Volatility, state of mixing and solid ultrafine aerosol particles in the urban atmosphere

(THE MI-TRAP project)

Maria Gini, Christina Spitieri, Luís Mendes§, and Konstantinos Eleftheriadis

Environmental Radioactivity & Aerosol technology for atmospheric and climate impact Lab

NCSR Demokritos, Athens, Greece

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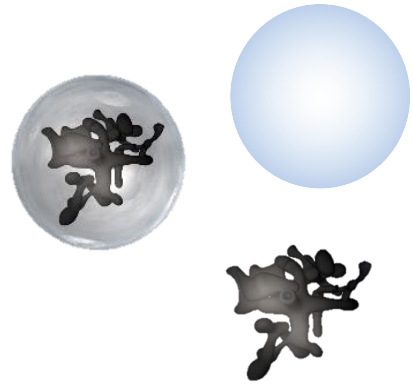

The need

WHO global air quality guidelines (2021) address the health concerns related to currently non-regulated pollutants like Black Carbon (BC) and Ultrafine Particles (UFP).

The adopted EU Air Quality Directive (2024), introduces monitoring of UFP Number and BC concentrations in urban areas but no limit values are suggested

Emission Standards (Euro 5, 6 and future Euro7) and technology solutions like Diesel Particle Filters have already a large impact in reducing transport emissions at optimum performance

There is a challenge to link the impact of specific sources like transport on air quality in terms of ambient UFP number and BC mass concentration levels.

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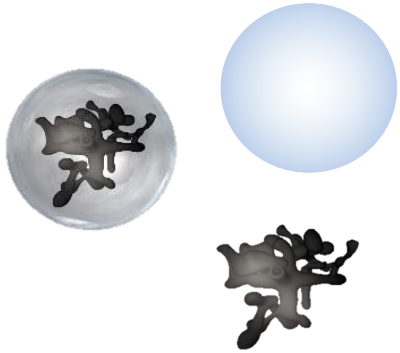
Measurement techniques and metrics for Ultrafine particles



The state of the art – Emission standards

Vehicle solid particle number (SPN) emissions are regulated in Europe since 2011 (Euro 5b) (EC-692/2008, 2008) The SPN regulation aim to force diesel particulate filters to diesel vehicles

Need for defining primary emitted particles

The dynamic process of gas to particle condensation at the tailpipe led to SPN at 300-350 ^{0}C

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Contents lists available at ScienceDirect

Journal of Aerosol Science

journal homepage: www.elsevier.com/locate/jaerosci

Review JAS 2014

Review of motor vehicle particulate emissions sampling and measurement: From smoke and filter mass to particle number

Barouch Giechaskiel [a,1], Matti Maricq [b], Leonidas Ntziachristos [c,*], Christos Dardiotis [d], Xiaoliang Wang [e], Harald Axmann [f], Alexander Bergmann [a], Wolfgang Schindler [g]

[a] AVL List GmbH, 8020 Graz, Austria
[b] Ford Motor Company, P.O. Box 2053, MD 3179, Dearborn, MI 48121, USA
[c] Aristotle University of Thessaloniki, Lab of Applied Thermodynamics, 54124 Thessaloniki, Greece
[d] European Commission, Joint Research Centre, I-21027 Ispra, VA, Italy
[e] Desert Research Institute, 2215 Raggio Pkwy, Reno, NV 89512, USA
[f] AVL DiTest Fahrzeugdiagnose GmbH, 8020 Graz, Austria
[g] AVL North America Inc., Plymouth, MI 48170-2438, USA

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The state of the art – Emission standards

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Journal of Aerosol Science 159 (2022) 105873

Solid particle number emissions of 56 light-duty Euro 5 and Euro 6 vehicles

Tero Lähde, Barouch Giechaskiel *, Jelica Pavlovic, Ricardo Suarez-Bertoa, Victor Valverde, Michaël Clairotte, Giorgio Martini

European Commission, Joint Research Centre JRC, 21027, Ispra, VA, Italy

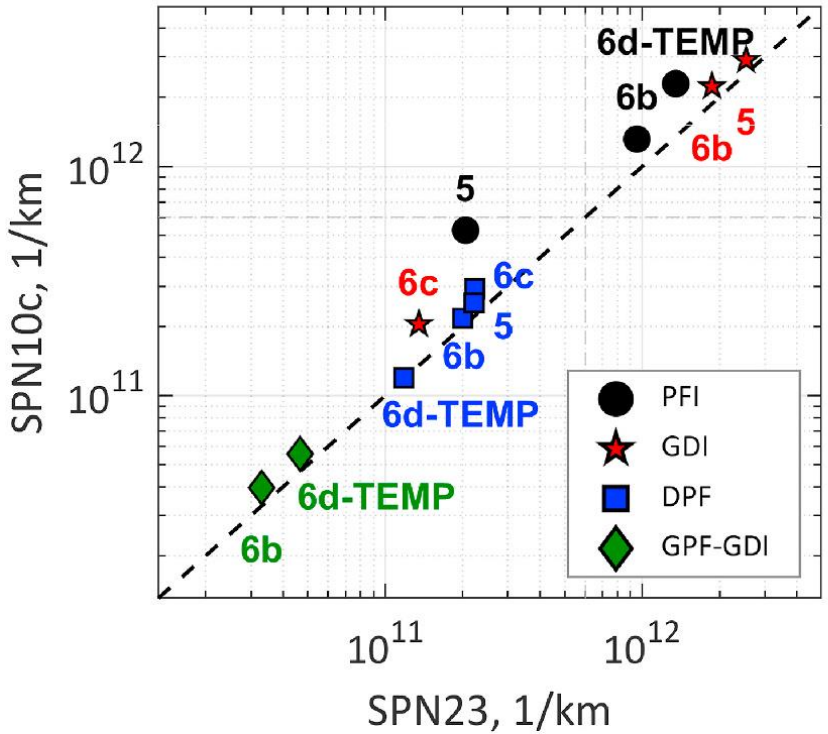
The state of the art – Emission standards

