



AVL



Advanced Air Quality Assessment by Ultrafine Particle and Black Carbon Monitoring

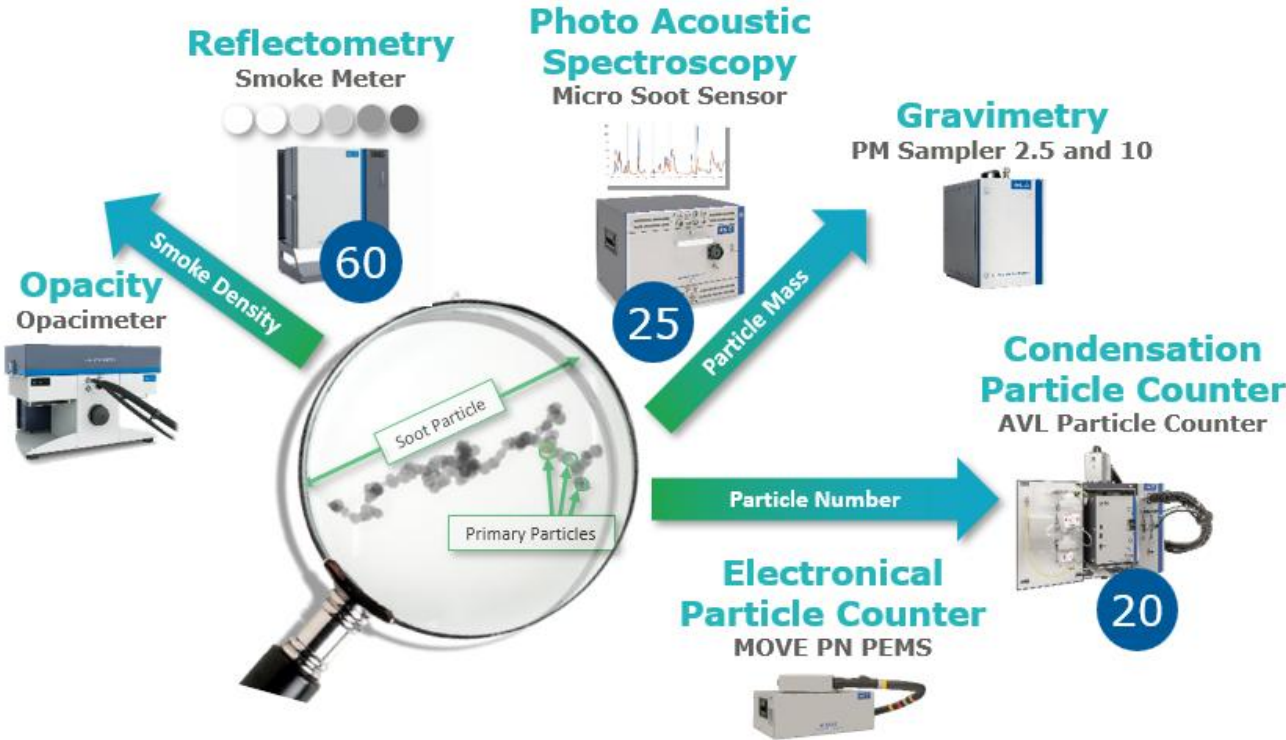
Petra Kotnik, J. Murg, Ch. Dardiotis, S. Martikainen, H. Reingruber

AQRTE 2026 Symposium, 9th September 2026

AVL Aerosol Measurement



From Exhaust to Exposure



2024



AVL UltraFine Particle Monitor

2027

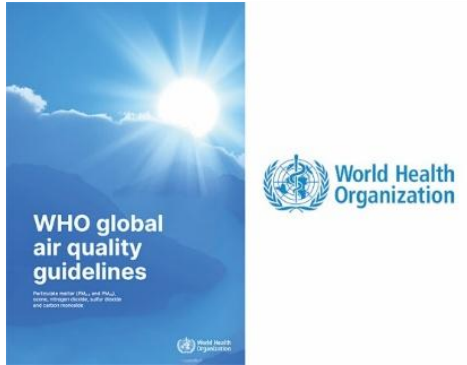


AVL Black Carbon Monitor



● Years of AVL expertise

UFP and BC Monitoring – a new Regulatory Focus



Latest Release: 2021



Source: web; 25.04.23;
[WHO releases updated Global Air Quality Guidelines \(rehva.eu\)](#)

Air pollution caused 4.2 million premature deaths worldwide in 2019. (WHO, [Link](#))

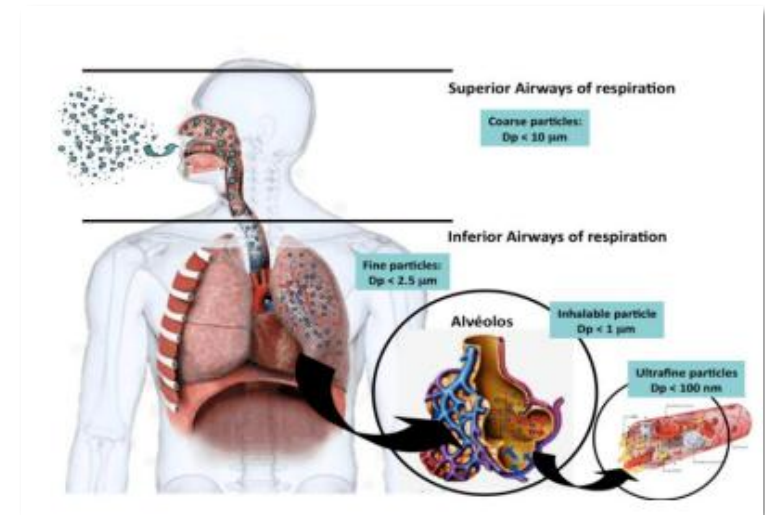
WHO: - Air Quality Guidelines (AQG) include and continuously refine limits of SO₂, NO₂, O₃, CO, PM₁₀ and PM_{2.5}.

