Urban Air Quality: Challenges and future directions

Martine Van Poppel

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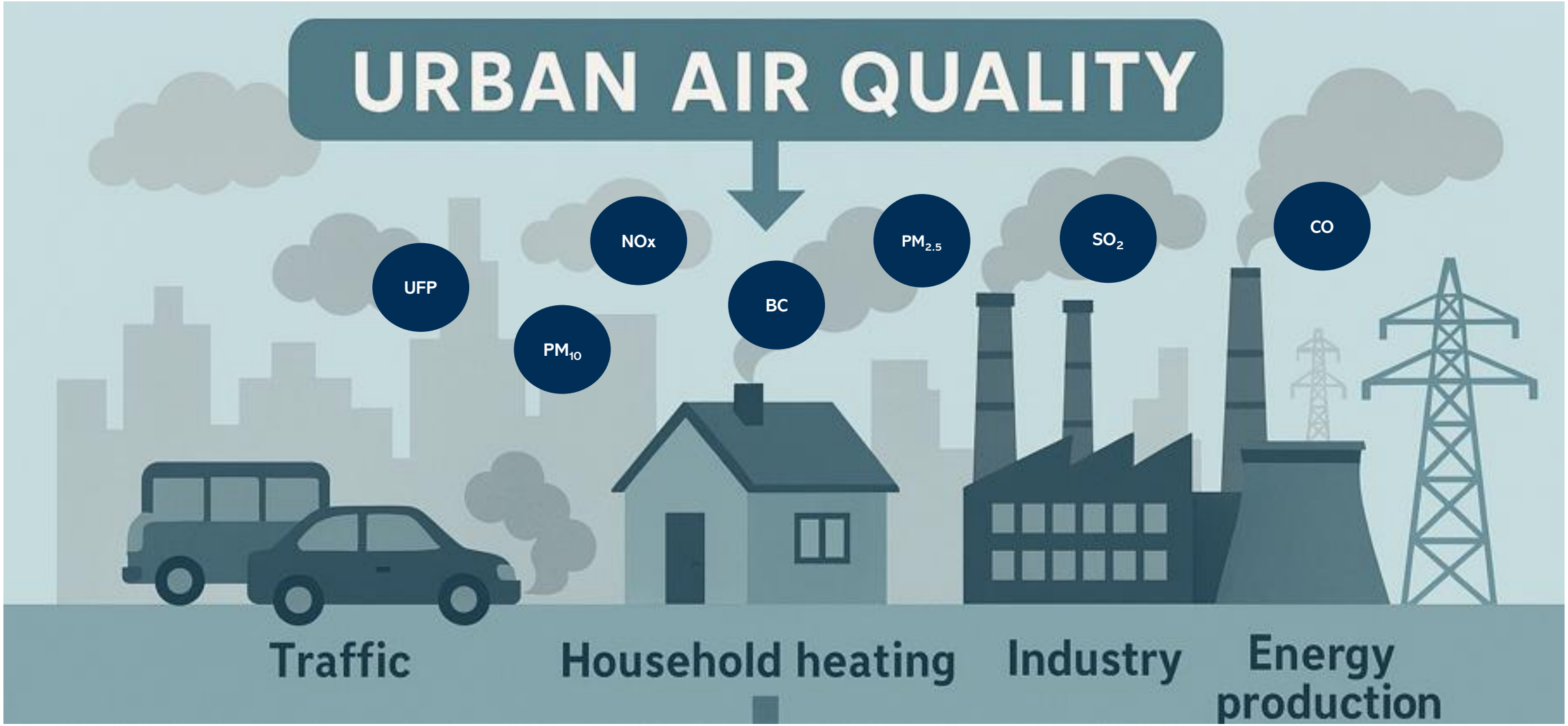
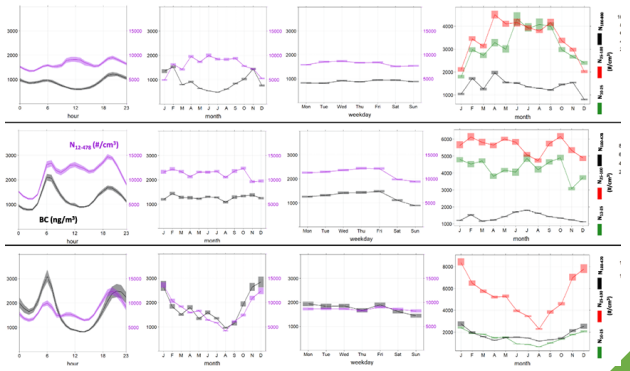

URBAN AIR QUALITY
UFP
NOx
PM10
BC
PM2.5
SO2
CO
Traffic
Household heating
Industry
Energy production

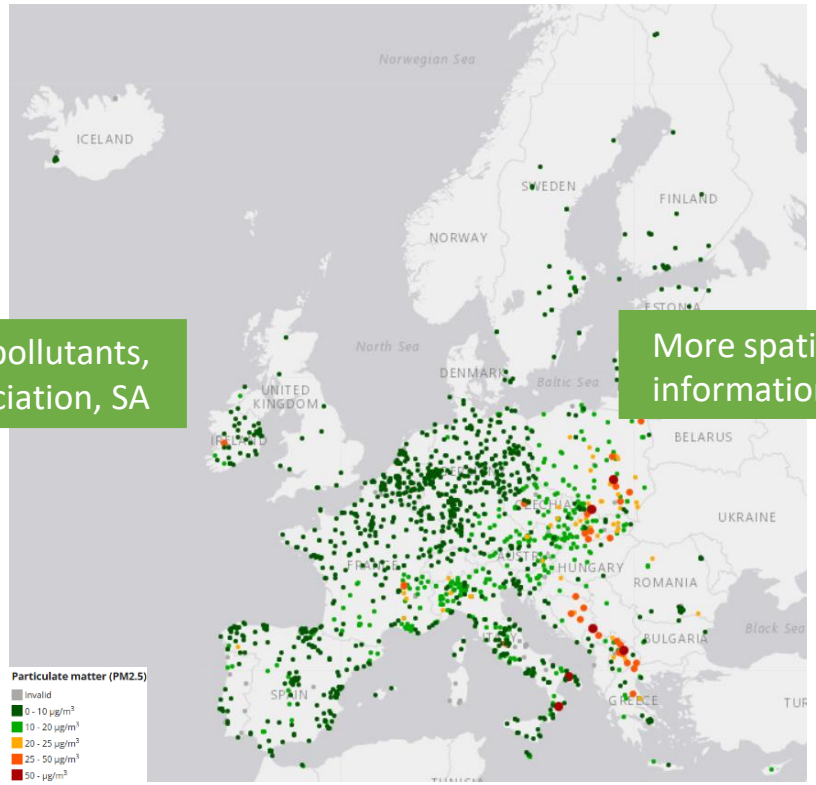
Urban AQ in Europe



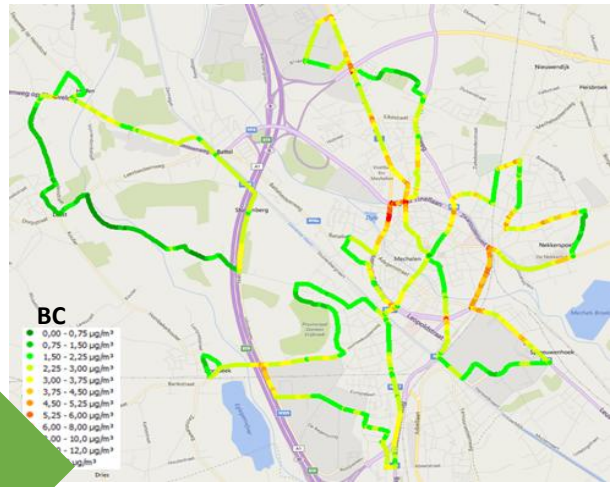
Trenchera P. et al., Env. Int. (2023)

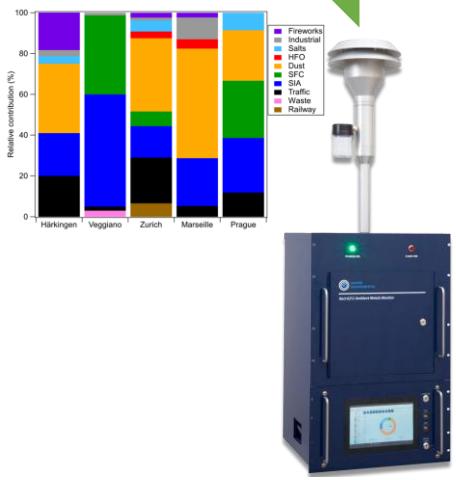
Novel AQ pollutants, speciation, SA

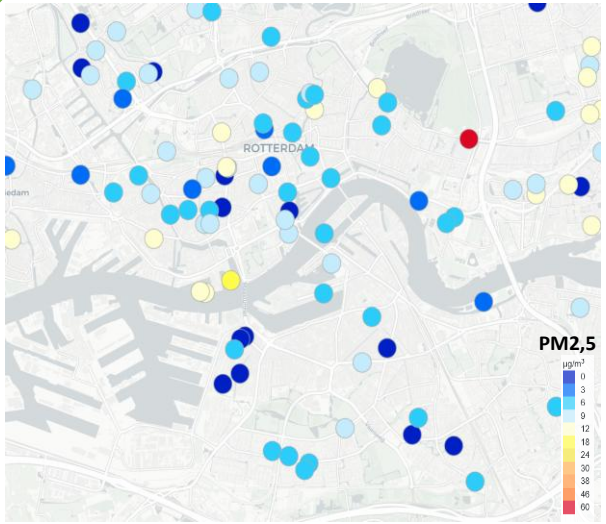
EUROPE



More spatial information







New AQD (2024/2881):

requires/recommends measurements

of UFP (PNC, PSD), NH_3, BC, OP …

at urban background and/or rural supersites

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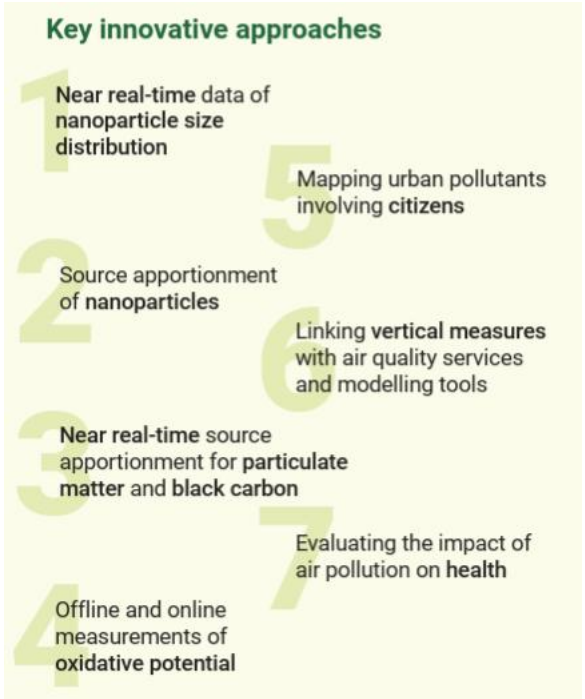
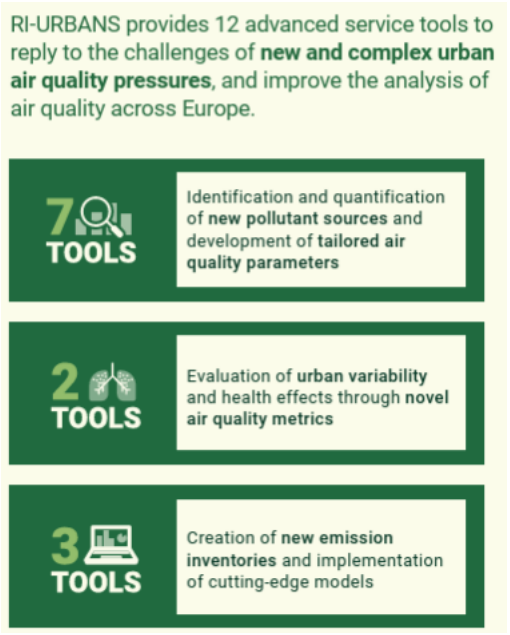
RI-URBANS