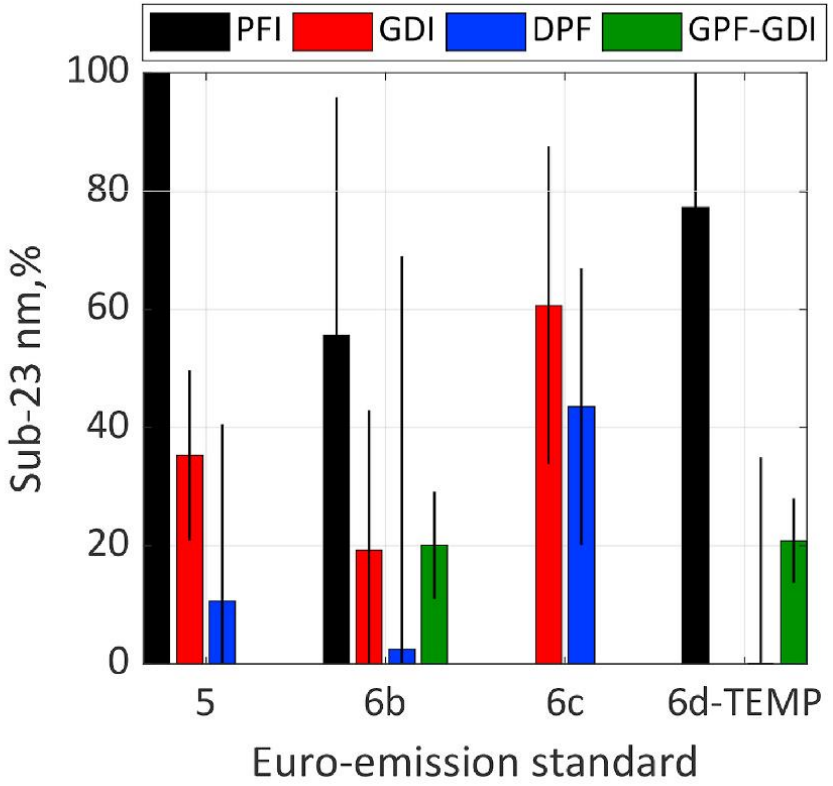
PFI: Port Fuel Injection

GDI: Gasoline Direct Injection

DPF: Diesel equipped with particulate filter

GDF-GDI: GDI with gasoline particulate filter





Average SPN10c (1/km) vs. average SPN23 (1/km)
for the Euro-emission standards and vehicle types.

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The state of the art - UFPs

Ultrafine particles emitted from combustion sources (i.e. transport) are continually mixed and evolve with other particles in the atmosphere.

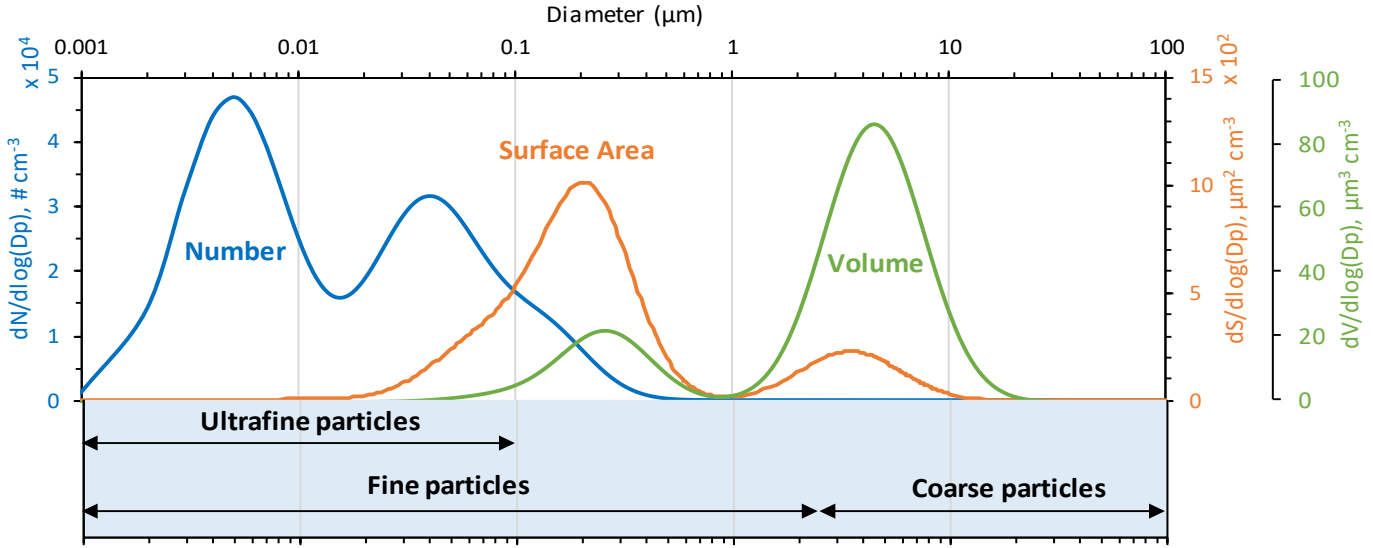
Quality assured and traceable measurements of the ambient Ultrafine particles

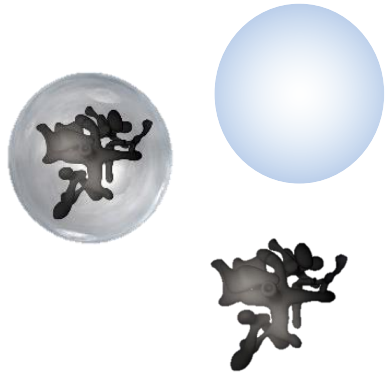
EN 16976 for atmospheric aerosol number concentrationsby Condensation Particle Counters (CPCs)

CEN/TS 17434:2020 for the Particle size distribution (PSD) ‘Mobility Particle Size Spectrometer’

(abbreviated as ‘MPSS’) is used to cover a size range from 10 nm to 800 nm (ambient PNSD range)

The aerosol size distribution is often a powerful tool for the dynamic behavior of particles.





Measurement techniques and metrics for Ultrafine particles

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The state of science in the Urban atmosphere (the Tandem DMA)

Aerosol volatility

Refractory fraction (300 °C)

- Low volatility organics
- Soot
- Minerals
- Sodium Chloride

Volatile fraction

- Ammonium nitrate and sulphuric acid (<150 °C)
- Ammonium sulphate and bisulphate(150-280 °C)
- Water soluble organics (<280 °C)