Ultra Fine Particles (UFP) are particles <100nm; for the 1st time introduced as “metric of interest”

Ambient Air Quality Directive EU-2024/2881 –
Mandate of UFP and BC monitoring

Harmonization of

- **UFP** measurement with **EN 16976**
- **BC** measurement in draft phase.



Health effects of aerosol particles [1]

[1] Nani Guarieiro LL et al. (2013) Vehicle Emissions: What Will Change with Use of Biofuel? Biofuels - Economy, Environment and Sustainability. InTech.

UFP Monitoring Platform for Comparable Data



AVL UltraFine Particle Monitor™

- ✓ EN 16976-compliant CPC measurement
- ✓ 10 nm lower detection threshold
- ✓ Continuous 24/7 operation
- ✓ Harmonized processing and quality control



AVL UFP Sampling System



AVL Butanol Remover

AVL Expertise In Particle Number Counting

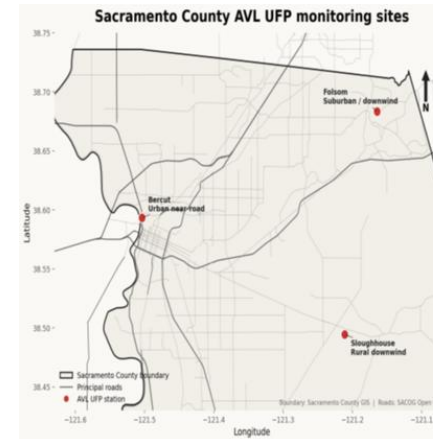
- 60 years of proprietary technology in aerosol particle measurement
- 20 years of AVL technology in Condensation Particle Counting (CPC)
- 1600+ CPCs installed worldwide
- Global customer base in industry and academia
- In-house design and production
- Global sales & service network

Recent Transatlantic Study spans Urban to Rural Conditions



Graz, Austria

- **Graz-Süd station:** in urban and commercial-industrial zone, near major road (~30k vehicles/day)



Sacramento, CA

- **Bercut station:** in urban area near Interstate-5 (CA-MX), 197k vehicles/day
- **Folsom station:** east of city center, suburban
- **Sloughhouse station:** southeast of city center, rural location



Analysis period:
April 2022–July 2026

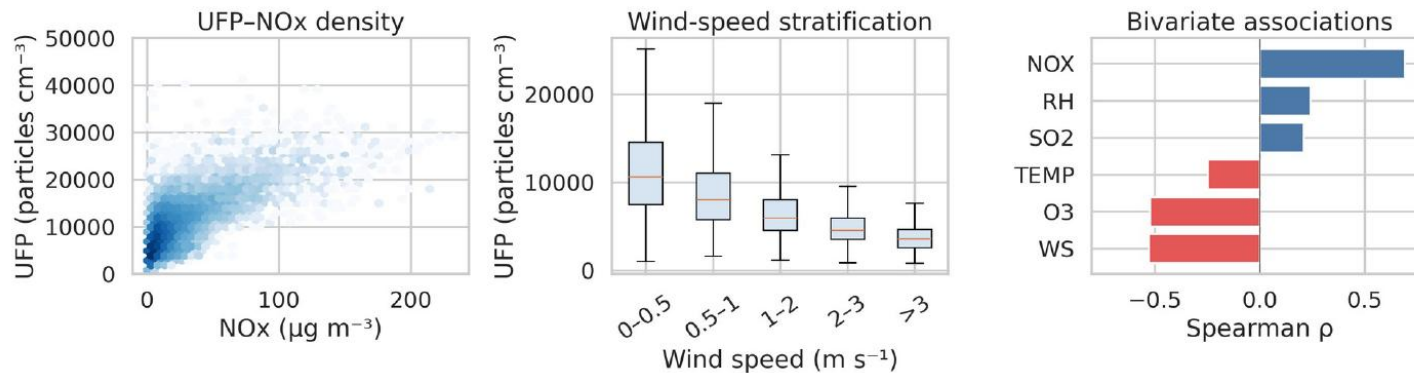


Analysis period:
April 2025–July 2026

NOx links UFP to Local Combustion at Urban Sites



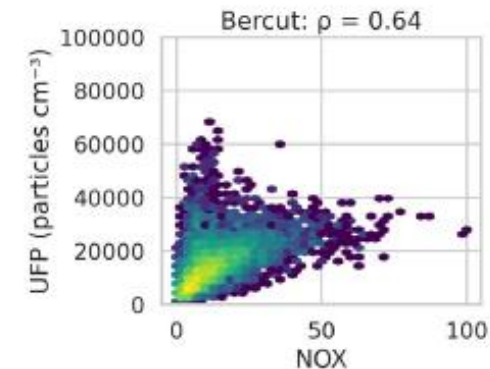
Graz, Austria



- UFP rise systematically with NOx ($\rho = 0.69$), consistent with local combustion influence.
- Wind speed and ozone are the strongest inverse correlates.