Research infrastructures services reinforcing air quality monitoring capacities in European urban and industrial areas

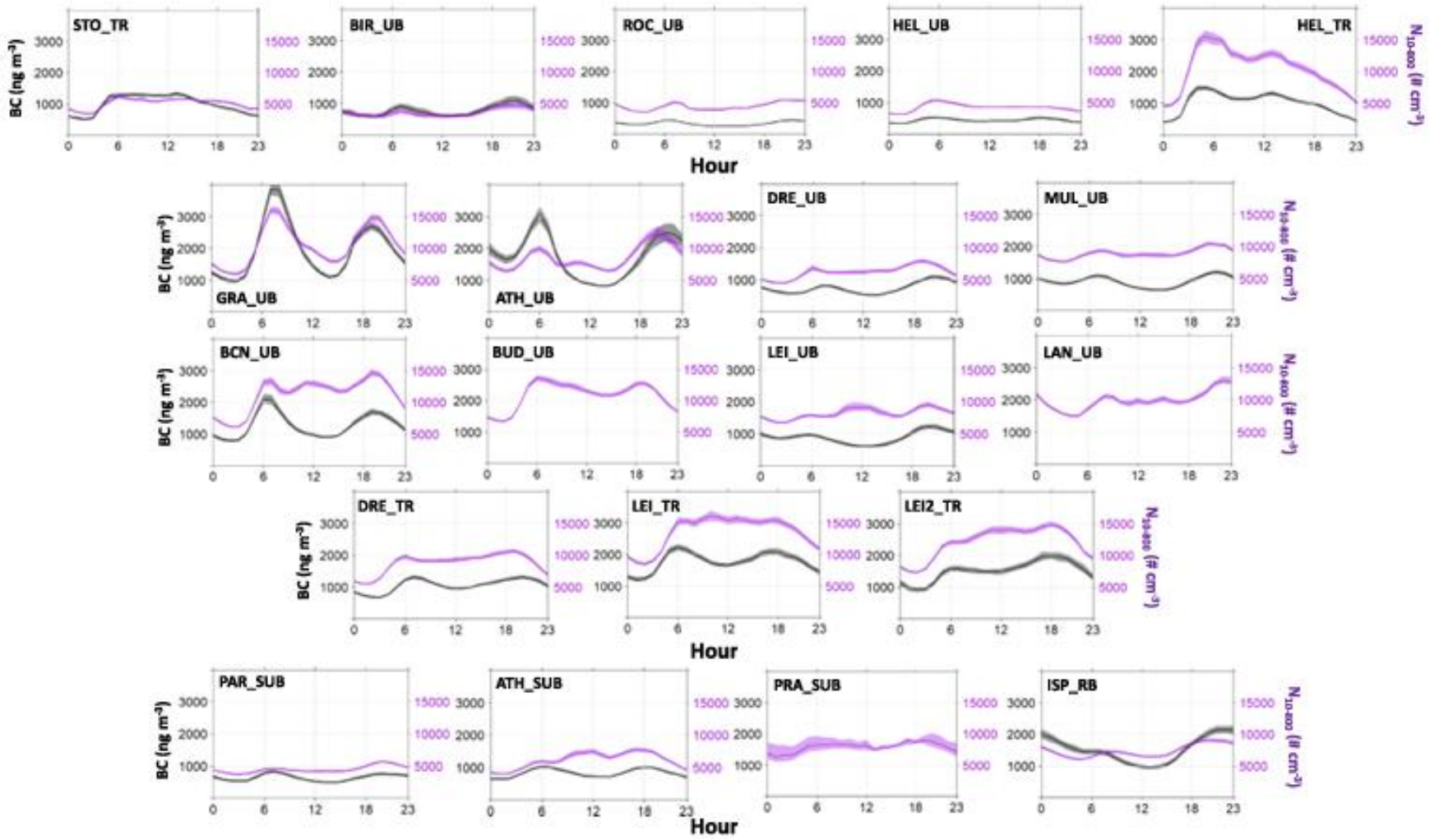
- Improve tools for better AQ assessment and management in EU cities
- Focus on human exposure to outdoor nanoparticles and Particulate Matter (PM), their constituents, sources and precursors





See https://riurbans.eu/project/

PNC and BC



Trenchera P. et al., Env. Int. (2023)

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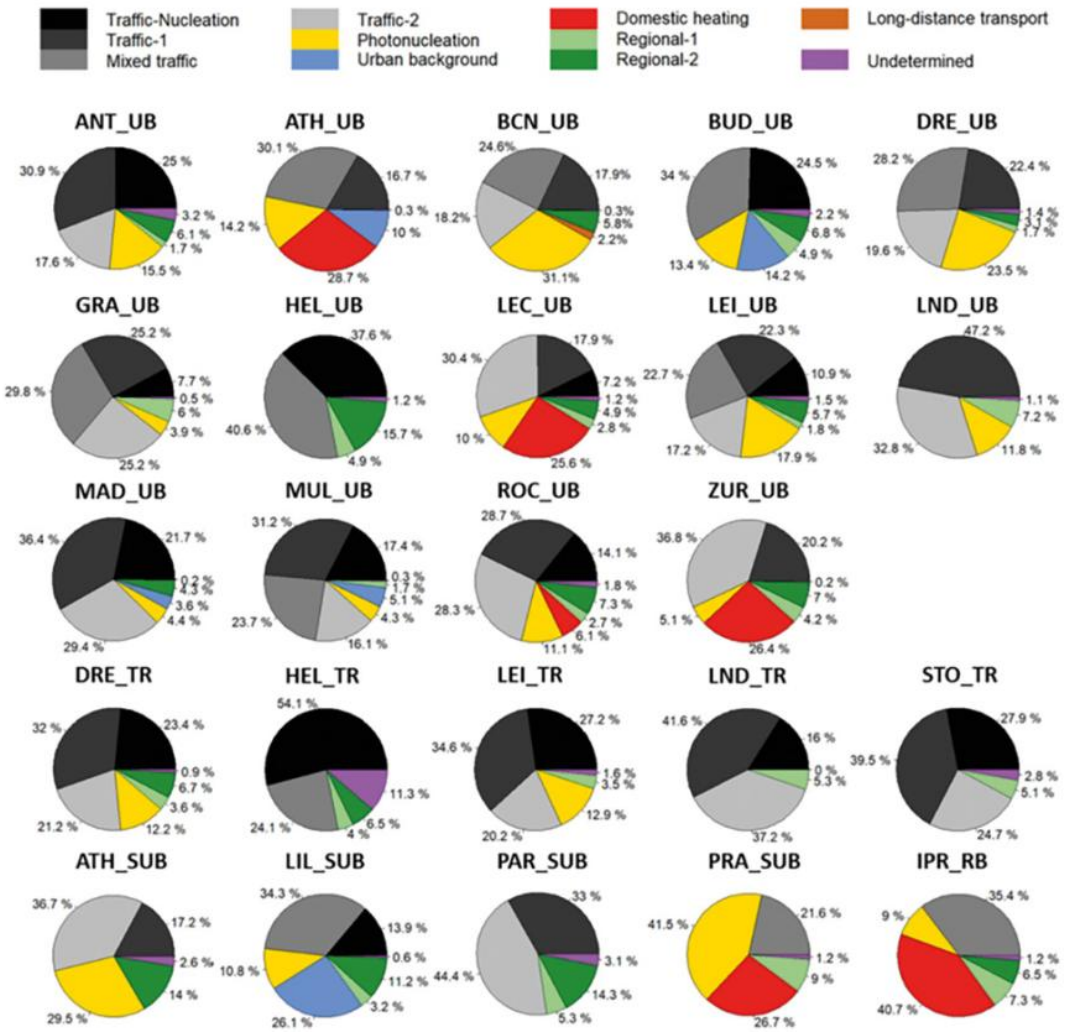
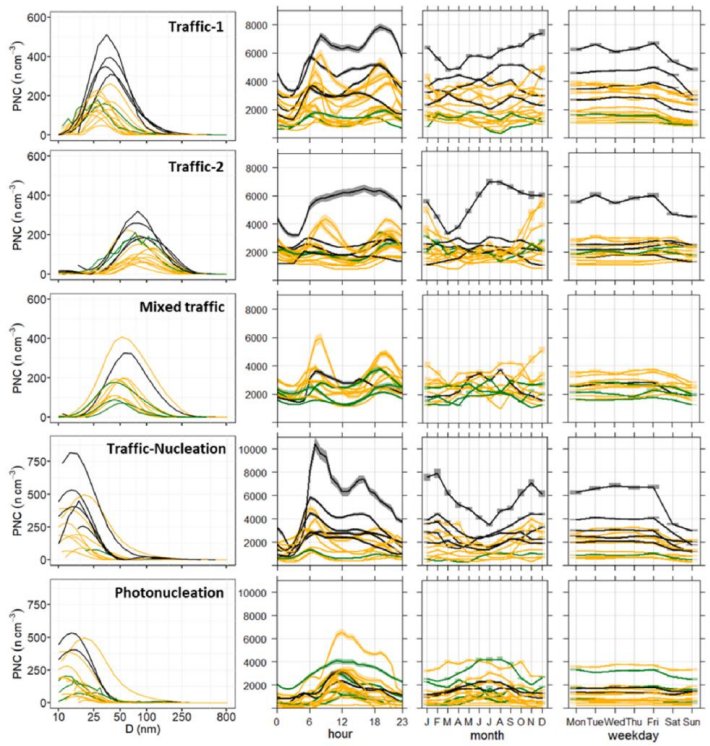
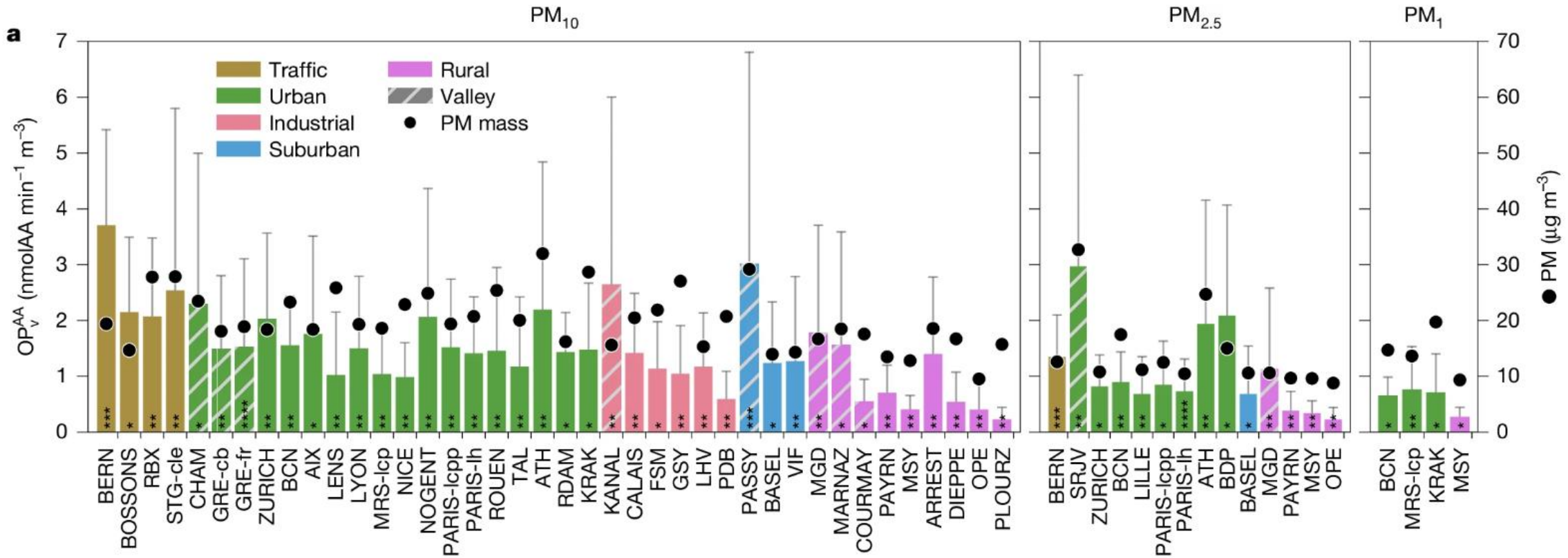
UFP sources



