WP4: Pilot implementations for testing and demonstrating services

RI-URBANS

Research Infrastructures Services Reinforcing Air Quality Monitoring Capacities in European Urban & Industrial AreaS

Tuukka Petäjä and Teresa Moreno

UHEL and IDAEA-CSIC

RI-URBANS (101036245)

8/9/2025

European Commission

HORIZON 2020

HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

Athens, Barcelona, Birmingham, Bucharest, Helsinki, Milano, Paris, Rotterdam, Zurich

WP4 will implement 5 pilots for testing and demonstrating services:

- the **NRT aerosol** source apportionment of carbonaceous aerosols (T4.1) and **NRT nanoparticle**-PNSD data (T4.2)
- the **urban fine scale mapping** including innovative modelling, monitoring, and crowdsourcing (T4.3) with **novel health indicators** of nanoparticles and PM components and source contributions (T4.4)
- The emission sources will be quantified in/near urban areas (with intense traffic and/or industries) identifying contribution of **hotspots** to air pollutant exposure (T4.5).

The synthesis of outcomes of pilot studies will be done (T4.6).

Milestone M28 (M4.12)
Pilot studies finished in 9 cities

Table 1. *RI-URBANS pilots and participating cities. X indicates planned pilot contribution and F indicates a follower-activity.*

Pilot - Task City	ATH	BCN	BIRM	BUC	HEL	MIL	PAR	ROT	ZUR
P1 - T4.1 - NRT aerosols	X	F		F	X	X	X		X
P2 - T4.2 - NRT nanoparticles		X	X		X + F				F
P3 - T4.3 - Urban fine scale mapping	X		X	X	F		X	X	
P4 - T4.4 - Novel health indicators	X	X					F		X
P5 - T4.5 - Pollution hotspots				X	F	X		X	

WP 4 Deliverables and Milestones (all done)

D24 (D4.3):	Summary: source apportionment pilots, sustainability and associated benefits (31 January, 2025)
D26 (D4.5):	Summary: nanoparticle aerosol pilots, sustainab., assoc. benefits for AQMNs and AQ policy (17 January, 2025)
D28 (D4.7):	Summary: Mapping procedures, sustainability and applicability for upscaling (16 January, 2025)
D29 (D4.6):	Summary: health effects of novel AQ metrics, source contributions: epidemiology (28 February, 2025)
D30 (D4.9):	Summary: OP of PM, PM components and PM source contributions (17 January, 2025)
D31 (D4.10):	Summary: novel health effect indicator pilots, sustainability, associated benefits (28 July, 2025)
D33 (D4.12):	Summary of AQ hotspot pilots, sustainability and associated benefits (4 April, 2025)
D34 (D4.13)	Synthesis of RI-URBANS pilot actions, sustainability and importance on upscaling (28 May, 2025)

M24 (M4.8): Analysis of novel AQ metrics and source contributions (19 September, 2024)

Near real-time source apportionment of carbonaceous aerosols in 13 sites across Europe

Hilkka Timonen[1], Jean-Eudes Petit[2], and the RI-URBAN NRT-SA pilot sites*

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[2] Laboratoire des Sciences du Climat et de l'Environnement, Gif-sur-Yvette, France (jean-eudes.petit@lsce.ipsl.fr)

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RI-URBANS Science Meeting - 08/09/2025 - Barcelona

Summary of Pilot Phase : BC Source Apportionment

<u>Results</u>

- NRT-SA of BC is feasible, and best to be performed centrally
- Special care to keep in mind regarding
  - SA parameters (Savadkoohi et al., 2025)
  - Number and type of BC sources

➡ Finalization of ACTRIS level3 products planned within ACTRIS-NEXT

Summary of Pilot Phase : OA Source Apportionment

Results

- NRT-SA of OA is feasible, even centrally
- Requires monitoring, and regular checks

- Identification of benefits and limitations of NRT-SA of OA
- List of recommendations

Summary of Pilot Phase : OA Source Apportionment

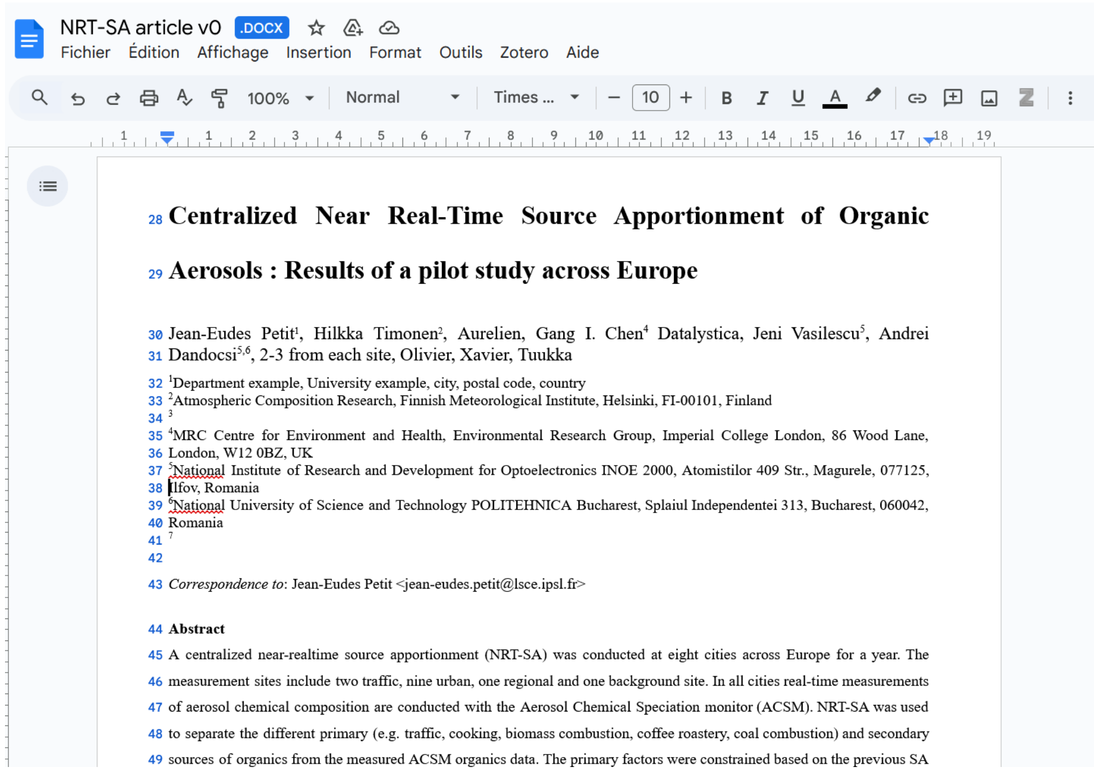
Future tasks

- Ensuring Reliability and Trustworthiness
- Traceability, Data Documentation and standardization Across Monitoring Sites
- Expanding SA Beyond Organic Aerosols (OA) and multi-instrument approach
- Fairness and Open-Source Access

➡ Developing framework for OA data submission within ACTRIS-NEXT

Summary of Pilot Phase : OA Source Apportionment

<u>Future tasks</u>



Centralized Near Real-Time Source Apportionment of Organic Aerosols : Results of a pilot study across Europe

Jean-Eudes Petit[1], Hilkka Timonen[2], Aurelien, Gang I. Chen[4] Datalystica, Jeni Vasilescu[5], Andrei Dandocsi[5,6], 2-3 from each site, Olivier, Xavier, Tuukka

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[2]Atmospheric Composition Research, Finnish Meteorological Institute, Helsinki, FI-00101, Finland
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Abstract

A centralized near-realtime source apportionment (NRT-SA) was conducted at eight cities across Europe for a year. The measurement sites include two traffic, nine urban, one regional and one background site. In all cities real-time measurements of aerosol chemical composition are conducted with the Aerosol Chemical Speciation monitor (ACSM). NRT-SA was used to separate the different primary (e.g. traffic, cooking, biomass combustion, coffee roastery, coal combustion) and secondary sources of organics from the measured ACSM organics data. The primary factors were constrained based on the previous SA

Paper to be submitted by the end of 2025

Near real-time aerosol number concentrations and number size distributions in 3 cities in Europe

David Beddows[1] and Katrianne Lehtipalo[2,3]

[1] University of Birmingham, UK (d.c.beddows@bham.ac.uk)

[2]University of Helsinki, Finland (katrianne.lehtipalo@helsinki.fi)

[3]Finnish Meteorological Institute, Finland

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Work Package 4.2: Implementation of NRT PNSD.

