INAR

INSTITUTE FOR ATMOSPHERIC AND EARTH SYSTEM RESEARCH

FOR THE ONLY PLANET WE HAVE

2019

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UNIVERSITY OF HELSINKI

Ultrafine aerosol particles in the atmosphere: instrumentation and results

Tuukka Petäjä

Institute for Atmospheric and Earth System Research (INAR) / Physics, University of Helsinki, Finland

European Federation of Clean Air and Environmental Protection Associations (EFCA)
International Symposium
Ultrafine Particles – Air Quality and Climate
Brussels, Belgium

July 5 and 6, 2022

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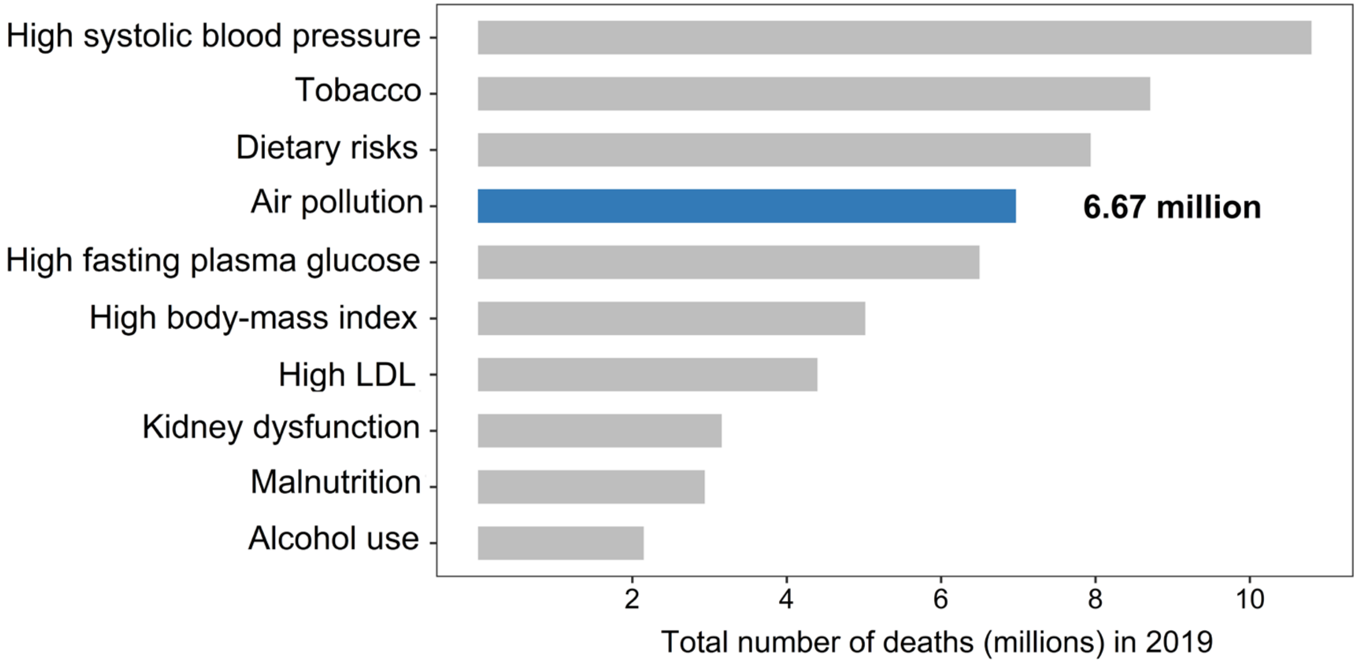
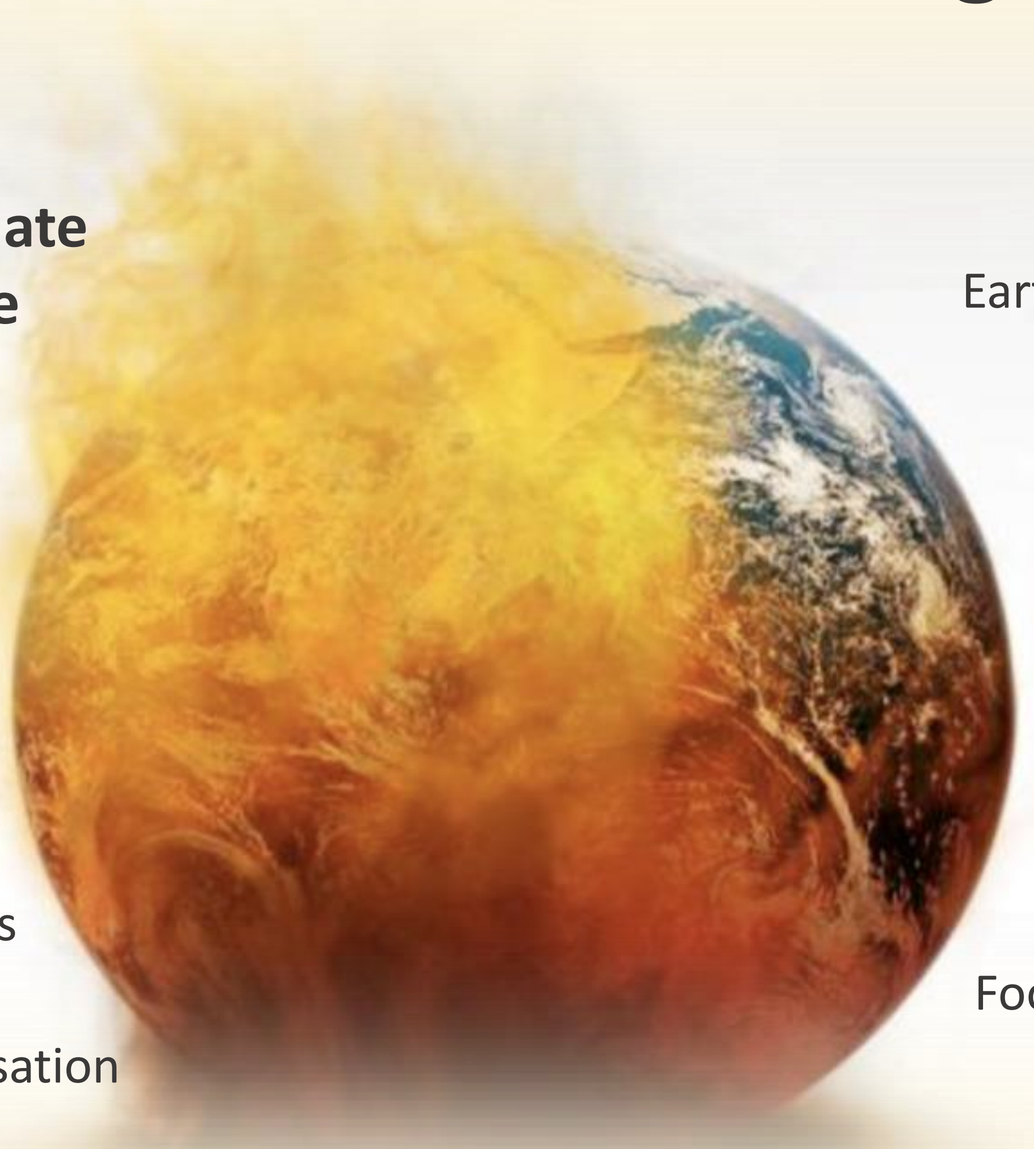
INSTITUTE FOR ATMOSPHERIC AND EARTH SYSTEM RESEARCH

Global Burden of Disease (GBD, 2020)



Health Effects Institute. 2020. State of Global Air 2020. Special Report.