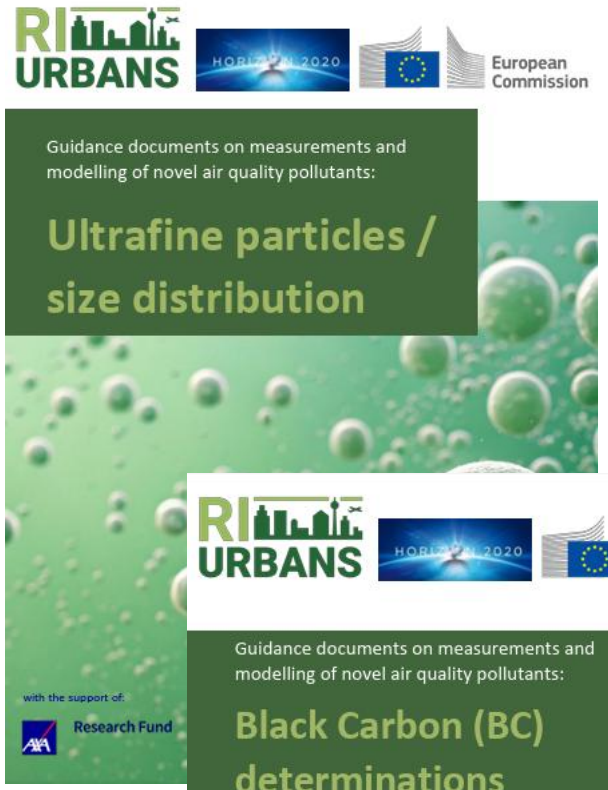


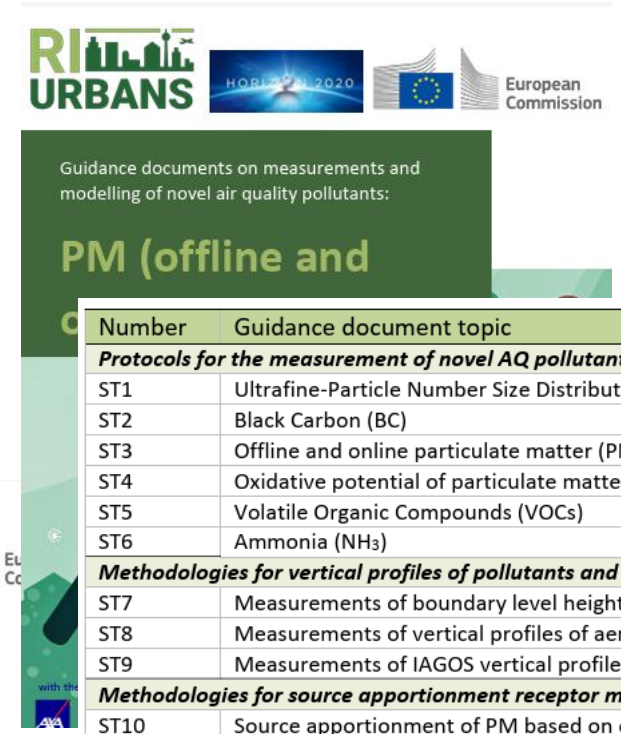
Garcia-Marlès et al., Env. Int. 2024

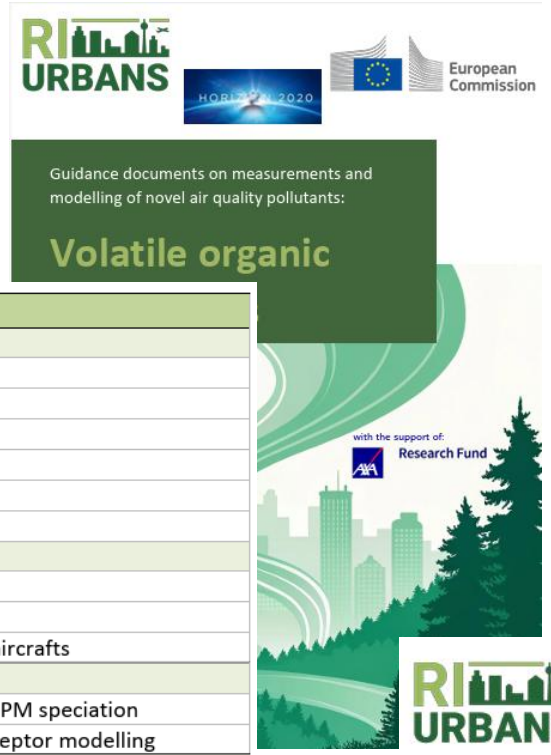
Oxidative potential



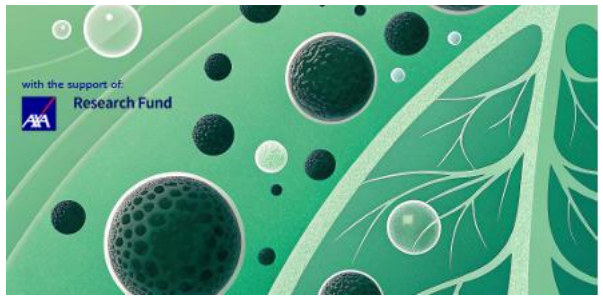
Tassel, C., et al., Nature. 2025







Number	Guidance document topic
Protocols for the measurement of novel AQ pollutants	
ST1	Ultrafine-Particle Number Size Distributions (UFP-PNSD)
ST2	Black Carbon (BC)
ST3	Offline and online particulate matter (PM) speciation
ST4	Oxidative potential of particulate matter (OP of PM)
ST5	Volatile Organic Compounds (VOCs)
ST6	Ammonia (NH_3)
Methodologies for vertical profiles of pollutants and meteorology	
ST7	Measurements of boundary level height
ST8	Measurements of vertical profiles of aerosols
ST9	Measurements of IAGOS vertical profiles by commercial aircrafts
Methodologies for source apportionment receptor modelling	
ST10	Source apportionment of PM based on offline and online PM speciation
ST11	Source apportionment of UFP, BC, OP and VOCs using receptor modelling
Methodologies for urban mapping of novel AQ pollutants	
ST12	Deterministic urban modelling of fine PM and PNC
ST13	Mapping ultrafine particles and citizen science
Methodologies for evaluating the health effects of novel AQ pollutants	
ST14	Evaluation of health effects of novel AQ parameters
Obtaining emission inventories for novel AQ pollutants	
ST15	First UFP-PNSD and non-exhaust vehicle PM EU emission
Modelling methodologies for novel AQ pollutants	
ST16	UFP-PNSD multiscale modelling



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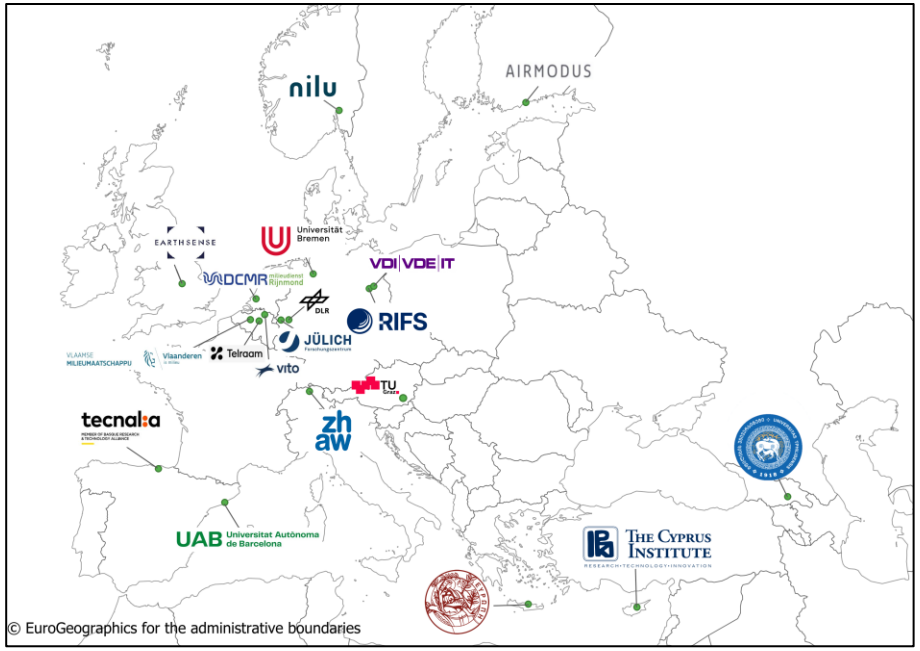
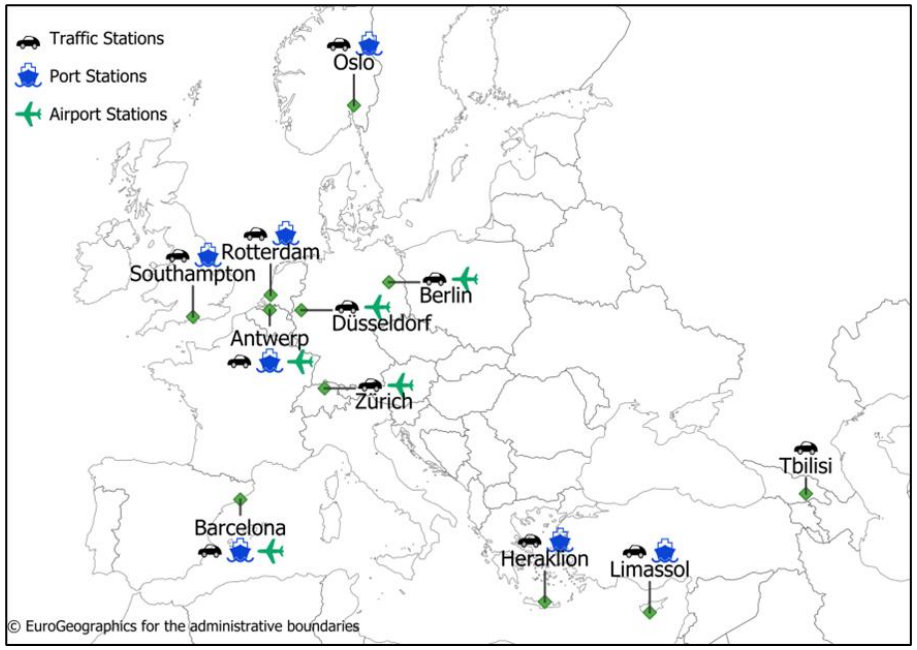
Net4Cities