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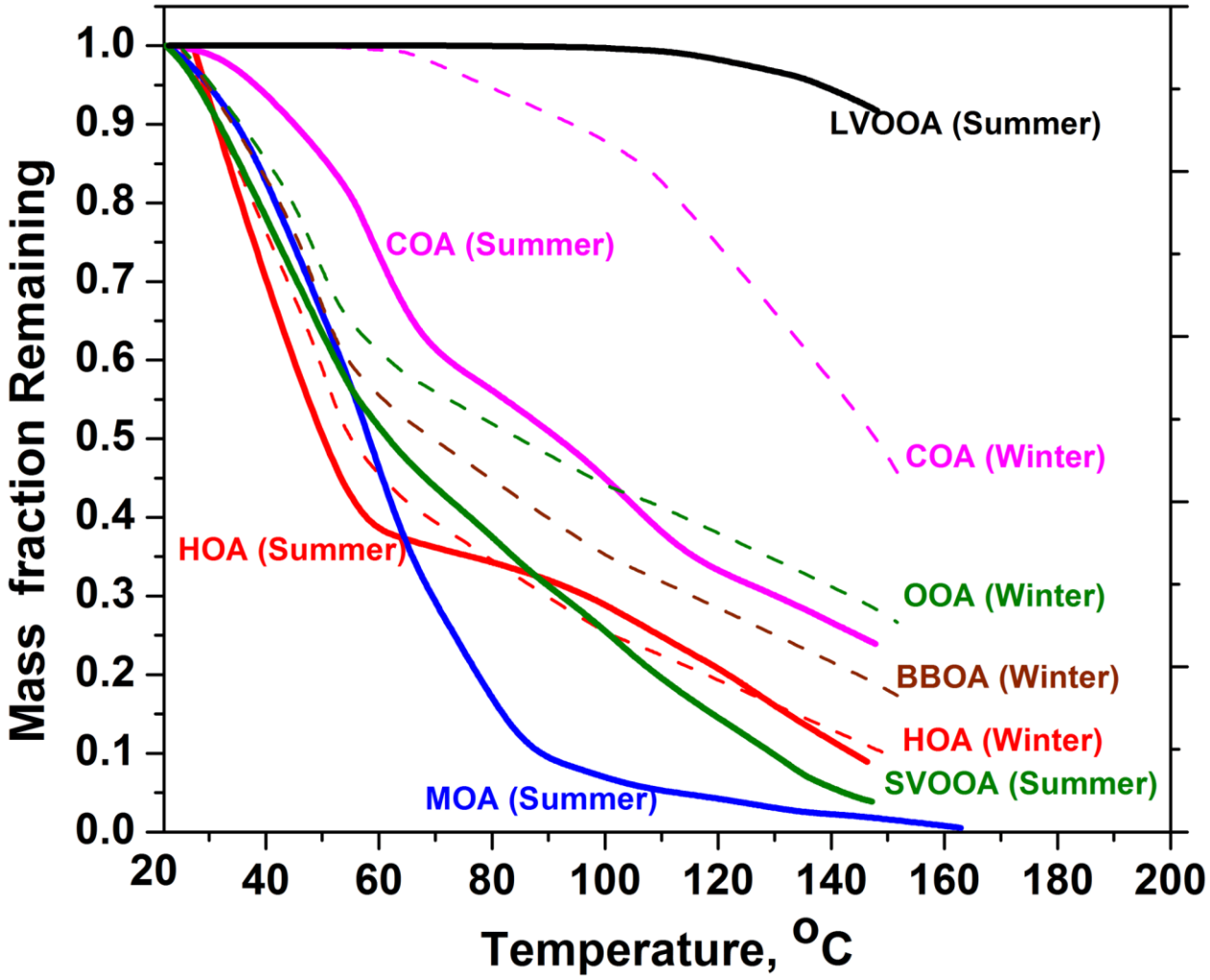
High Variability of Volatilities for fresh and aged organics



Data from Paris

C-OA Cooking

M-OA Marine

LVO-OA Low Volatility Oxygenated

BB-OA Biomass Burning

H-OA Hydrocarbon

A. Paciga, Atmos. Chem. Phys., 16, 2013–2023, 2016

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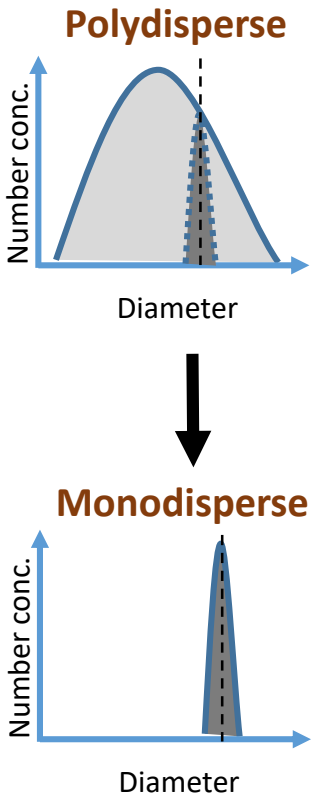
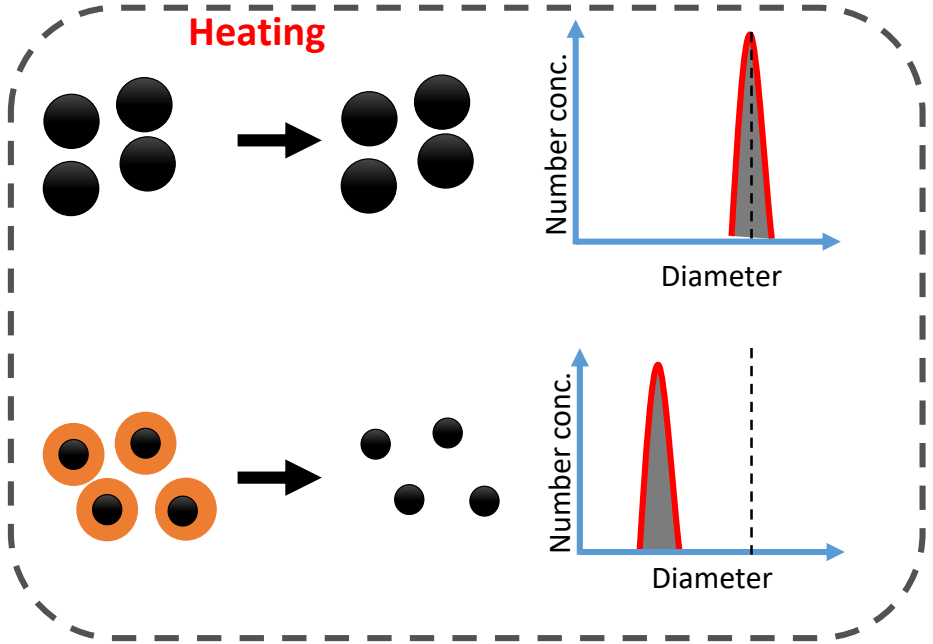
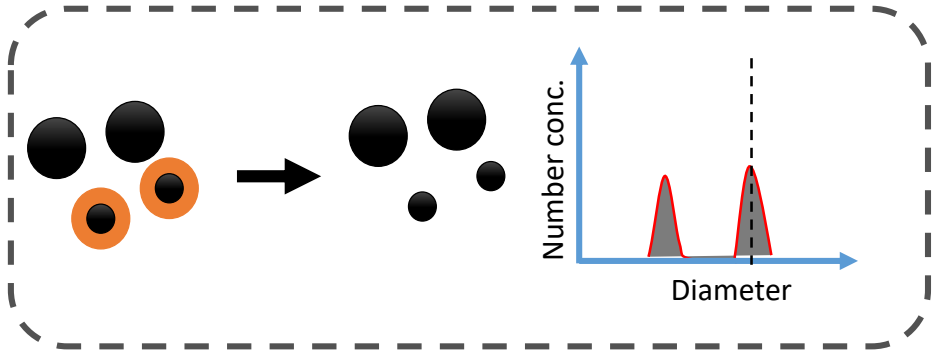
Mixing state and volatility





