.5}$

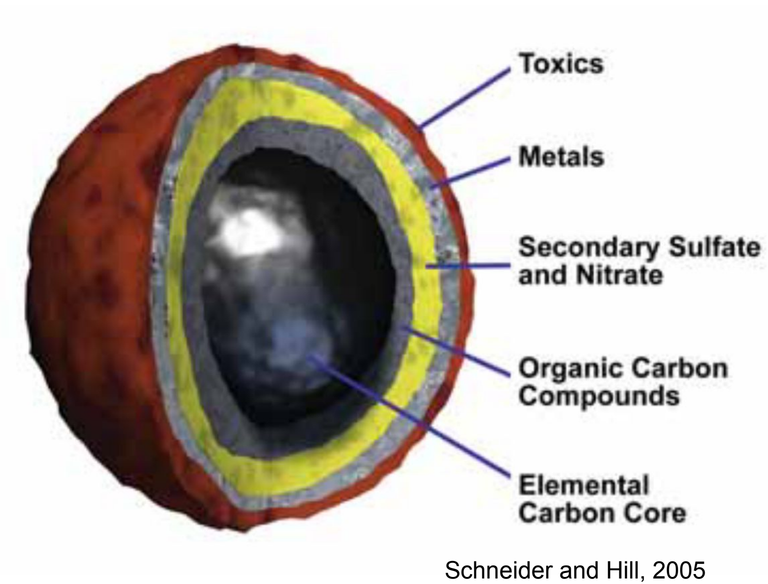
- $PM_{2.5}$ kills ~ 6.4 mil annually

Attracts nasty surface chemicals to its surface

- Toxics, metals, sulfates, nitrates

Biologically relevant size (< 1µm)

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



Schneider and Hill, 2005

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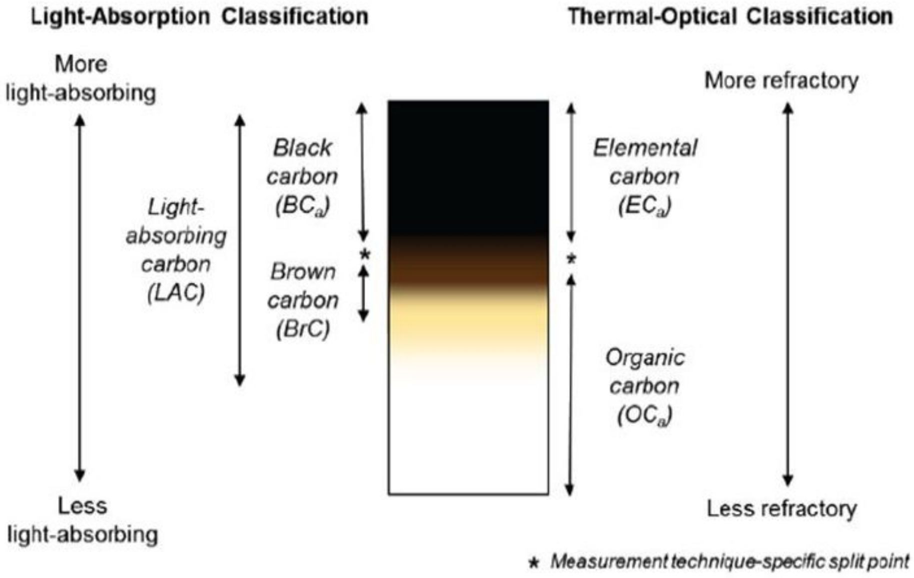
Climate Effects

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!)

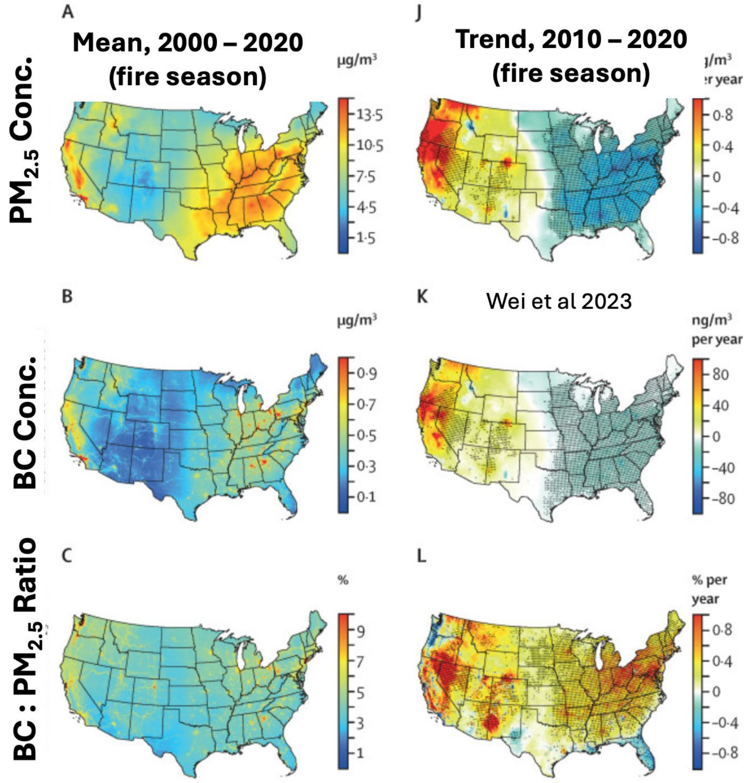
- Increased BC due to wildfires, especially in Western US
  - Increase in exposures, non-attainment
- 2-4% *per year* increase in BC:$PM_{2.5}$ ratio
  - Increasing $PM_{2.5}$ toxicity
- Transport to Europe

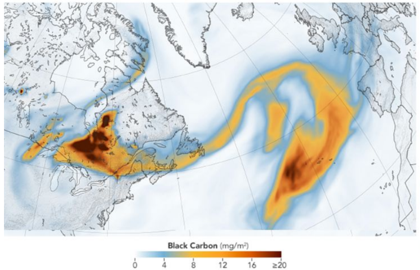
South Asia & Himalayas

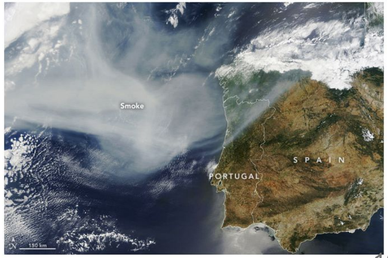
- Increasing BC → Tibetan Plateau (Asia's water tower)
- Darkening glaciers, reducing rain
- Water scarcity for billion+ people

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.

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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

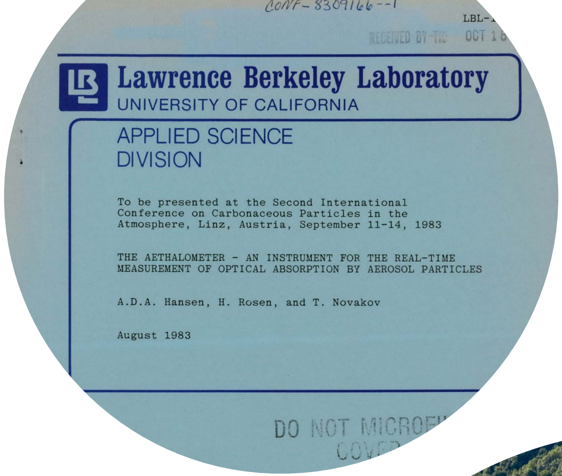
Our devices allow users to quantify BC by its sources (fossil fuel vs. biomass burning)

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.



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

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microAeth® AE51

Dimensions: 11.7cm x 6.6cm x 3.8cm

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

Collects particulates on filterstrip with single sampling spot

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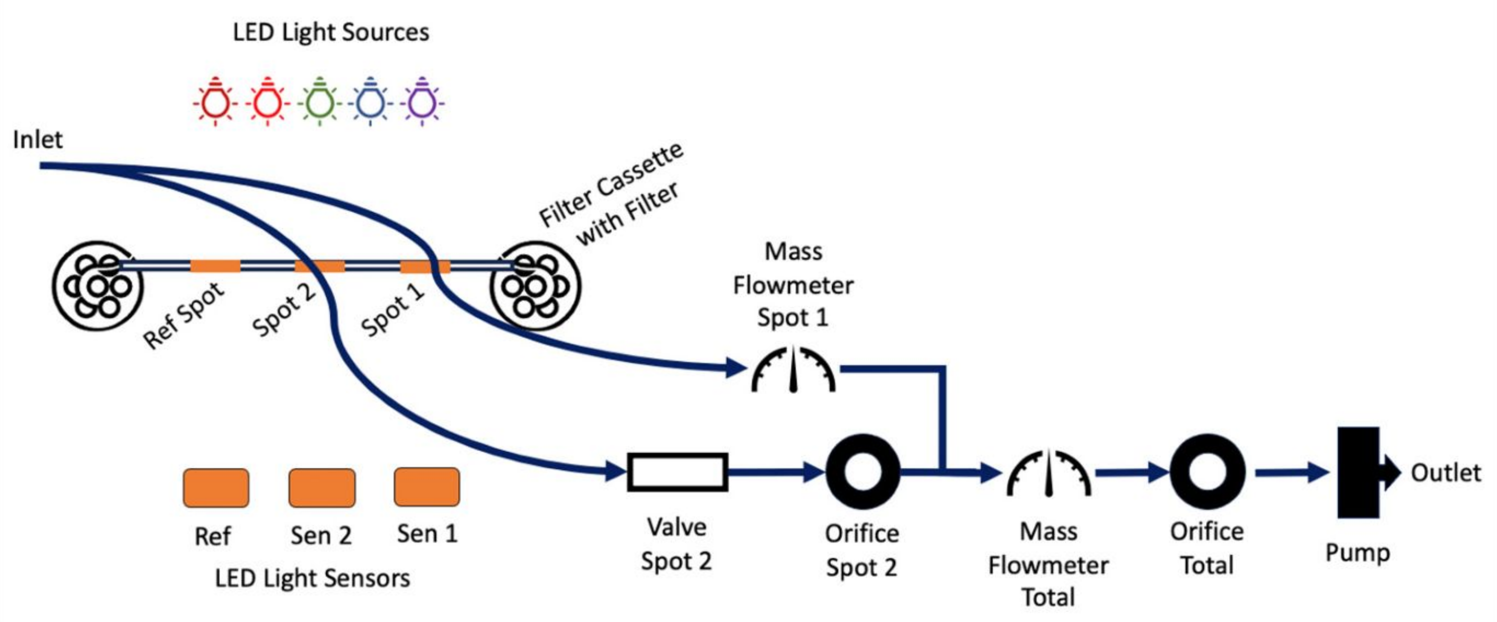
Principle of Operation: DualSpot™

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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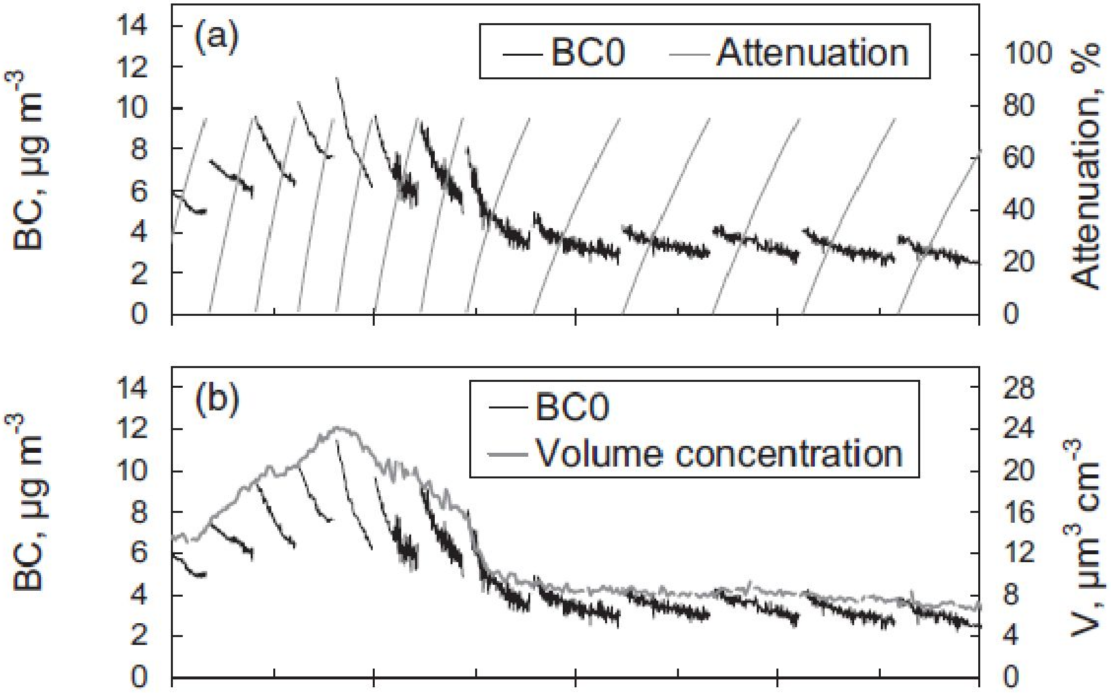
Principle of Operation: DualSpot™



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

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BC Standardization Effort in Europe

StanBC project

1. Traceable in situ reference methods for aerosol light absorption coefficient
   a. calibration chain
   b. uncertainties for the reference methods ≤ 10 %.
   c. Use intercomparisons to establish the relationship between eBC mass, rBC mass and EC mass (EN 16909:2017).
2. Develop methods for calibrating filter-based light absorption photometers
3. Develop a new CEN standard on reference and calibration methods
4. Encourage adoption of developed technology and reference infrastructure in laboratories, monitoring networks, by manufacturers etc.