- Overall aim of Net4Cities is to facilitate the realization of the EU Green Deal's Zero Pollution Action Plan by **advancing air and noise pollution monitoring infrastructure** and providing **evidence-based support for implementing effective transport policies** via the Net4Cities Studio products and thereby improving air quality and mitigating noise pollution
- 2024 - 2027

See https://www.net4cities.eu/





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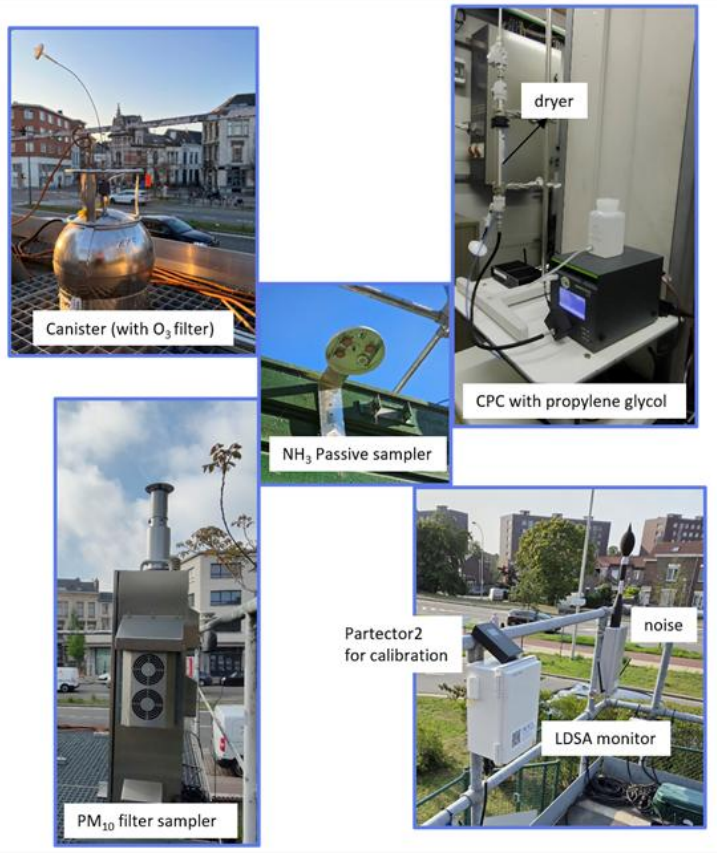
Net4Cities

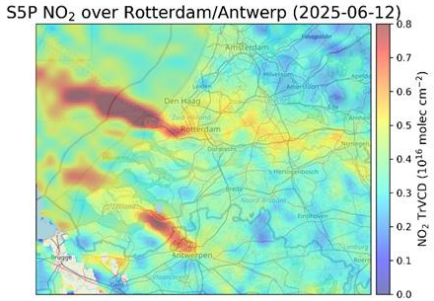
- 11 partner cities (multiple locations in each city)
- Focus on urban traffic locations and around ports and airports
  - 6 airport sites, 6 port sites, 18 urban traffic sites,
    2 rural/1 urban background site
- > 2 years of (continuous) measurements
  - Air Quality (emerging pollutants), noise, traffic counts
- EGU presentations

📍 Oral session: Friday, 08 May, 08:30–12:30 (CEST) | Room F2
📍 Poster session: Friday, 08 May, 14:00–15:45 (CEST) | Hall X5

🔹 Oral presentation
- Continuous Monitoring of Lung Deposited Surface Area (LDSA) Across 11 European Cities: First Results from the Net4Cities Project (Saskia Drossaart van Dusseldorp et al.)

🔹 Posters
- Black Carbon Trends and Source Apportionment in Berlin: A Multi-Year Analysis (Erika von Schneidemesser, Himanshu Setia et al.)
- Characterizing urban traffic emissions across Europe: Insights from canister sampling in Net4Cities (Archita Rana, Ph.D. et al.)
- High-Time-Resolution Analysis of Organic and Inorganic Trace Gases and Particles in a Major European Port Using Mobile and Stationary Measurements (Himadri Bhowmik, Robert Wegener, et al.)





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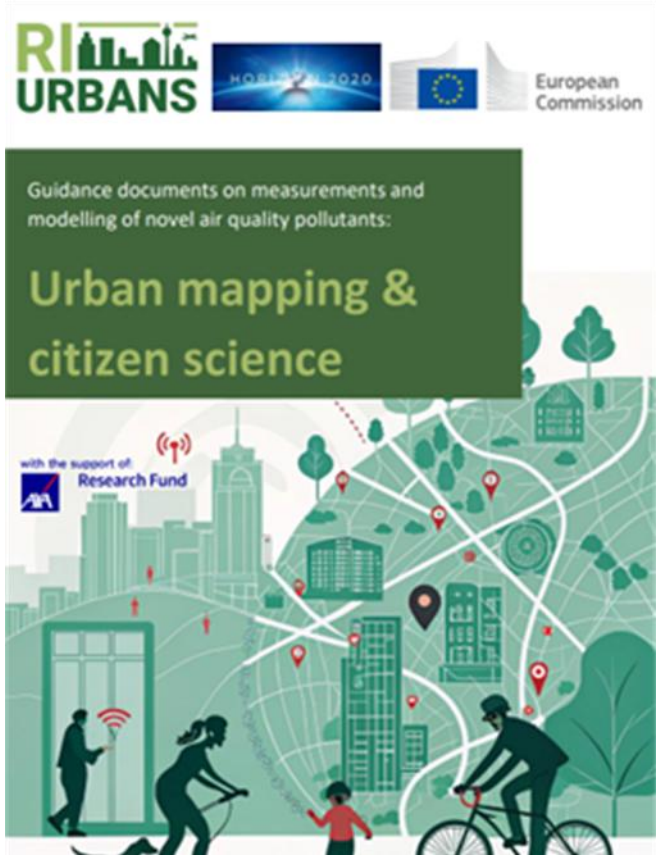
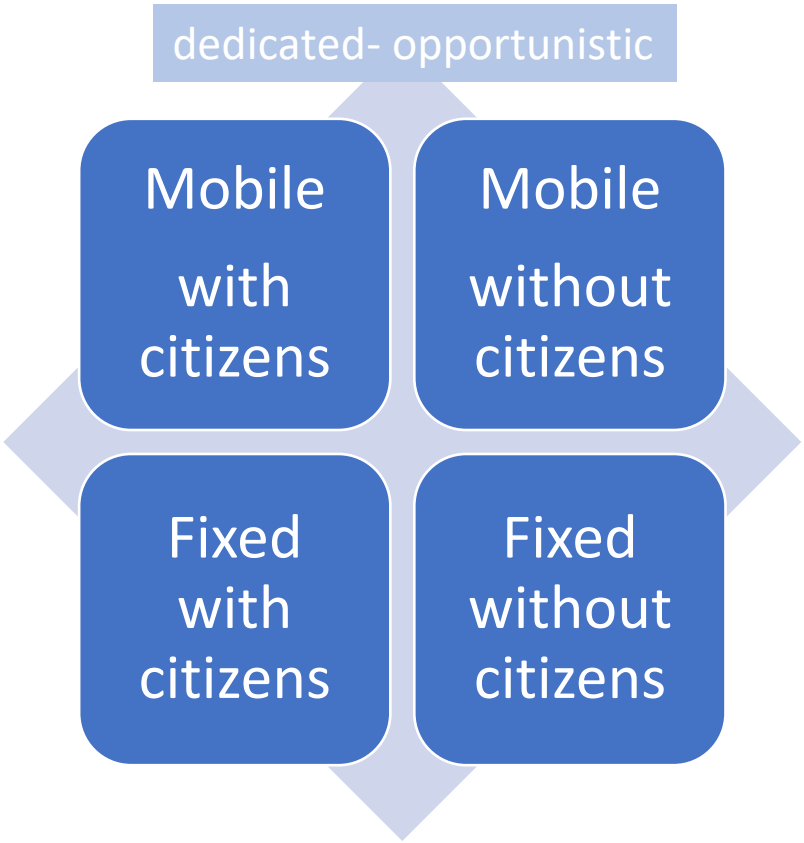
Towards denser AQ data: urban mapping

- Service tool developed in RI-URBANS
- New insights from mobile monitoring campaigns or low-cost sensor (LCS) networks
  - limited duration (weeks to months)
  - with a proper design
  - different approaches ~ research question
- Complementary to stationary AQMN
  - Longer campaigns can result in more precise estimates of air pollution patterns



Approaches for urban mapping



users

use cases

- Hot spot detection
- Evaluation of measures
- Evidence-based policies
- Evaluation models
- Health studies
- Route planner
- Gap-filling AQMN
- …

Data processing

Interpolation

Modelling

- QA/QC
- Aggregation
- Background correction
- LUR models
- ML models
- …

Mobile mapping of air pollution

- Mobile monitoring as efficient tool to complement fixed AQMN by adding spatial resolution
- Experimental design is important and is function of the use case
- Mobile approaches – experimental design:
  - **Dedicated** vs **opportunistic**
  - Mobile platform: **vehicle** vs **portable**
  - Instruments - routes
  - **Temporal coverage**: season (sources, dispersion, meteo,…), time of day
- Mobile monitoring supports public engagement and actionability
- Data processing: data-only vs modelling