Internally mixed



Externally mixed

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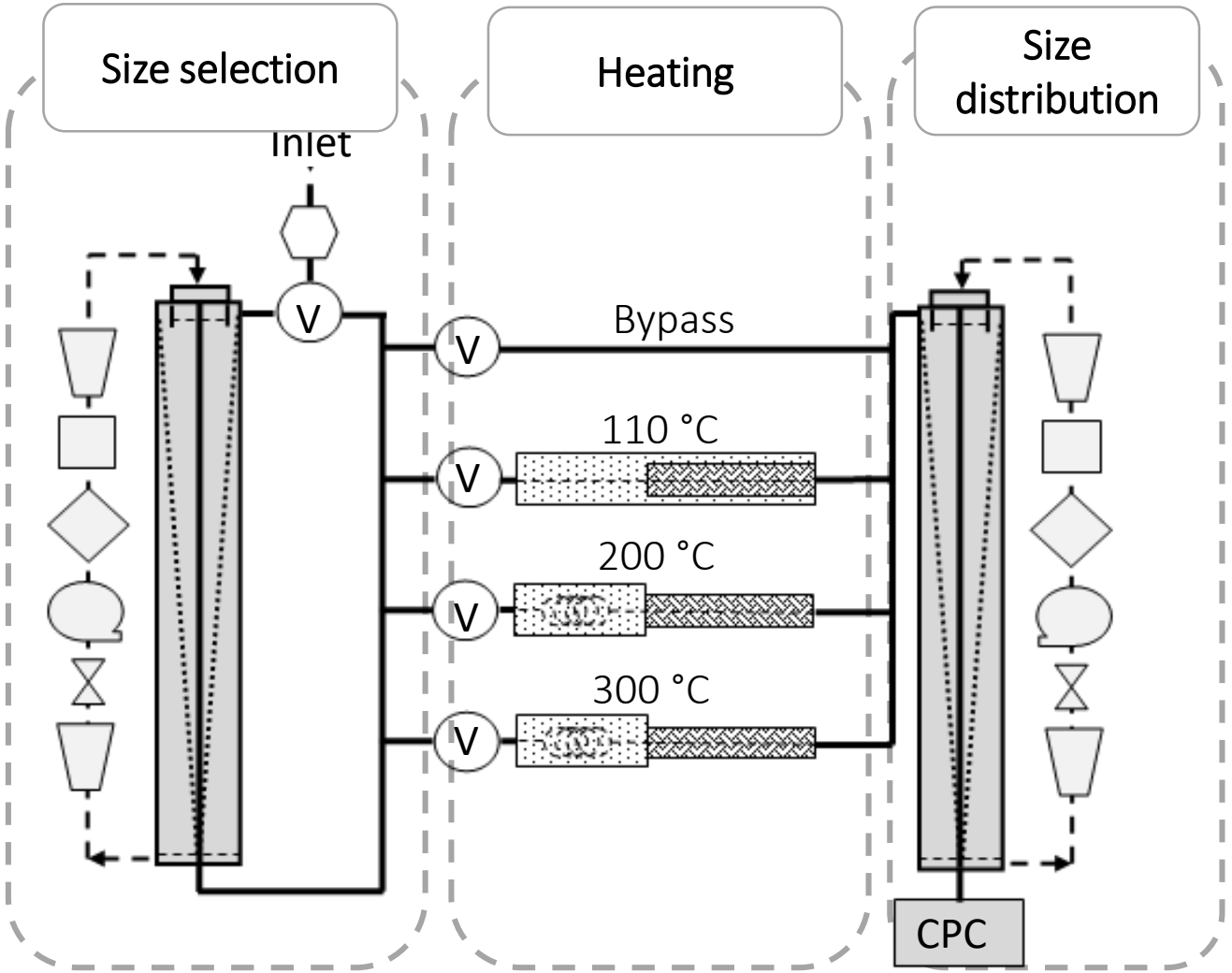
Volatility TDMA



[1] Mendes, L.; Eleftheriadis, K.; Biskos, G. Performance comparison of two thermodenuders in Volatility Tandem DMA measurements. *J. Aerosol Sci.* **2016**, *92*, 38–52.

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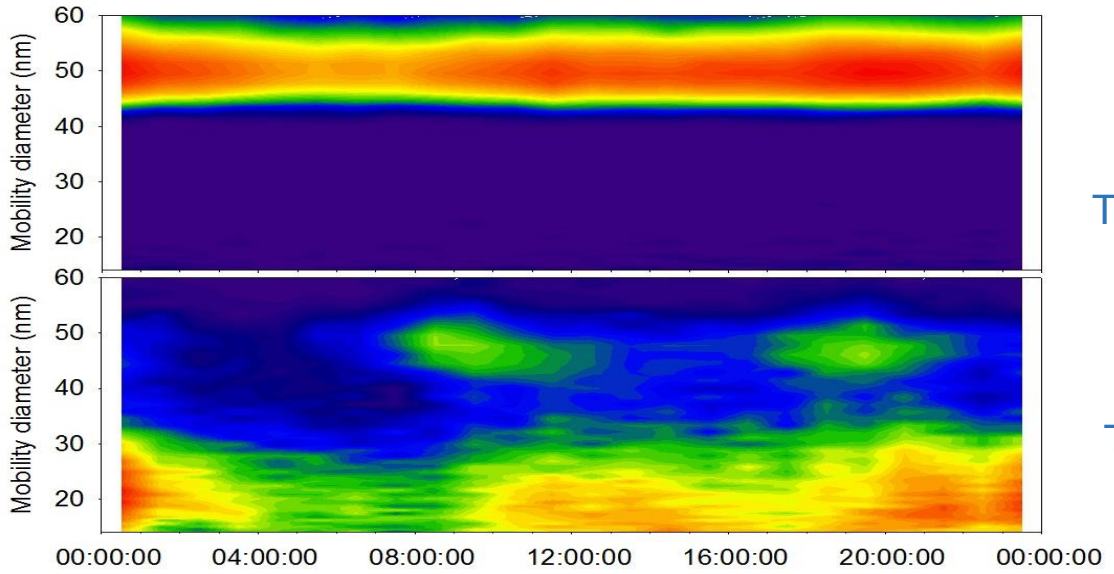
Results from previous studies in Athens and plans in MI-TRAP

The effort to narrow down the uncertainty requires robust metrics and standardization:

There is a need to link the monitoring methods in the ambient environment and the tailpipe.

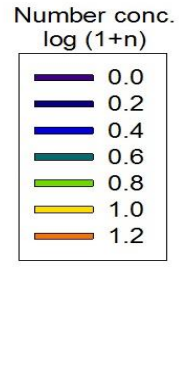
Ambient Solid particles is a choice towards this direction and may provide the link between ambient UFP number concentration levels and transport emissions.