European Partnership

Co-funded by the European Union

METROLOGY PARTNERSHIP

EURAMET

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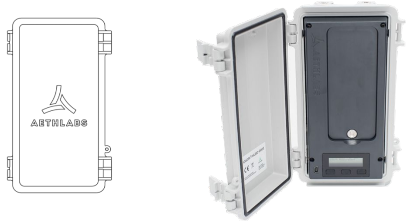
AethLabs microAeth® MA350 vs. Magee Scientific AE33

	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
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*
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

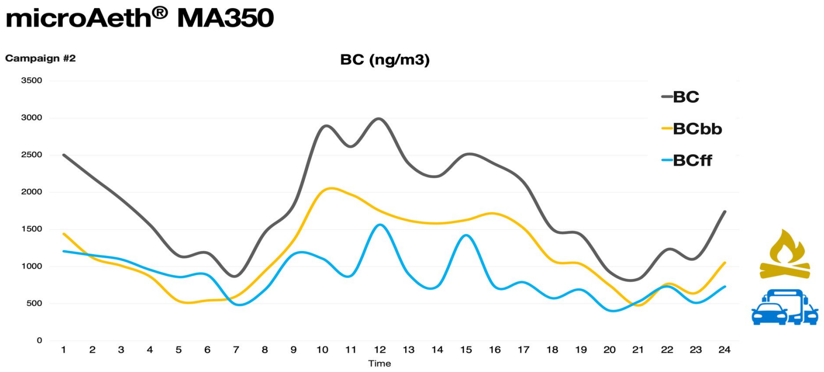


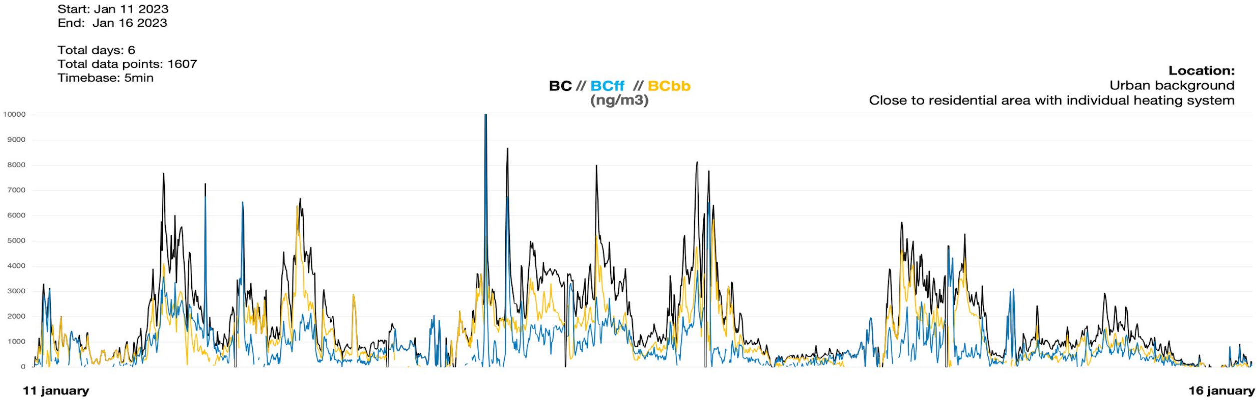
Magee Scientific

Pictures approximately to relative scale

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.
-

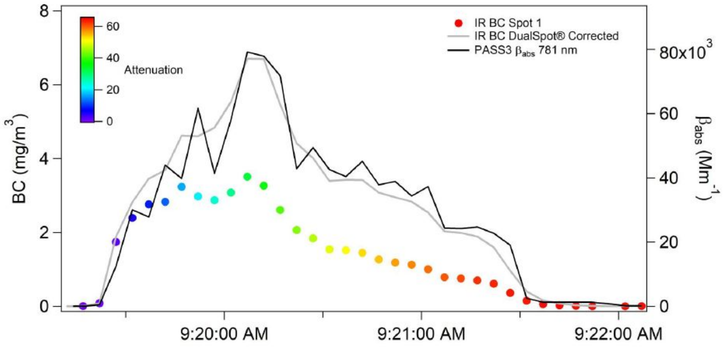
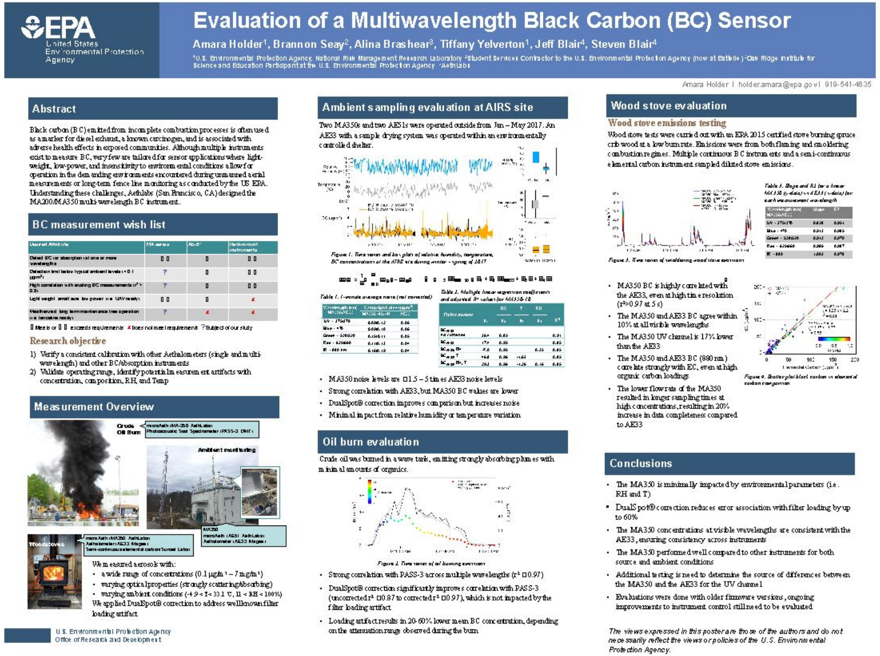


Figure 2. Time series of oil burning emissions



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MA350 Early Validation: Conclusions

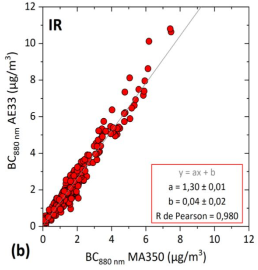
1. Through DualSpot® correction technology, the MA350 effectively mitigates errors associated with filter loading, resulting in a significant reduction of up to 60%.
2. Concentrations measured by the MA350 at visible wavelengths exhibit consistency with those of the AE33, ensuring uniformity and reliability 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

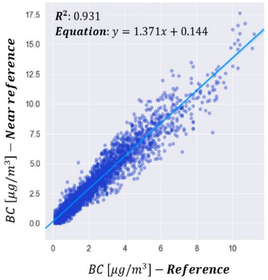
131 Google Scholar results

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

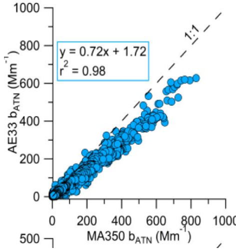
Numerous performance evaluations



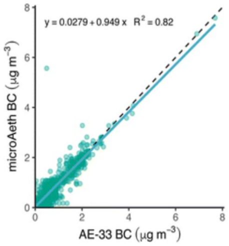
Atmo Nouvelle-Aquitaine 2019



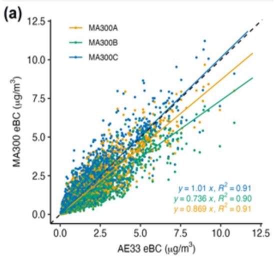
Moroni et al 2022



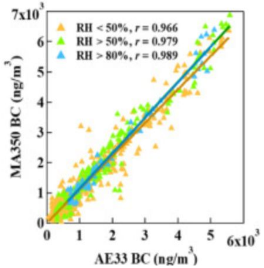
Stavroulas et al 2022



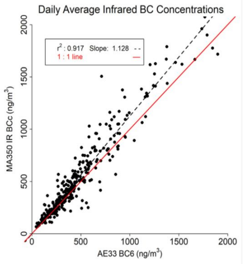
Robinson et al 2023



Chakraborty et al 2023



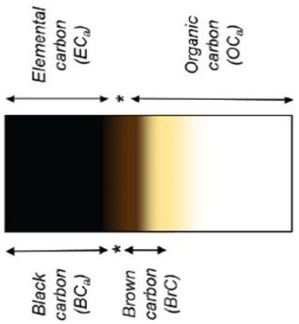
Wu et al 2023



Mendoza et al 2024

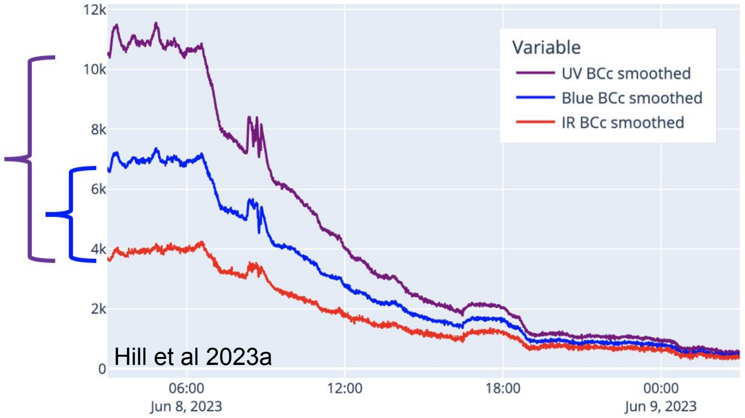
Source Apportionment

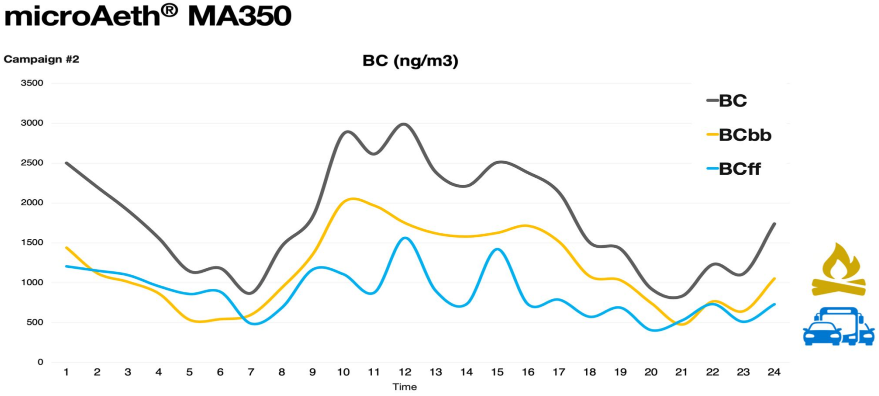
- Biomass vs Fossil Fuel
  - Fossil fuel combustion → more-purely BC
  - Biomass combustion → stronger OC presence
- As OC content increases, aerosols will absorb more-strongly in Blue & UV wavelengths than in IR wavelength (Sandradewi et al 2008)



Lack et al. 2013

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





INERIS, ATMO in France

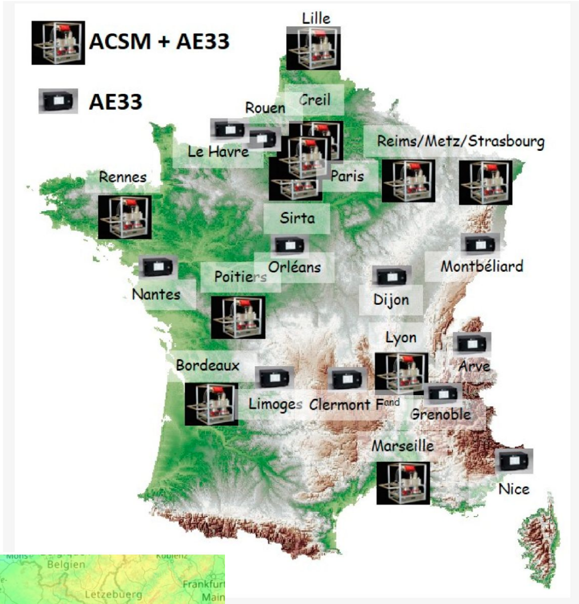
Complex aerosol landscape

- Residential wood heating, traffic
- Regional transport, orography

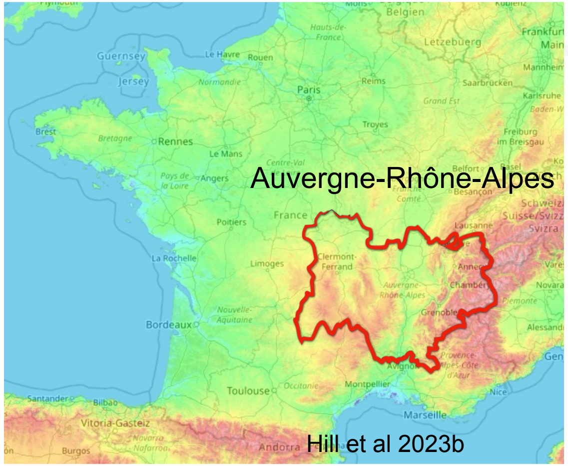
Understanding source contributions is key to effectively reducing concentrations

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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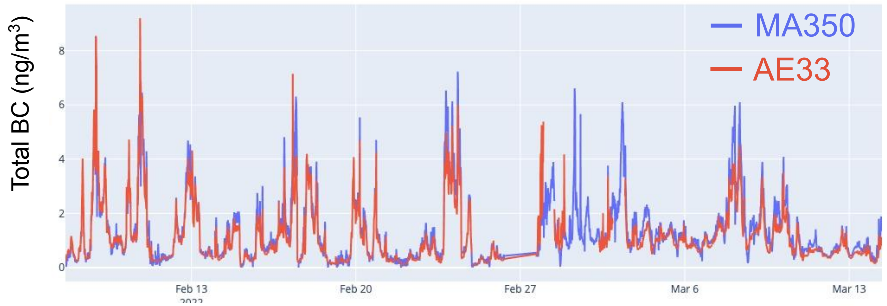
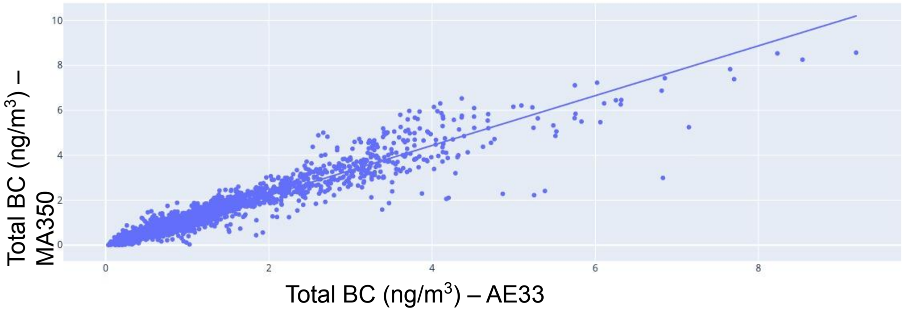
Lyon Results

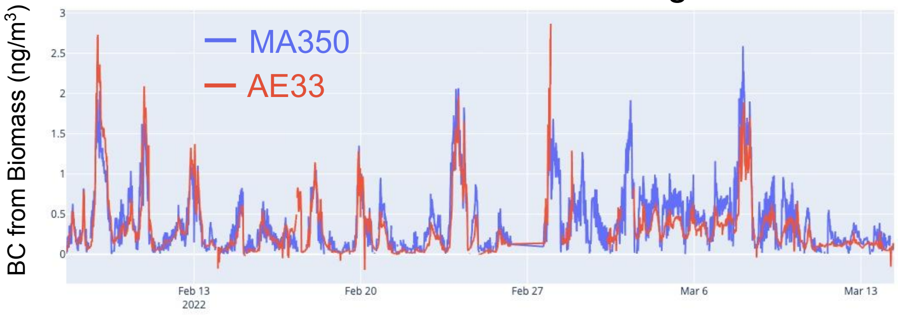
Black Carbon (Total)



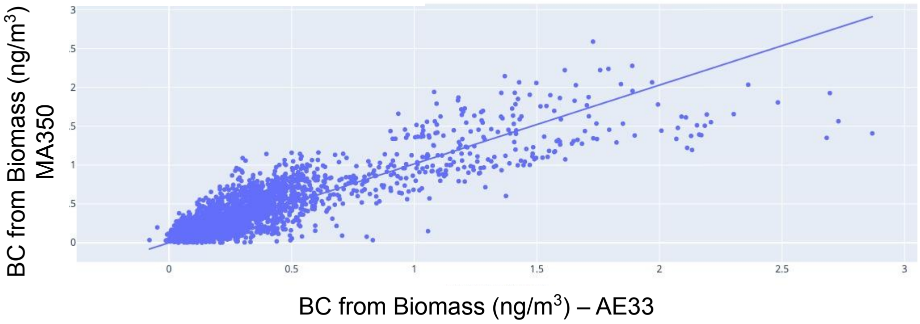
Slope = 1.11
Adjusted r^2 = 0.96



Black Carbon from Biomass Burning



Slope = 1.01
Adjusted r^2 = 0.87



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Hill et al 2023b

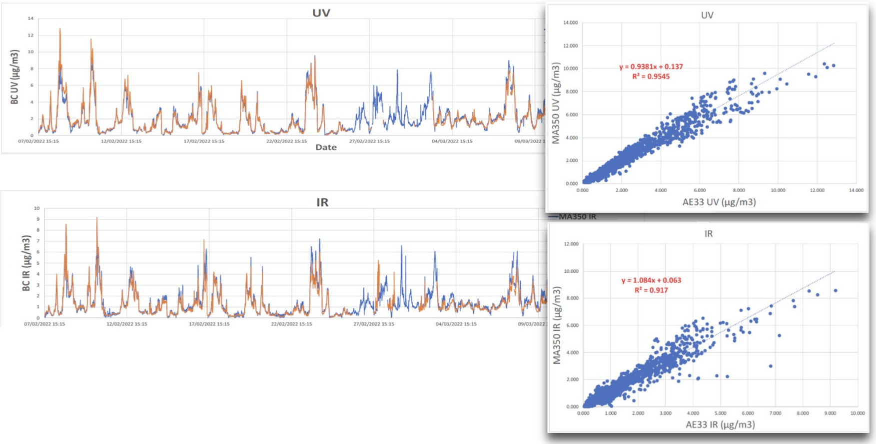
MA350: Approved for long-term monitoring of Black Carbon by French authorities

MicroAeth® MA350 approved as equivalent to the most widely used rack-mount aethalometer for long-term Black Carbon monitoring.