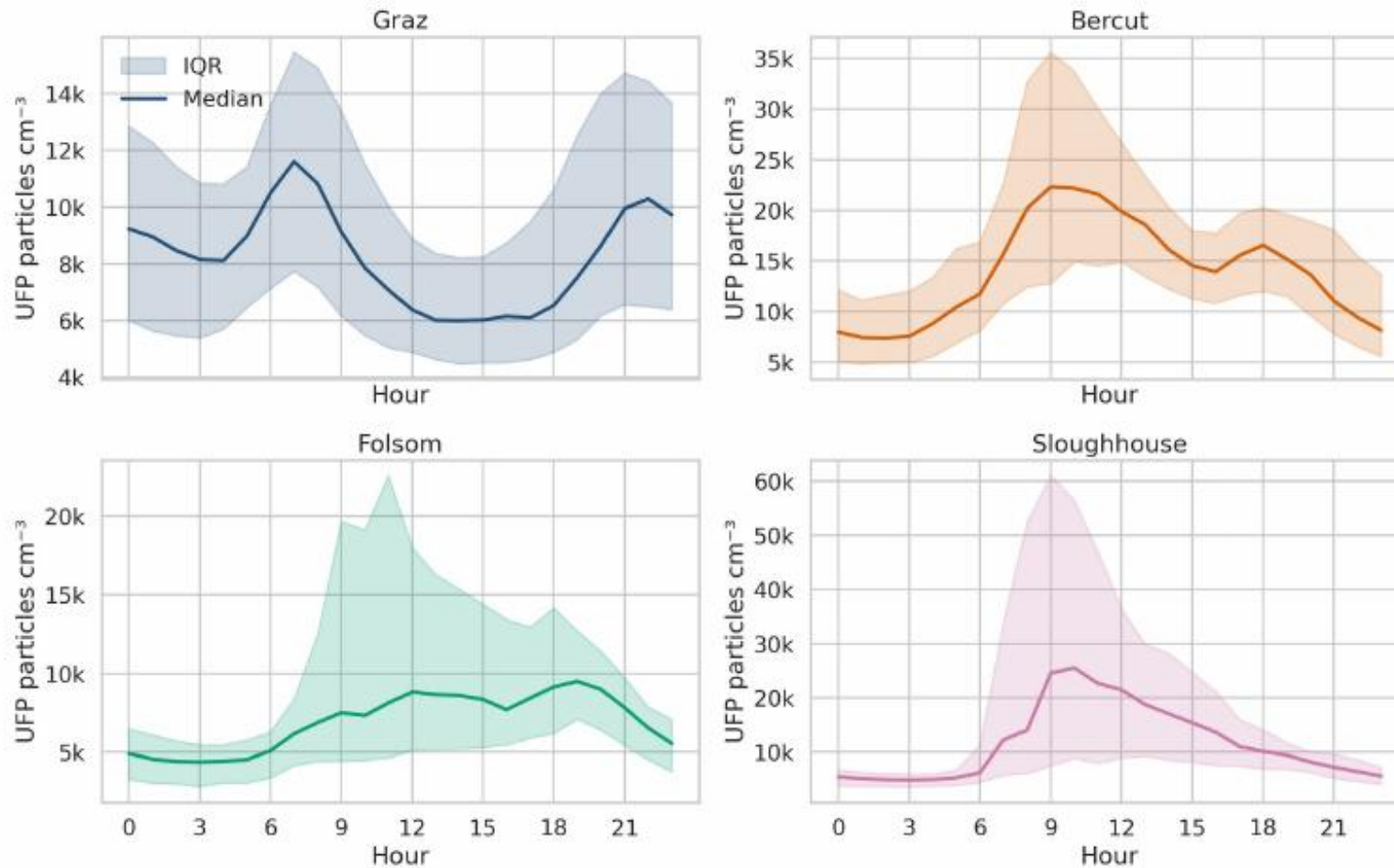


Sacramento, CA

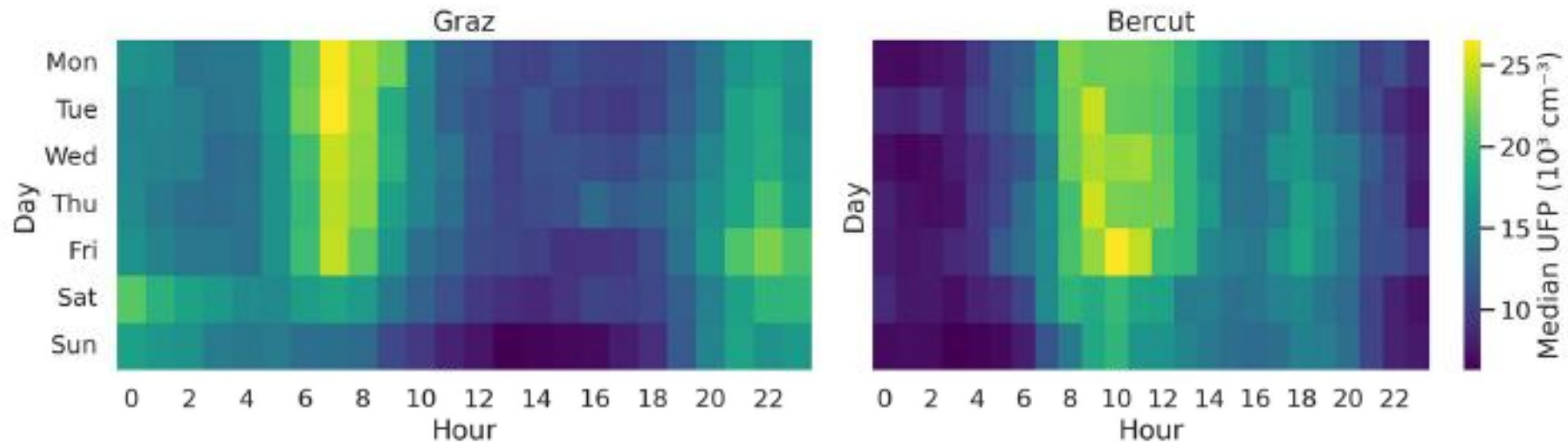


- Bercut has a strong UFP-NOx association ($\rho = 0.63$).
- Consistent with primary combustion influence.

Diurnal Cycles in Graz and Sacramento



Weekday Effects on UFP Concentrations



Strong weekday-weekend contrast

Graz (AT) shows morning and evening UFP peaks across weekdays, with stronger working-day mornings.

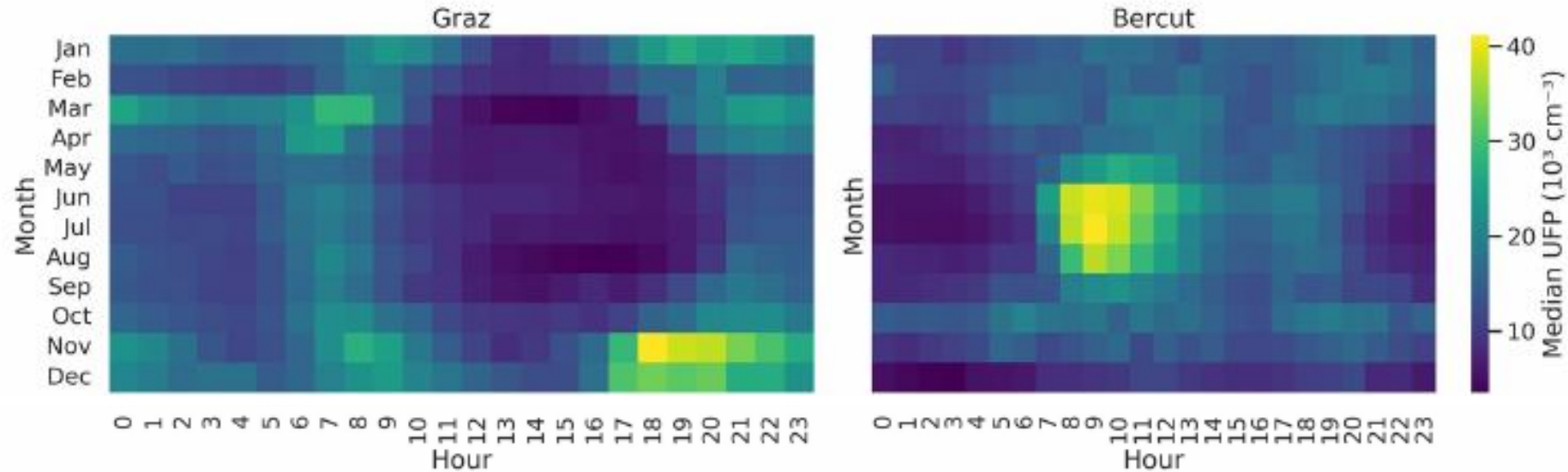
Weekends lack morning peaks and show longer activity into the night.

Similar timing, lower weekend levels

Bercut (US) shows morning UFP peaks, independent of weekday.

Weekends show a similar pattern at lower UFP concentrations.

Seasonal UFP Fingerprints



Cool-season bimodal pattern

Morning and evening UFP enhancements dominate during the cooler months, with the strongest evening concentrations in November and December.

Summer concentrations are lower and show a much weaker bimodal structure.

Warm-season morning pattern

A pronounced morning-to-midday UFP enhancement emerges from late spring through summer, peaking in June-August.

Outside this seasonal window, concentrations are lower and the diurnal pattern is less distinct.

Take-Aways UFP Monitoring

Harmonized UFP measurements acc. to EN 16976 provide reliable & comparable data.

Results from GRAZ

Multi-year data reveal a consistent cool-season bimodal pattern & show a station-specific UFP fingerprint.

Results from SACRAMENTO

All three sites show warm-season UFP enhancement during morning-to-midday, indicating a broader regional influence.

SOURCE-RELATED ANALYSIS

Further BC and PSD analyses are needed to understand atmospheric processes, source influences and spatial variability.

Why is Black Carbon of Interest?