Contribution to solving grand challenges



Climate change

Volcanoes

Energy

Biodiversity loss

Epidemic diseases

Chemicalisation

Earthquakes

Air quality

Fresh water

Ocean acidification

Deforestation

Food supplies

Demography / Population / Urbanization

DISCIPLINES

Natural Sciences

Social Sciences

Economy; Medicine;

Technology etc

PEEX / IEAS / AASCO

Science Diplomacy

WMO/GAW
Global SMEAR

From ideas
to implementation

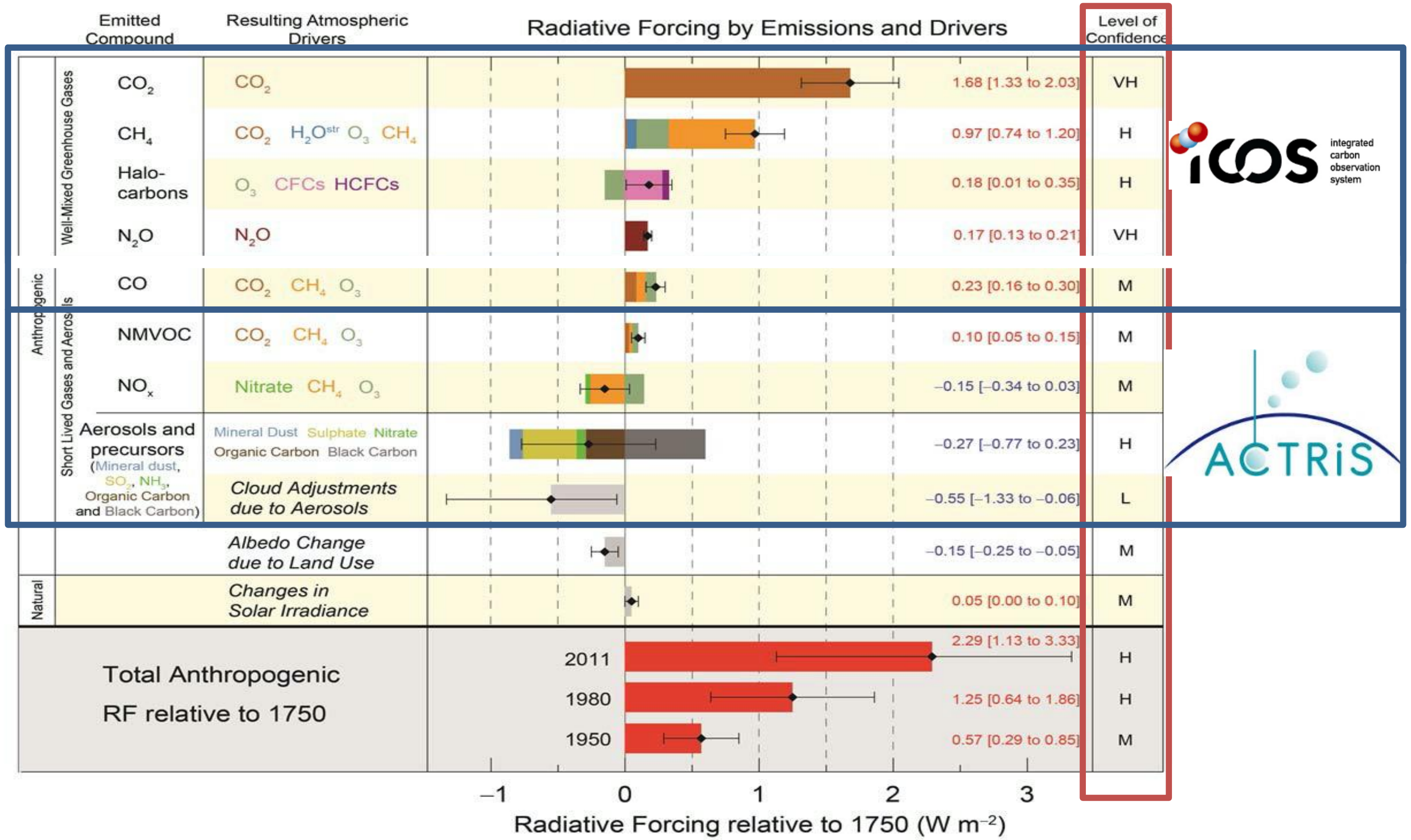
INTEGRATED APPROACH:
THE GLOBAL EARTH OBSERVATORY

Current observations are fragmented:

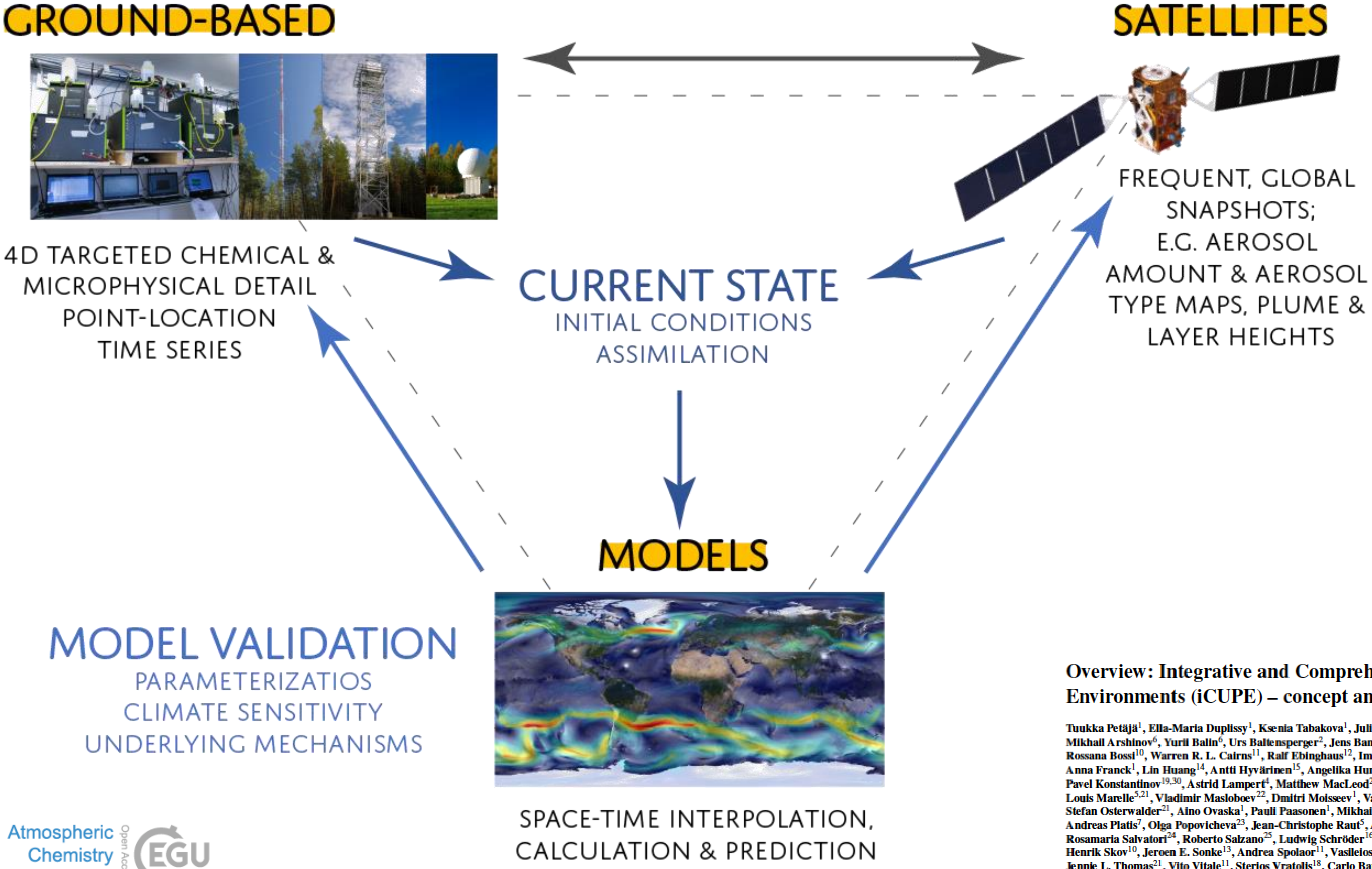
1) Greenhouse gases
2) Aerosols
3) Air quality
4) Ecosystems
5) Climate
6) …

Future aspiration: Integrated approach

To understand feedbacks
To reduce uncertainties
To mitigate and adapt effectively