Issued by French authorities **AASQA** (Approved Air Quality Monitoring Association) and **LCSQA** (Central Air Quality Monitoring Laboratory).

Campaigns conducted between winter 2019 and 2022. Multiple microAeth® MA350 units were intensively tested in conjunction with pre-installed rack-mount aethalometers. Tests focused on monitoring BC concentrations and implementing a new source apportionment algorithm.

Official certificate from LCSQA in French and English



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Conclusions

Black carbon is:

- soot
- a major component of $PM_{2.5}$
- responsible for a great deal of illness and death
- the 2nd 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

microAeth technology is well established and comparable to rack-mount Aethalometers

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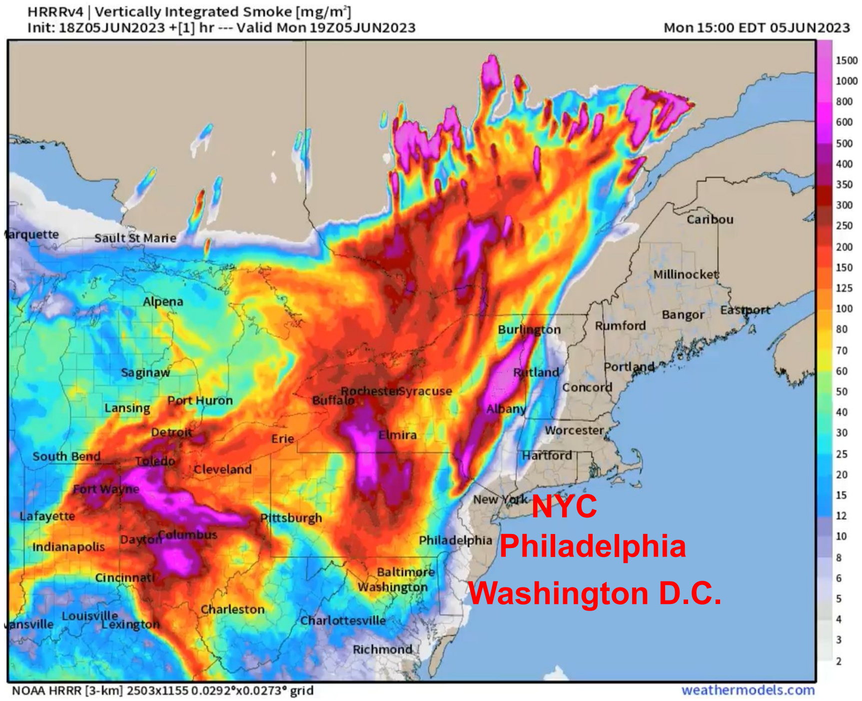
Thank you!

Jeff Blair (CEO, Head of Engineering)

Jeff.blair@aethlabs.com

Smoke from 2022 Ontario Wildfires



AETHLABS

The EU’s Clean Air Policies

SETTING OBJECTIVES FOR GOOD AIR QUALITY

Ambient Air Quality (AAQ) Directives

Maximum concentrations of air polluting substances

($PM_{2.5}$, PM_{10}, NO_2, O_3, SO_2, CO, C_6H_6, BaP, As, Cd, Ni, Pb)

REDUCING EMISSIONS

National Emission Reduction Commitments Directive

National emission totals

(SO_2, NO_x, NMVOC, $PM_{2.5}$, NH_3)

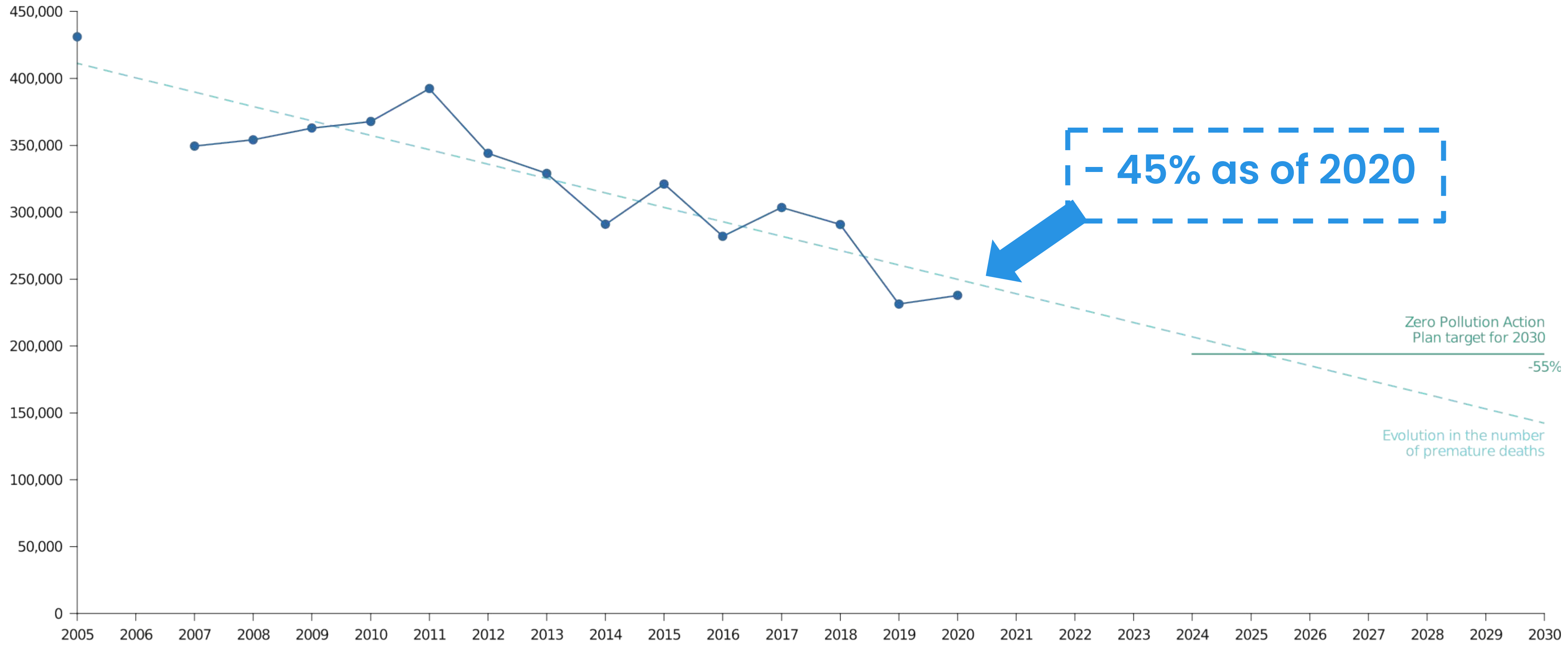
Source-specific emission standards

- IE Directive
- MCP Directive
- Eco-design Directive
- Energy efficiency
- Euro and fuel standards

Source: Thomas Henrichs: Ambient Air Quality: The EU approach. March 18th, 2024 at the 15th CONCAWE Symposium.

Is EU clean air policy effective?

Declining number of premature deaths due to PM exposure



Source: https://www.eea.europa.eu/publications/air-quality-in-europe-2022/health-impacts-of-air-pollution

How good we are when we consider AQ monitoring?

Example of PM2.5 monitoring sites across Europe (2022) to current limit values of pollutants vs. WHO guidelines

EU Standard today - 25 µg/m^3

1789 Total Sampling Points
98.7% Below Limit
1.29% Above Limit

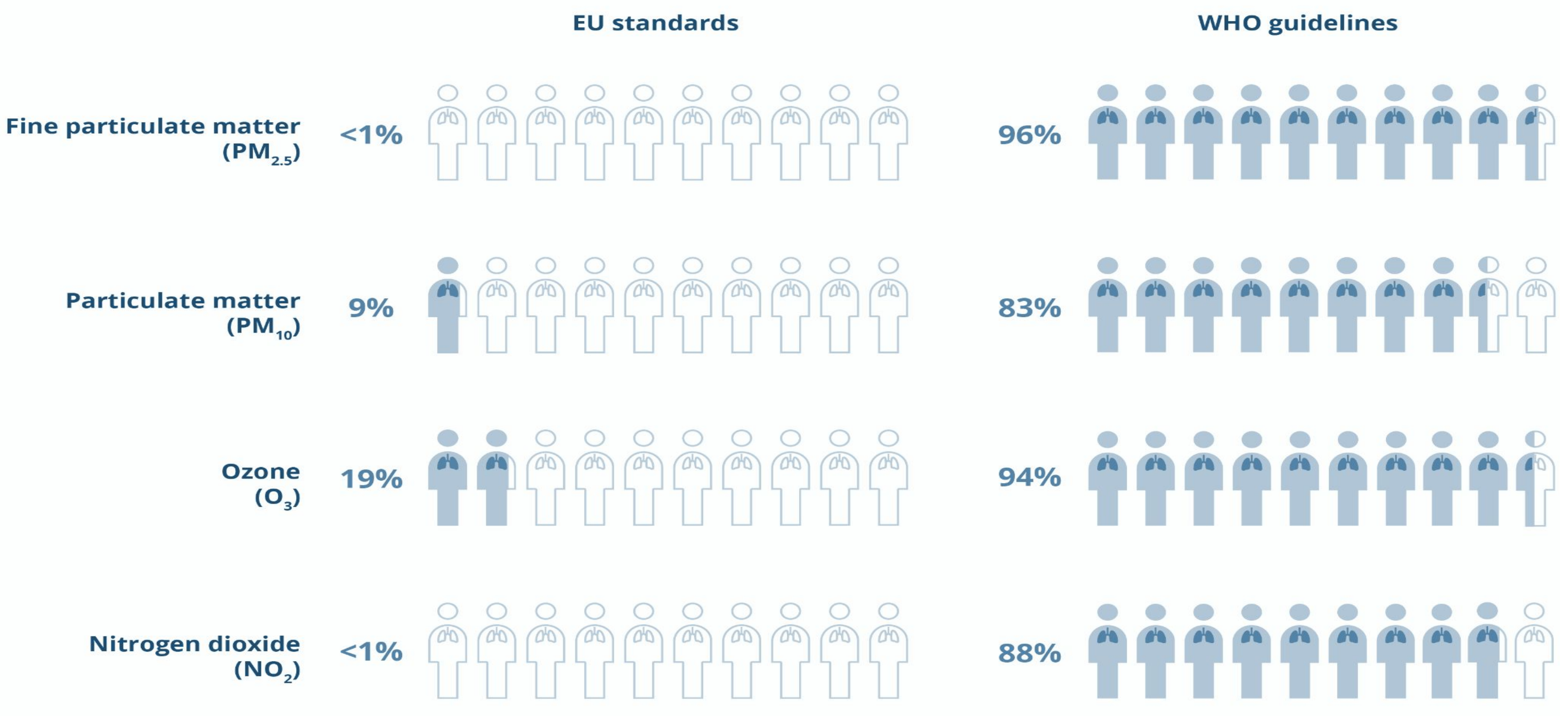
WHO AQG - 5 µg/m^3

1789 Total Sampling Points
3.80% Below Limit
96.2% Above Limit

Source: Concawe Air Quality Analysis Tool (CAQAT) using EEA's AQ e-Reporting Data

Air pollution remains a problem in the EU

2022 urban air pollution exposure exceeds EU standards & WHO guidelines



Source: https://www.eea.europa.eu/publications/europes-air-quality-status-2024

Air pollution remains a problem in the EU

Significant societal costs associated with air pollution

- **Health impacts:** Air pollution is the number one environmental cause of health impacts in the EU, with significant morbidity. Estimates of up to **300.000 premature deaths per year.**
- **Social impacts:** It **disproportionally affects vulnerable groups** - children, elderly, persons with pre-existing conditions, socioeconomically disadvantaged.
- **Environmental impacts:** Causes **eutrophication (74%) and acidification (5%)** of ecosystem area exceeding critical loads, as well as crop and forest damage.
- **Economic impacts:** It causes annual costs at **€231-853 billion (bn) in health impacts**, €8 bn in lost workdays, €4-12 bn in ecosystems damage, €10-11 bn in crop yield loss, €19 bn in forest damage, €1 bn in damage to buildings.
- **Europeans care about the air they breathe** (Eurobarometer 2022)

Revision of EU Air Quality Rules

- The **European Green Deal** aims to reduce premature deaths from fine particulate matter (PM2.5) by 55% by 2030 compared to 2005 levels, with a **goal of zero significant health impact from air pollution by 2050**.
- In **2022, the European Commission proposed more stringent air quality standards**, including halving the annual limit values for PM2.5 and NO2, and increasing air quality sampling points in cities.
- Co-legislators agreed on more ambitious EU air quality standards in February 2024, though these are still less strict than WHO guidelines. The **European Parliament adopted a revised directive in April 2024**.
- Next steps: -the official acceptance of the new legislation
  -acceptance in each Member State; followed by two year time for the implementation
  -periodic 5yrs review of network design and monitoring site locations (supported by modeling and/or **indicative measurements**)
  -if target criteria not met, a Member State has to present two year plan to meet the standard
  -all "transition" acts should become fully operational no later then 2040

EU Directive

Implementation, reporting and …justice

- Supersites combine multiple sampling points to gather long-term data on air pollutants covered by Directive, as well as on air pollutants of emerging concern (UFP, BC and NH3) and other relevant metrics.
- Modelling and indicative measurements may play a significant role in choosing the right location of the monitoring site (!NGOs, individuals)
- Reporting of all crucial pollutants on 1h time-base
- The right for compensation and justice in case of damage on human health (individuals or NGOs)
- Introduces sampling points for ultrafine particles (UFP), black carbon (BC), ammonia (NH3) or the oxidative potential of particulate matter.

What does the directive improve?