In Helsinki, the MPSS measurements at Kumpula site (urban background) continue indefinitely. At Mäkelänkatu (street canyon) the measurements continued until end of 2024 and from beginning of 2025 they were moved to a nearby location "Teollisuuskatu". Both send NRT data, available at: https://ebas-nrt.nilu.no/

In Birmingham, the MPSS measurements at BAQS (urban background) continue indefinitely. We have also implemented a script-based method of reading total concentration from our CEN-CPC3750. In addition, we have been working on a source apportionment method which depends on long term data series (at least 10years), Wide-Positive Matrix Factorisation of particle number size distributions: A new approach accounting for cyclically changing source profiles – ScienceDirect

In Barcelona, the MPSS measurements at Palau Reial (urban background) continue indefinitely

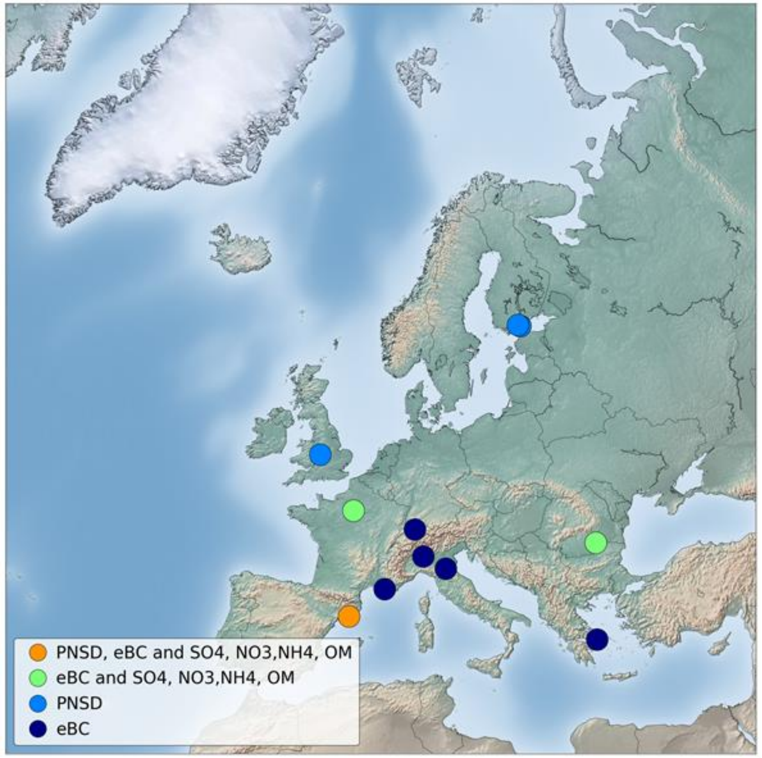
Status NRT (9 cities -12 sites)

Atmosphere Monitoring Service

ACTRIS

Fulfilled the obligations of 1 year pilot NRT from 9 pilot cities

Continue the service



Pilots	Code	Site	Instrument	Start	Stop
Zürich	CH0010U	Zürich-Kaserne	AE33	Jan-23	ongoing
	CH0010U		CPC	Jun-24	ongoing
Barcelona	ES0019U	Barcelona (Palau Reial)	AE33	Mar-23	ongoing
	ES0019U		ACSM	Mar-23	Nov-23
	ES0019U		SMPS	Nov-23	ongoing
Helsinki	FI0038U	Kumpula (SMEAR III)	DMPS	Aug-23	ongoing
	FI0039U	Mäkelänkatu	DMPS	Aug-23	ongoing
	FI0040R	Luukki	DMPS	Aug-23	ongoing
Paris	FR0020R	SIRTA	AE33	Feb-23	Jul-24
	FR0020R		ACSM	Feb-23	ongoing
Marseille	FR0035U	Marseille Longchamp	AE33	Mar-23	ongoing
Birmingham	GB0101U	Air Quality Site (BAQS)	DMPS	Nov-23	ongoing
Athens	GR0100B	DEM_Athens	AE33	Nov-23	ongoing
Po Valley	IT0022C	ISAC Bologna II	AE33	Dec-22	ongoing
	IT0025U	Milano Pascal	AE33	Jan-23	Mar-23
Bucharest	RO0010R	RADO-Bucharest II	ACSM	Mar-23	ongoing
	RO0010R		AE33	Jan-23	ongoing

WP4:

Pilot – Task European City	ATH	BCN	BIRM	BUC	HEL	MIL	PAR	ROT	ZUR
P1 - T4.1 - NRT aerosols	x				x	x	x		x
P2 - T4.2 - NRT nanoparticles		x	x		x				

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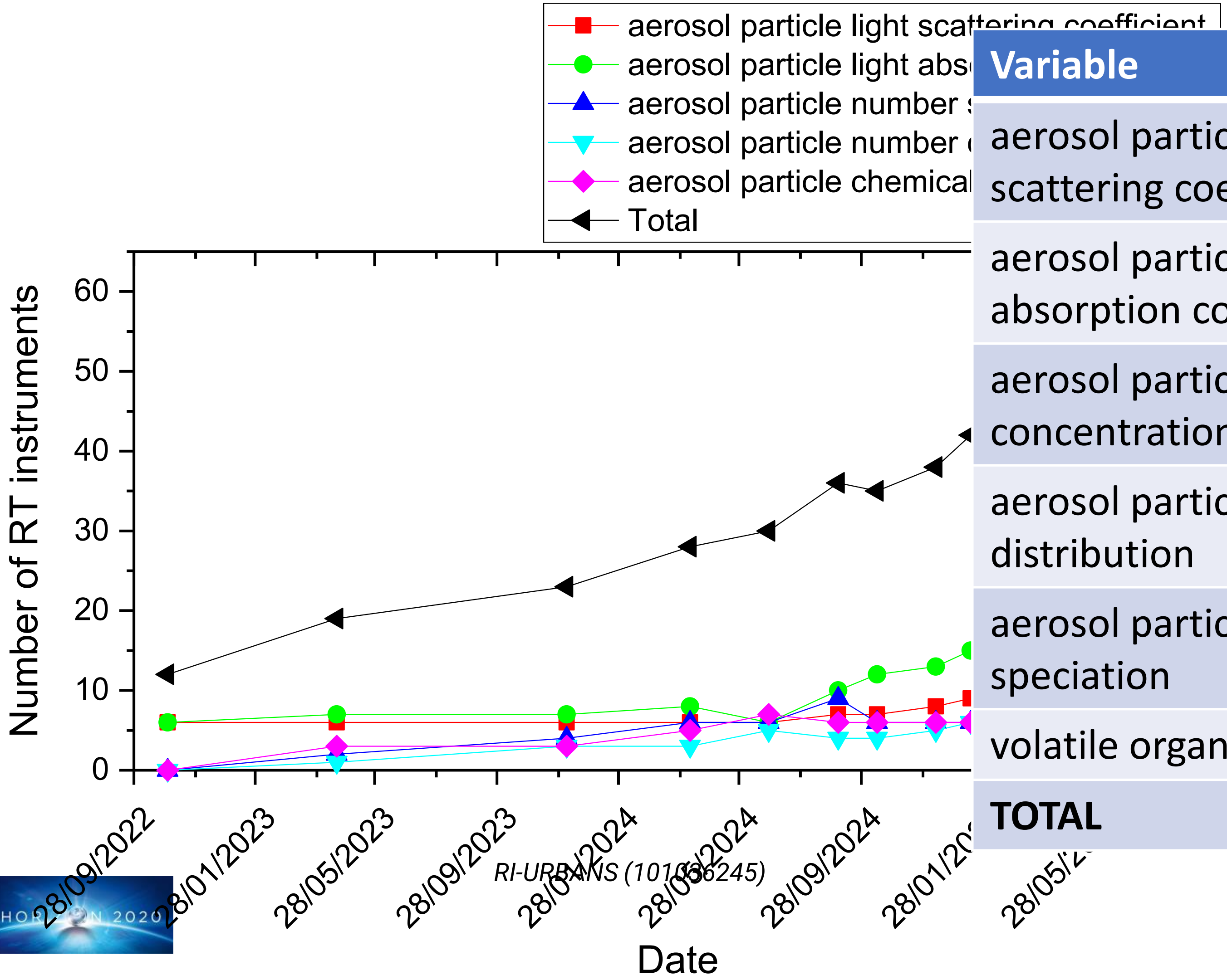
Number of Instruments Online