Define the measurement conditions (high dependence on temperature)



50 nm
T Ambient

50 nm
T 330 °C



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Measurement techniques and metrics for Ultrafine particles

Athens Data from Traffic area

(reprossed from Mendes et al., Env. Pollution, 2018)

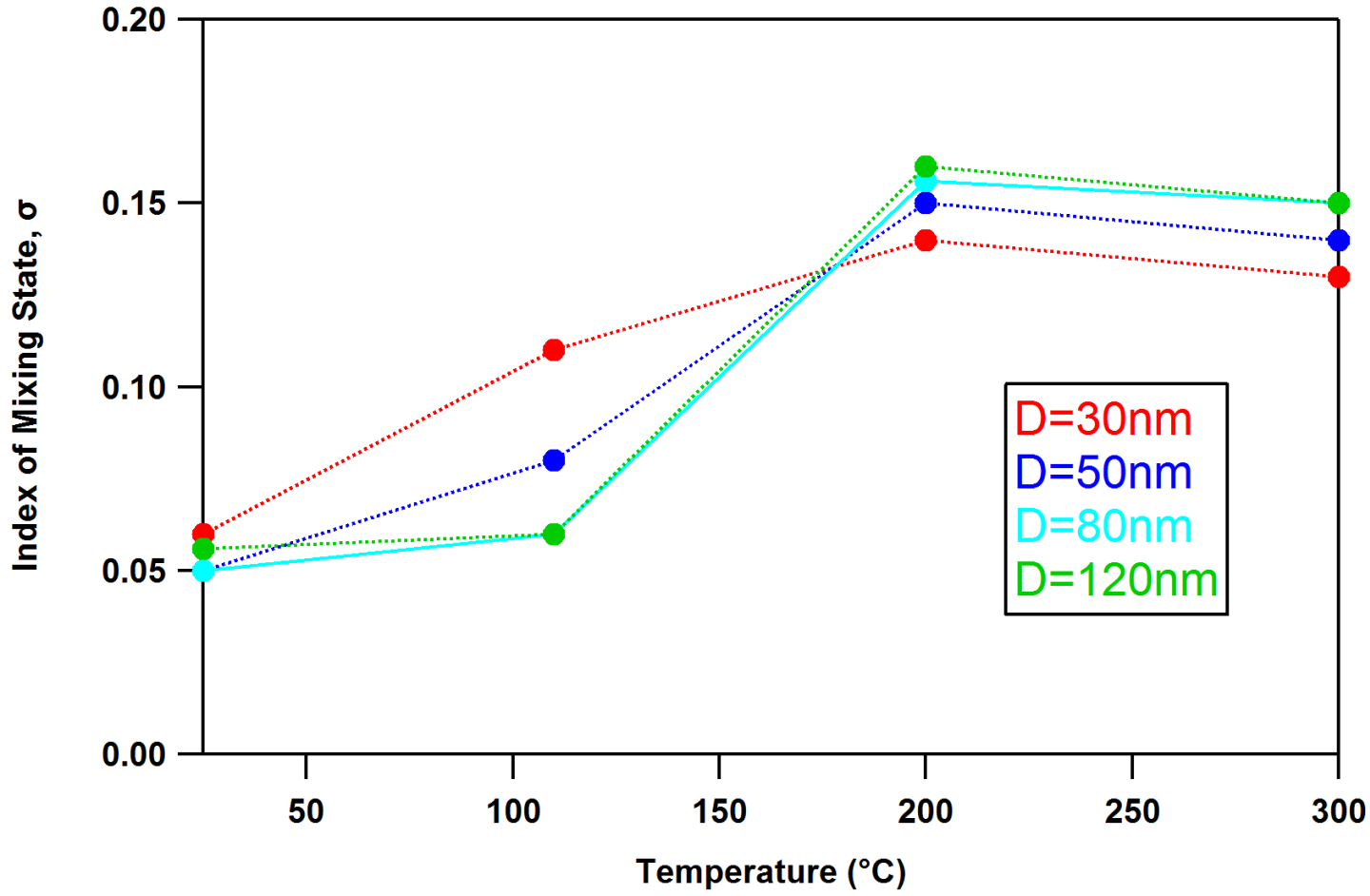
σ ≤ 0.07 - Internally Mixed

0.07 < σ < 0.15 - Continuum of Mixing State

σ ≥ 0.15 - Externally Mixed

Using the TDMA inverse retrieval by

Gysel, M., et al,J. Aerosol Sci., 40, 134–151, 2009.



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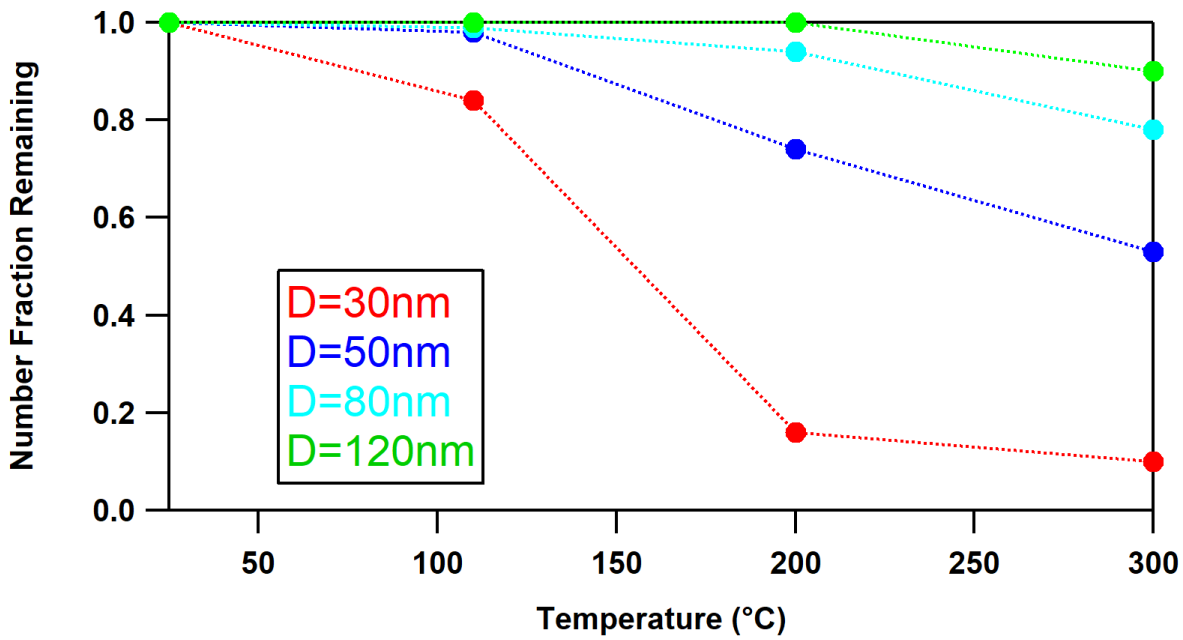
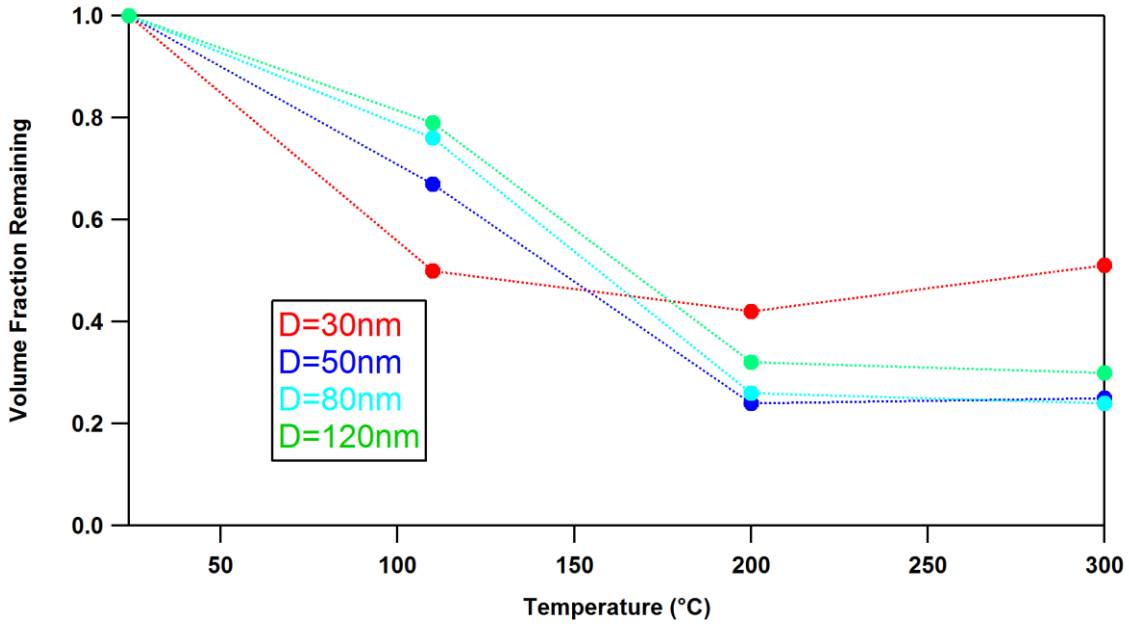
Athens Data from Traffic area