Environment and Health

- **Zero pollution** level by 2050
- Intermediate AQ standards
- Update of air quality standards (**stricter limit values**)
- **Regular review mechanisms** (5 yr)

Monitoring and assessment

- **Refined approach to AQ monitoring**, increased use of AQ **modelling** and/or **indicative measurements**
- Additional information on **representativeness of sampling points**
- Monitoring of **pollutants of emerging concern (UFP, BC and NH4)**

Governance and enforcement

- AQ plans for more **effective preventing of exceedances**
- Improved enforceability: **new provision on justice, compensation and penalties**
- **More "cross-border" collaboration** on AQ

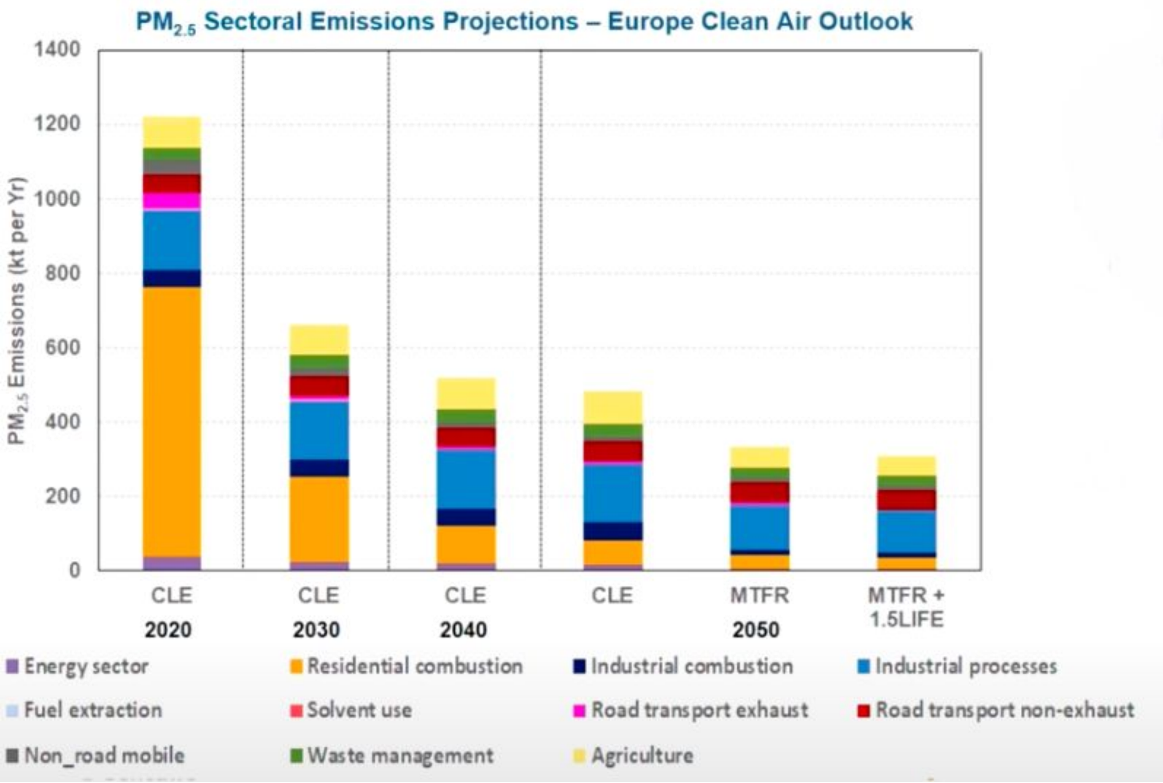
Information and communication

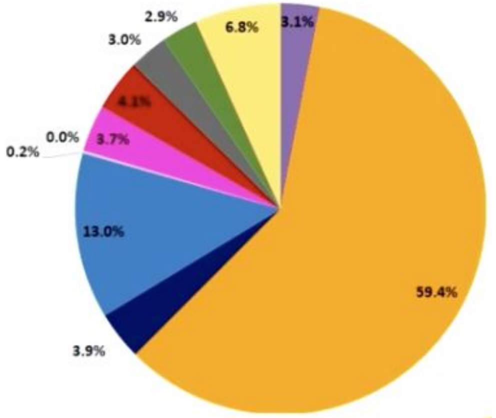
- **Up-to-date AQ information**
- Requirement to provide **hourly data reporting**
- Informing the public about possible health impact and provide recommendations

Source: Thomas Henrichs: Ambient Air Quality: The EU approach. March 18th, 2024 at the 15th CONCAWE Symposium.

Where to start, what are the next steps?

Understanding the pollution source(s) is a key.





Road traffic is NOT the main source of pollution.

Source: Concawe Air Quality Analysis Tool (CAQAT) using EEA's AQ e-Reporting Data

Centre for Research into Atmospheric Chemistry

CRAC

A TRADITION OF INDEPENDENT THINKING

UCC

University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Studies of Black carbon in Ireland

Stig Hellebust, presenting work by
John Wenger, Paul Buckley, Eimear Heffernan, Rosin Byrne

Centre for Research into Atmospheric Chemistry

- Based in the School of Chemistry at University College Cork
- Academic staff and research team leaders:
  - Professor John Wenger
  - Professor Andy Ruth
  - Dr Dean Venables
  - Dr Stig Hellebust
- The CRAC was set up in 1999 by Professor emeritus John Sodeau and Professor John Wenger, the current chair
- The research activity of CRAC is wide-ranging and encompasses laboratory, field and modelling studies

https://www.ucc.ie/en/crac/

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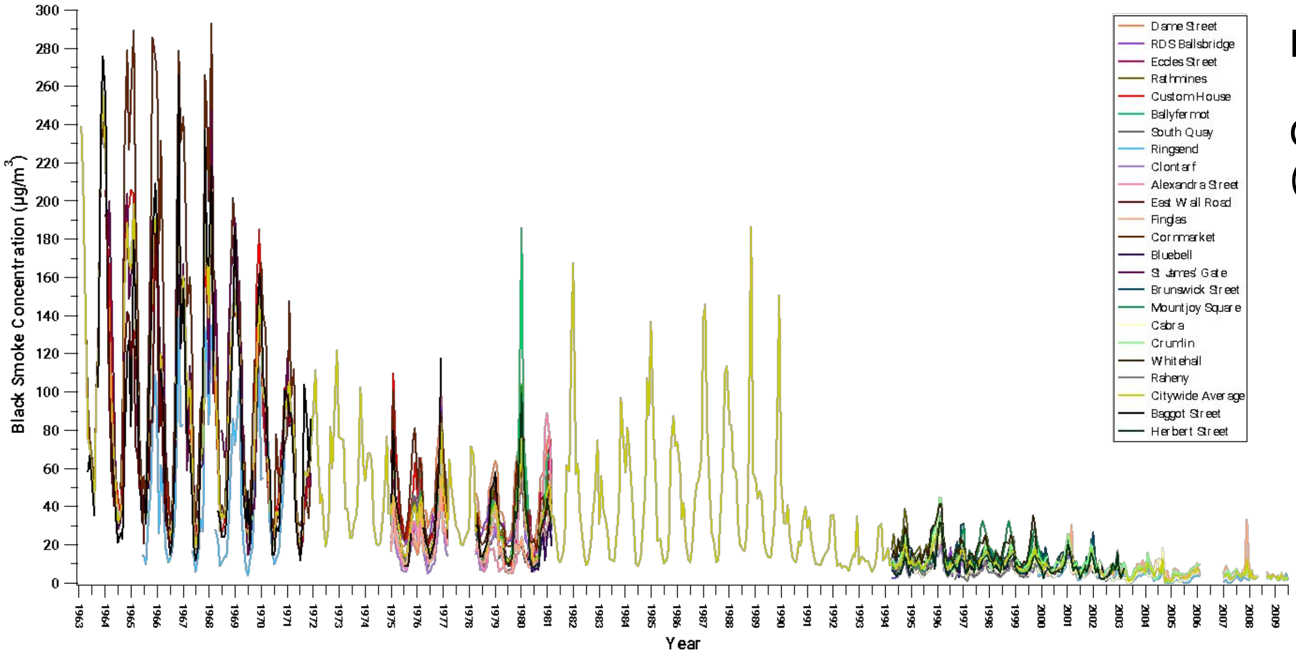
Historical Black smoke measurements in Dublin



BS measured 1963 – 2009

CAFÉ Directive (2008/50/EC) : No BC

Monthly average BS concentrations at monitoring sites in the Dublin city area 1963 – 2009 (Data from Dublin City Council). The citywide average value is also shown (Paul Buckley 2020)

Legislative changes and impacts on BS levels

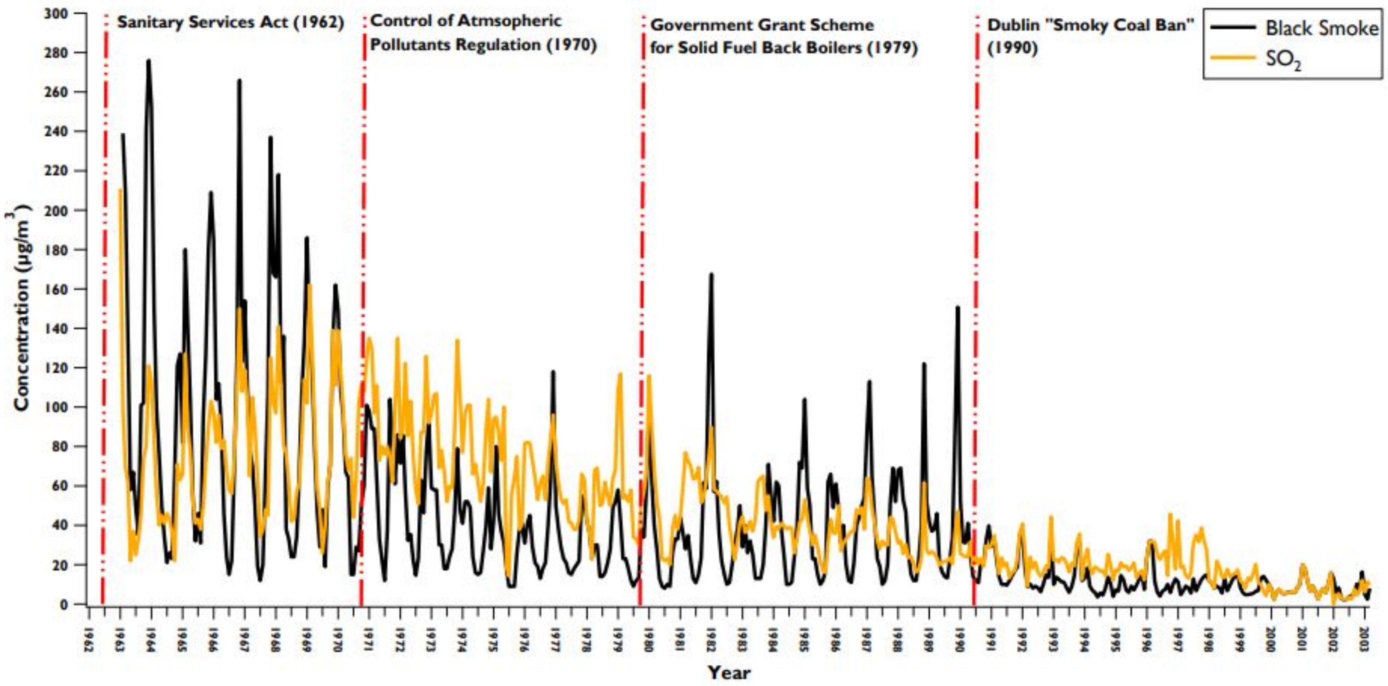


Figure 5.8. Monthly average concentrations of black smoke (black) and SO_2 (yellow) in Dublin city from Baggot Street and Herbert Street (1963 – 2003), supplemented by citywide average values (1972 – 1974, 1977 – 1978, and 1981 - 1994). Some key legislative changes are marked in red.

P. Buckley, PhD thesis, 2020

Black smoke reinterpreted as black carbon

BS: Absorption of reflected light
BC: Absorption of transmitted light

Conversion based on Heal and Quincey (2012)

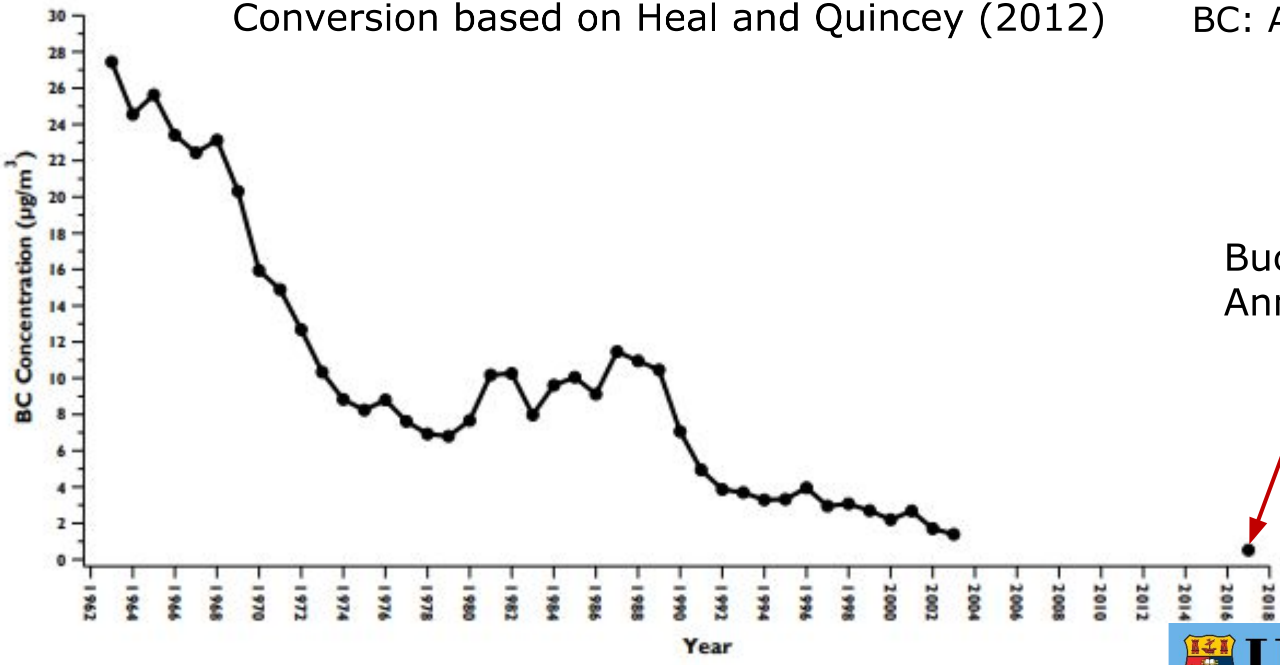


Figure 5.19. Annual average calculated BC concentrations (µg/m³) in Dublin, 1963 – 2017.