Variable	number
aerosol particle light scattering coefficient	14
aerosol particle light absorption coefficient	19
aerosol particle number concentration	8
aerosol particle number size distribution	9
aerosol particle chemical speciation	7
volatile organic compounds	4
TOTAL	**61**

Urban mapping

Karine Sartelet and Gerard Hoek

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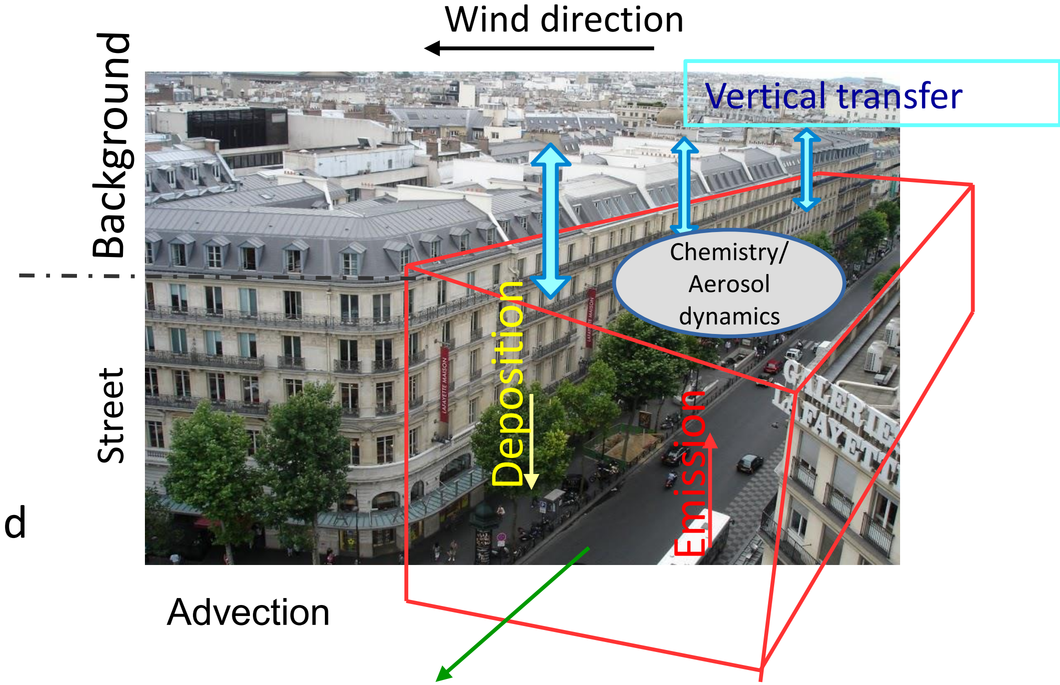
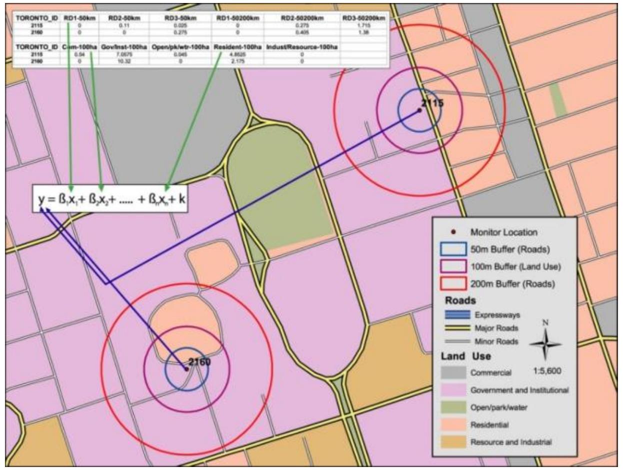
T4.3. Urban mapping

K. Sartelet, G. Hoek

- Resolution of ten/hundred meters
- Mapping with deterministic modelling
  - 3D Eulerian model (CTM) with sub-grid Eulerian dispersion and chemistry/aerosol dynamic at all scales
    => NO_2, $PM_{2.5}$, BC, PN and $PM_{2.5}$ detailed size & composition
  - 3-D Eulerian model (CTM) with sub-grid Gaussian dispersion)
    => NO_2, $PM_{2.5}$
  - Urban background observations coupled to Gaussian-based model
    => NO_2, $PM_{2.5}$ and PN
- Mapping with mobile measurements
  - Land-Use Regression based models
    => NO_2, $PM_{2.5}$ BC and PN



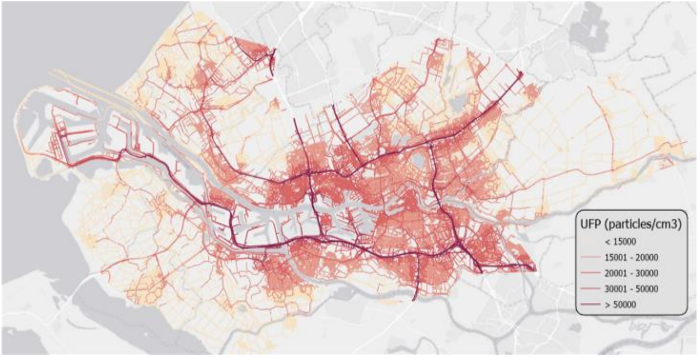


Accomplishment

- Measurement campaigns in each pilot city
  - Rotterdam (cars, cyclists)
  - Birmingham (pedestrian, cyclists)
  - Paris (fixed measurements+climatology)
  - Bucharest (cars)
- Set-up mapping methodologies and maps
  - Deterministic modelling (Paris, Birmingham, Athens)
  - LUR approach (Rotterdam, Birmingham and Bucharest)

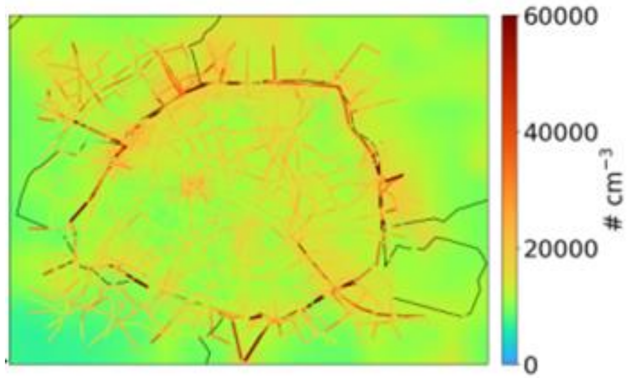
Rotterdam – UFP in winter

(maps from mobile measurements)