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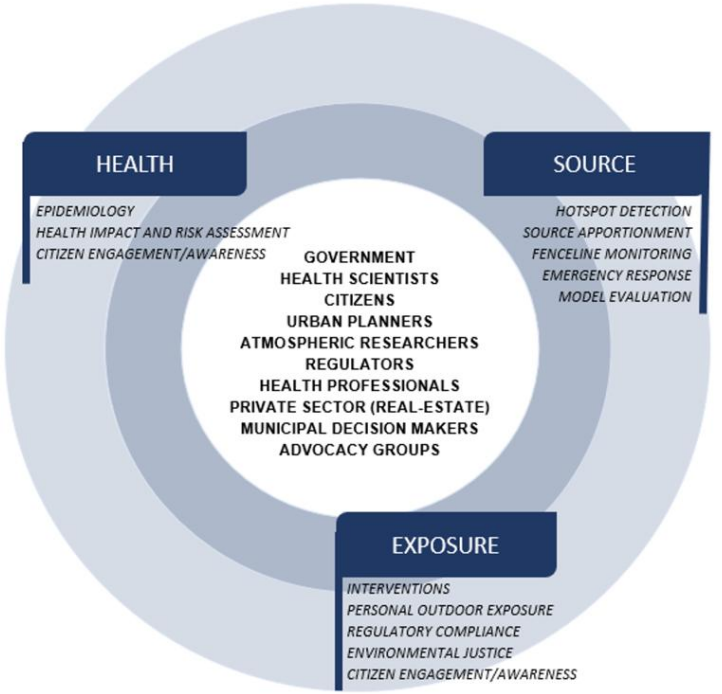
Discussion

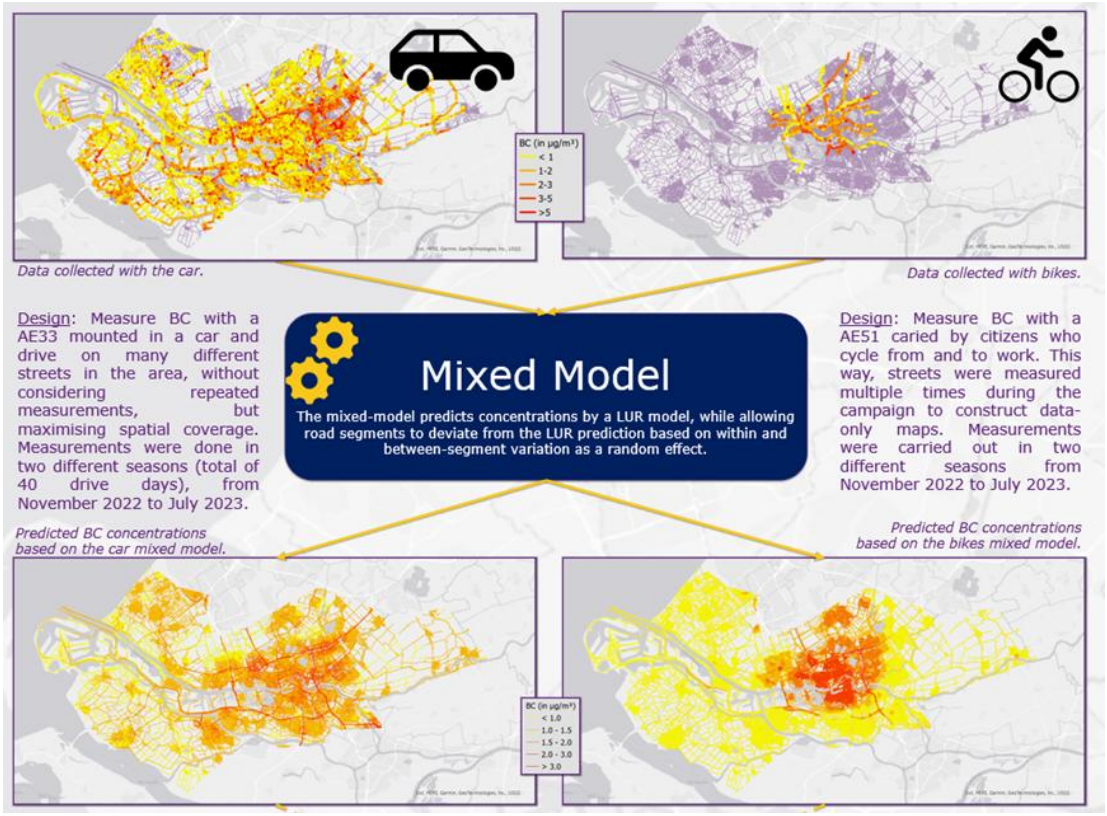
Mobile monitoring of air pollution – a position paper on use cases, good practices, challenges, and opportunities

Jules Kerckhoffs [a,1,*], Jelle Hofman [b,1], Jibran Khan [c,d], Matthew D. Adams [e], Magali N. Blanco [f], Priyanka deSouza [g], John L. Durant [h], Sasan Faridi [i,j], Scott Fruin [k], Steve Hankey [l], Mohammad Sadegh Hassanvand [i,j], Marianne Hatzopoulou [m], Gerard Hoek [a], Kees de Hoogh [n,o], Neelakshi Hudda [h], Meenakshi Kushwaha [p], Julian D. Marshall [q], Laura Minet [r], Allison P. Patton [s], Tuukka Petäjä [t], Jan Peters [b], Albert A. Presto [u], Kerolyn Shairsingh [v], Lianne Sheppard [f], Matthew C. Simon [w], Sreekanth Vakacherla [x], Keith Van Ryswyk [y], Martine Van Poppel [b], Roel C.H. Vermeulen [a], Robert Wegener [z], Zhendong Yuan [a], Heresh Amini [aa]



Data processing of mobile measurements

- **Data-only** vs **modelling approach**
- Data-only approach:
  - Mobile data as validation for deterministic models
  - Limited spatial coverage
  - High accuracy/measured
- Modelling approach:
  - Mobile data as input for empirical models
  - Wider spatial coverage
  - Model assumptions



Mobile mapping with citizens in Rotterdam

- BC measurements
  - AE51 and GPS
- Commuters of DCMR
  - Opportunistic (but restricted area)
  - During peak hours (mainly)
  - Different road segments collected at different days
- Summer and winter campaign

Hofman J. et al. 2026, submitted

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Gemeente Rotterdam

DCMR milieudienst Rijnmond

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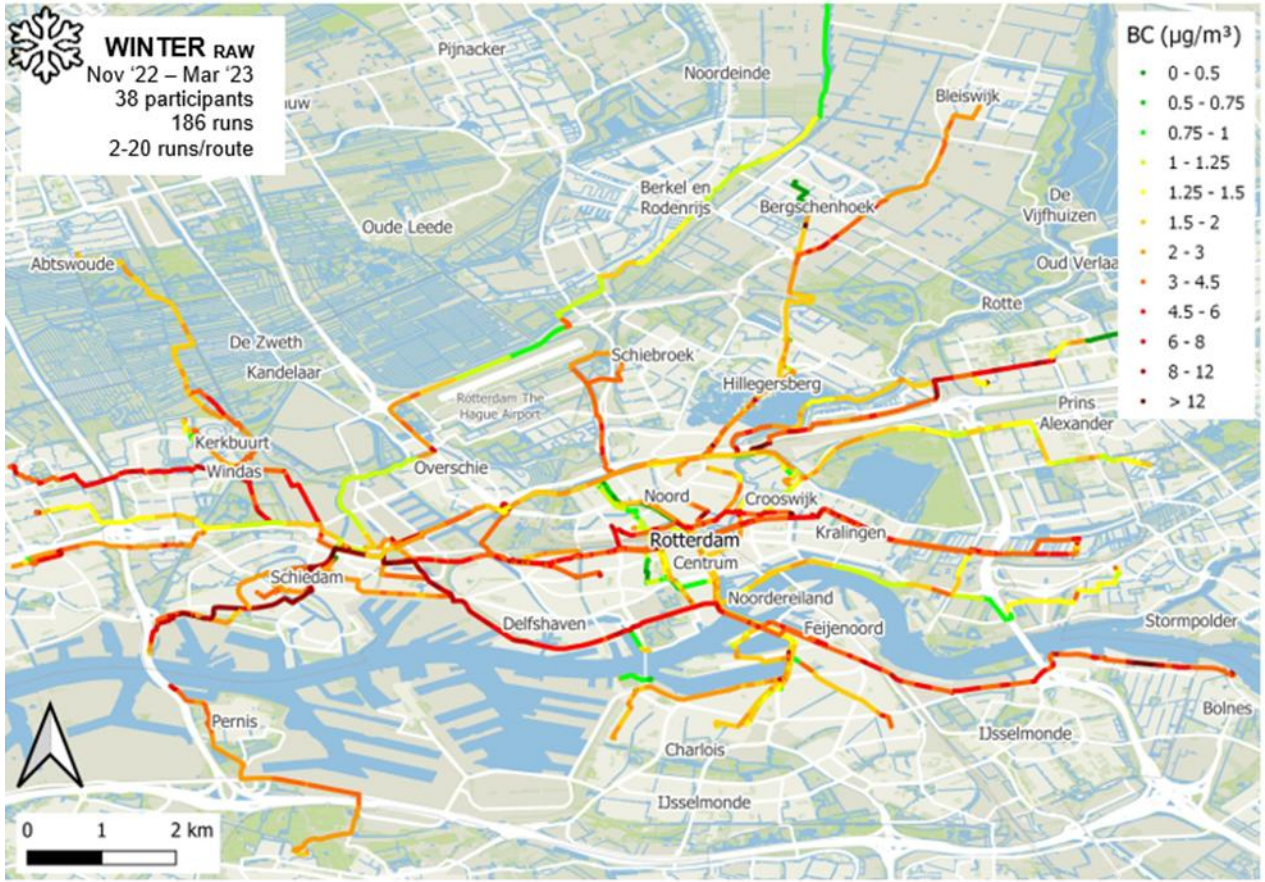
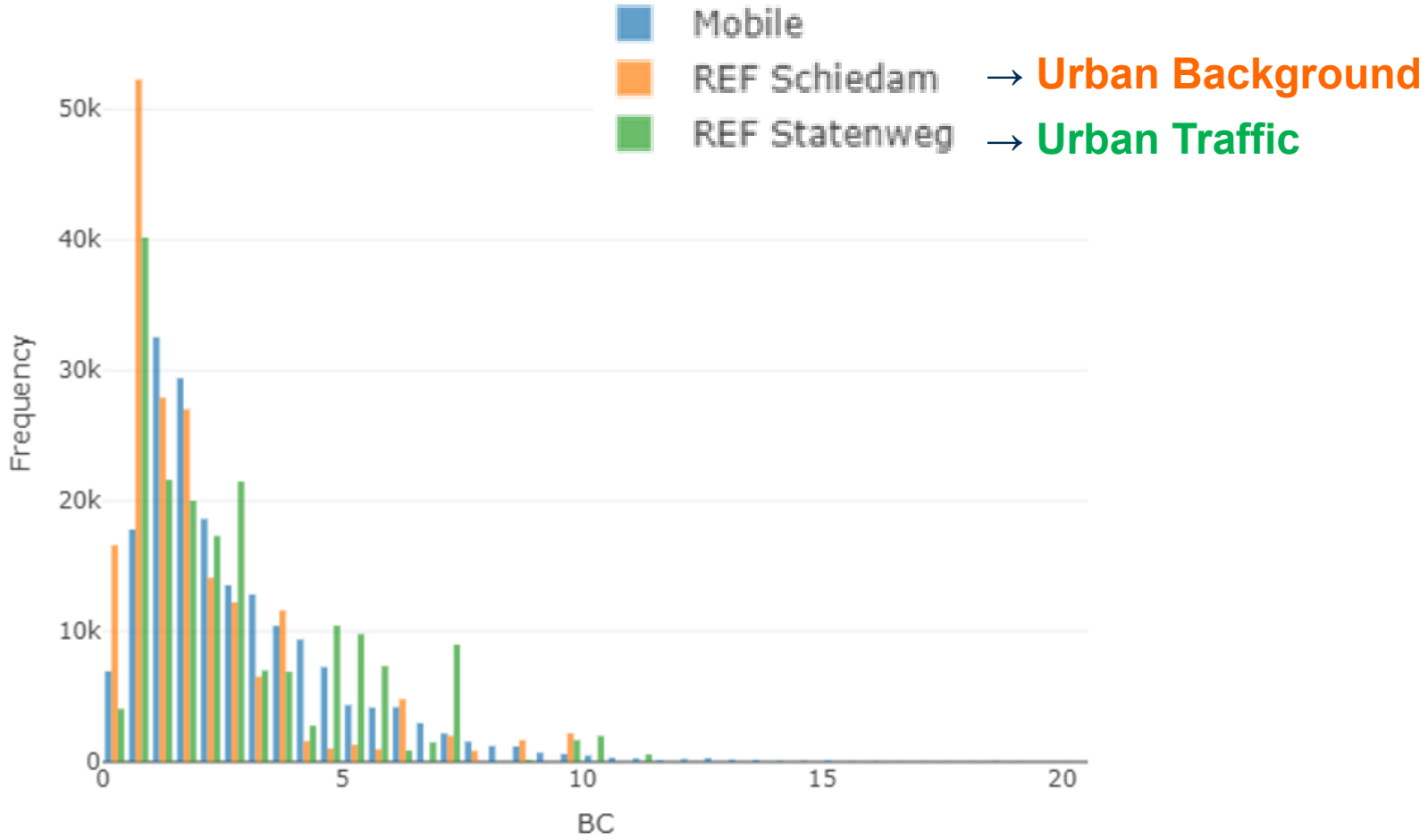
Results (aggregated raw data)