Buckley, 2017
Annual average < 1 $\mu g/m^3$

P. Buckley, PhD thesis, 2020

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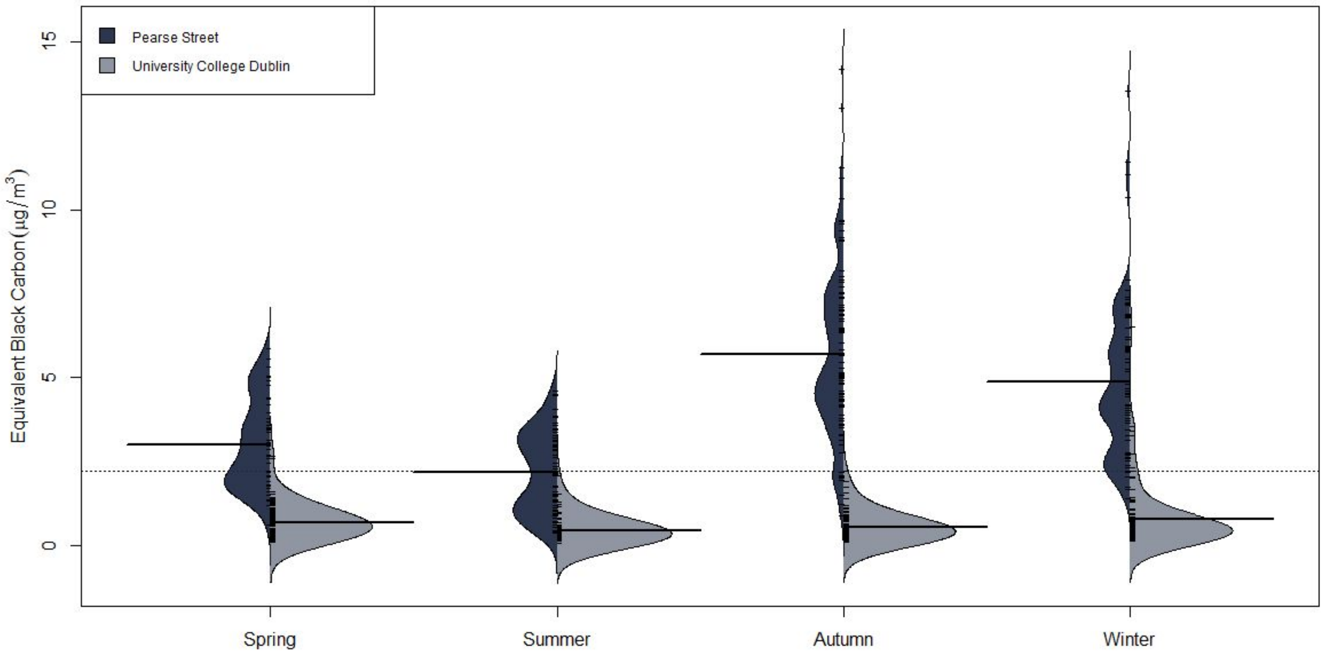
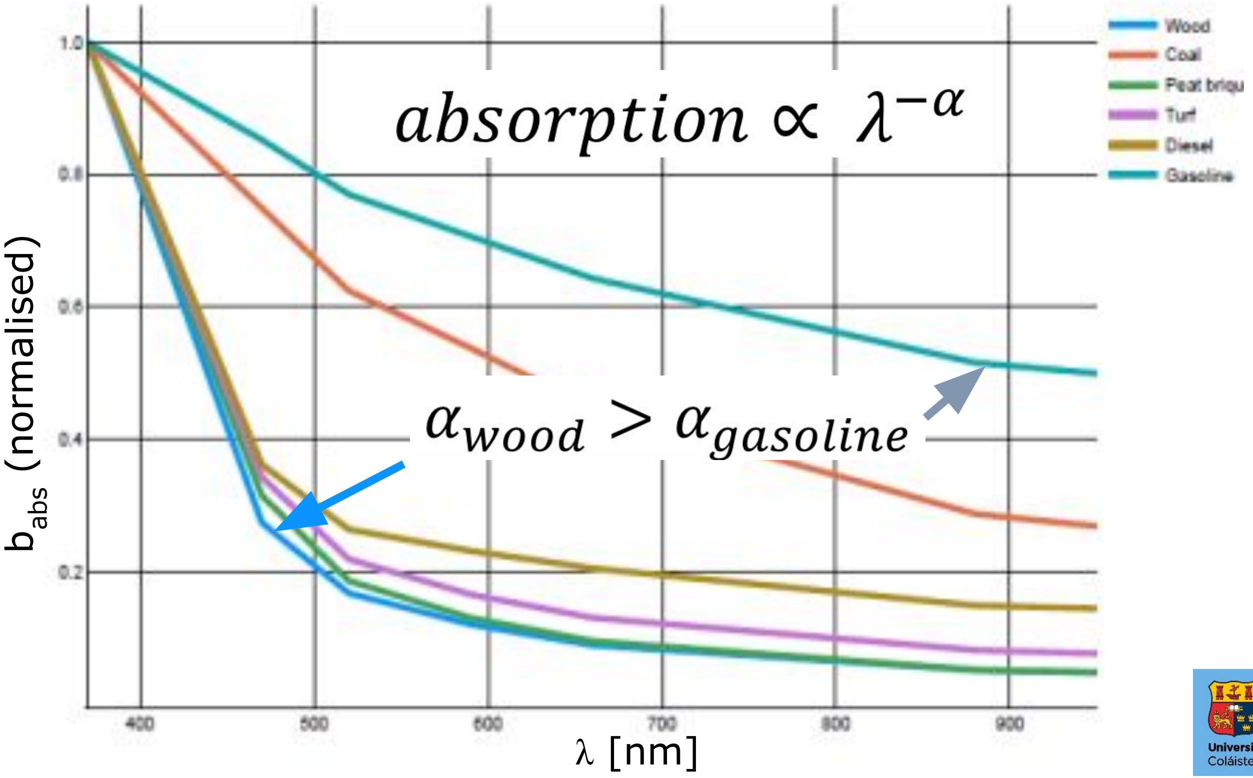
Dublin 2018: Suburban << City centre



Despite great improvements, levels in the city centre are still considerable, and much higher than in the suburbs

Seasonal distribution of daily average eBC concentrations measured at Pearse Street (September 2018 – August 2019) and University College Dublin (September 2017 – August 2018). Analysis at Pearse Street was based on 49, 74, 91 and 72 sampling days in spring, summer, autumn and winter, respectively. **(Eimear Heffernan, PhD Thesis, 2022)**

Multi-wavelength aethalometer data – revealing the fuel type



- Some fuels (wood, peat, turf) shown enhanced absorbtion in the UV end of the spectrum (UVBC)
- This is due to organic compounds ("Brown Carbon") formed from combustion of these fuels
- Black carbon from combustion of fossil fuel does not absorb as strongly in the UV
- So the contributions of fuel types (fossil fuel vs. biomass) can be estimated separately!
- Two-parameter model!

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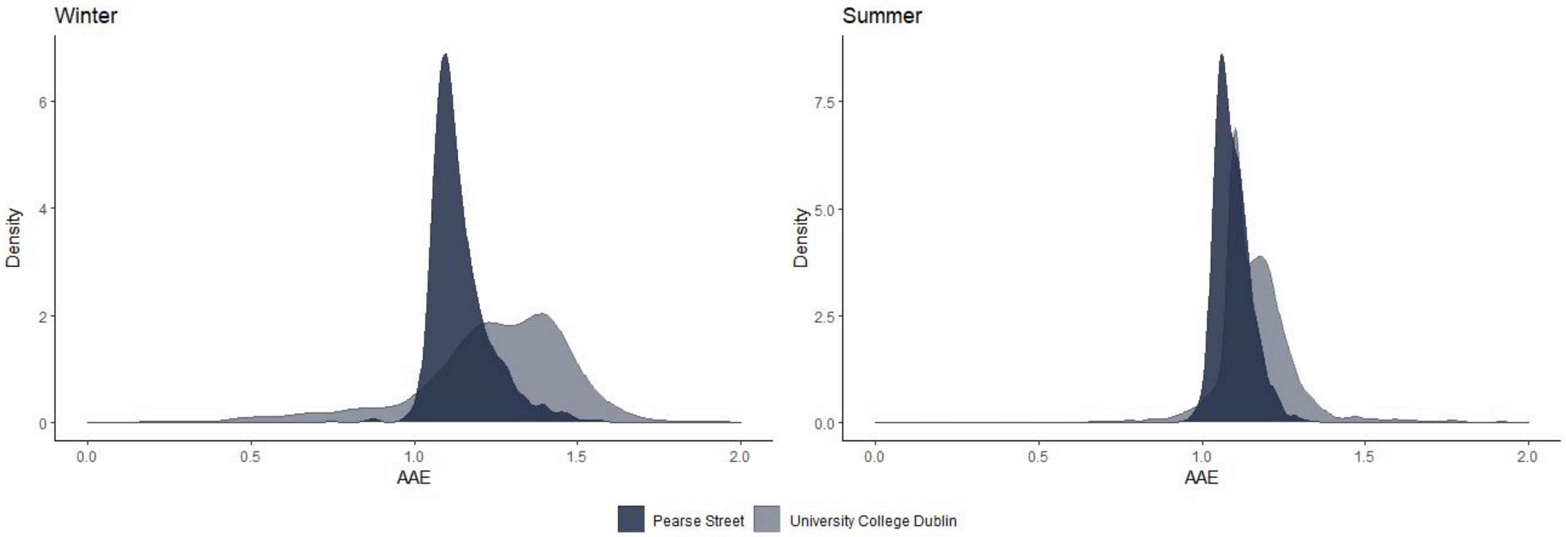
UVBC: Suburban >> City Centre

$$\alpha_{wood} > \alpha_{gasoline}$$



Distribution of absorption Ångström exponent calculated for Pearse Street (September 2018 – August 2019) and University College Dublin (September 2017 – August 2018) during summer and winter. ***Eimear Heffernan, PhD Thesis 2022***

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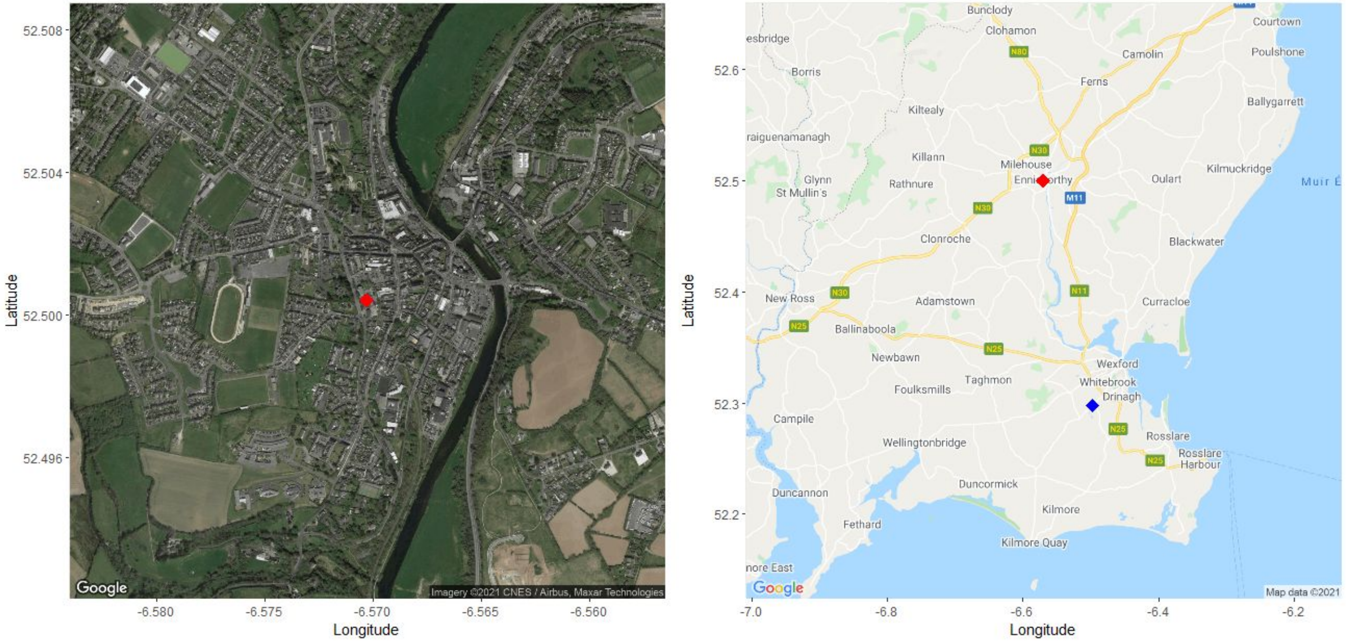
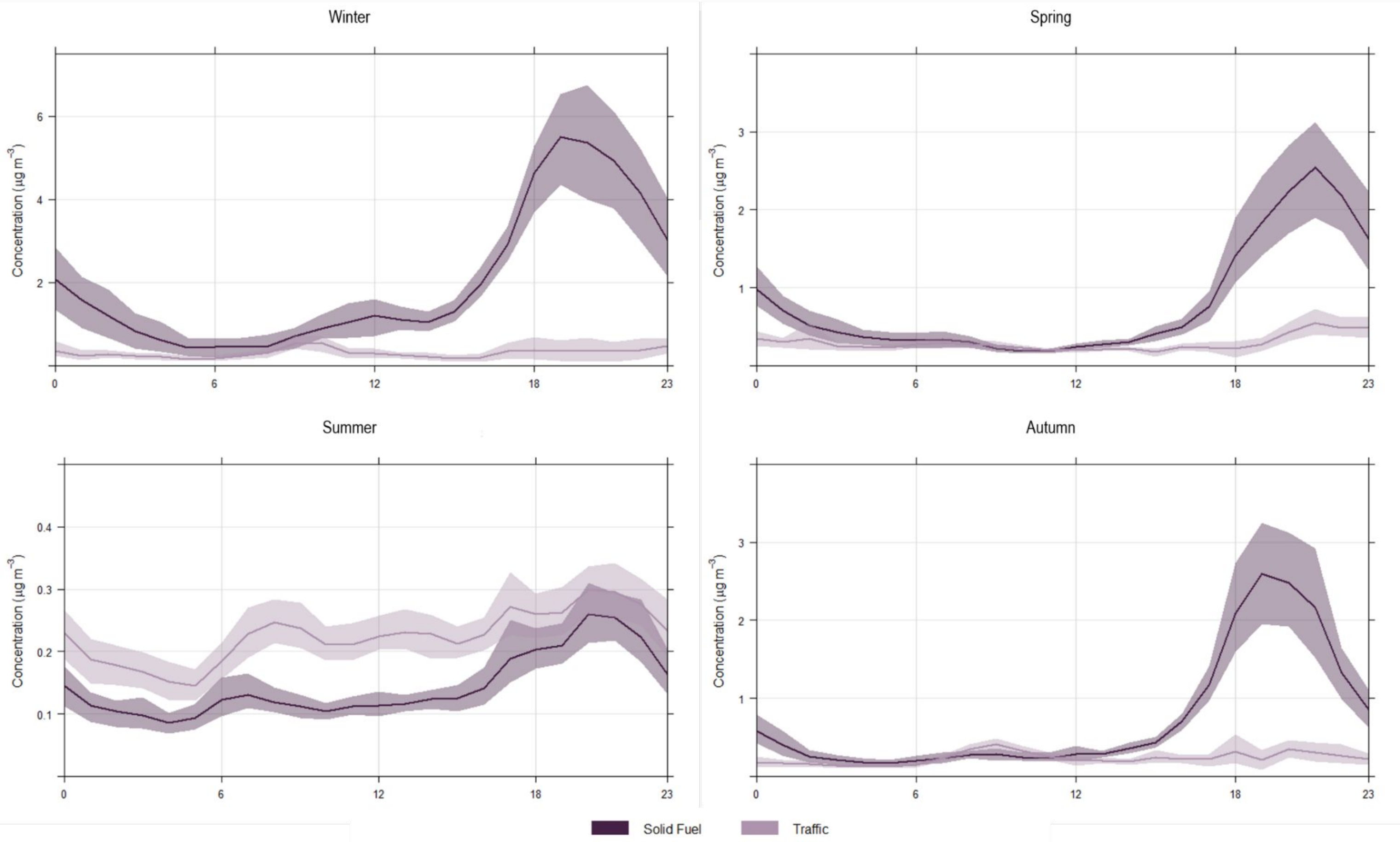
Small towns – high BC levels



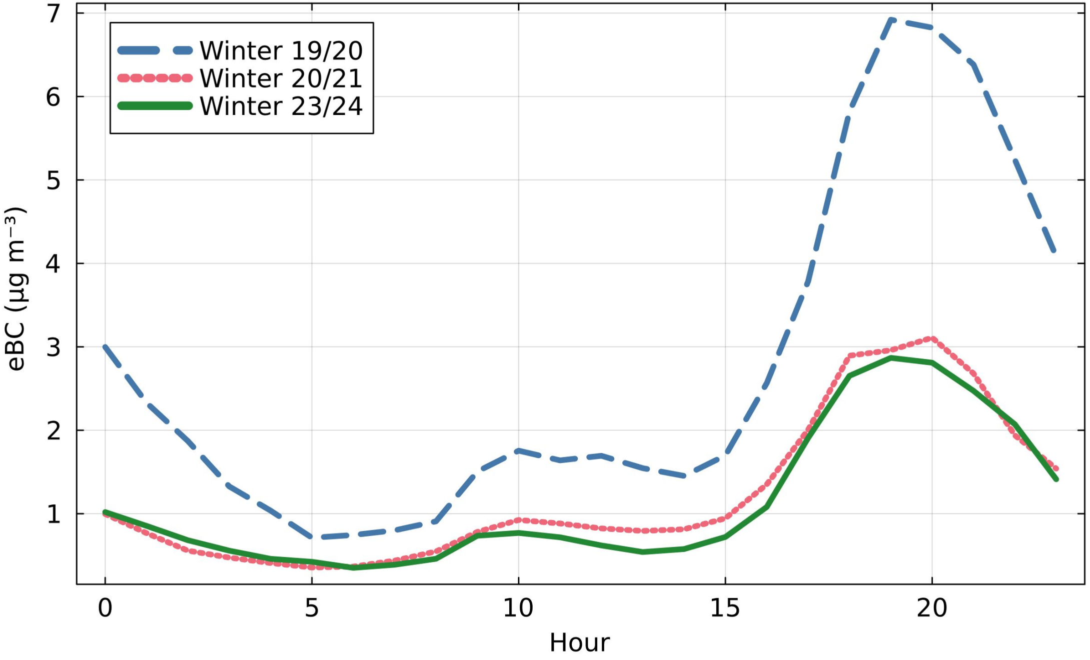
Satellite image of the town of Enniscorthy, Co. Wexford with red marker indicating the location of the sampling site (left). The relative locations of the sampling site in Enniscorthy (red) and the weather station (blue) at Johnstown Castle, Co. Wexford (right).
E. Heffernan 2022



The main problem here is solid fuel burning!