(reprossed from Mendes et al., Env. Pollution, 2018)

Number Fraction Remaining



Volume Fraction Remaining



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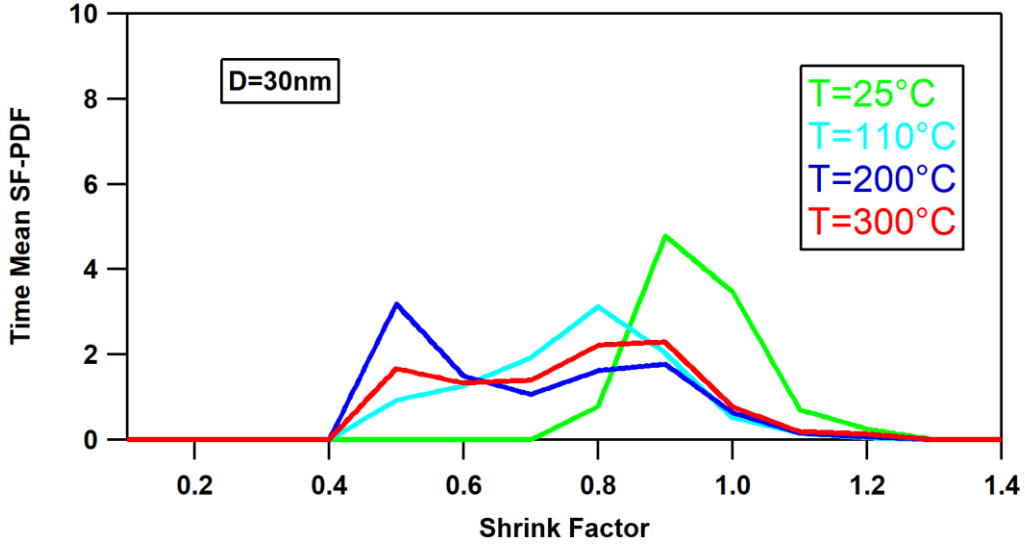