HEALTH

Cardiovascular and respiratory relevance

CLIMATE

Strong light absorption and short-lived climate forcing

REGULATION

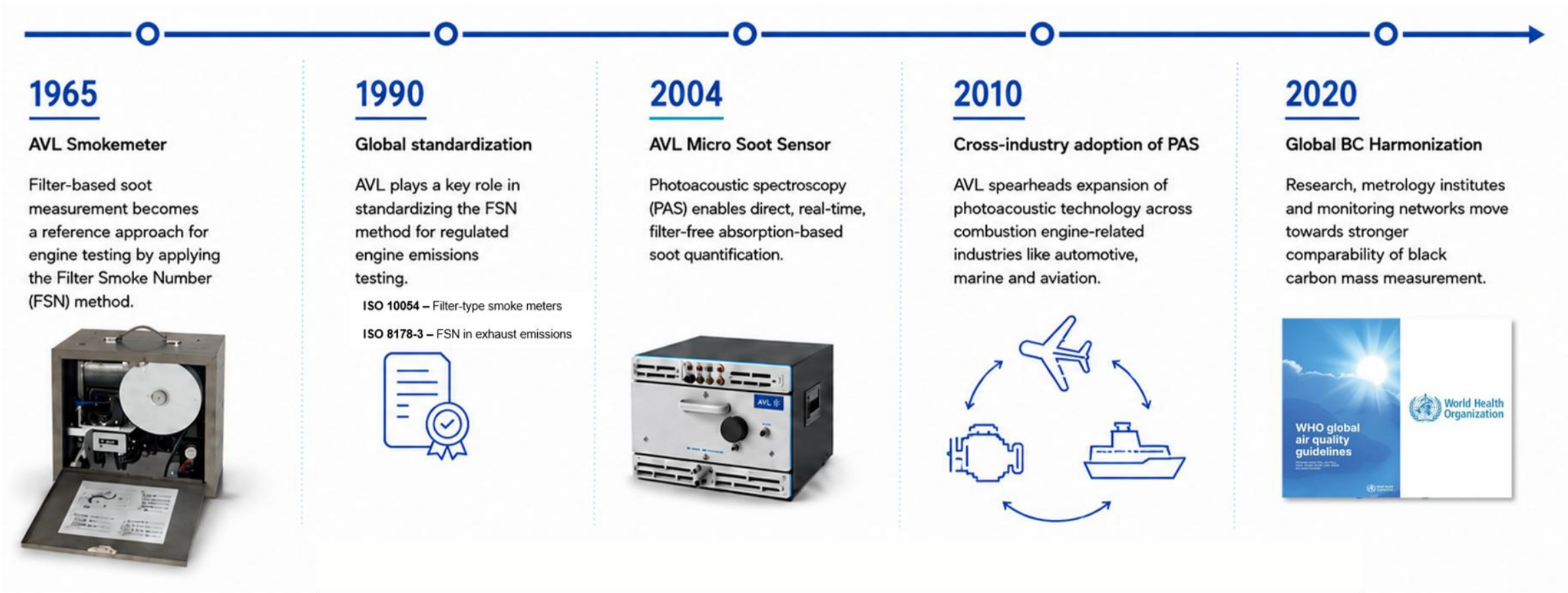
A growing requirement for accurate, intercomparable data

Ambient Air Quality Directive EU 2024/2881

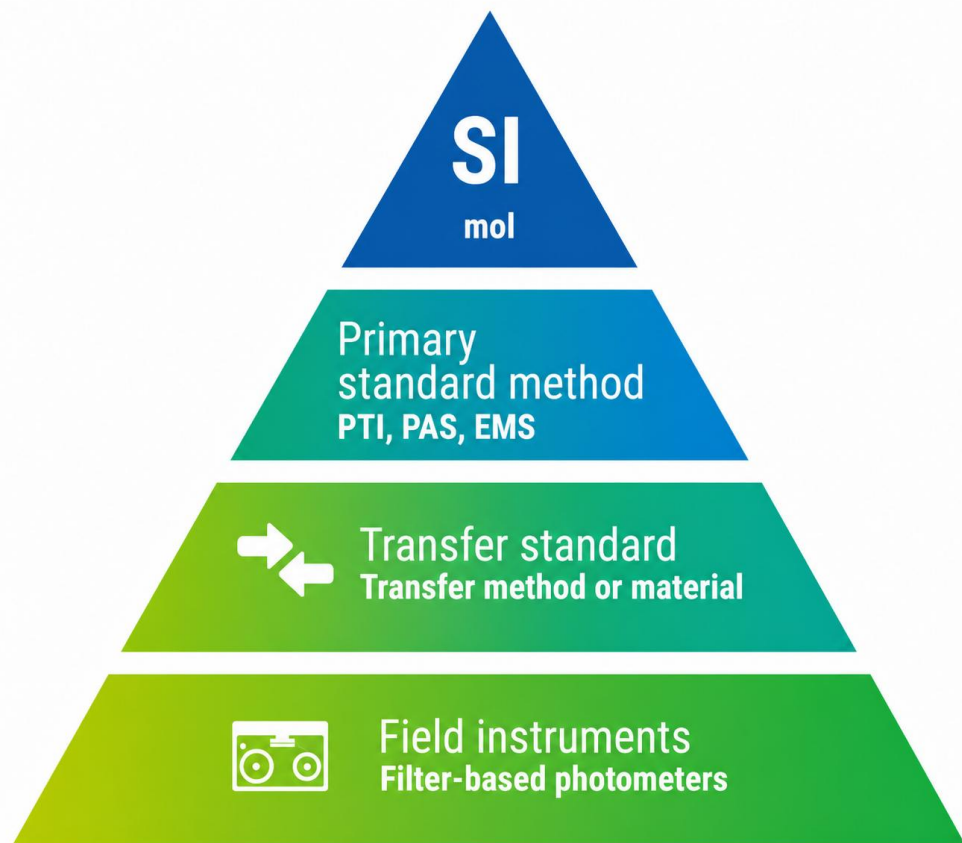
Black carbon monitoring at supersites.