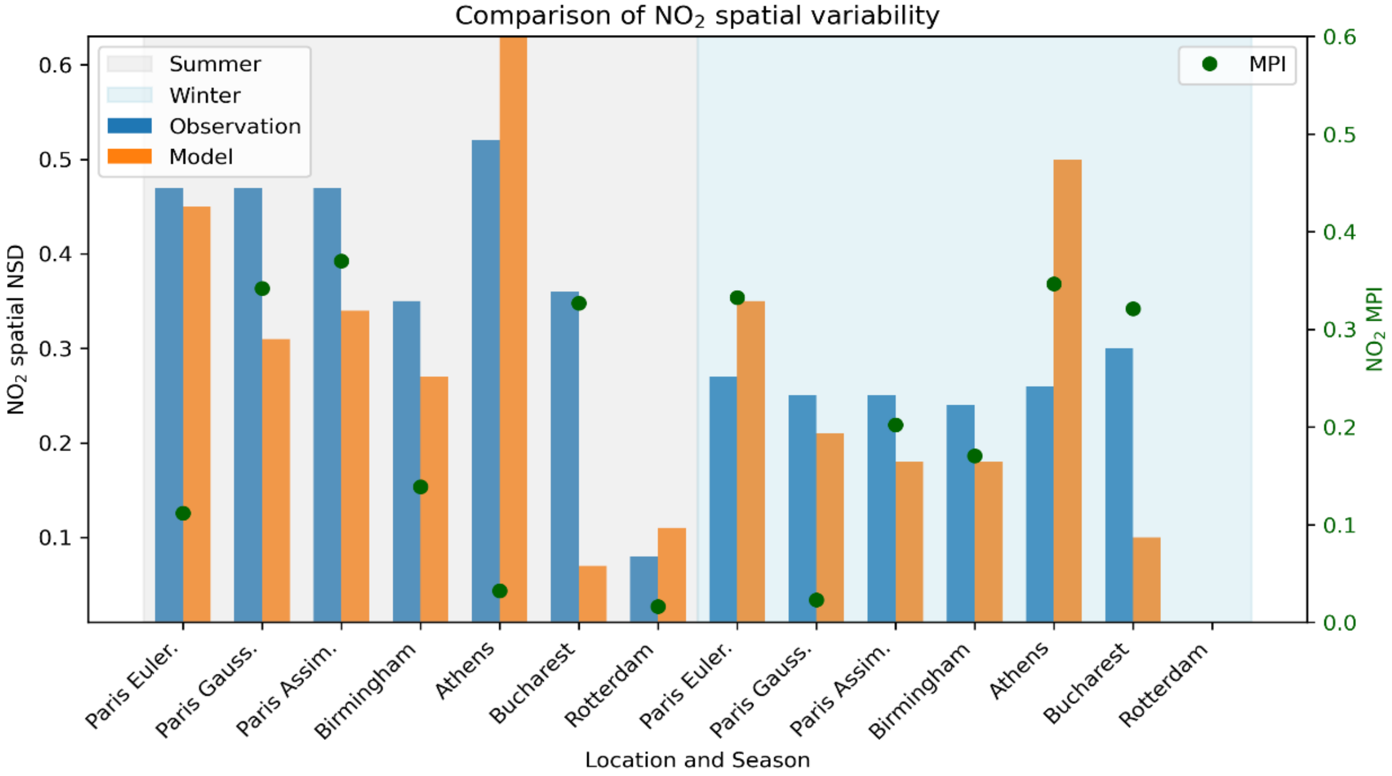
Paris – UFP in winter

(maps from deterministic modelling)



Accomplishment

- Compare simulated concentrations with fixed measurement stations (see ST)
- Compare simulated spatial and temporal variability using fixed measurements



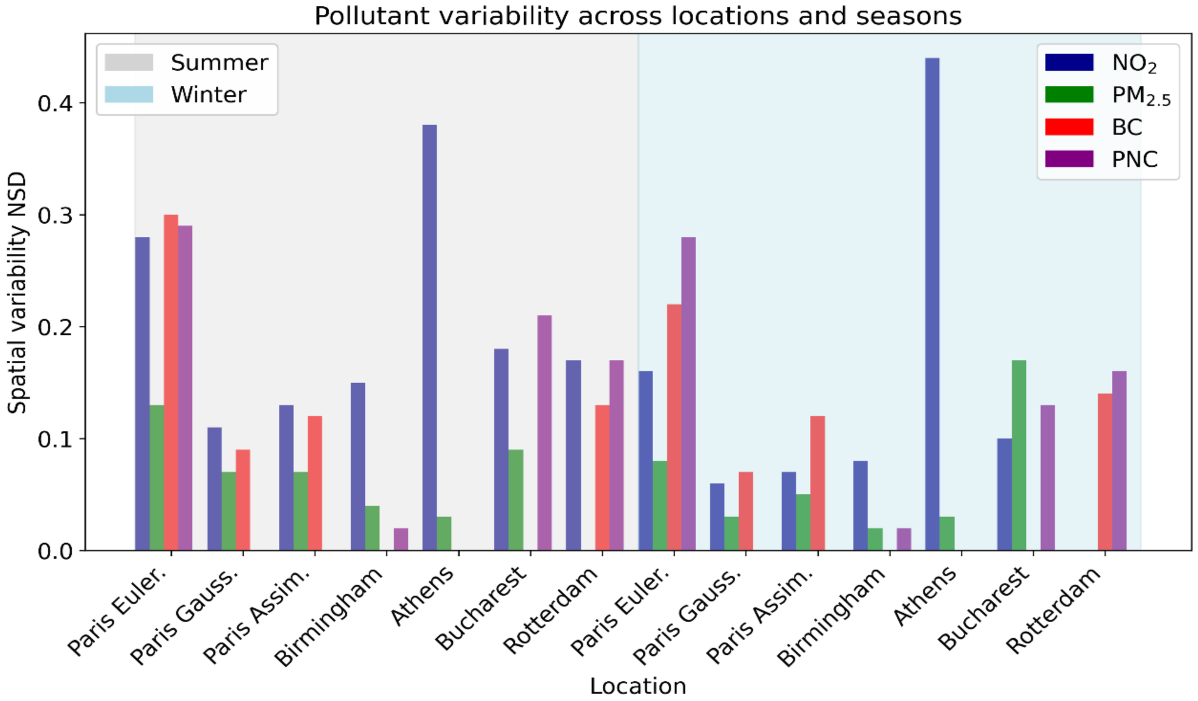
The model performance indicator MPI quantifies the differences between model and measurements.

Should be lower than 1.

Accomplishment

- Compare variability of pollutants using the same methodology for all methodologies and cities

=> High variability of UFP – higher or similar to NO_2



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Further work

- Extend the mapping to other domains/cities and for longer time periods
- Use the mapped concentrations for epidemiological studies
- Define more advanced health indicators from chemical and size distribution of particles

Task 4.4.
Novel health indicators of nanoparticles and PM components and source contributions – PILOTS

Vanessa Nogueira, Ioar Rivas, Xavier Basagaña

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Task 2.1: Study the short-term associations between novel pollutants and mortality

Harmonized AQ timeseries
[2021 – 2023] (except Zurich: 2018-2019)

Particle Number
($\#/cm^3$)

- Nucleation [10-25 nm]
- Aitken [25-100 nm]
- UFP [10-100 nm]
- Accumulation [>100 nm]
- Ntotal [> 10 nm]

Particle Mass
($\mu g/m^3$)

- BC
- BC sources
- PM_1
- $PM_{2.5}$
- PM_{10}
- PMcoarse (PM_{10}-$PM_{2.5}$)

Oxidative Potential (OP)
($nmol\ min^{-1}\mu g^{-1}$, $nmol\ min^{-1}\ m^{-3}$)

- From PM_1, $PM_{2.5}$ and PM_{10}
- DTT assay
- AA assay

Regulated gases
($\mu g/m^3$)

- NO_2
- SO_2
- O_3

+ many other pollutants
(e.g. sources of UFP, sources of BC, sources of OP)