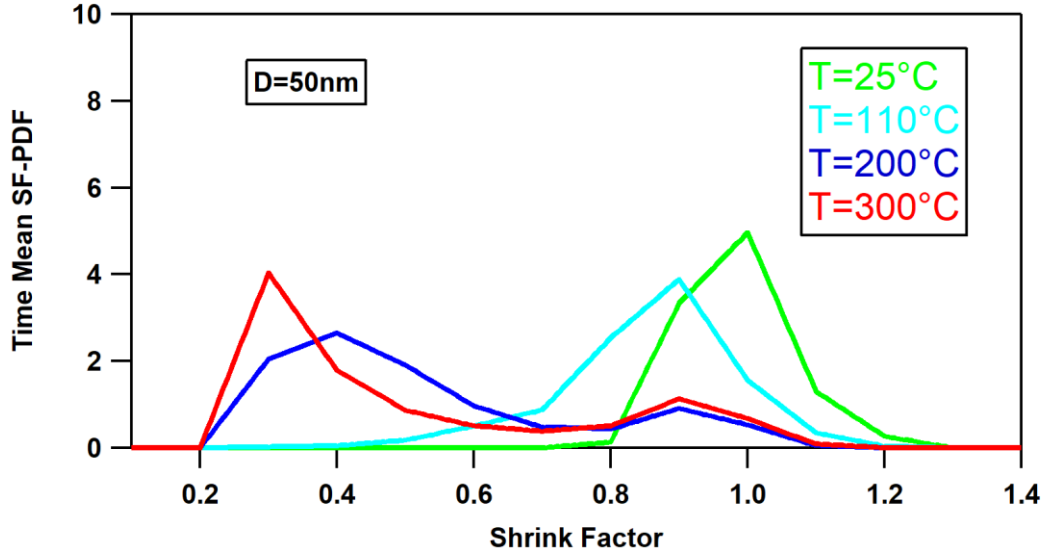

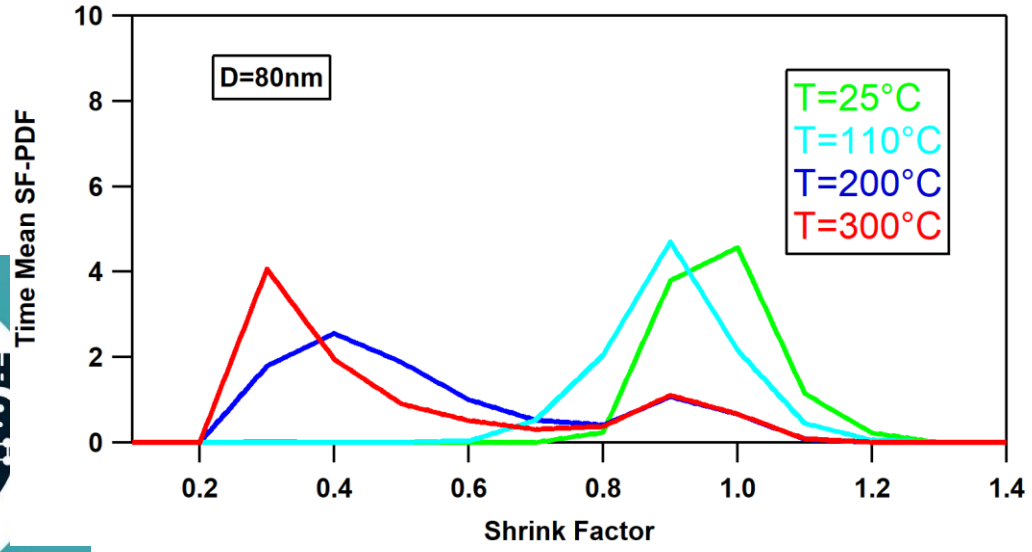

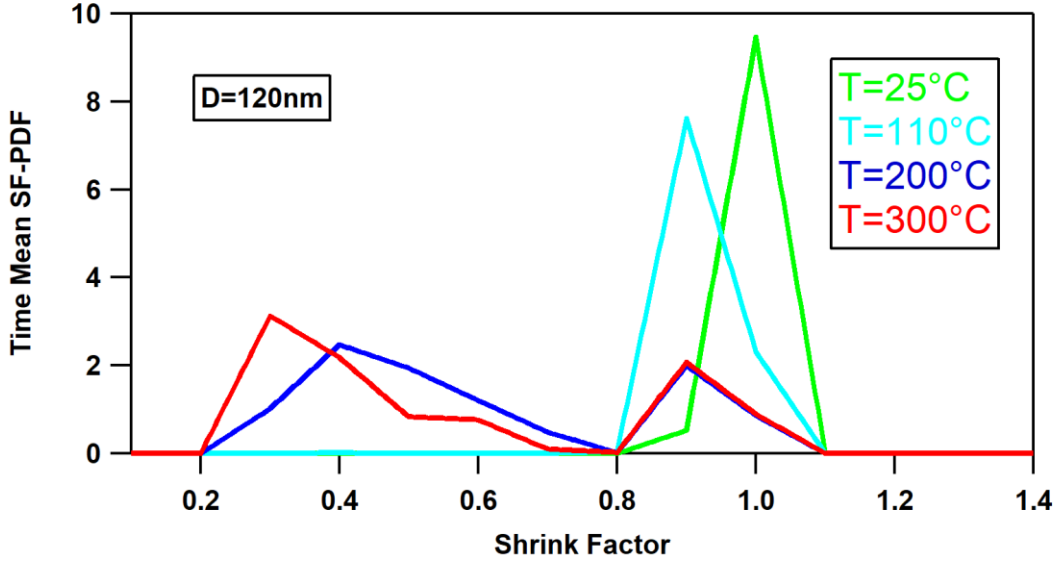

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Several efforts are on-going towards satisfying goals related to MI-TRAP

CEN Standardized methods are updated and members of this consortium are active there (WG35 EC/OC, WG32 Particle number/surface)
EMPIR EURAMET projects

EMPIR BLACK CARBON

AEROMET
Aerosol metrology for atmospheric science and air quality

StanBC : Standardisation of Black Carbon aerosol metrics for air quality and climate modelling

stanBC

Monitoring of emerging pollutants (particles & gases) is currently well established in Research Infrastructures ACTRIS, ICOS, GAW

GAW

ACTRiS

And demonstrated their capacity in Green Deal Projects

RI URBANS

the existing gaps are highlighted in New Horizon projects
EASVOLEE (Effects on Air quality of Semi-VOLatile Engine Emissions)

EASVOLEE

Catalytic Stripper technology enables measurement of solid particle size and concentration Contribution to the MI-TRAP Project*

CS Definition and Design

- A heated catalytic element used to remove the particle and gas phase semi-volatile fraction of an aerosol
- Typical Constant operating temperature of 350°C
- Flowrate 0.3 to 25 L/min or more
- Integration in the MI-Trap Project to measure TPN vs SPN

- Predictable solid particle loss characteristics as shown in Figure 1

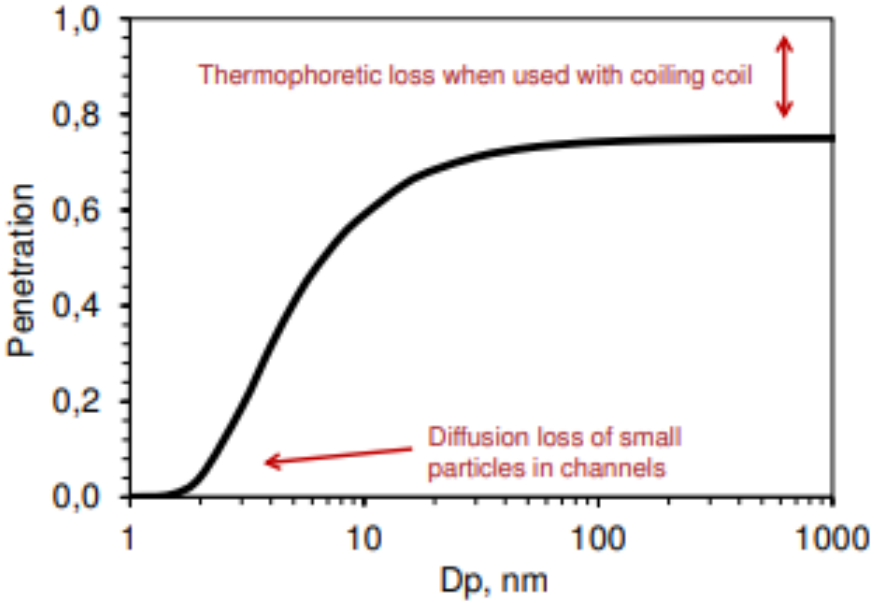
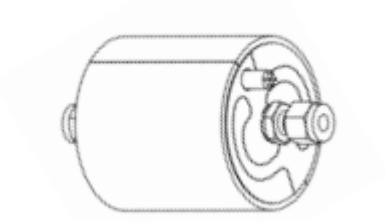
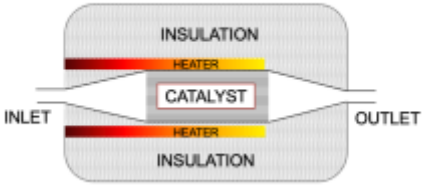
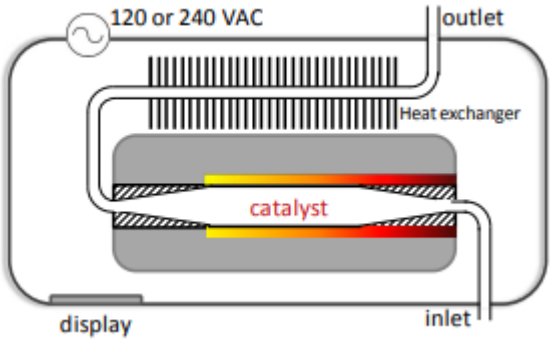


Figure 1: Typical solid particle penetration for design with >99% HC removal efficiency.