Seasonal diurnal profiles of eBC attributed to solid fuel burning and traffic-related emissions in Enniscorthy (December 2019 – November 2020). ***E. Heffernan 2022***

It’s improving!



Seasonal diurnal profiles of eBC in Enniscorthy 2019 - 2024
(Byrne *et al.*, in preparation)

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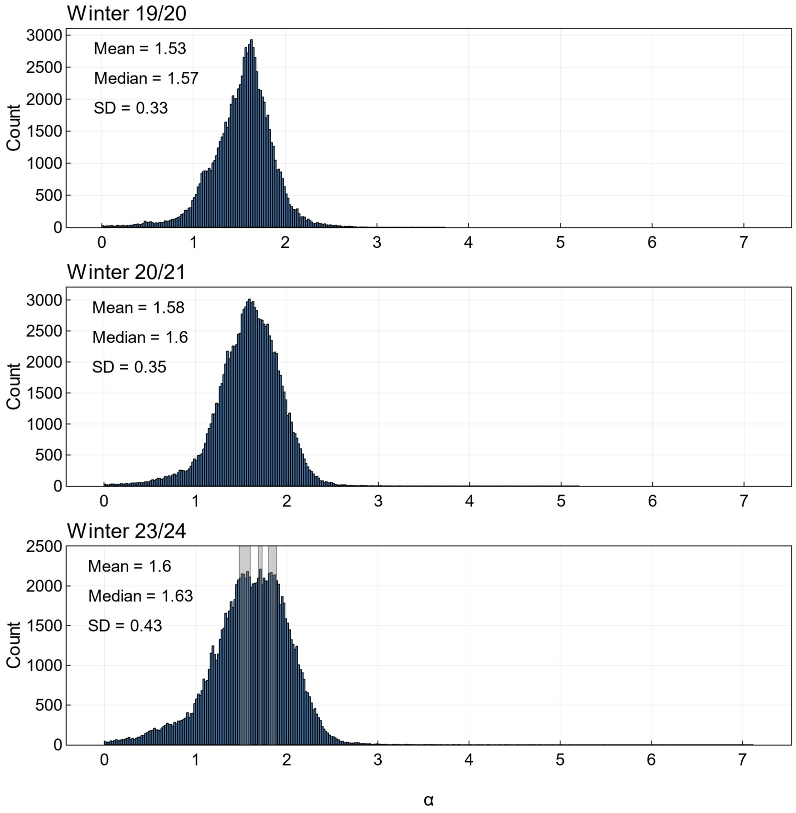
School of Chemistry

The nature of BC changing, too

Frequency distribution and summary information of the absorption Ångström exponent measured in Enniscorthy during each winter period.

The characteristic absorption is changing – this shows that the fuel mixture is changing!

The influence of "brown carbon", or UVBC, is increasing



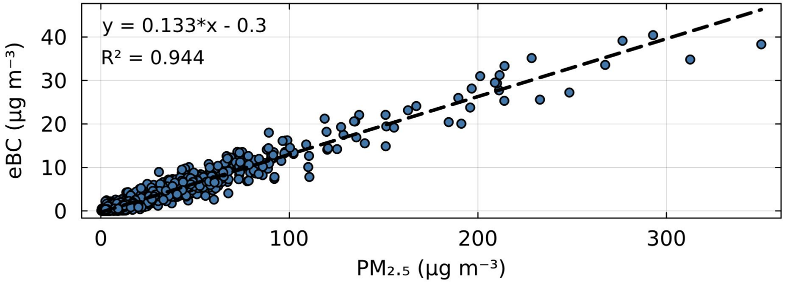
Byrne *et al.*, in preparation

BC and $PM_{2.5}$

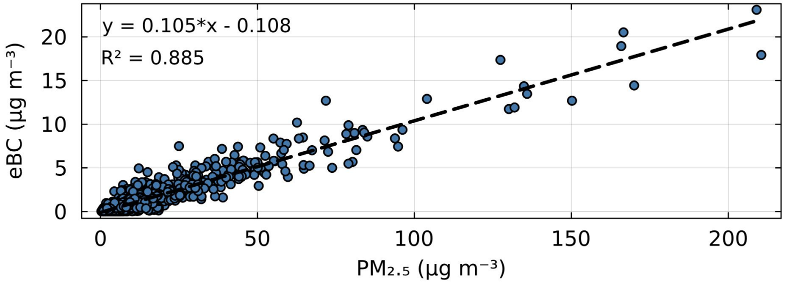
Seasonal comparison of $PM_{2.5}$ and eBC over three winters:

- *They become less correlated*
- *The fraction of $PM_{2.5}$ that is BC is reducing*
    - *Suggestive of changing fuel mixture*
    - *$PM_{2.5}$ less influenced by primary emissions*
        - *more influenced by secondary aerosol?*
- *Combined measurements of BC/BrC and $PM_{2.5}$ tell a more comprehensive story than they do separately*

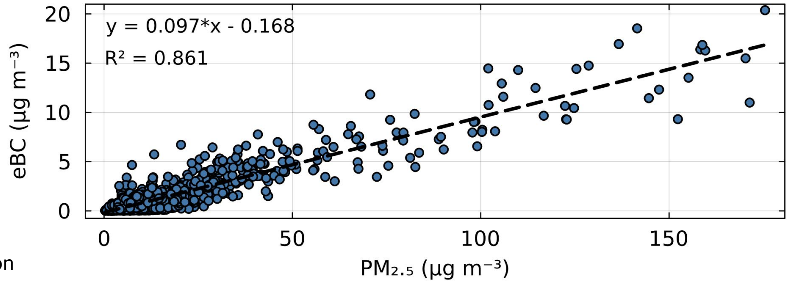
Winter 19/20



Winter 20/21



Winter 23/24



Byrne *et al.*, in preparation

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Future opportunities from expanding BC monitoring network

- Continued monitoring for evidence of changing fuel mixture, impacts of changing legislation
- Developing aethalometer model for mixed fuel environments
  - Optimising location-specific model parameters
  - From two-parameter model to three-parameter model
- Augmenting AQ networks with BC data
  - Information on the direct contribution of combustion sources to $PM_{2.5}$
  - Mapping the changing nature of carbonaceous aerosol
  - Spatial variation – environment types – urban, rural, roadside
  - Exposure assessment

Thank you

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School of Chemistry

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Empowering the world to reduce air pollution

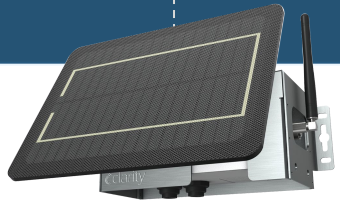
We are on a **mission** to empower the world to **reduce air pollution**

Lee Swanson

Regional Account Manager

A fully integrated air quality monitoring service

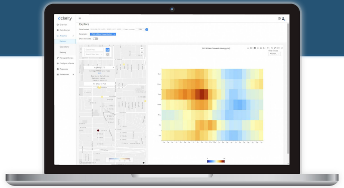
Sensing-as-a-Service℠



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

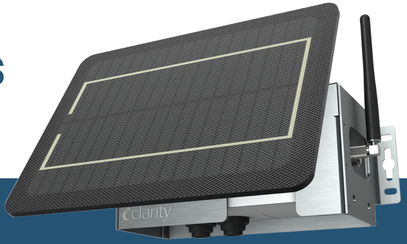
Easy installation in 10 minutes or less

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



Wind Module

Determine where air pollution is coming from.

Ozone Module

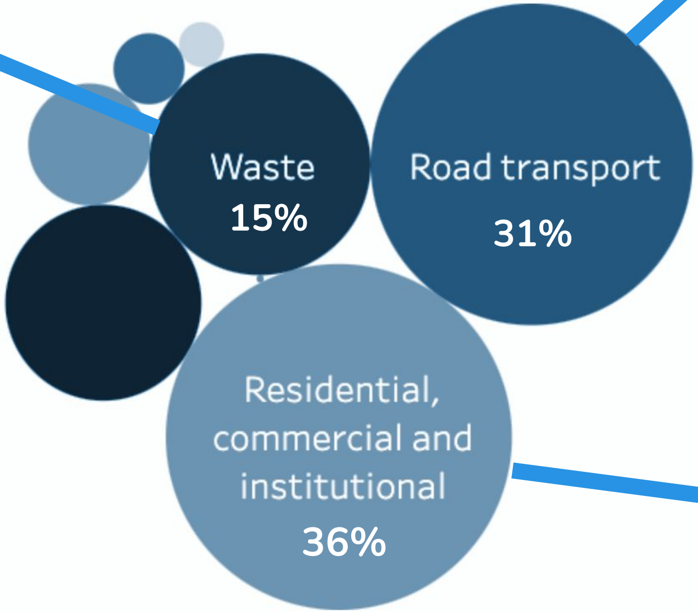
Confirm ozone attainment with this FEM-capable device.

Black Carbon Module

Understand the composition and sources of particulates.

Black Carbon sources in the EU

Contributing sectors and activities



Source: European Environment Agency, June 25th, 2024. Air pollution in Europe: 2024 reporting status under the National Emission reduction Commitments Directive

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 $PM_{2.5}$, NO_2 and BC

Deploy anywhere with Clarity

Built for continuous, outdoor deployment

- Field deployment takes a few minutes
- Outdoor enclosure protects against temperature and environmental conditions
- Robust pump for 2 years continuous operation without flow calibration
- Solar operation requires only 40 minutes of direct sunlight per day
- Battery for 14-day operation without sunlight
- Seamless cellular connectivity with via Clarity Cloud through companion Node-S
- Low maintenance with long filter tape life

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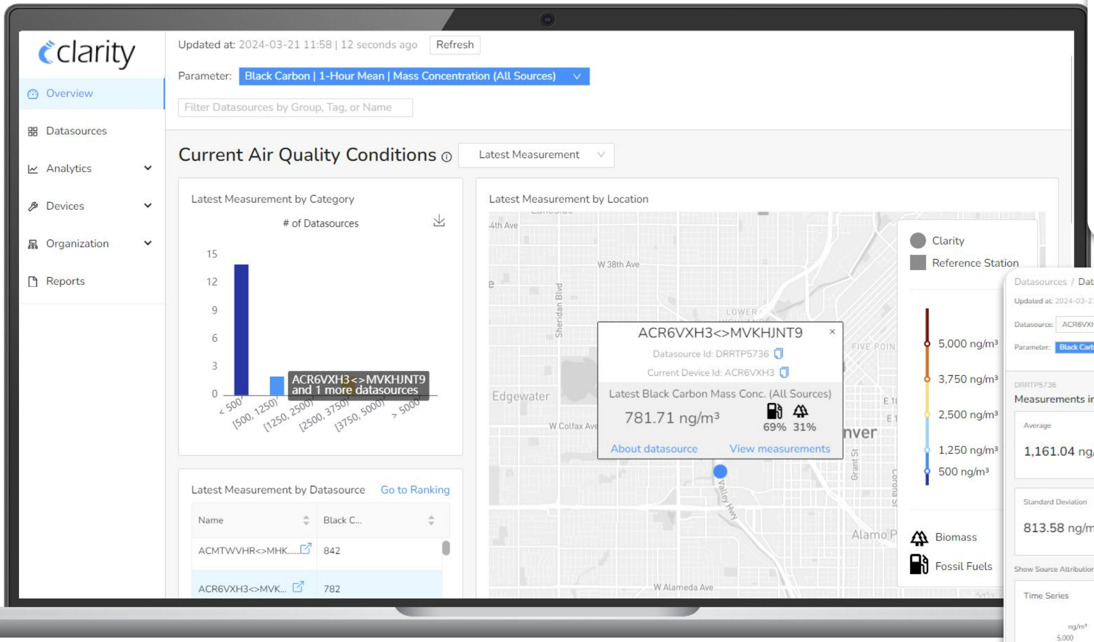

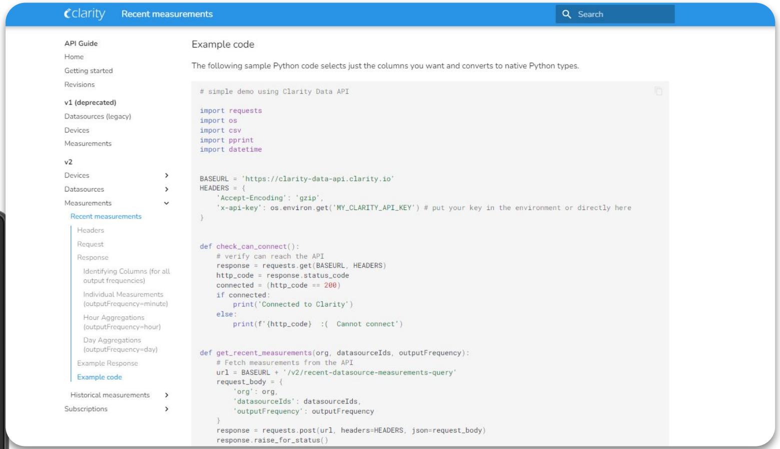

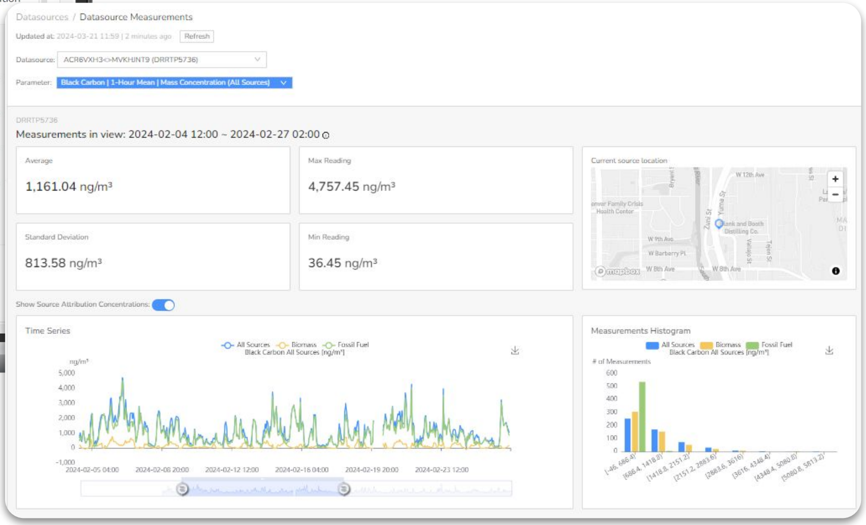

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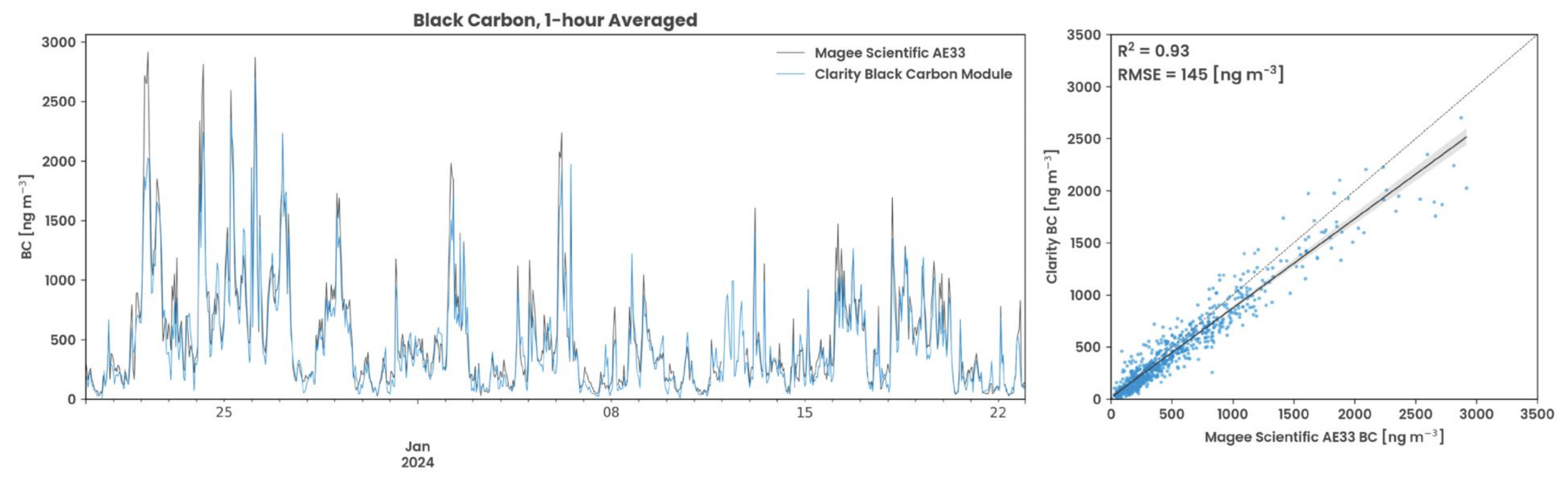
Best in class data quality