Time series – data available

Harmonized AQ timeseries

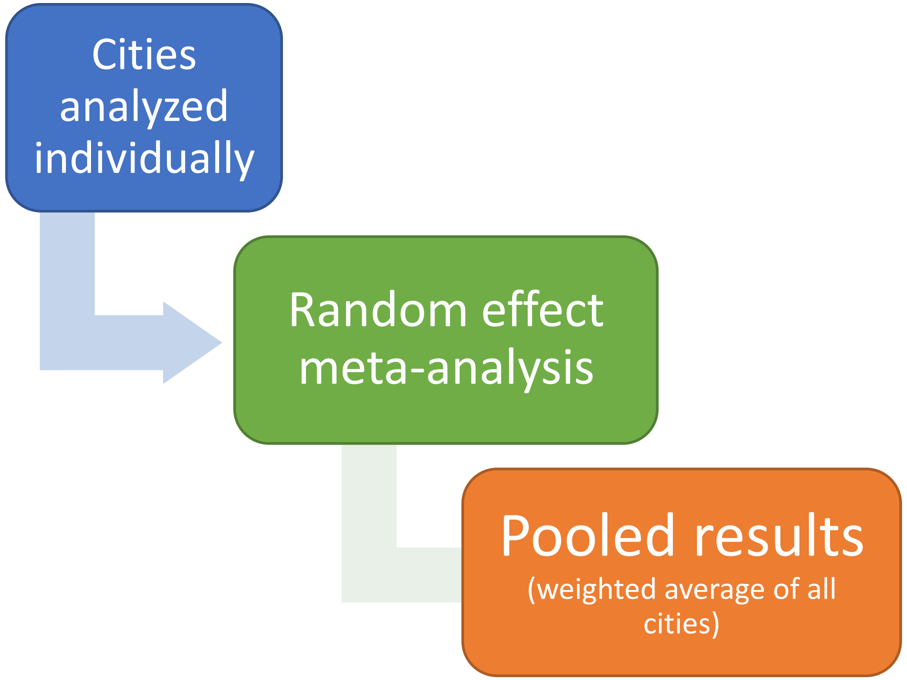
Variables	Athens (Thissio)	Barcelona (Palau Reial)	Paris2 (Les Halles)	Zurich_2018 (Kaserne)	Zurich_2021 (Kaserne)
PNSD	01.2021 – 12.2023	01.2021 – 12.2023	01.2021 – 12.2023	01.2018 – 07.2018	-
PM2.5, PM10 and PMcoarse	01.2021 – 12.2023	01.2021 – 12.2023	01.2021 – 12.2023	01.2018 – 12.2019	01.2021 – 12.2022
eBC and eBC sources	01.2021 – 12.2023	01.2021 – 12.2023	01.2021 – 12.2023	01.2018 - 12.2019	01.2021 – 12.2022
PM2.5 OP and PM10 OP	06.2022 – 06.2023	03.2022 - 12.2023	04.2022 – 09.2023	06.2018 – 05.2019	-

Methodology

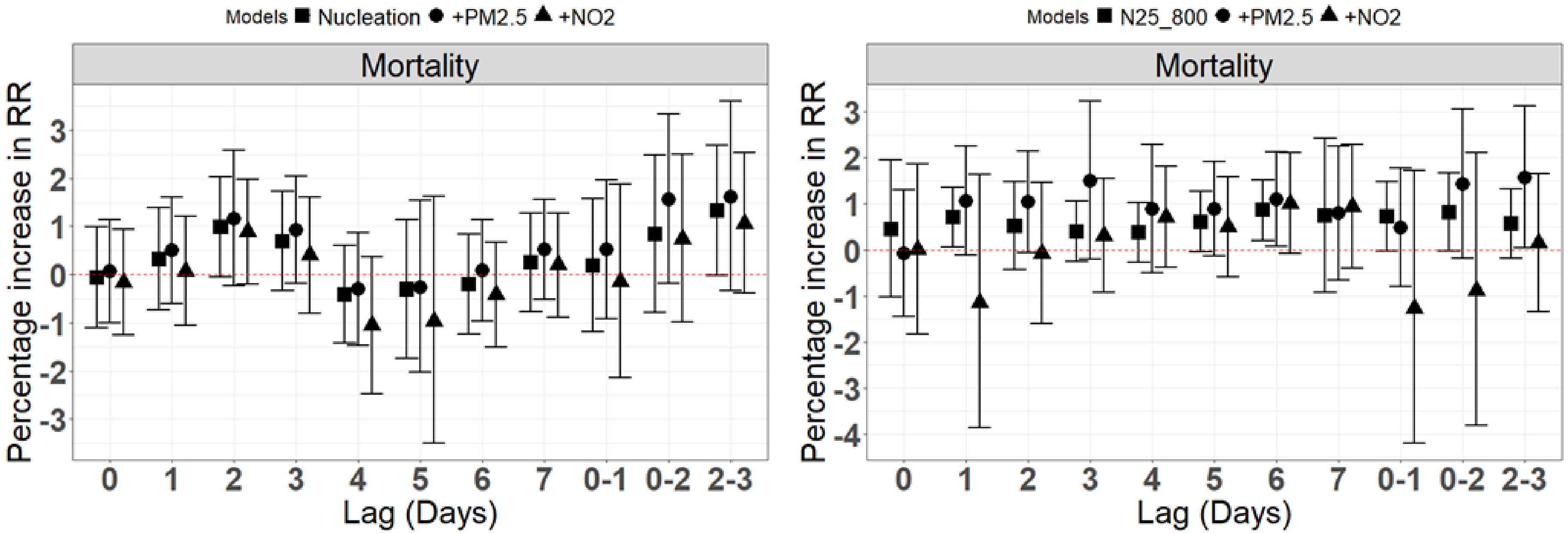
Models used for the time series analysis:

Single and **two-pollutant** GNM quasi-Poisson regression models, adjusted for:
- Seasonality (time-stratified case-crossover)
- Temperature (a spline for cold and a spline for hot temperatures)
- Relative humidity (natural spline with 3 df)
- Bank holidays
- Day of the week

Random effect meta-analysis



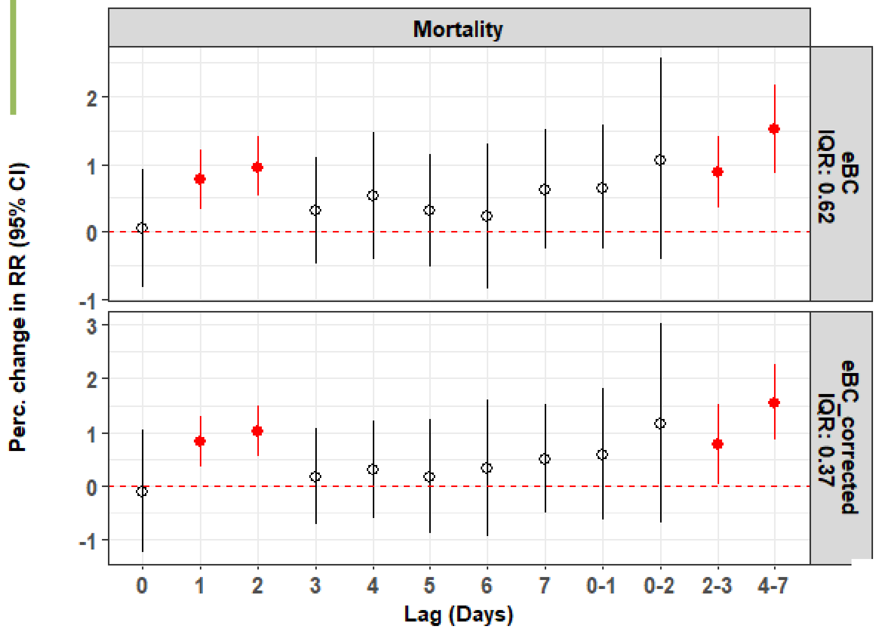
UFP: Nucleation mode



Variable	Single pollutant model	Model adjusted for $PM_{2.5}$	Model adjusted for PM_{10}	Model adjusted for NO_2
UFP-PNSD				
Nucleation				
Aitken	1, 6	7		
UFP	1	2-3, 4-7		
Accumulation	5, 6, 4-7	2, 3, 0-2, 2-3, 4-7		
N25_800	1, 6, 4-7	6, 2-3, 4-7		
Ntotal	1, 6	2, 2-3, 4-7		
PNSD sources				
Photonucleation		0-2		4, 2-3
Traffic 1				
Traffic 2				
Mixed traffic	0, 4-7			0, 0-2
Regional 1		0-1		
Regional 2	0, 2, 0-2, 2-3	0, 2, 0-2, 2-3		0, 2, 0-1, 0-2, 2-3
Domestic heating		3		