Comparison to AQMS

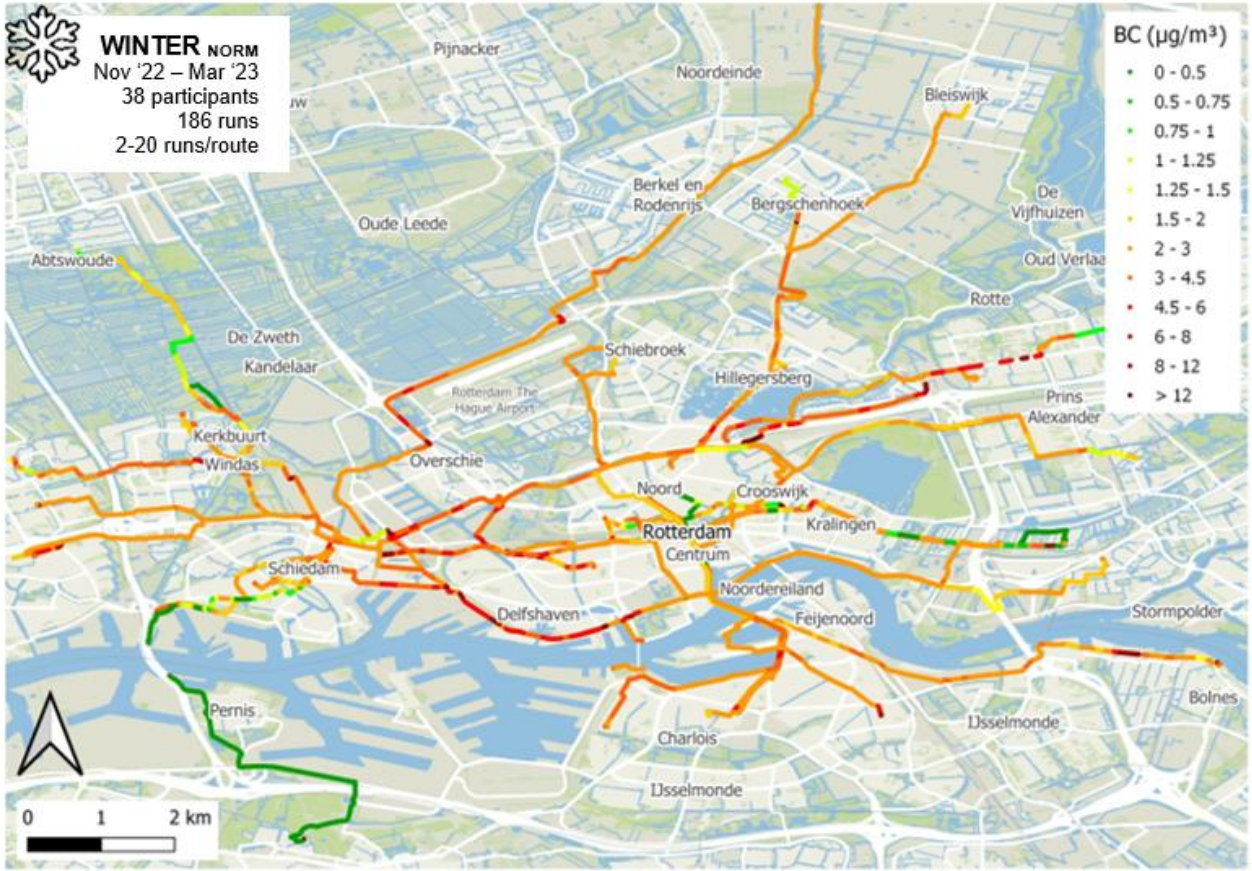


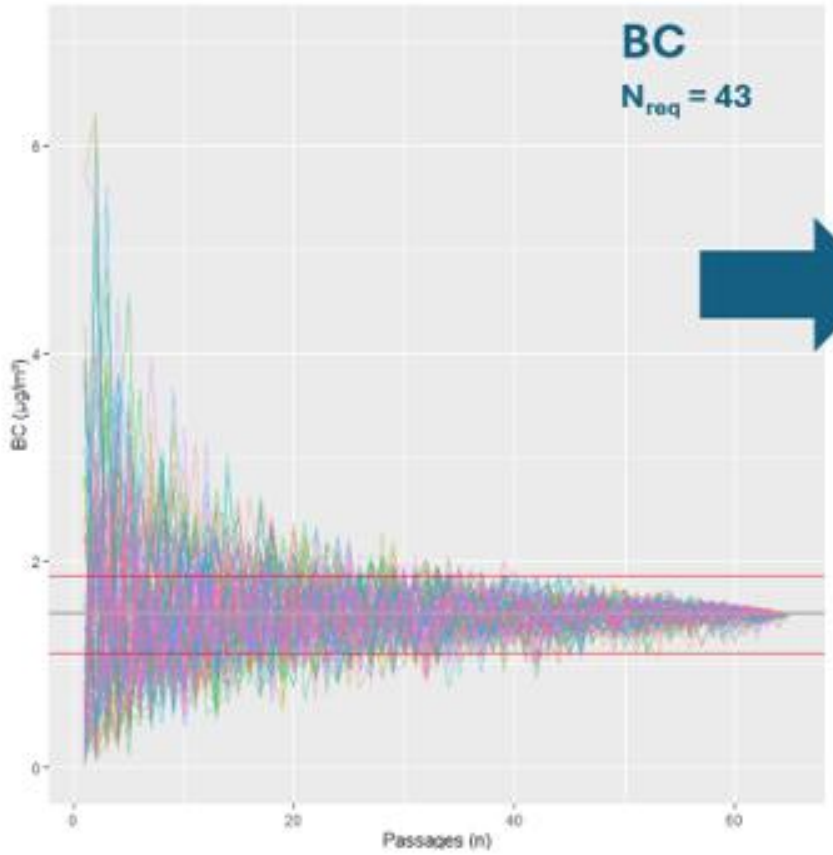
Challenges mobile measurements

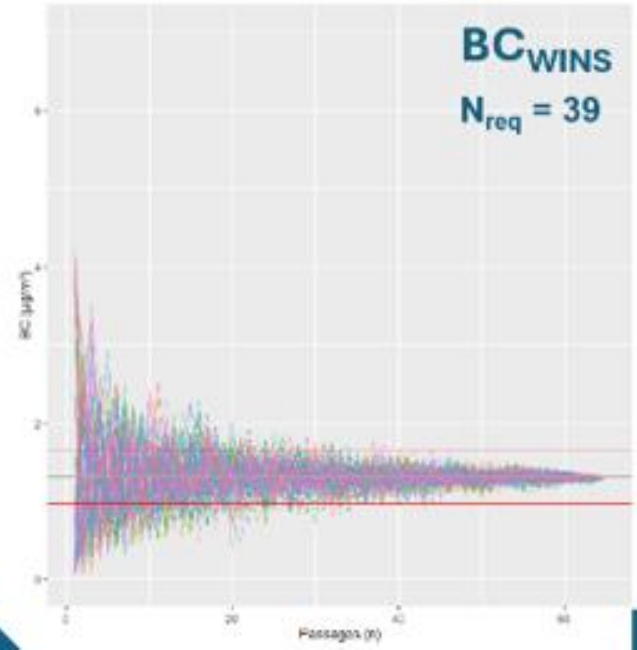
- Measurements at different space & time instances
  - Background concentrations
  - Temporal pattern of emission sources
  - Meteorological conditions
  - Specific local conditions
- Normalization (using fixed AQMS data) to:
  - Extrapolate campaign to long-term (annual) exposure maps
  - Compensate for data collected at other time instances (~opportunistic)
- Additive normalization and winsoring

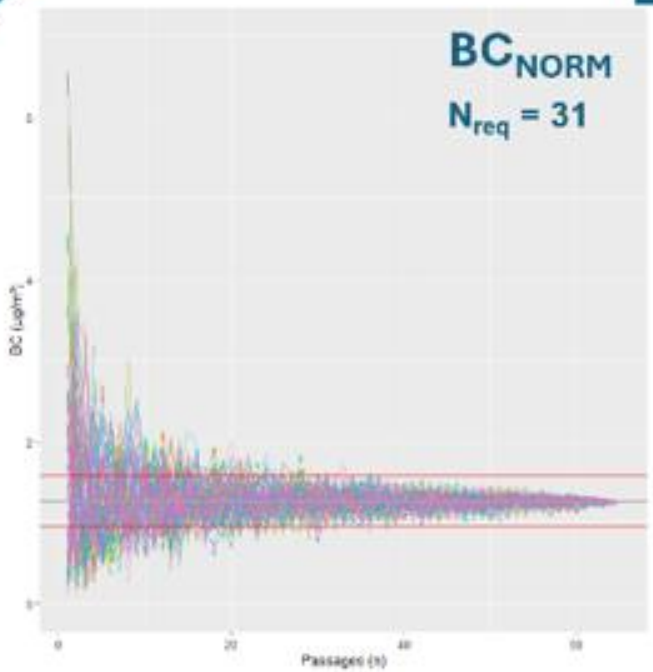
$$BC_{norm\ bg,i} = BC_{i,b} - BC_{i,bg} + \overline{BC}_{bg}$$