AethLabs & Clarity Black Carbon Module

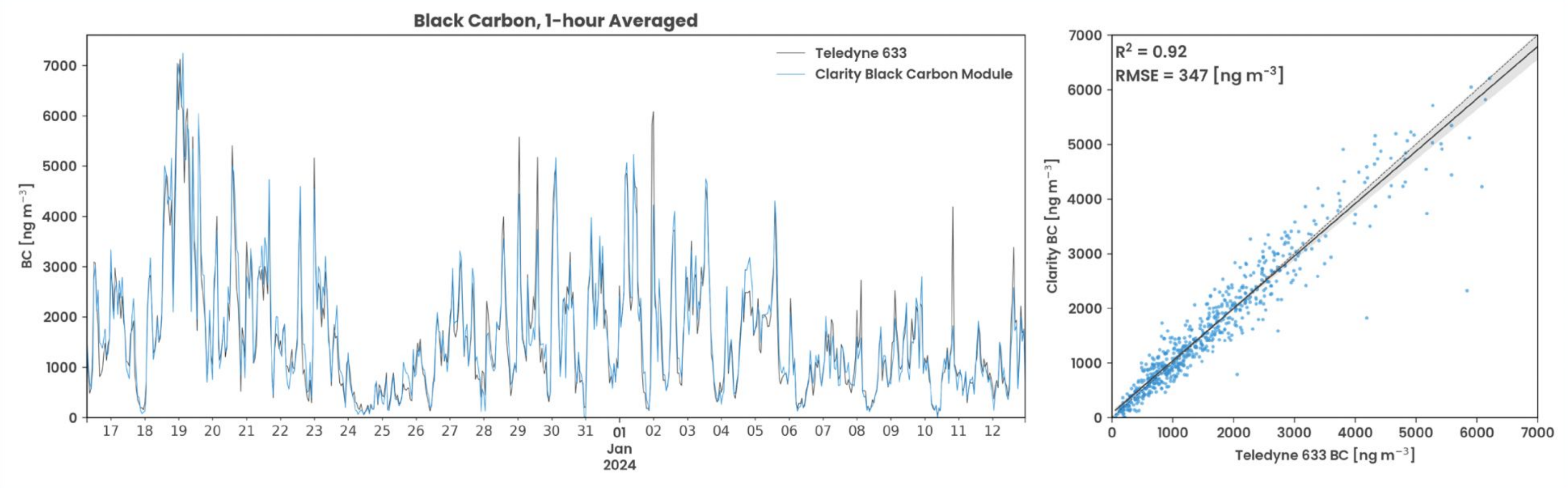
BERKELEY, CA, USA



Best in class data quality

AethLabs & Clarity Black Carbon Module

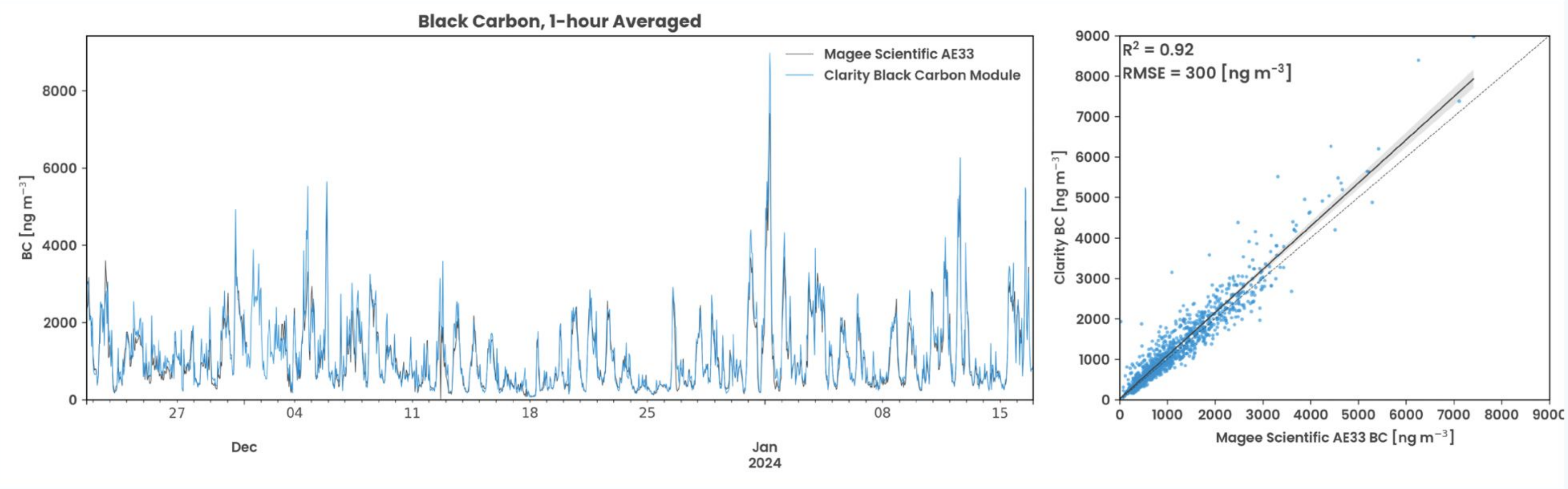
DENVER, CO, USA



Best in class data quality

AethLabs & Clarity Black Carbon Module

BROWARD COUNTY, FL, USA



What makes the Black Carbon Module unique?

AethLabs & Clarity Black Carbon Module

1

Ease of deployment

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Seamless data access

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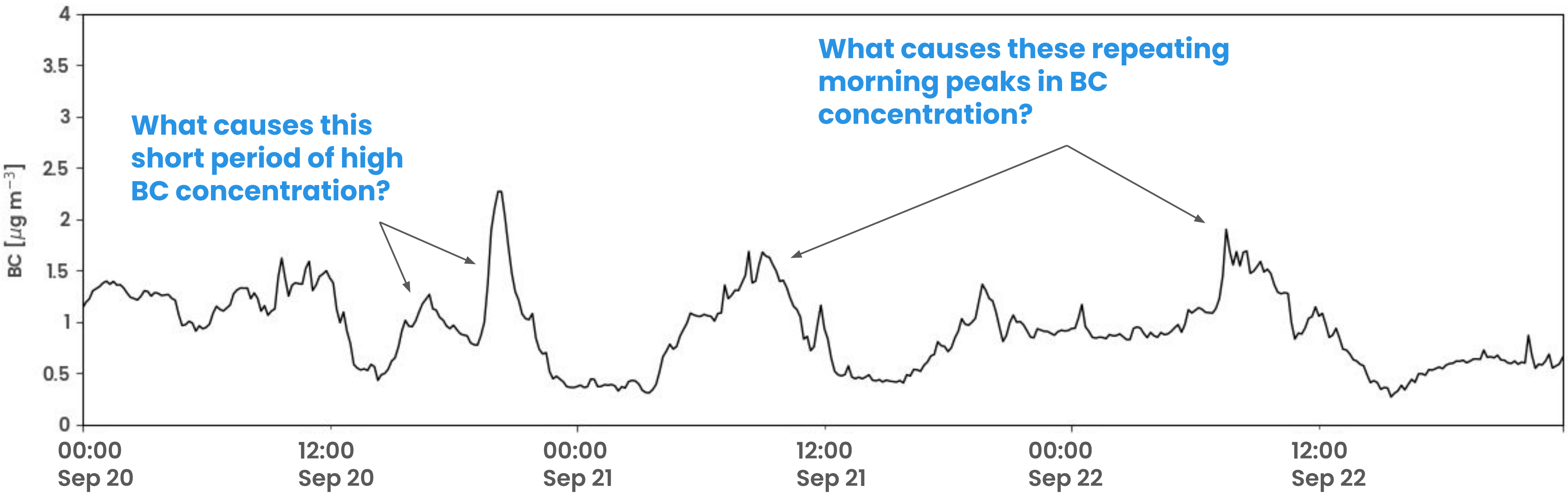
Best-in-class data quality

4

Collocated $PM_{2.5}$, NO_2 and BC

Case Study: Collocated $PM_{2.5}$ & Black Carbon

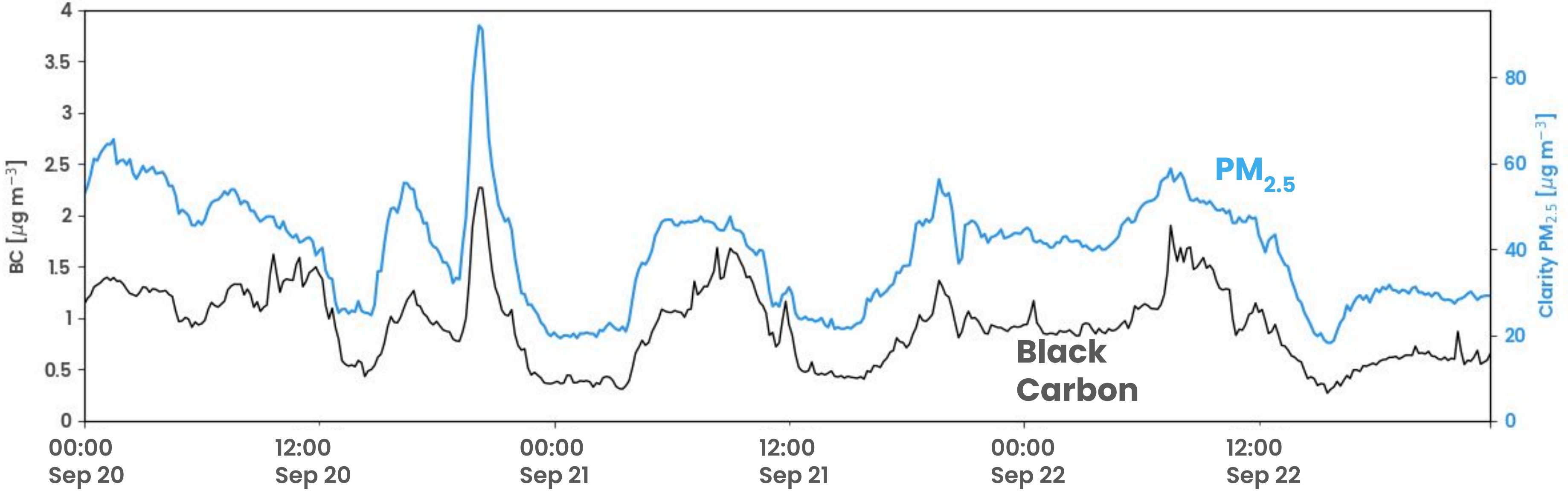
What's driving $PM_{2.5}$ air pollution in Berkeley, California?



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?

Case Study: Collocated $PM_{2.5}$ & Black Carbon

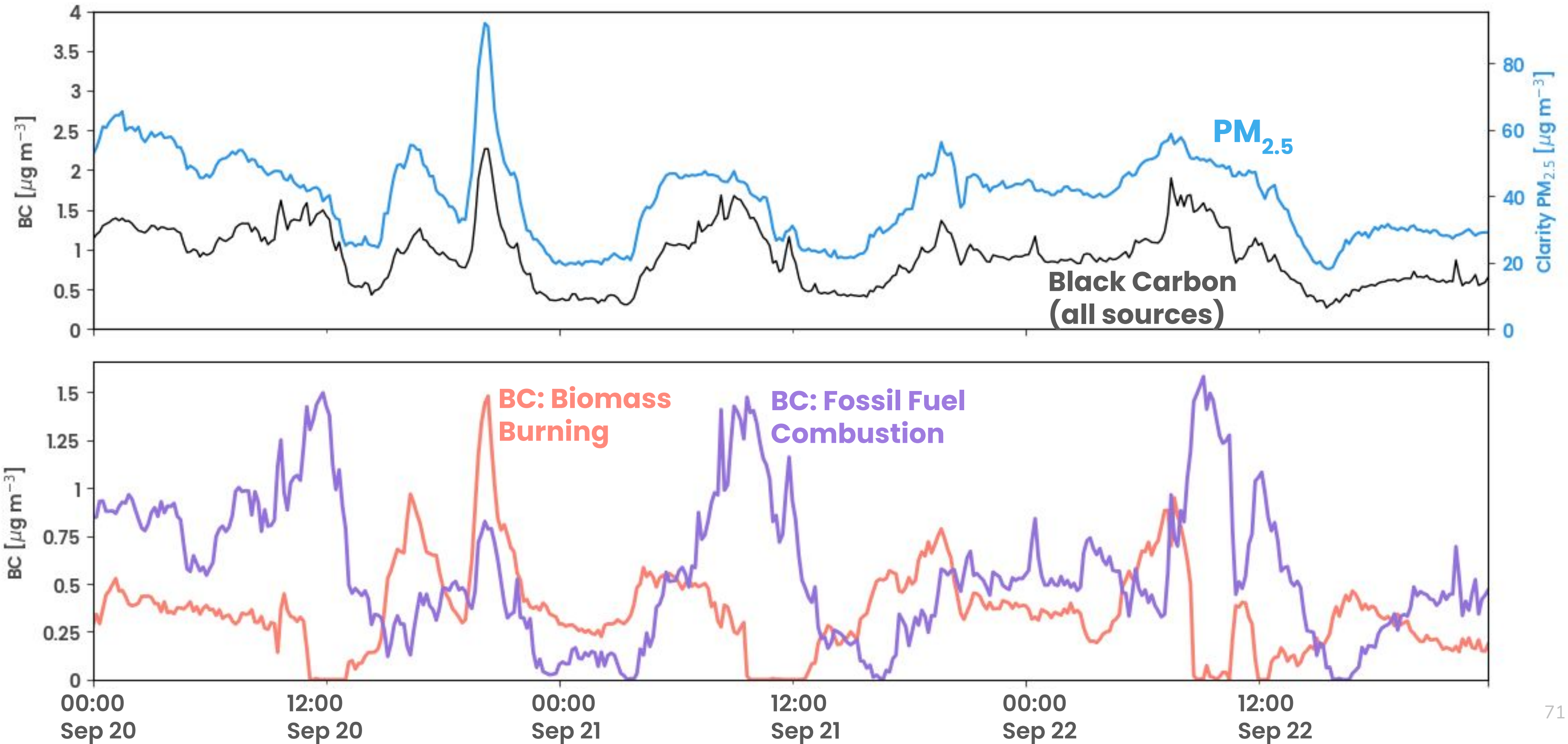
What's driving $PM_{2.5}$ air pollution in Berkeley, California?