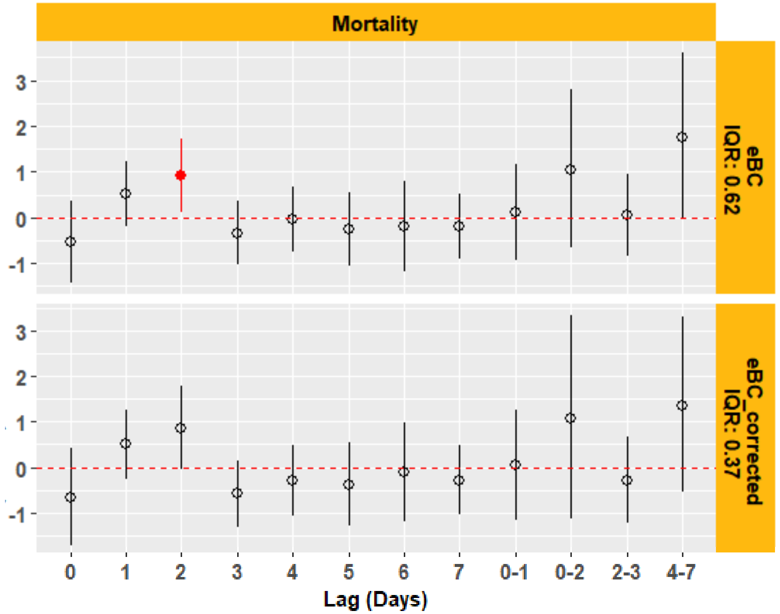
eBC

WP4 Meta-analysis – Pooled single pollutant model



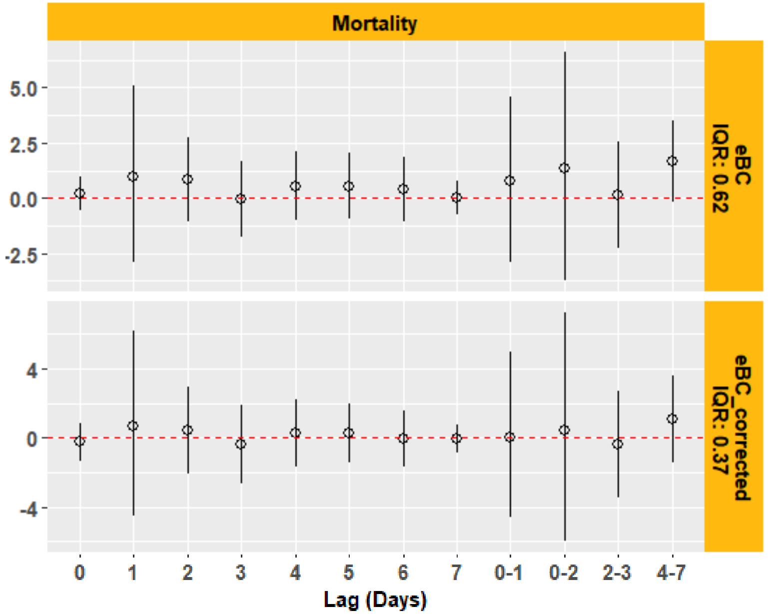
Based on 4 to 5 cities

WP4 Meta-analysis - Pooled two pollutant adjusted for PM2.5



Based on 4 to 5 cities

WP4 Meta-analysis - Pooled two pollutant adjusted for NO2

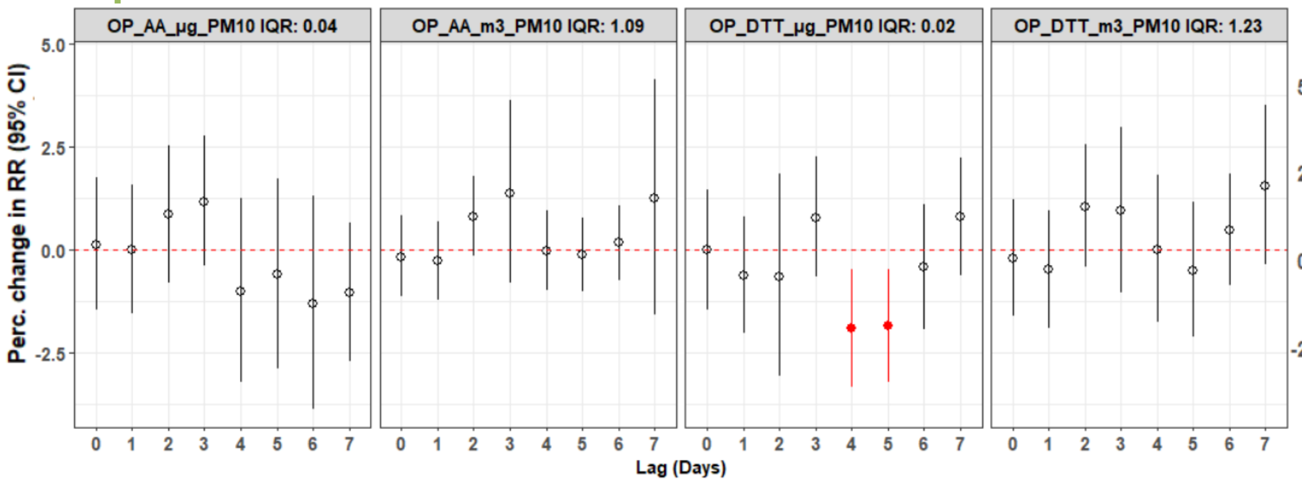


Based on 4 to 5 cities

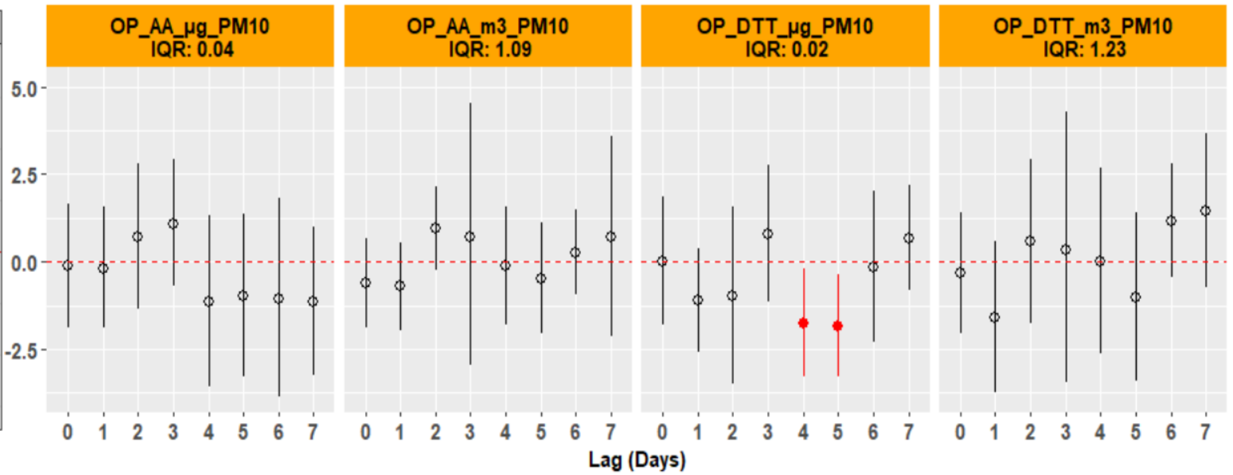
Variable	Single pollutant model	Model adjusted for $PM_{2.5}$	Model adjusted for PM_{10}	Model adjusted for NO_2
eBC and eBC sources				
eBC	1, 2, 2-3, 4-7	2		
eBC_corrected	1, 2, 2-3, 4-7			
eBCT	2, 0-2, 4-7			
eBCRC	1, 2, 0-2, 2-3, 4-7	1, 2		5, 0-1, 4-7

OP Meta-analysis

Single pollutant model



Two-pollutant model (OP + NO2)



Variable	Single pollutant model	Model adjusted for $PM_{2.5}$	Model adjusted for PM_{10}	Model adjusted for NO_2
OP				
OP AA µg $PM_{2.5}$				
OP AA m3 $PM_{2.5}$				
OP DTT µg PM2.5				
OP DTT m3 PM2.5		5		1
OP AA µg PM10				
OP AA m3 PM10				
OP DTT µg PM10	4, 5		4, 5	4, 5
OP DTT m3 PM10			4, 5	

Summary

- **UFP:** We found associations for all the fractions except for nucleation. Results were more consistent for the coarser part of UFP (Aitken + Accumulation) and for lag between 4 and 7. When adjusting for NO_2, all associations were lost.