IPCC, 2013



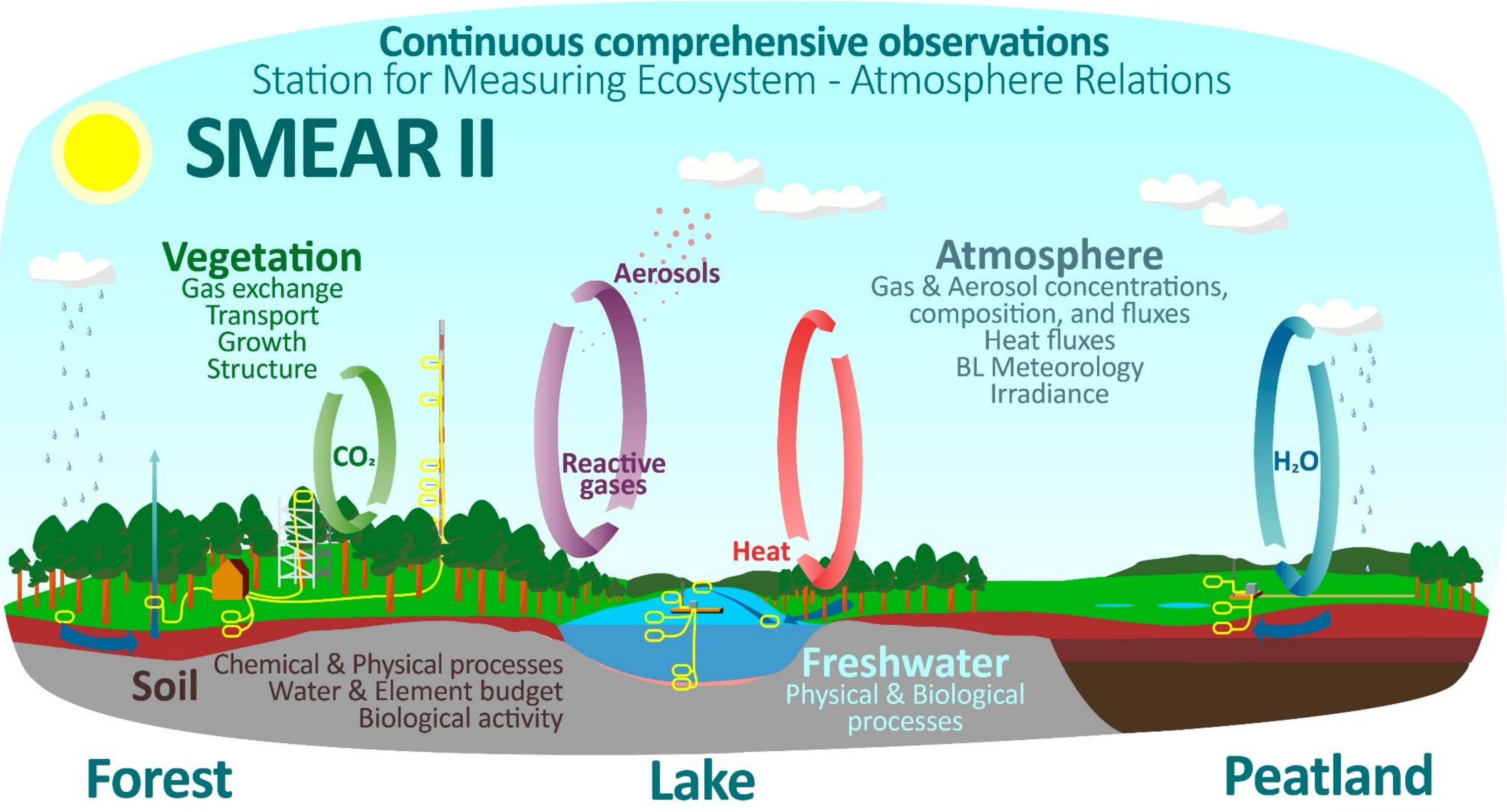
Atmospheric Chemistry and Physics
Open Access
EGU

Overview: Integrative and Comprehensive Understanding on Polar Environments (iCUPE) – concept and initial results

Tuukka Petäjä[1], Ella-Maria Duplissy[1], Ksenia Tabakova[1], Julia Schmale[2,3], Barbara Altstädter[4], Gerard Ancellet[5], Mikhail Arshinov[6], Yurii Balin[6], Urs Baltensperger[2], Jens Bange[7], Alison Beamish[8], Boris Belan[6], Antoine Berchet[9], Rossana Bossi[10], Warren R. L. Cairns[11], Ralf Ebinghaus[12], Imad El Haddad[2], Beatriz Ferreira-Araujo[13], Anna Franck[1], Lin Huang[14], Antti Hyvärinen[15], Angelika Humbert[16,17], Athina-Cerise Kalogridis[18], Pavel Konstantinov[19,30], Astrid Lampert[4], Matthew MacLeod[20], Olivier Magand[21], Alexander Mahura[1], Louis Marelle[5,21], Vladimir Masloboev[22], Dmitri Moisseev[1], Vaios Moschos[2], Niklas Neckel[16], Tatsuo Onishi[5], Stefan Osterwalder[21], Aino Ovaska[1], Pauli Paasonen[1], Mikhail Panchenko[6], Fidel Pankratov[22], Jakob B. Pernov[10], Andreas Platis[7], Olga Popovicheva[23], Jean-Christophe Raut[5], Aurélie Riandet[9,a], Torsten Sachs[8], Rosamaria Salvatori[24], Roberto Salzano[25], Ludwig Schröder[16], Martin Schön[7], Vladimir Shevchenko[26], Henrik Skov[10], Jeroen E. Sonke[13], Andrea Spolaor[11], Vasileios K. Stathopoulos[18], Mikko Strahlendorff[15], Jennie L. Thomas[21], Vito Vitale[11], Sterios Vratolis[18], Carlo Barbante[11,27], Sabine Chabrillat[8], Aurélien Dommergue[21], Konstantinos Eleftheriadis[18], Jyri Heilimo[15], Kathy S. Law[5], Andreas Massling[10], Steffen M. Noe[28], Jean-Daniel Paris[9], André S. H. Prévôt[2], Ilona Riipinen[20], Birgit Wehner[29], Zhiyong Xie[12], and Hanna K. Lappalainen[1,15]

SMEAR II station in Hyytiälä, Finland

Over **1200** different variables



Flagship site for integration: combines all IPCC components.

Contributes to :

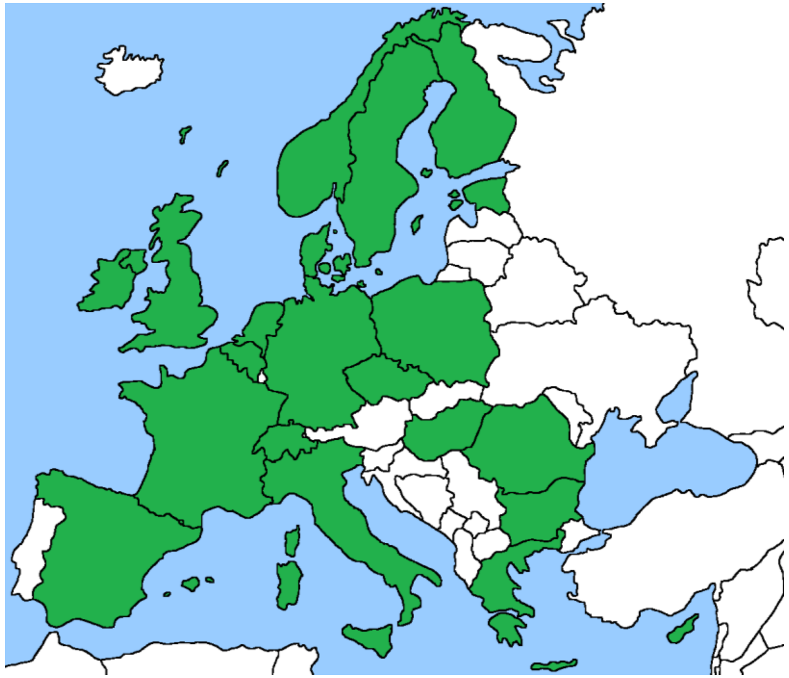
ACTRIS, ICOS (Integrated Carbon Observation System), AnaEE (Analysis and Experimentation on Ecosystems), LTER Europe, Pan-Eurasian Experiment PEEX, World Meteorological Organisation

Aerosols, Clouds, and Trace gases Research Infrastructure - European ESFRI research infrastructure