Monitoring networks therefore need data that remain comparable across instruments, sites and time.

AVL and Black Carbon: A Brief Retrospective



Harmonization of BC Measurement and Traceability



[1] Jorge Saturno, EAC2025

stanBC investigates potential SI-traceable calibration methods for intercomparable black carbon measurements.

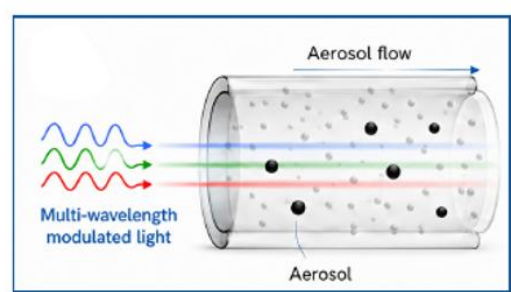
Photoacoustic Spectroscopy

PAS measures aerosol absorption directly in situ and can be used as primary standard method.

Harmonization is required

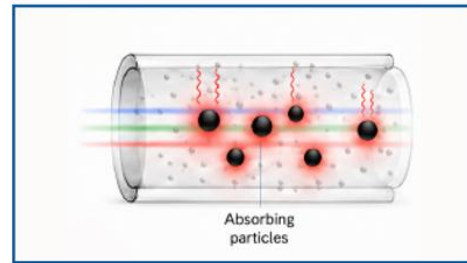
European standardisation work within CEN/TC 264, working group 35.

Photoacoustic Spectroscopy (PAS) Method



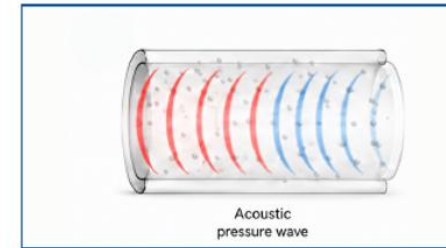
1 MODULATED LIGHT

Three wavelengths pass through the aerosol sample.



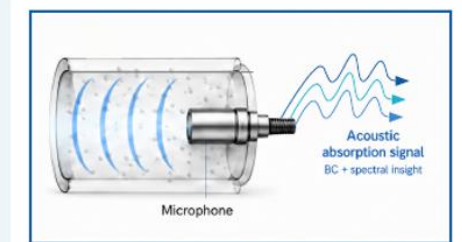
2 PARTICLE HEATING

Absorbing particles convert optical energy into heat.



3 PRESSURE WAVE

Periodic heating generates an acoustic wave.



4 MICROPHONE SIGNAL

The acoustic signal quantifies aerosol absorption.

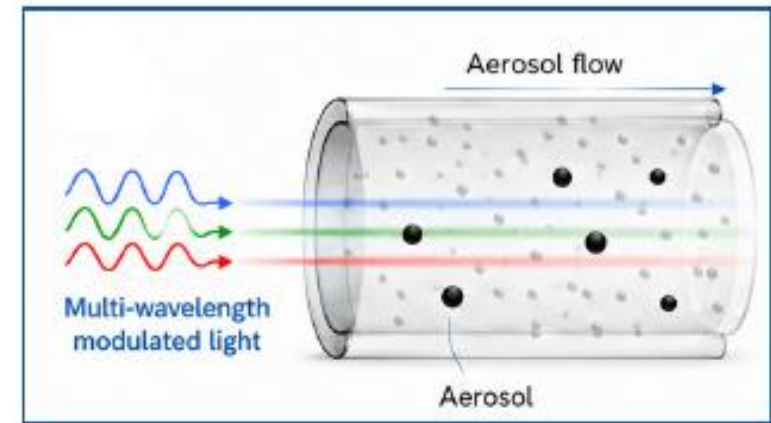
PAS enables direct, in-situ aerosol absorption measurement.