- **eBC: we found associations at different lags covering the period 1 to 7**.

- **OP**: We did not find associations, with the exception of some unexpected protective effect.

- In many cases, the association was lost when adjusting for a second pollutant.

- **Need for long-time AQ time series with a completely harmonized data collection protocol**.

Acknowledgements

We would like to thank WP1 researchers for their efforts in compilating the air pollution datasets.
A special thanks go to **Anouk Marsal, Antonis Analitis, and Evi Samoli** for their help in running some of the analyses.

We would like to acknowledge the EARLY-ADAPT project (funded by the European Research Council under the European Union's Horizon 2020 research and innovation programme; grant agreement No. 865564) and its research team, and the statistics centers below for providing mortality data for this study.

- Barcelona, Madrid and Granada: Spanish Statistical Office (INE)
- Athens: Hellenic Statistical Authority (ELSTAT)
- Zurich: Swiss Federal Statistical Office (BFS)
- Paris: Center for Epidemiology on Medical Causes of Death (Inserm)
- Air quality data from Paris was provided by the air quality observatory in Île-de-France (Airparif)

Task 4.5. hot-spots

Arnoud Apituley, Jeni Vasilescu, Doina Nicolae, Angela Marinoni

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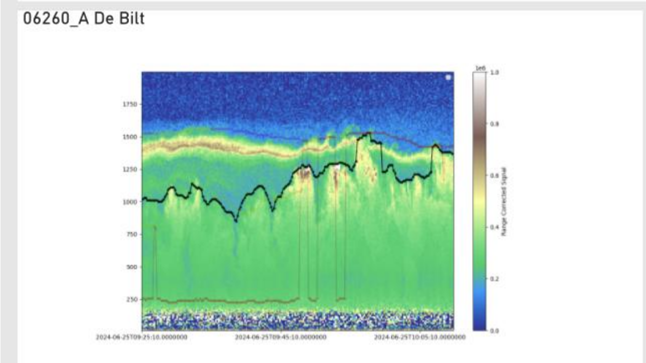
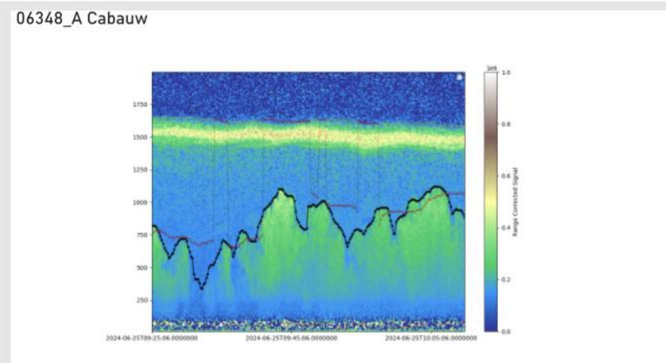
Rotterdam outcome: NRT implementation of AI/ML MLH detection algorithm

- Based on the experience with the RI-Urbans hot-spot pilots (T4.5) KNMI is upscaling and implementing the Deep Pathfinder (Wijnands et al, 2024) algorithm, in near real time for a representative number of ceilometers in the Dutch network.
- MLH estimates shall be available every 15 minutes with 12 second time resolution
- Example of NRT retrievals of MLH for two locations in Cabauw and De Bilt. Examples are shown for 45 minutes at full resolution.





Wijnands, J., Apituley, A., Gouveia, D. A., Noteboom, J. W., Yan, M., de Haij, M., and Trani, L.: Deep-Pathfinder: Near-real-time detection of mixing layer height based on lidar remote sensing data and deep learning, EMS Annual Meeting 2025, Ljubljana, Slovenia, 7–12 Sep 2025, EMS2025-700, https://doi.org/10.5194/ems2025-700, 2025.

Wijnands, J. S., Apituley, A., Gouveia, D. A., and Noteboom, J. W.: Deep-Pathfinder: a boundary layer height detection algorithm based on image segmentation, Atmos. Meas. Tech., 17, 3029–3045, https://doi.org/10.5194/amt-17-3029-2024, 2024.

Bucharest

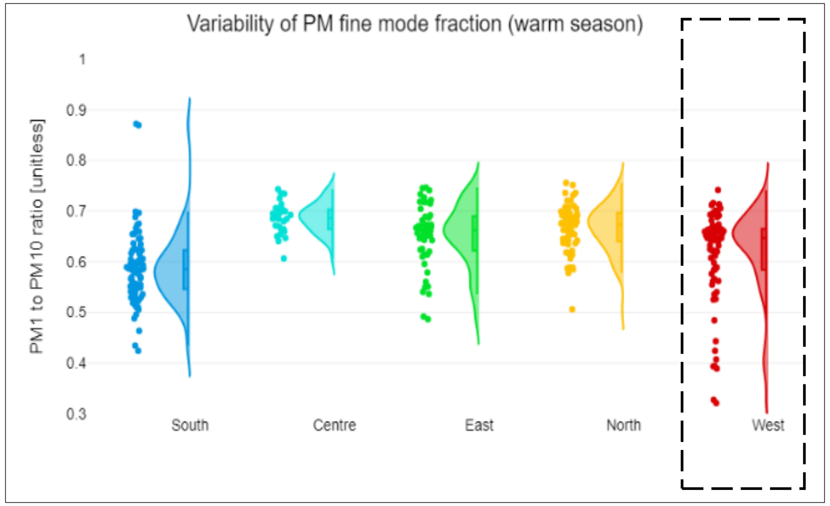
- impact of a thermal power plant site on air quality in Bucharest, Romania
- emphasizes the importance of accurate air pollutant inmission measurements in urban areas and demonstrate the integration of :
  - mobile measurements with low-cost sensors and modelling (LUR mixed effect),
  - Copernicus' Atmosphere Monitoring Service (CAMS) and
  - Copernicus Land Monitoring Service (CLMS), and
  - satellite retrieval to better understand climate change drivers and their potential impact on near- surface concentrations and column densities of NO2, CO, and PM.

➢ the limits of typical mesoscale air quality models in effectively capturing pollution dispersion and distribution using LUR (Land Use Regressions) retrievals

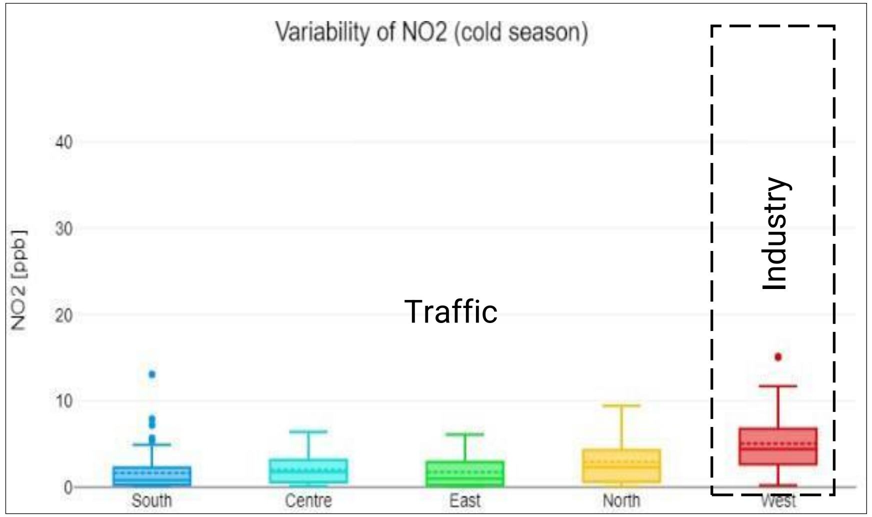
➢ the placement of a power plant may affect air quality in the nearby residential areas