- ACTRIS provides data and research, instrument, industry, and training services for the various user groups

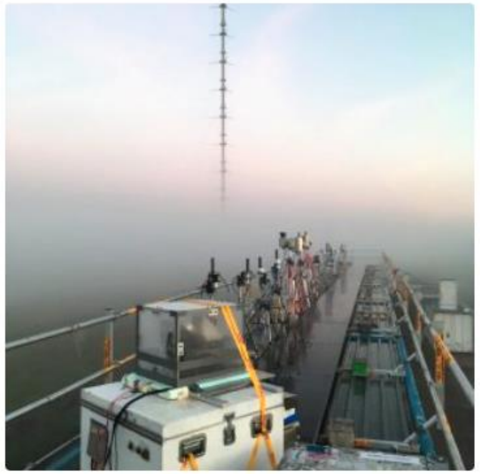
- ACTRIS consists of observing stations, exploratory platforms, instrument calibration centres, data centre, and Head Office

- ACTRIS implementation is led by Finland and UHEL and FMI contributes to ACTRIS Head Office, Data Centre and have several ACTRIS national stations






ACTRIS Operations



Pan-European research infrastructure producing high-quality data and information on short-lived atmospheric constituents and on the processes leading to the variability of these constituents in natural and controlled atmospheres.

Aerosol, clouds and trace gases through in-situ and remote sensing measurement techniques

100+ atmospheric variables
20+ atmospheric data products

Composition, Properties
Processes, Emissions
Transport, Removal
Trends, Feedbacks

- Data service & digital tools
- Research services
- Technical services
- Innovation services
- Tailored services
- Training services

ACTRIS
Exploring the Atmosphere

European level Central Facilities	Head Office
	Data Centre
	Centre for Aerosol In Situ Measurements Centre for Aerosol Remote Sensing Centre for Cloud In Situ Measurements Centre for Cloud Remote Sensing Centre for Reactive Trace Gases In Situ Measurements Centre for Reactive Trace Gases Remote Sensing
National Facilities	Observational Platforms Exploratory Platforms

European level:
~ **150** scientists & technicians working in ACTRIS

National level:
~ **800** scientists and technicians

Main tasks at INAR/UHEL

Contact:
Tuukka Petäjä (tuukka.petaja@helsinki.fi)
Silja Häme (silja.hame@helsinki.fi)

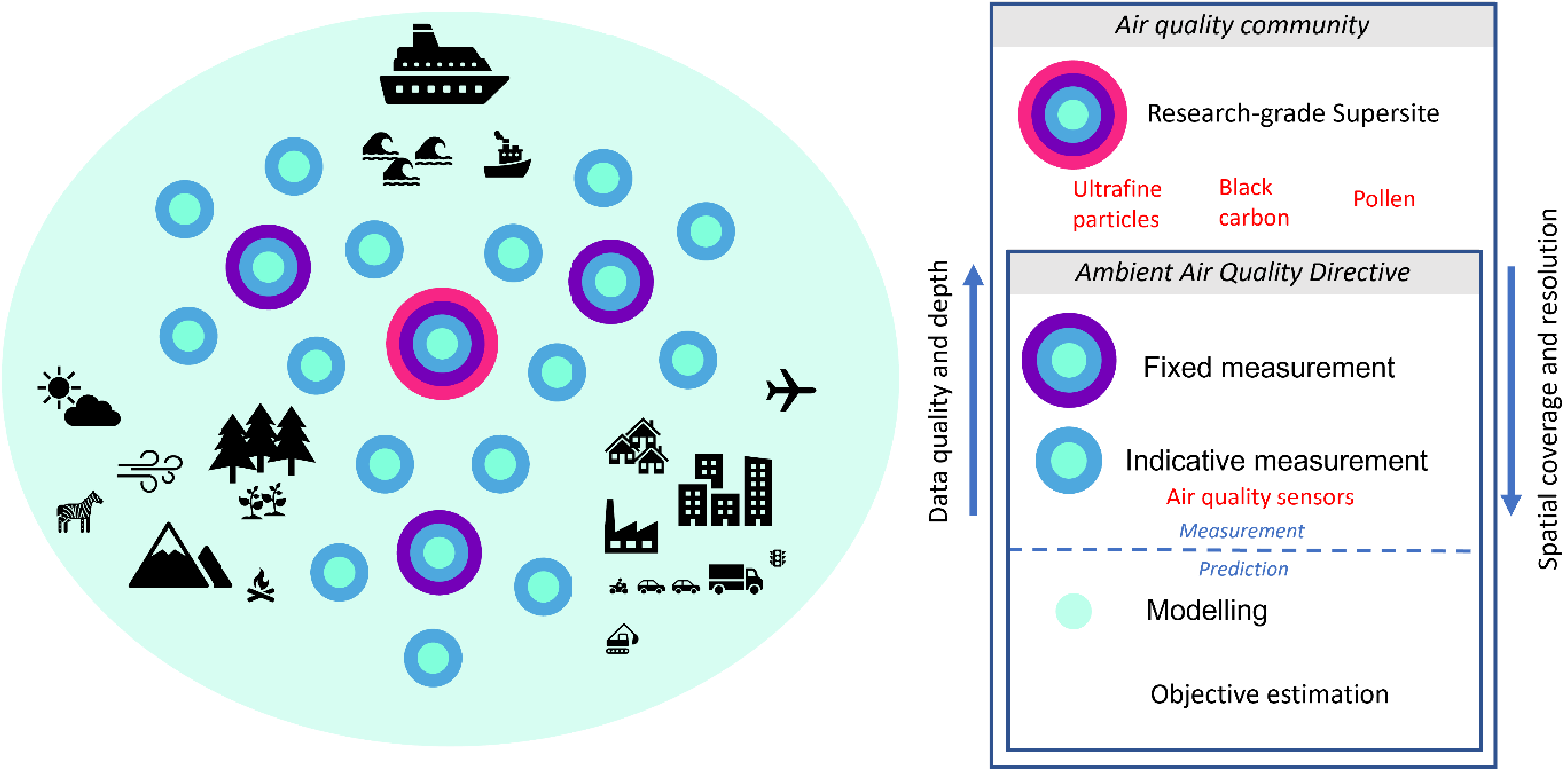
- **CiGas-INAR (reactive trace gases)**
- Measurements of condensing gases
- Provision of ***measurement guidelines*** and individual instrument ***calibrations*** for nitrate CI-APi-TOF
- ***intercomparison*** and ***training*** workshops,
- NF site performance tests
- ***Method development*** and mobile calibration standard provision
- Consultation in aerosol precursor measurements.

- **CCC in ECAC (Aerosols, <10 nm)**
- Physical & chemical aerosol properties
- Individual instrument ***calibrations***, intercomparison of nanoparticle and ion counters (PSM & NAIS).
- NF ***site performance tests*** (PSM or NAIS).
- ***Training*** of PSM and NAIS operators and scientist.

Intrumentation relevant in ambient measurements and in controlled chamber experiments.