AVL Black Carbon Monitor



AVL Black Carbon Monitor™

Direct, filter-free aerosol absorption measurement



405 nm

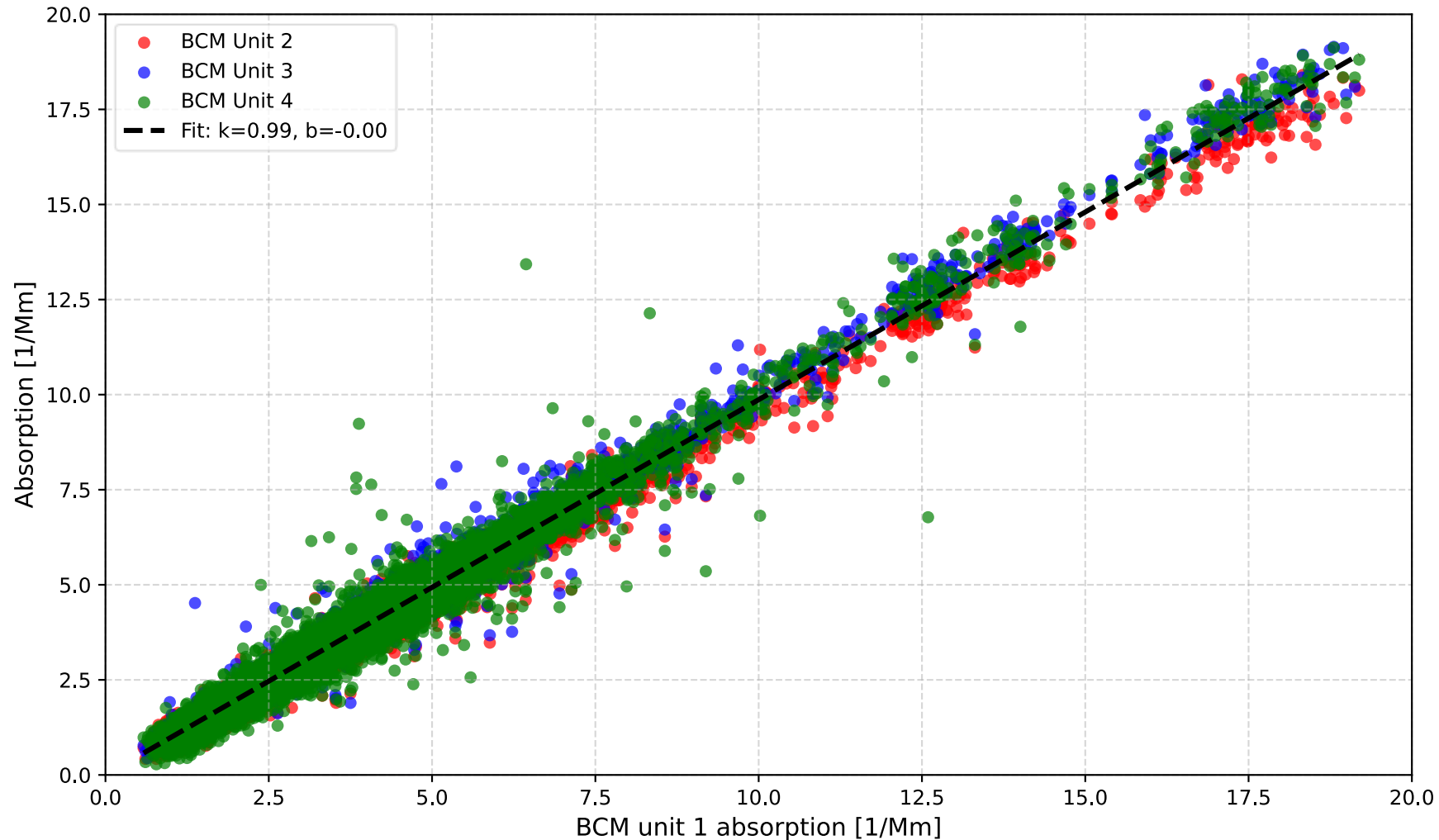
532 nm

880 nm

Simultaneous three-wavelength analysis in a single cell

Spectral absorption supports BC/BrC differentiation and source-oriented analysis.