*https://mitrap-project.eu/

METAS Calibration Campaign

Goals:

CS Calibration:

• Achieve high accuracy in VPR efficiency using different test aerosols:

1. Tetracontante particles (with GMD of 20 nm and PNC > 200.000 cm^-3)

2. Fresh soot particles (with GMD 10, 30, 60 and 90 nm)

3. Coated soot (SSA 0.5 – 0.7 for coated soot, SSA < 0.1 for fresh soot)

Picture taken at METAS (CCS with 0,4 L/min, Set temperature = 350°C)

MI-TRAP Metrics and methodologies (ACTRIS related)

Metric	Size range	Method of analysis
Particle Number (PN)	>10 nm	CN Counter (HR-A) Diffusion Charge (C-E)
Total Solid Particle Number (sPN)	>10 nm	CN Counter Diffusion Charge (C-E) Catalytic stripper/Heated inlet
PN Size Distribution (PNSD)	10-900	Electrical Mobility Spectrometer (HR-A)
Absorption/BC mass	PM2.5	Absorption Photometer (StanBC)
Absorption/BC mass (Constant MAC)	PM2.5	Absorption Photometer (StanBC)
Elements Mass concentration	PM2.5	NRT ED XRF (HR-A) Off-line ED XRF (C-E)
Chemical Speciation of NR-PM	PM1	NRT-SA (HR-A) Aerosol Chemical Mass Spectrometry Monitor
PM Mass concentration	PM2.5	Beta gauge/optical/TEOM
NOx/NO2 Gas Concentration	-	Chemiluminescence
CO2 Gas Concentration	-	Infrared absorption
Noise (dB)		Noise monitor
Fleet identification NRT	-	Image processing

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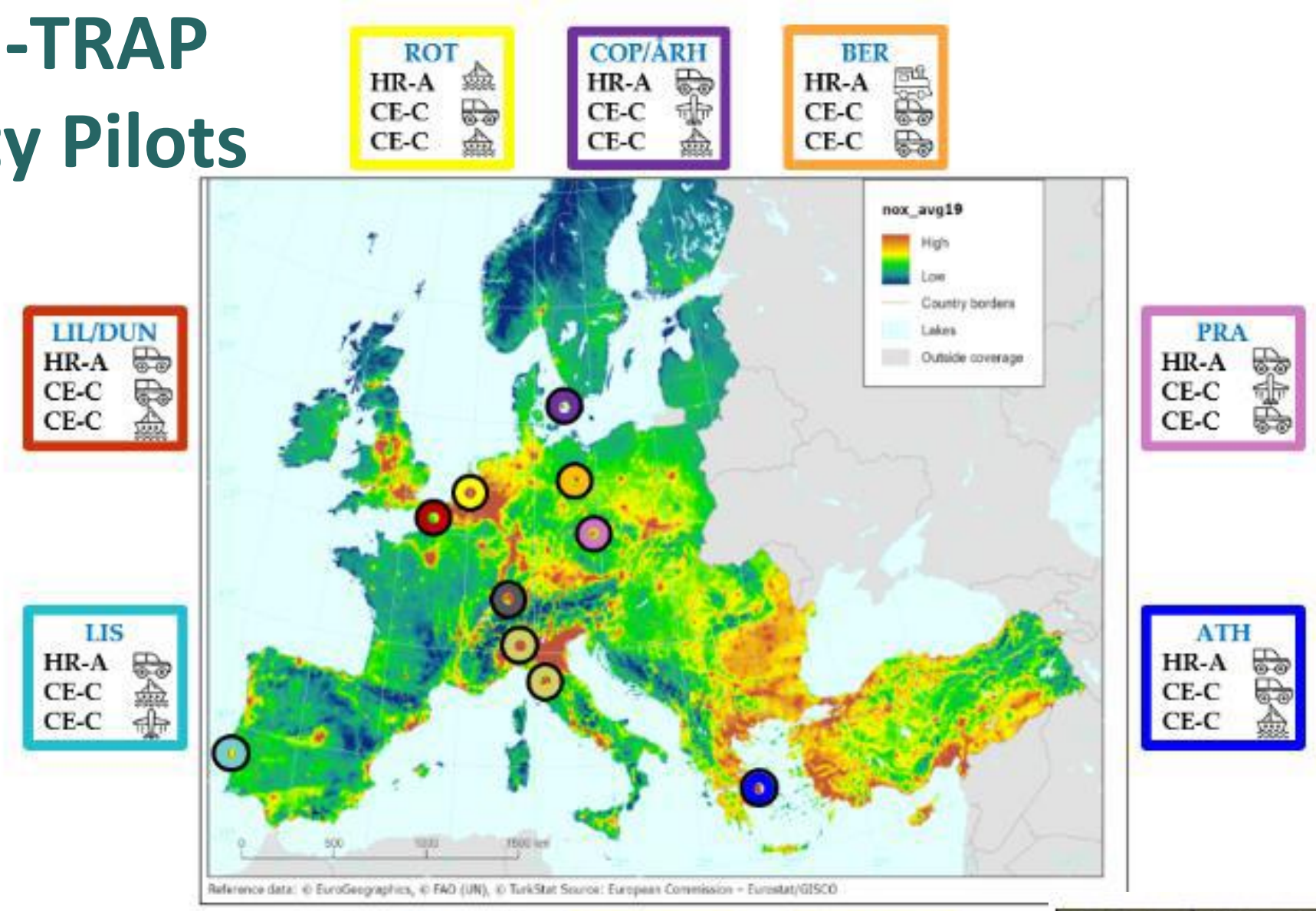
High Resolution Advanced Station (HR-A)

Compact cost-effective station (C-E)

ΔΗΜΟΚΡΙΤΟΣ

MI-TRAP City Pilots



HR-A	High Resolution Advanced station
CE-C	Cost-Effective Compact station

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Transport ○ Health ○ Data

Thank you!

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MI-TRAP

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Funded by the European Union

MI-TRAP objectives and ambition

- Provide **state of the art and innovative** measurement methods for **regulated and emerging air quality metrics** for transport-related pollutants and noise

- Demonstrate an established **network of stations** at key Pilot European cities to provide Near Real **Time (NRT)**
  i) advanced datasets ii) **higher level data products** and iii) **maps**
  for monitoring pollutants (exhaust and non-exhaust particles) and noise in **high traffic-density areas, ports and airports**

- To develop, test and establish in **an operational capacity** a MI-TRAP system of NRT **traffic, air quality and noise models** targeting the transport emissions from urban road/port and air in Europe to account for real world emission factors (incl **UFPs and Black Carbon, BC)**

MI-TRAP Metrics and methodologies

Are focused on Transport Hotspots

But

Two partners (ICPF-PACC, INFN-LABEC) are part of the **ACTRIS CAIS-ECAC** and will thus contribute to achieving harmonized measurements of aerosol metrics

&

four partners (NCSR-D, ICPF, AU, PSI) are operating **ACTRIS National Facilities***

Applying ACTRIS methodologies for ambient measurements

two partners (METAS,PTB) are **Metrology Institutes** with experience in air quality and emission monitoring methods

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* (Labelling process permitting)