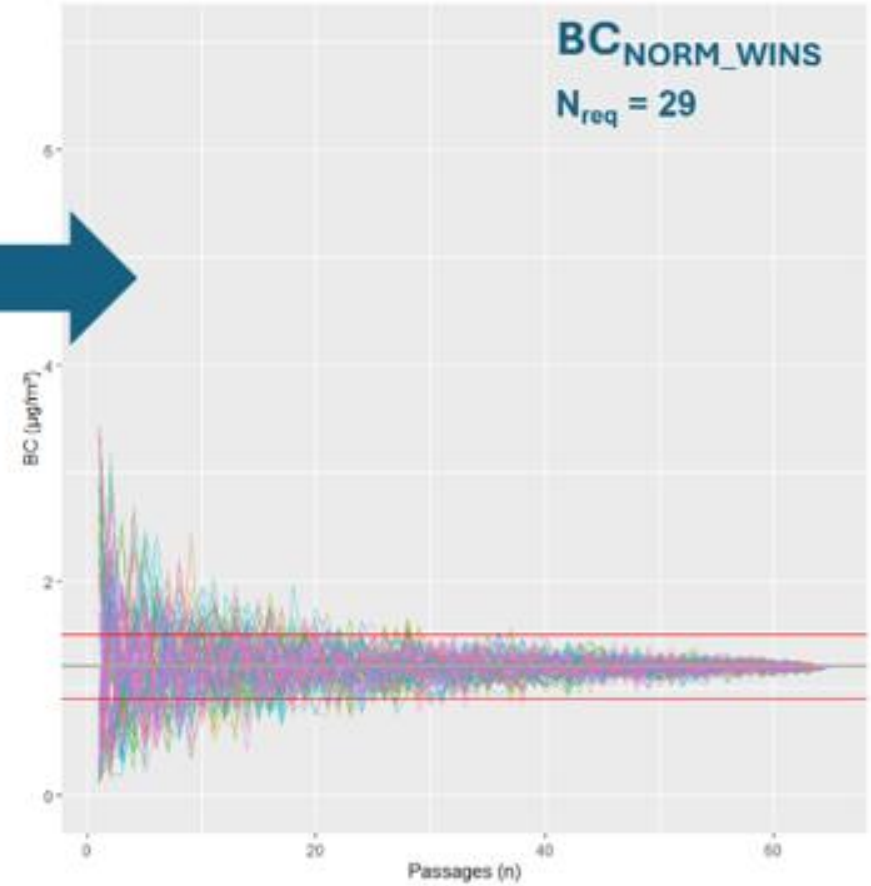
Results (aggregated rescaled data)



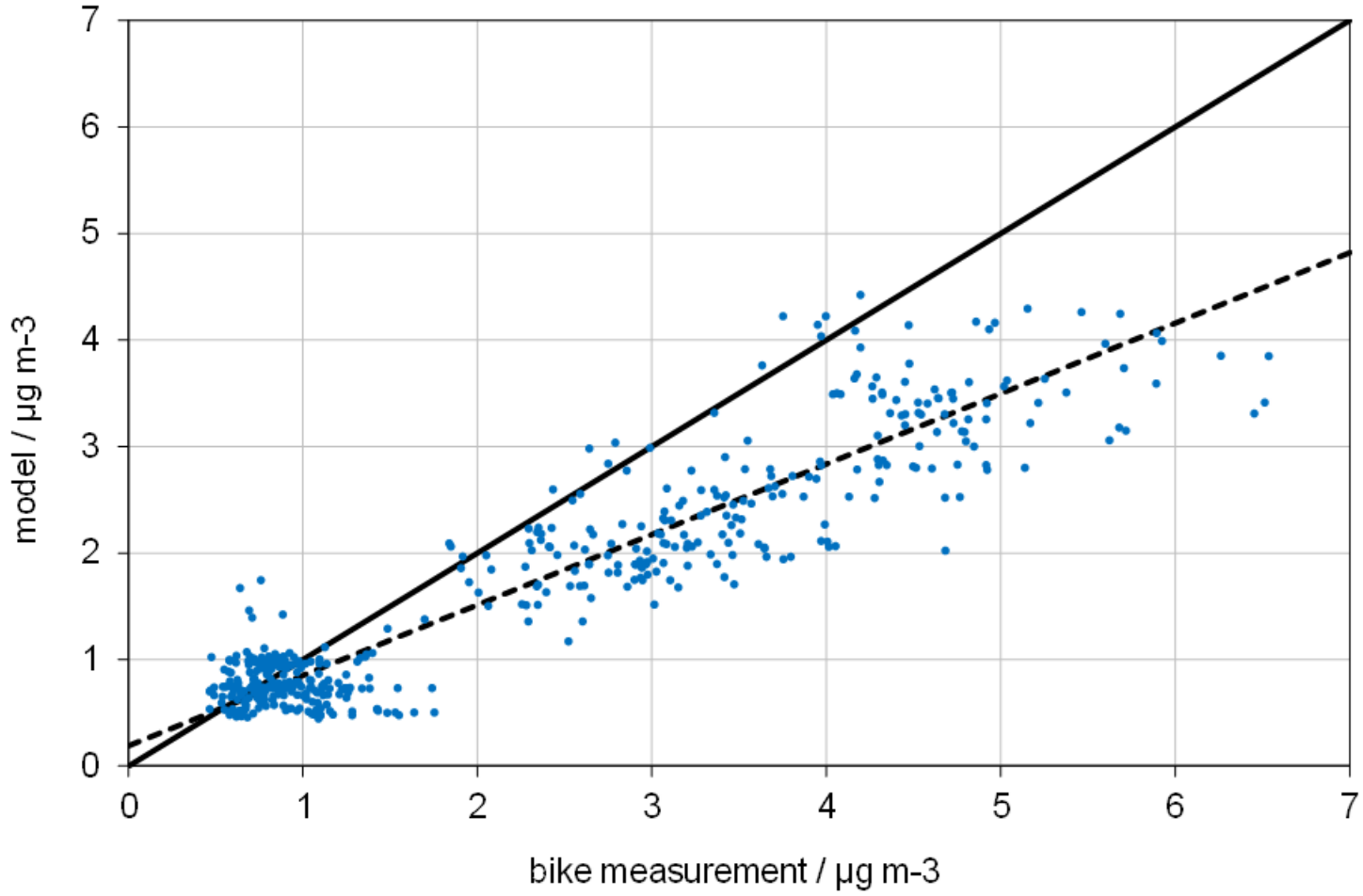

BC
N_{req} = 43
BC (µg/m³)
Passages (n)


BC_{WINS}
N_{req} = 39
Passages (n)

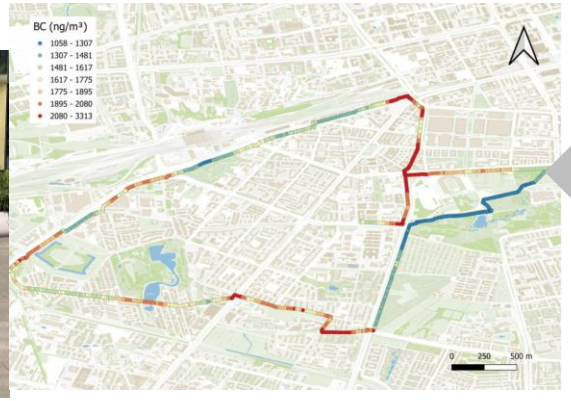

BC_{NORM}
N_{req} = 31
Passages (n)

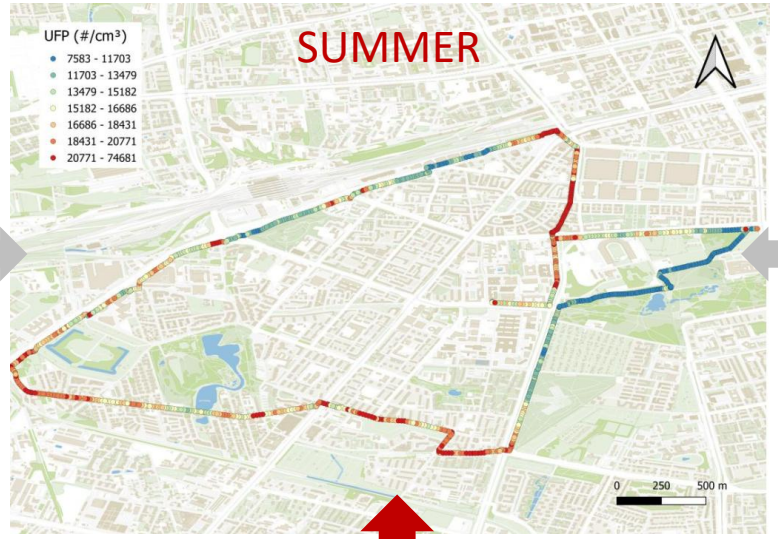

BC_{NORM_WINS}
N_{req} = 29
BC (µg/m³)
Passages (n)

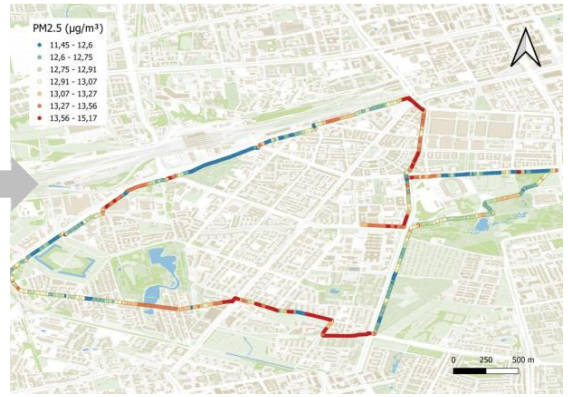
Mobile data for model validation



Mobile measurements in Warsaw







- BC, UFP, $PM_{2,5}$
- 2 seasons
- Rush hour
- Dedicated (fixed route)
- 40 repeats