Robust Sensor Design

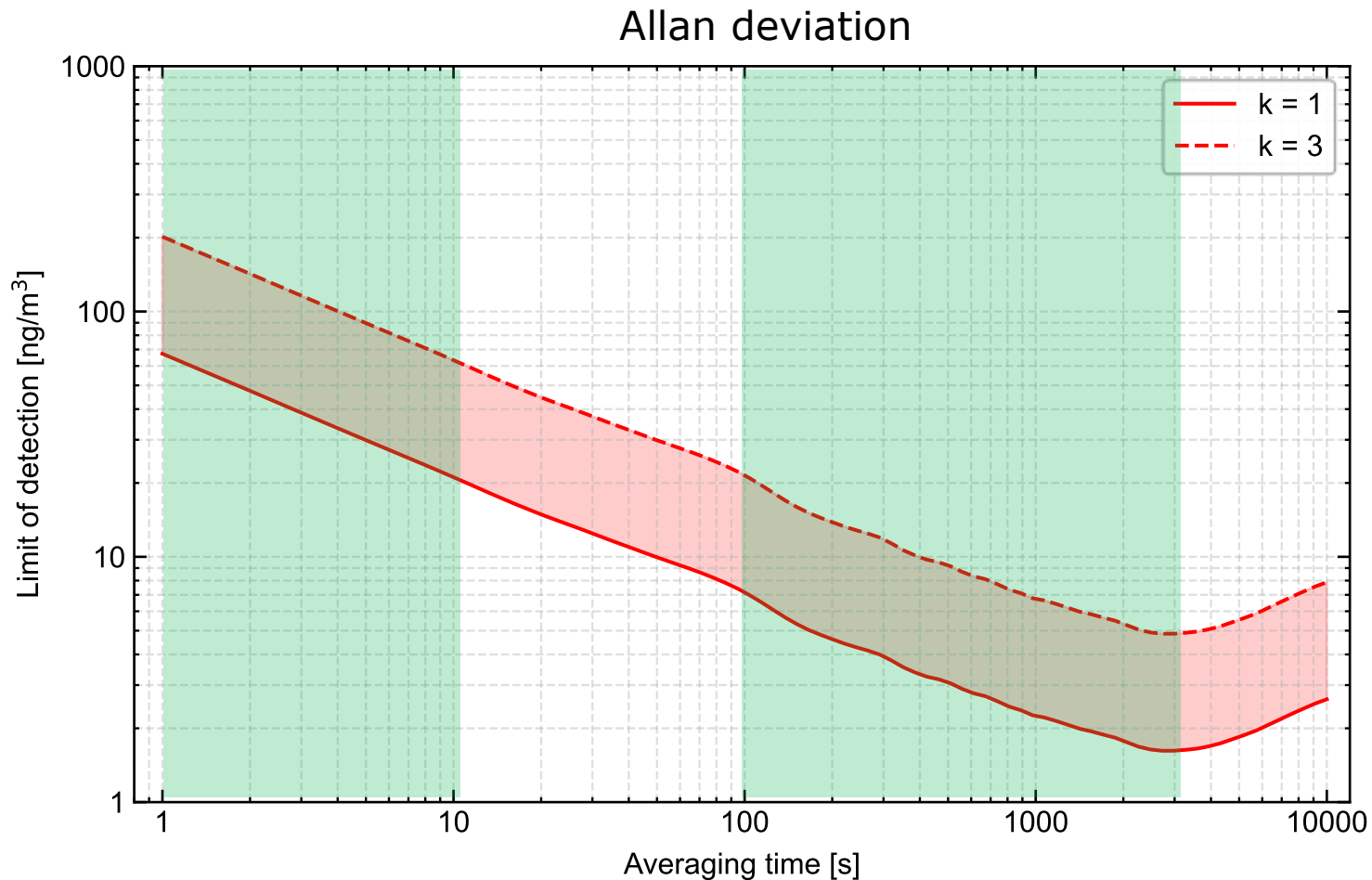


$k = 0.99$

$b \approx 0.00$

Strong unit-to-unit
comparability across
the tested range

Limit of Detection



1–10 s

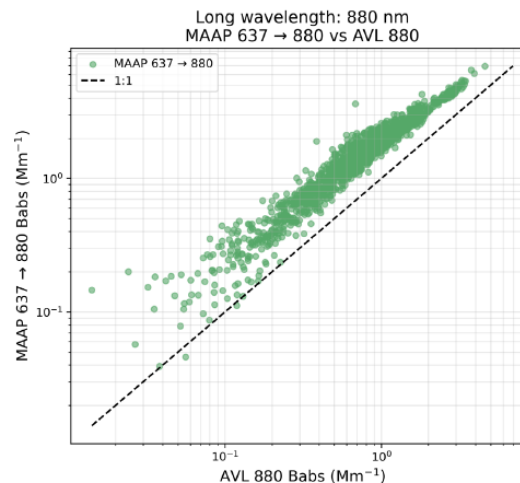
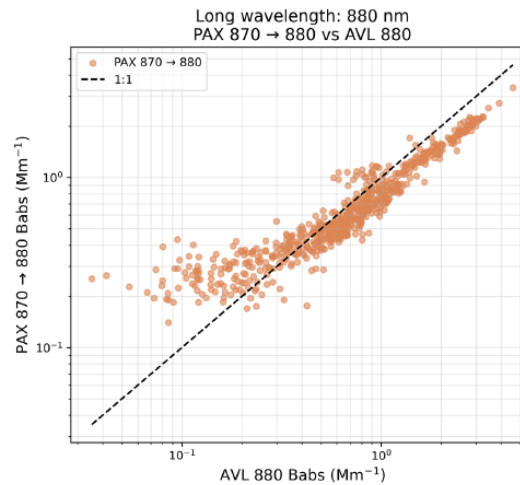
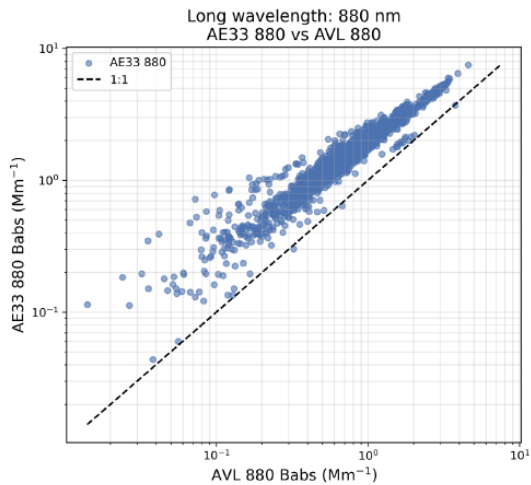
Rapid events and high time resolution

100–2000 s

Improved sensitivity for low ambient concentrations

Preliminary Intercomparison at PSI

Long-wavelength absorption intercomparison at 880 nm



Preliminary result

- Strong correlation with other BC instruments.
- Consistent tracking of ambient variability.
- Systematic offsets remain visible.

Final wavelength harmonization, calibration and joint QA/QC are still pending.



Aerosol Absorption and optical properties intercomparison at Payerne

A. Christodoulou, R.L. Modini, M. Gysel-Beer

Take-Aways BC Monitoring

Direct multi-wavelength PAS is a promising route towards traceable BC monitoring

NEED

BC monitoring requires comparable, traceable absorption data.

TECHNOLOGY

PAS provides direct, in-situ, simultaneous absorption data.

EVIDENCE

Reproducibility and field comparisons are promising; validation continues.

Conclusion

UFP and BC measurements are essential for a complete picture of air pollution!



AVL UltraFine Particle Monitor



AVL Black Carbon Monitor



The background of the slide is a photograph of the AVL building at the University of Applied Sciences (FH) in Salzburg. The building is a modern, multi-story structure with a grey facade and large windows. Two blue signs with the AVL logo are mounted on the upper part of the building. In the foreground, there is a paved area and a curved road. In the background, there is a green lawn and a small, modern, glass-enclosed structure. The sky is clear and blue.

Thank you



www.avl.com/ufpm