Insights into updating Ambient Air Quality Directive (AAQD, 2008/50/EC)

Kuula et al. (2021)



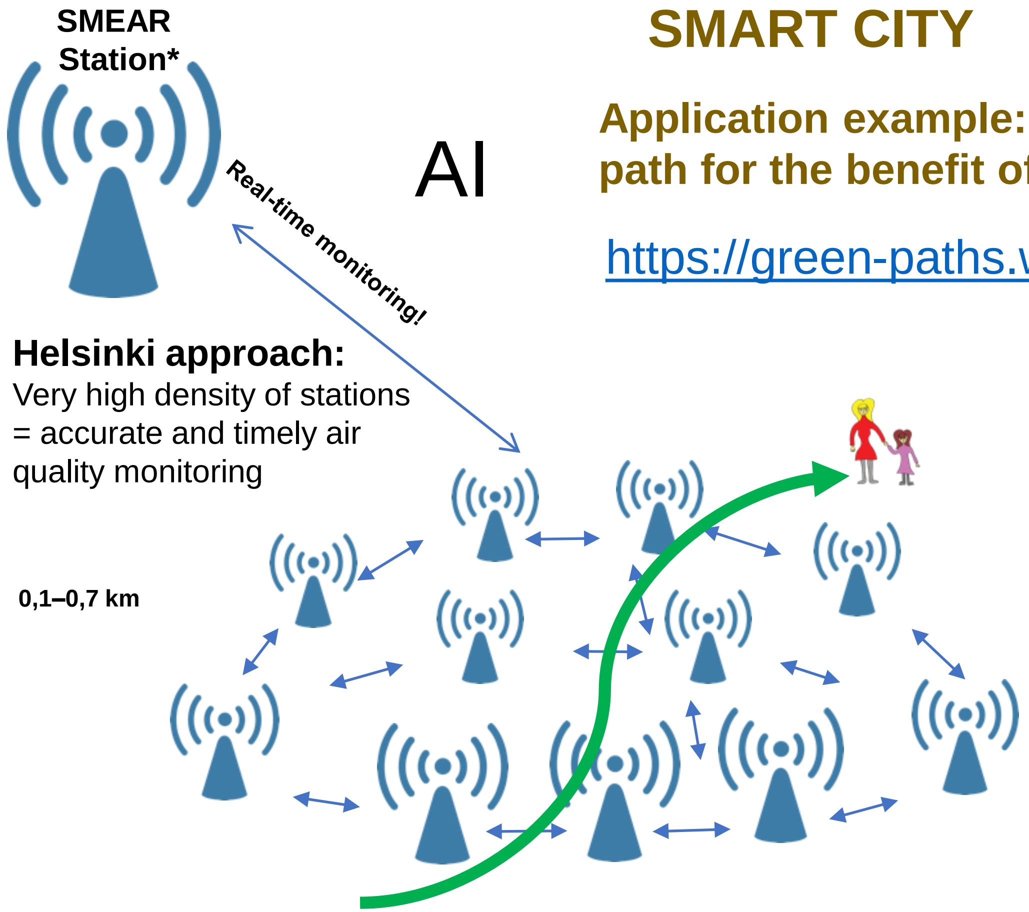
HIGH DENSITY OF MEASUREMENT STATIONS & AUTOMATICALLY CALIBRATED SENSORS PROVIDING REAL-TIME MEASUREMENT DATA

- Low cost mini- & micro-sensors and base stations across the environment supported by 4G NB-IOT network leading to a viable 5G service

- Field calibration by highly accurate atmospheric science SMEAR Station

Enables multiple applications:
- City planning, health and wellbeing, wearable and fitness devices, vehicular technology, mobile apps, HD-maps

- High quality maps and calibration technique that takes into account correlations across environments.



SMART CITY

Application example: Green path for the benefit of citizens

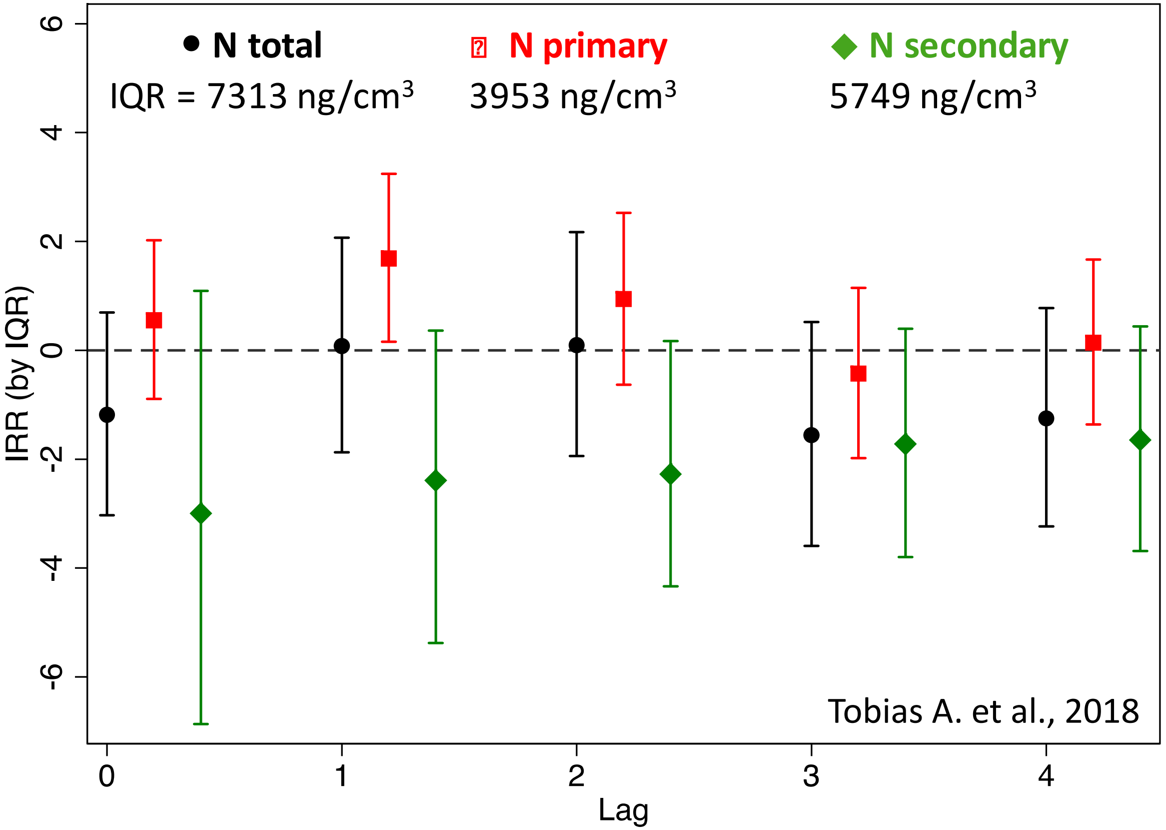
https://green-paths.web.app

Monitoring stations in urban and rural areas. Multiple ways to use sensors.

SMEAR* = Station for Measuring Earth Surface-Atmosphere Relations (SMEAR)
https://www.atm.helsinki.fi/SMEAR/

Health effects of ultrafine particle types

DAILY MORTALITY AND PRIMARY AND SECONDARY UFP IN BARCELONA 2009-2014



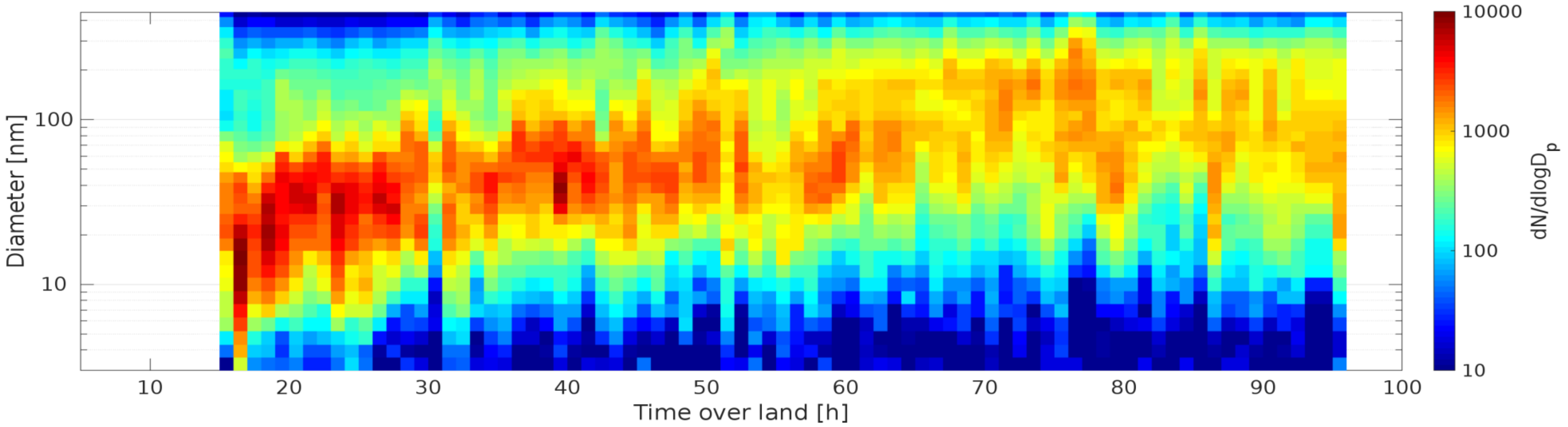
ARTICLES
https://doi.org/10.1038/s41561-021-00876-0