$PM_{2.5}$ 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.

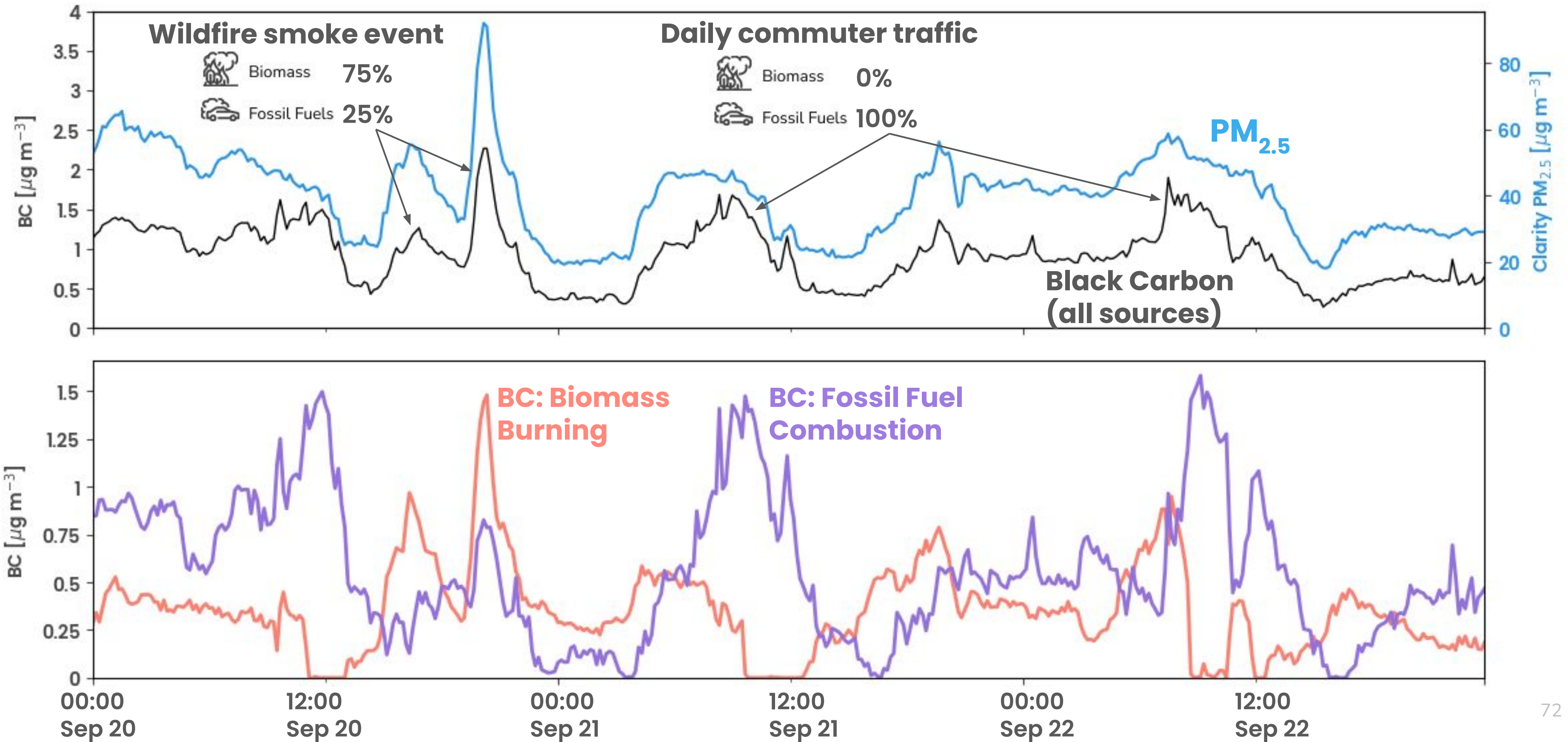
Case Study: Collocated $PM_{2.5}$ & Black Carbon

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



Case Study: Collocated $PM_{2.5}$ & Black Carbon

We can further separate the combustion sources



Case Study: Collocated PM

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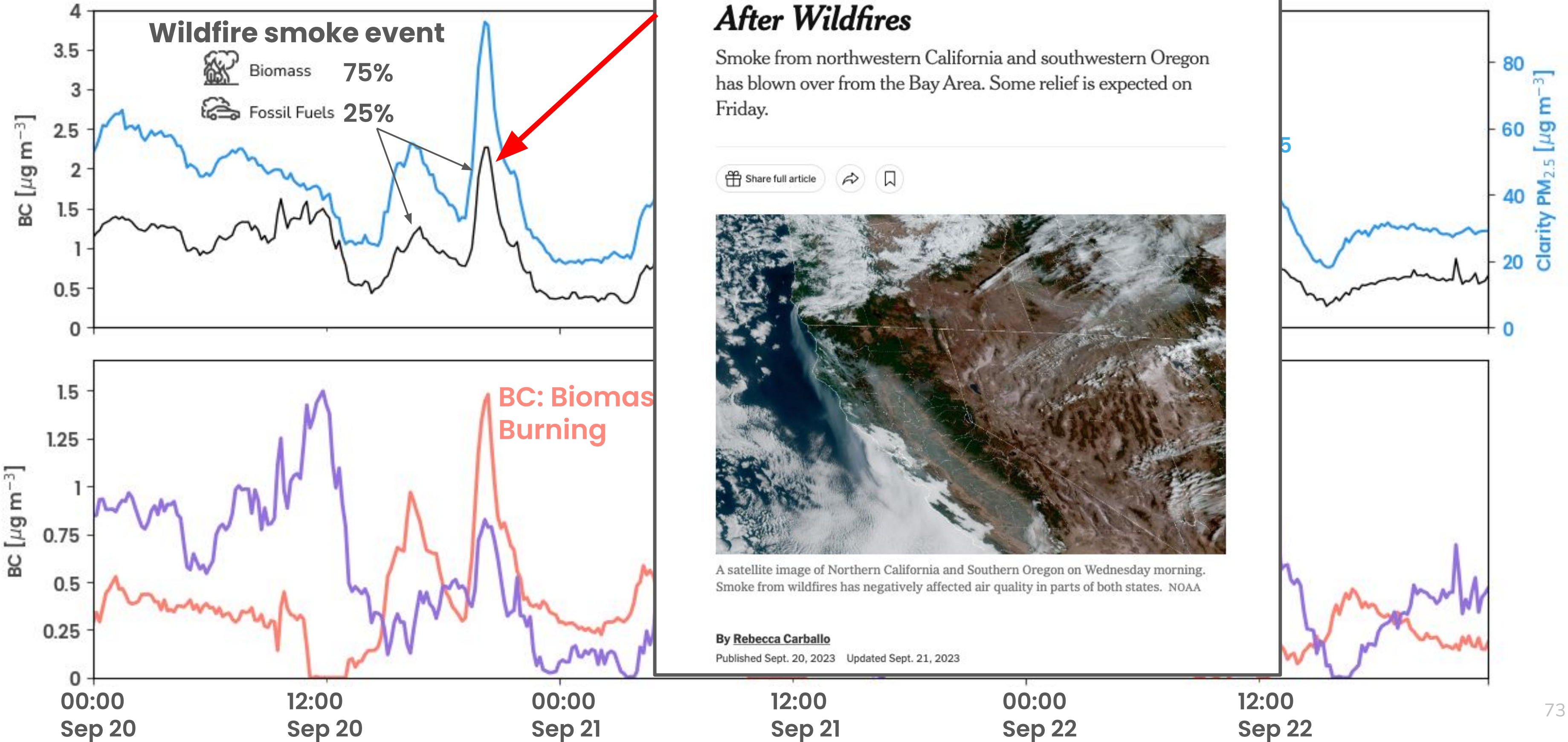


The New York Times

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

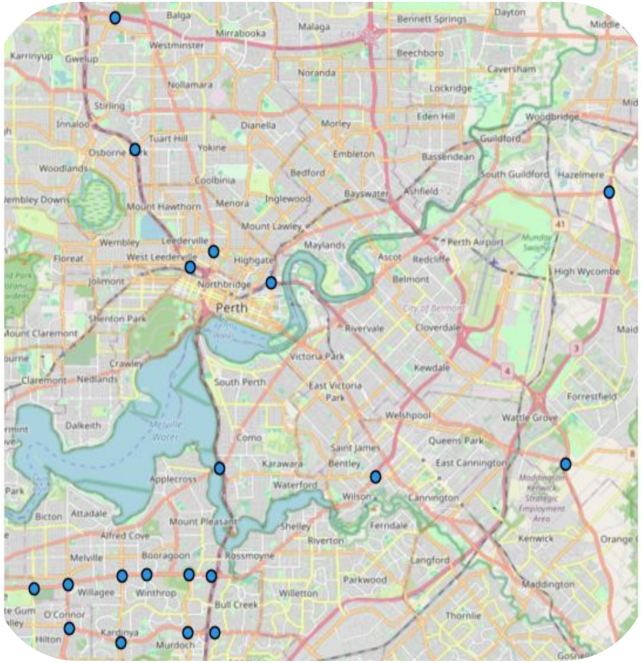
By Rebecca Carballo

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

Case Study: Collocated NO_2 and Black Carbon

Perth RAC Air Health Monitor (200+ sensors) Traffic Study

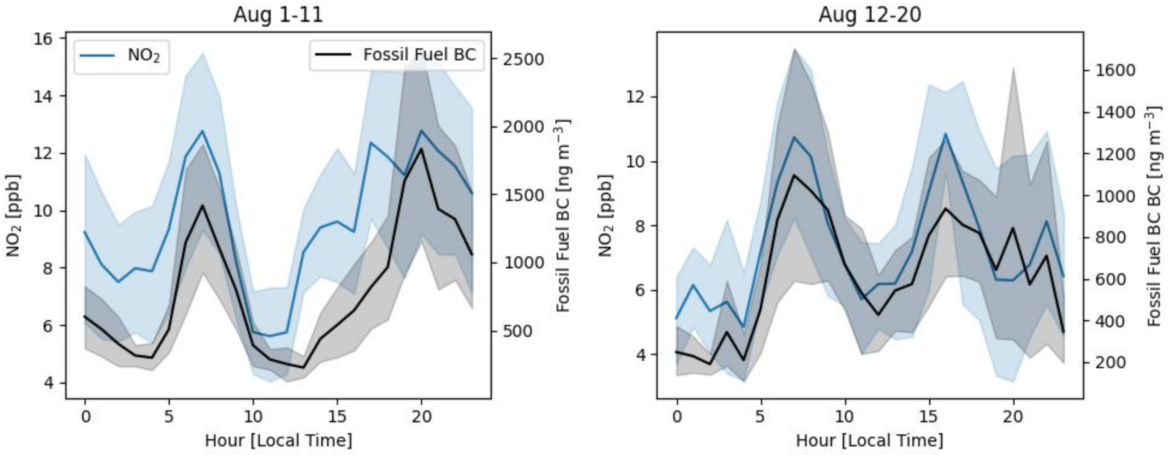
- **Node-S and Black Carbon Modules** deployed at 20 Main Roads Western Australia sites
- Spread out geographically across Perth along major roads and intersections
- Allows for **insights into local traffic impacts on pollution and regional air quality events**



Case Study: Collocated NO2 and Black Carbon

Diurnal NO_2 pattern strongly associated with fossil fuel BC

- Two periods with differing air pollution profiles
  - **August 1st-11th:** Wildfire-impacted
  - **August 12th-20th:** Non-fire period
- **Diurnal pattern of NO2 correlated with diurnal profile of the Fossil Fuel BC** measured by the Clarity Black Carbon Module for both periods.

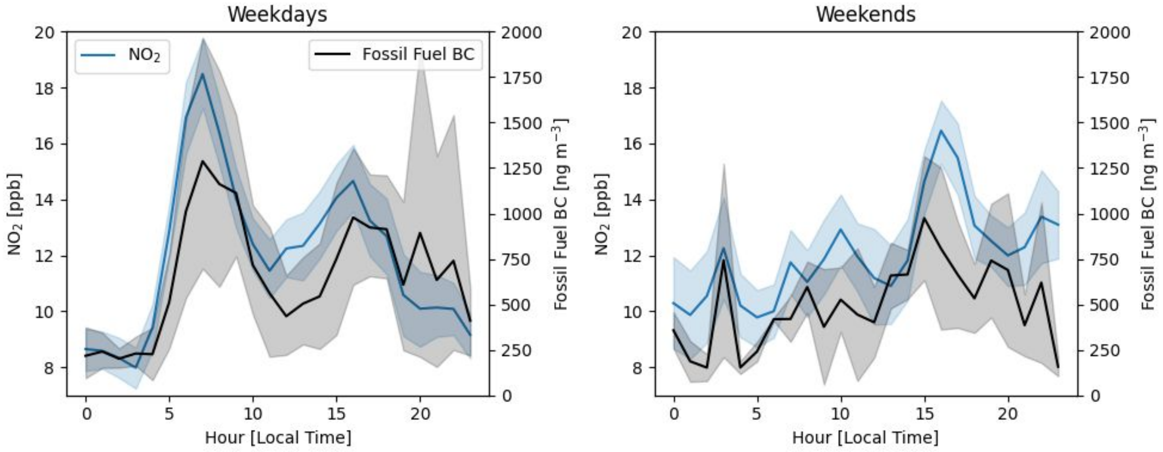


This strongly suggests a traffic source impacting daily air quality across Perth.

Case Study: Collocated NO2 and Black Carbon

Both BC and NO_2 show change in diurnal pattern for weekdays vs. weekends

- Diurnal profiles of NO2 (left hand y-axis) and fossil fuel BC (right hand axis) on weekdays (left) and weekends (right) during August 12-21.
- Both NO2 and fossil fuel BC show a notably different diurnal pattern on weekends.



The morning peak (commonly associated with commuter traffic) is missing on weekends.

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 $PM_{2.5}$, NO_2 and BC**

Cost comparison for 1 year of continuous monitoring

AethLabs & Clarity Black Carbon Module

	Multiwavelength Aethalometer		Dual Wavelength Aethalometer
	Magee AE33	MetOne BC1054	MetOne BC 1060
			
Savings with Clarity Black Carbon Module	$36,430	$30,910	$14,590
	80%	78%	62%

Source: Black Carbon Monitoring Feasibility Report, June 2024. Prepared by Mote Limited Consultancy for NZ Ministry for the Environment.

Additional questions?

Contact us or visit the Clarity website

We’re here to answer any questions!

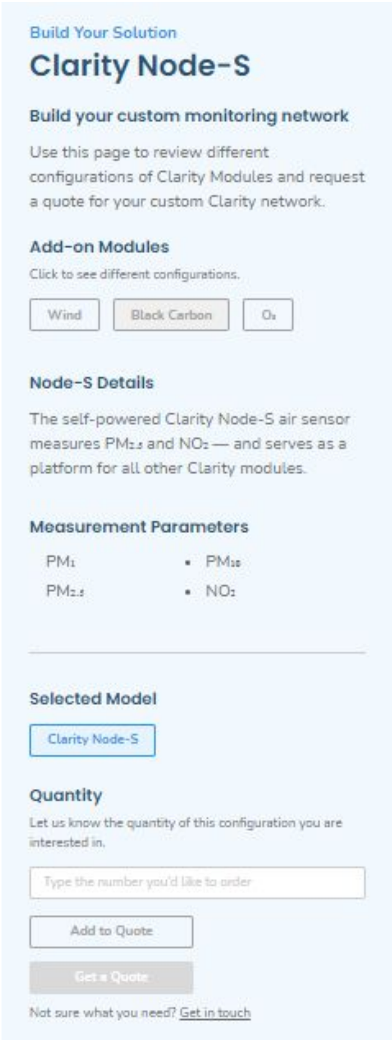
hello@clarity.io

Learn more on the Clarity website

clarity.io

Get a quote for your desired configuration

clarity.io/build-your-solution



clarity AETHLABS

Thank you!

Questions?