Hofman J. et al. in preparation

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Hot spots


3.2 µg/m³


3 µg/m³

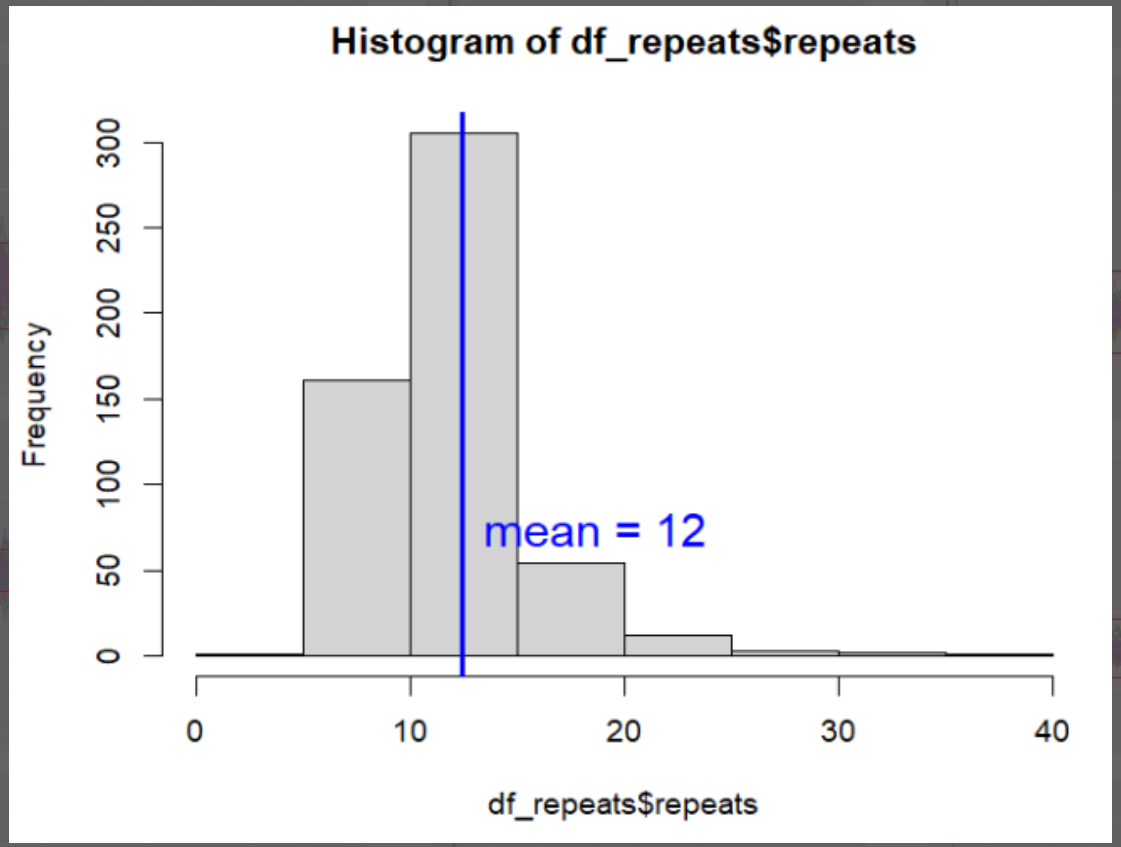
Black Carbon (ng/m³)
1069 - 1347
1347 - 1615
1615 - 1849
1849 - 2136
2136 - 2483
2483 - 2875
2875 - 3637
0
250
500 m


1 µg/m³

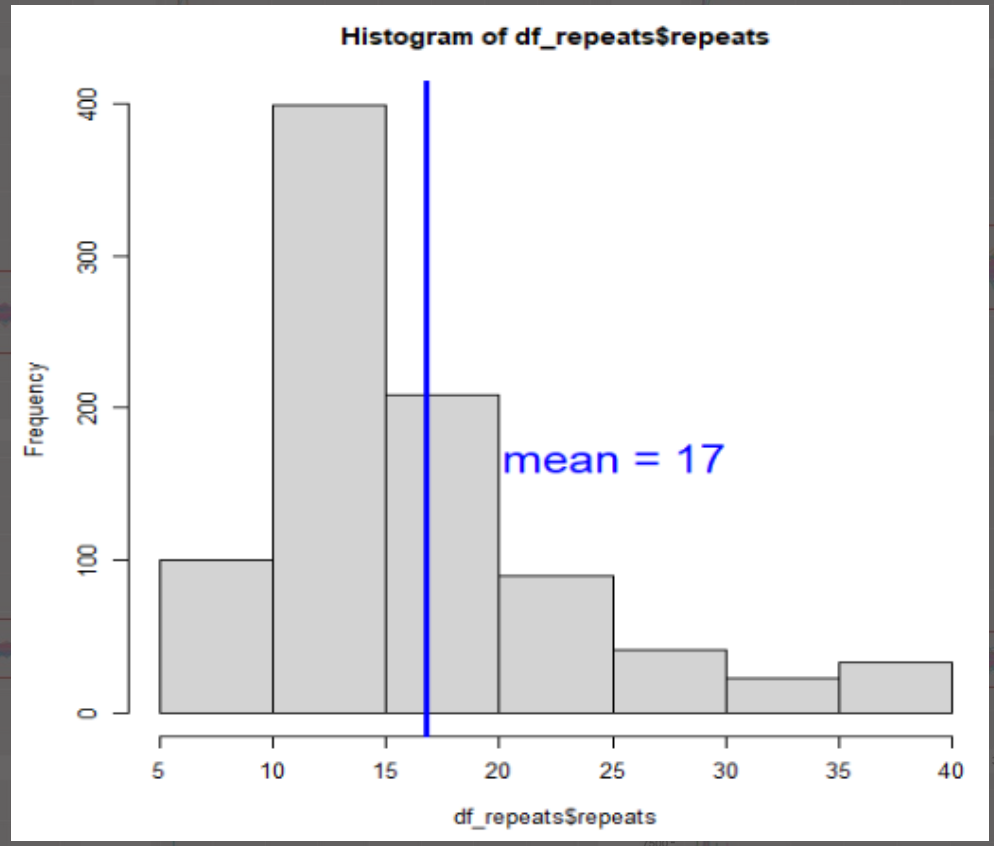

3.3 µg/m³


3.6 µg/m³

WINTER (n=539)

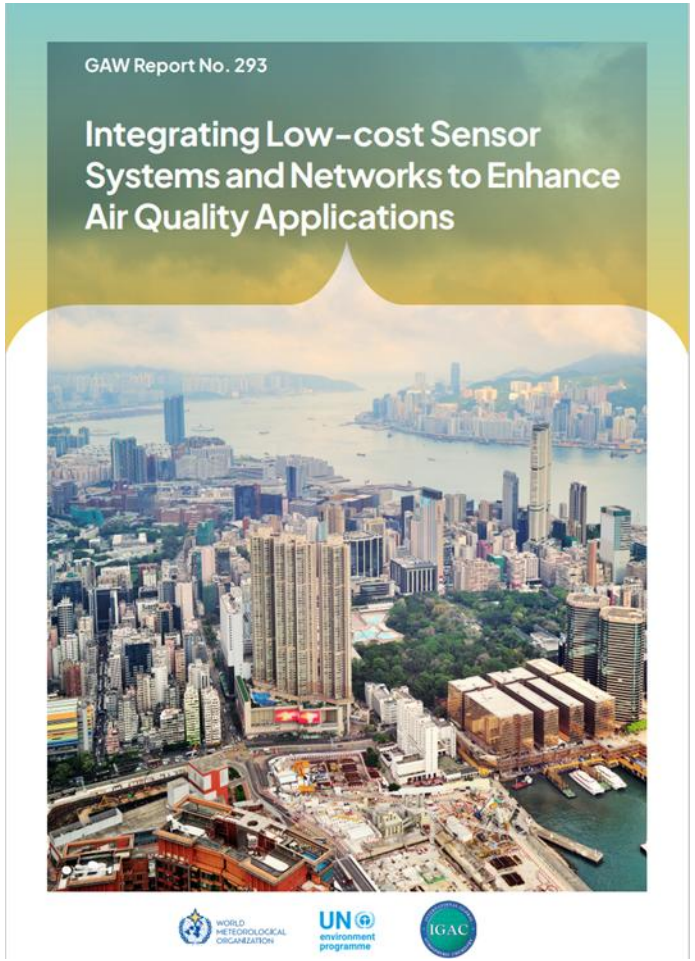


SUMMER (n=894)



Dense stationary sensor networks

- Diffusive tubes: low time resolution
- Data quality is important: data quantity ≠ data quality
  - Fit for purpose
- Quality control of sensor data by
  - Co-location campaign
  - Between instruments (BSU) + comparison against REF
  - Ideally on-site/similar conditions
  - On-going quality control – data cleaning
- Measurement set-up!
- To take into account:
  - Seasonal impact
  - Interferences
  - PM sensors: do they also measure PM_{10}



Example on how sensor networks can support policy: school street

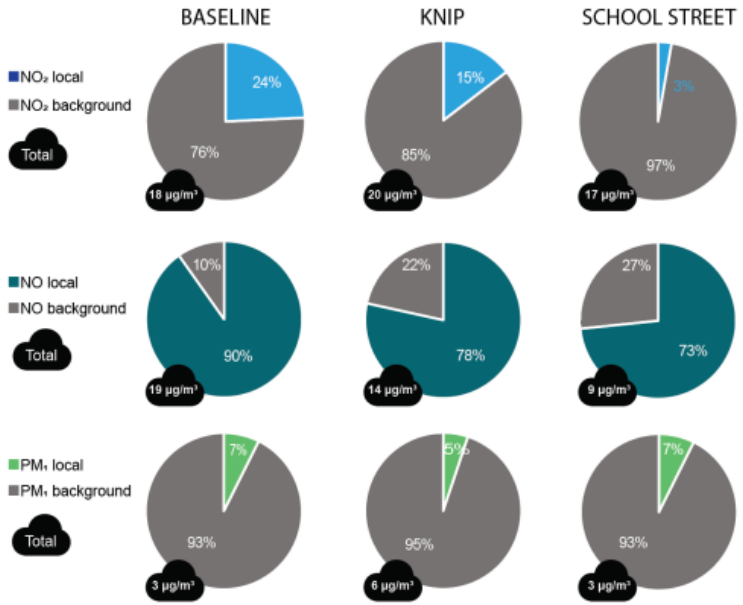
atmosphere

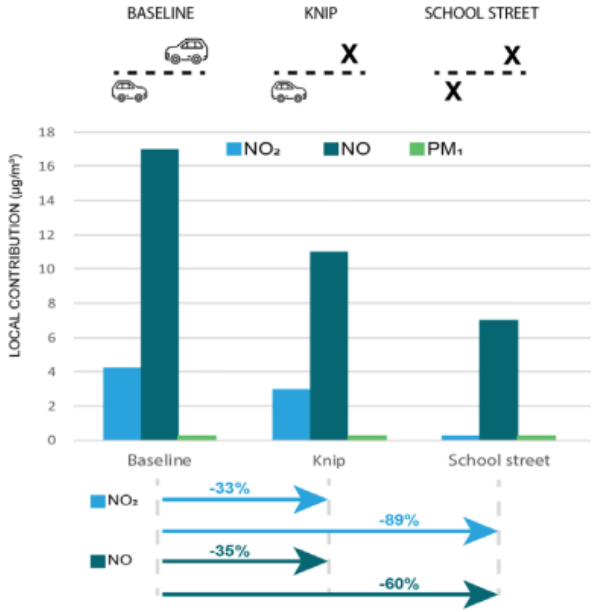
MDPI

Article

Air Quality Sensor Networks for Evidence-Based Policy Making: Best Practices for Actionable Insights

Jelle Hofman [1,*], Jan Peters [1], Christophe Stroobants [2], Evelyne Elst [2], Bart Baeyens [1], Jo Van Laer [1], Maarten Spruyt [1], Wim Van Essche [3], Elke Delbare [3], Bart Roels [4], Ann Cochez [5], Evy Gillijns [6] and Martine Van Poppel [1]





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Conclusions

- Innovative monitoring tools can contribute to improved policy and cleaner cities
- Larger-scale measurements of emerging pollutants in urban environments can support data-driven policy
- RI-URBANS has provided service tools for standardized measurement of emerging pollutants and contributed to insights in concentration patterns of these pollutants
- Sensor networks and mobile monitoring are complementary tools to AQMN that can help to understand urban sources and dynamics, assess exposure to air pollution
- Mobile monitoring can help to identify hot spots and sources, assess representativity of AQMS, assess AQ at higher spatial resolution (complementary to AQMS)
- A dedicated set-up, data processing and data quality control is important to have valuable results
- Involving citizens open opportunities to behavioral change and engagement but also comes with extra challenges

QUESTIONS?

Contact: martine.vanpoppel@vito.be