nature geoscience

Check for updates

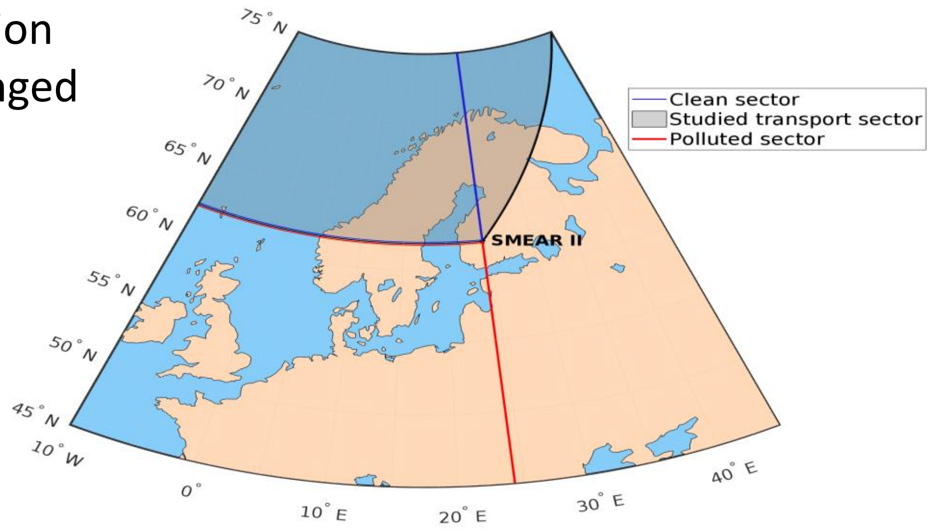
Influence of biogenic emissions from boreal forests on aerosol–cloud interactions

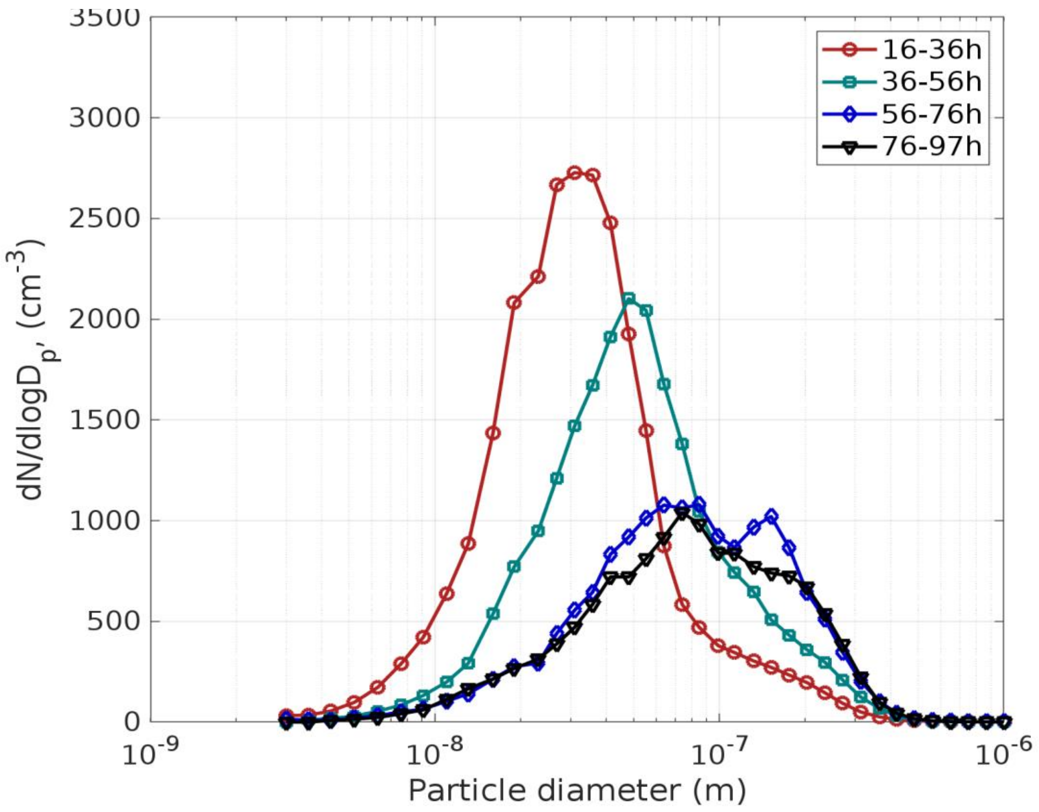
T. Petäjä[1,2] ✉, K. Tabakova[1], A. Manninen[1,3], E. Ezhova[1], E. O'Connor[3,4], D. Moisseev[1,3], V. A. Sinclair[1], J. Backman[1,3], J. Levula[1], K. Luoma[1], A. Virkkula[1,2,3], M. Paramonov[1,3], M. Räty[1], M. Äijälä[1], L. Heikkinen[1], M. Ehn[1], M. Sipilä[1], T. Yli-Juuti[5], A. Virtanen[5], M. Ritsche[6], N. Hickmon[6], G. Pulik[7], D. Rosenfeld[7], D. R. Worsnop[1,8], J. Bäck[9], M. Kulmala[1,2,10,11] and V.-M. Kerminen[1]



Aerosol size distribution as a function of time over land in the clean sector

Aerosol size distribution evolves during prolonged biogenic influence



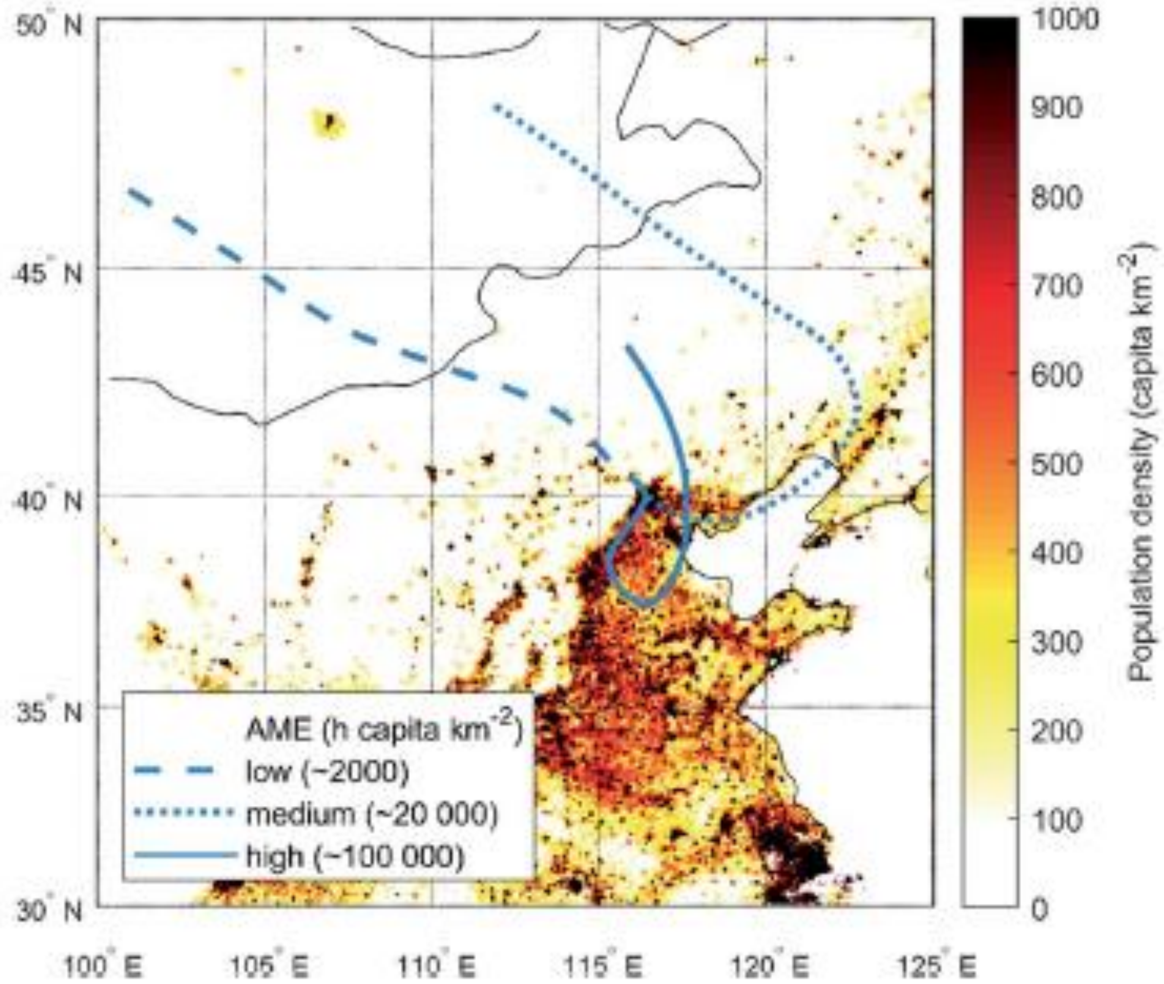


Observed coupling between air mass history, secondary growth of nucleation mode particles and aerosol pollution levels in Beijing†