➢ CET West power plant does not have a significant impact on the air quality in the surrounding residential areas

➢ the sole pollutant that can be attributed to the power plant as a source is NO_2, mostly during the winter season



Agriculture, constructions + traffic & industry

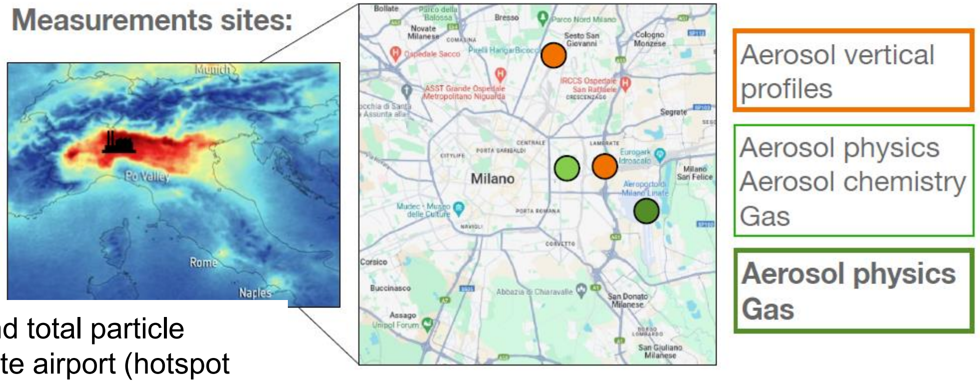


Traffic & heating

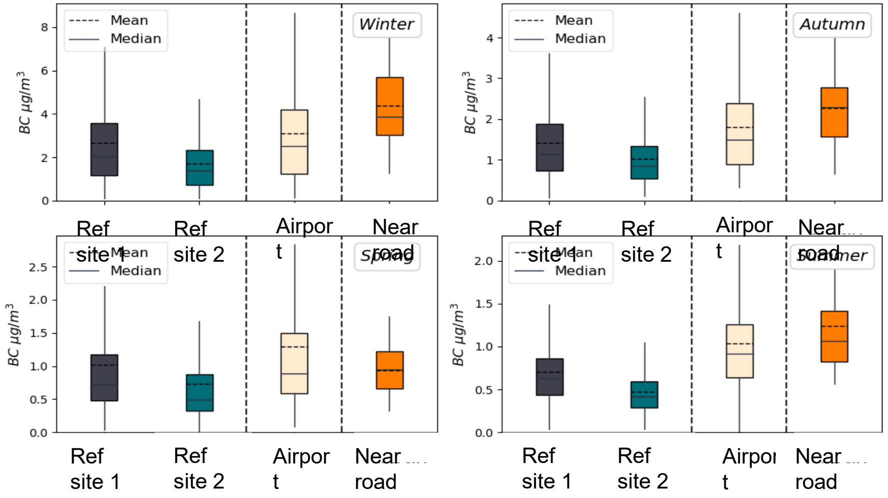
Nicolae et al. How Does the Location of PowerPlants Impact Air Quality in the UrbanArea of Bucharest? Atmosphere 2025, 16,636. https://doi.org/10.3390/atmos16060636

Milano

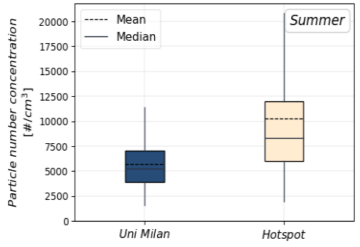
Measurements sites:

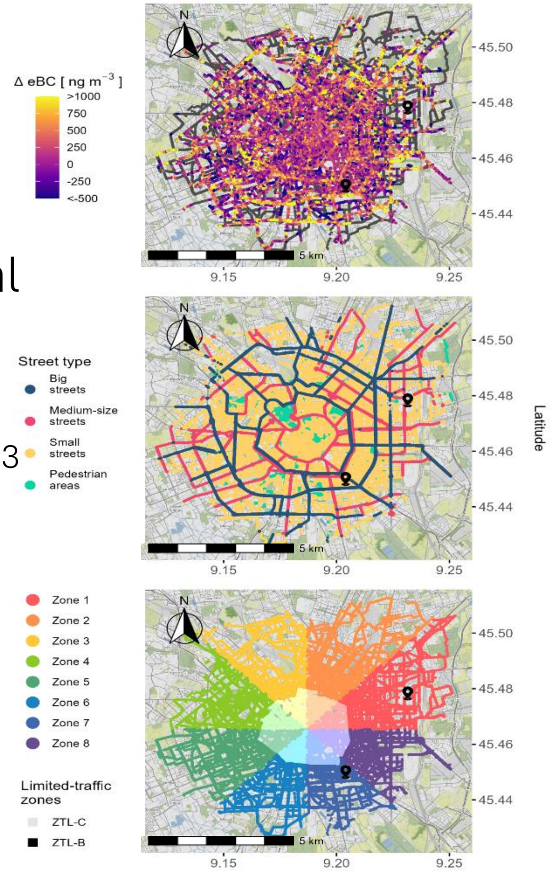


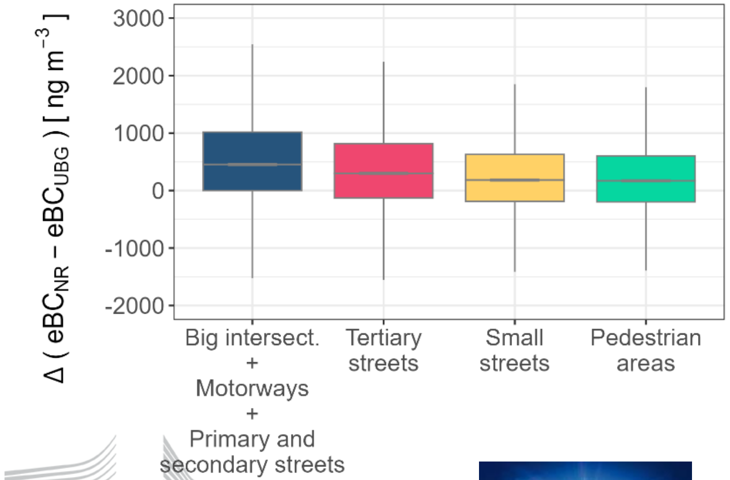
- Black carbon (BC) concentration and total particle number concentration (Ntot) at Linate airport (hotspot site) show a diurnal profile opposite to the mixed aerosol layer;
- Larger concentrations of BC and Ntot are measured in summer than in winter;
- Consistently larger concentrations of BC are measured at the airport and in the near road observation (from mobile measurements) compared with the concentrations measured at two urban background reference sites across all seasons;
- Larger Ntot was found at the airport than at the reference urban background site;



Near-road (NR) eBC concentrations were on average **1.6 times higher** than those measured at the urban background (UB) station







Higher concentrations tend to follow the arterial streets, particularly outside Milan downtown.
Based on OSM street classification, median ΔeBC concentrations were 50-470 ng m^{-3} annually,
with the highest values near "big" streets and the lowest near pedestrian areas.

RI-URBANS (101036245)

European Commission

HORIZON 2020

Hot-Spots beyond RI-Urbans

- The pilot studies performed for characterisation of pollution hot-spots in the framework of the RI-URBANS project in the cities of Rotterdam, Bucharest and Milano have shown that advanced observations have added value to the understanding of exposure to air pollution in general and UFP in particular.
- The pilot studies using remote sensing instrumentation have shown that valuable data can routinely be acquired from strategically located ceilometers and Doppler wind lidars in order to assess the atmospheric dynamics that drive the dispersion of air pollution.
- Mobile observations provide great insight in characterisation of pollution hot-spots. Once instrumented vehicles are available, they can be deployed in all kinds of cities.
- The bicycle measurement approach demonstrates that mobile measurement campaigns combined with citizen participation are an effective method to obtain detailed urban air quality data.
- the hot-spot pilot shows that a combined use of various techniques, in-situ and remote sensing, will gain the most complete dataset to address the pollution studies for a particular city, especially in cases of complex (orographic) terrain, or large/mega cities with very complex building structures.

Thank you for your attention!

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