Environmental Science: Atmospheres

ROYAL SOCIETY OF CHEMISTRY

S. Hakala, *ab V. Vakkari, cd F. Bianchi, ab L. Dada, abef C. Deng, g K. R. Dällenbach, abf Y. Fu, g J. Jiang, g J. Kangasluoma, ab J. Kujansuu, ab Y. Liu, a T. Petäjä, abh L. Wang, i C. Yan, ab M. Kulmala abh and P. Paasonen b



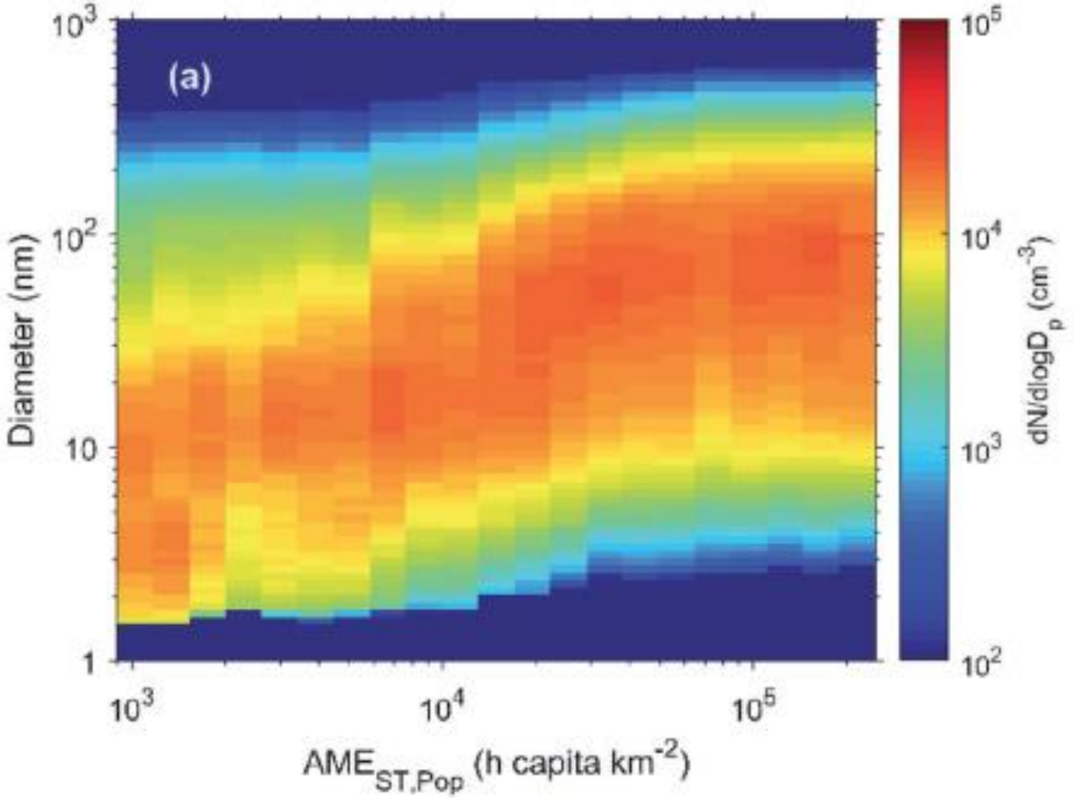
Air mass exposure to anthropogenic emissions (AME)

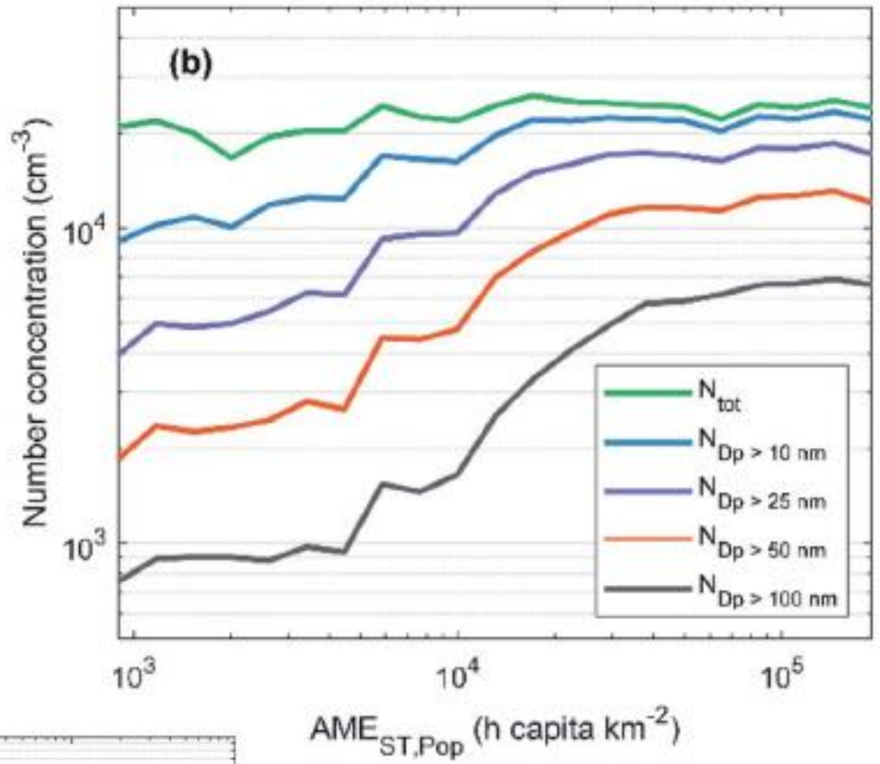
$$\mathrm{AME}_{\mathrm{ST},x,H}(t) = \sum_{t_b=1\ \mathrm{h}}^{72\ \mathrm{h}} A_x[\mathrm{lat}(t,t_b),\mathrm{lon}(t,t_b)] \times 1\ \mathrm{h}$$

$$\mid \text{trajectory height} \leq H$$

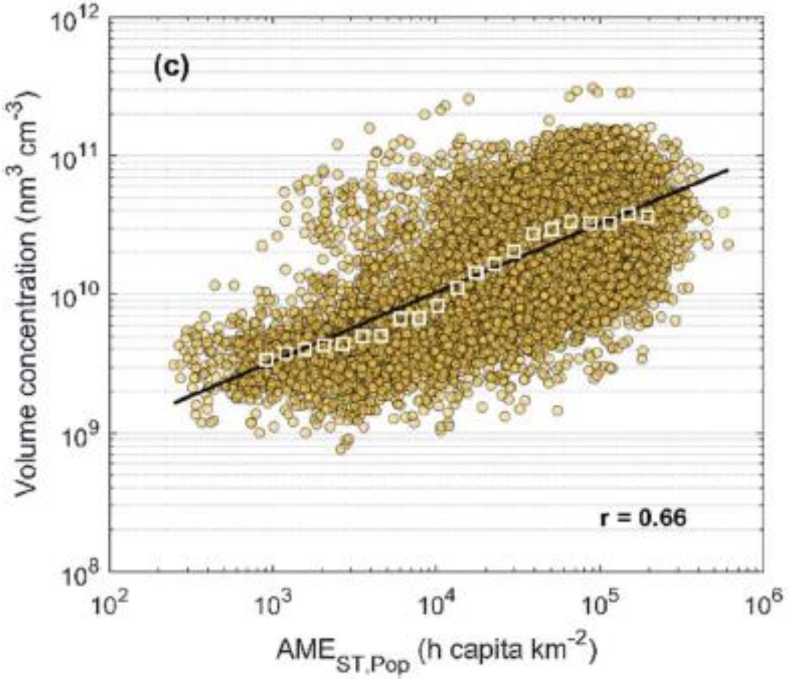
A describes the anthropogenic emissions in the certain grid.

Can be population, can be SO2 emissions, NOx emissions or column NO2 concentration





Aerosol size distribution is influenced by accumulated anthropogenic exposure



Environmental Research Letters

Environ. Res. Lett. 13 (2018) 103003

TOPICAL REVIEW

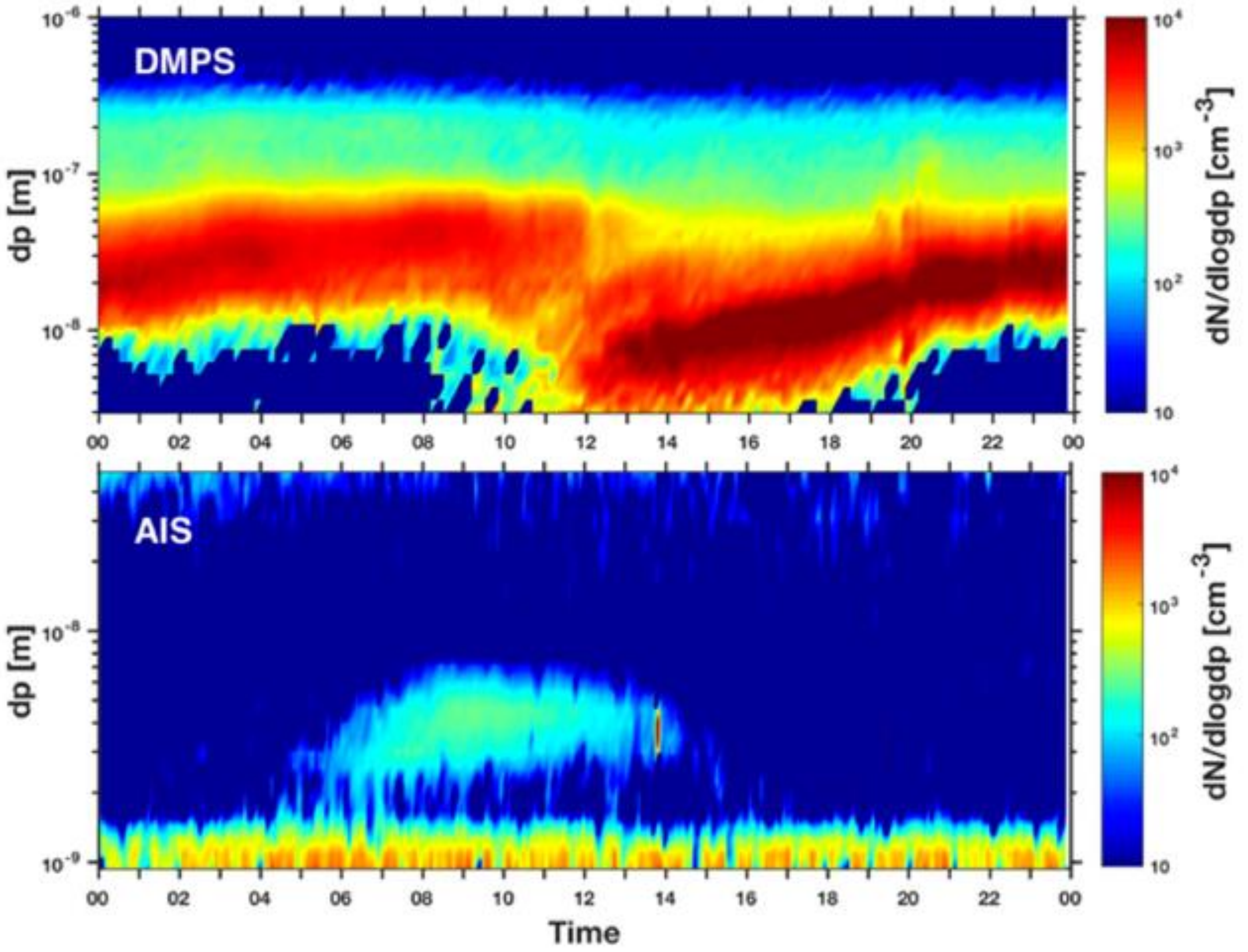
Atmospheric new particle formation and growth: review of field observations

Veli-Matti Kerminen[1], Xuemeng Chen[1], Ville Vakkari[2], Tuukka Petäjä[1], Markku Kulmala[1,3,4] and Federico Bianchi[1,3]

Atmospheric new particle formation in China

Biwu Chu[1], Veli-Matti Kerminen[1], Federico Bianchi[1,2], Chao Yan[1], Tuukka Petäjä[1,3], and Markku Kulmala[1,2]

Atmos. Chem. Phys., 19, 115–138, 2019

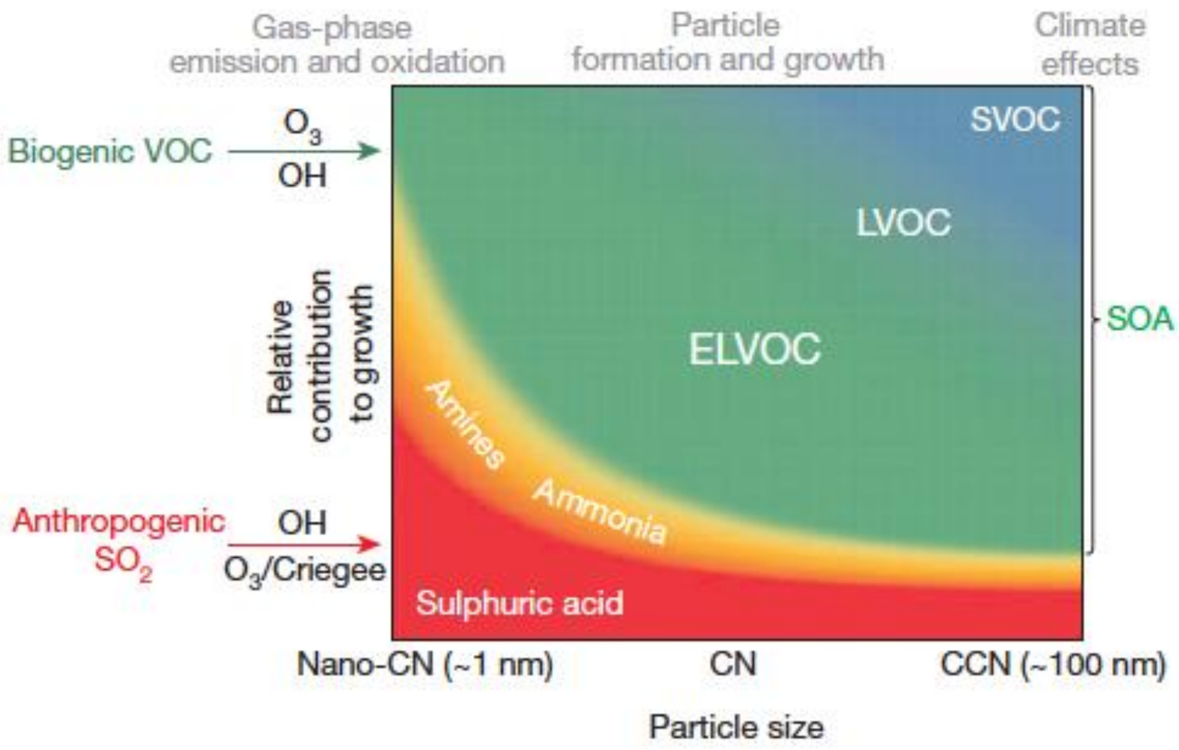


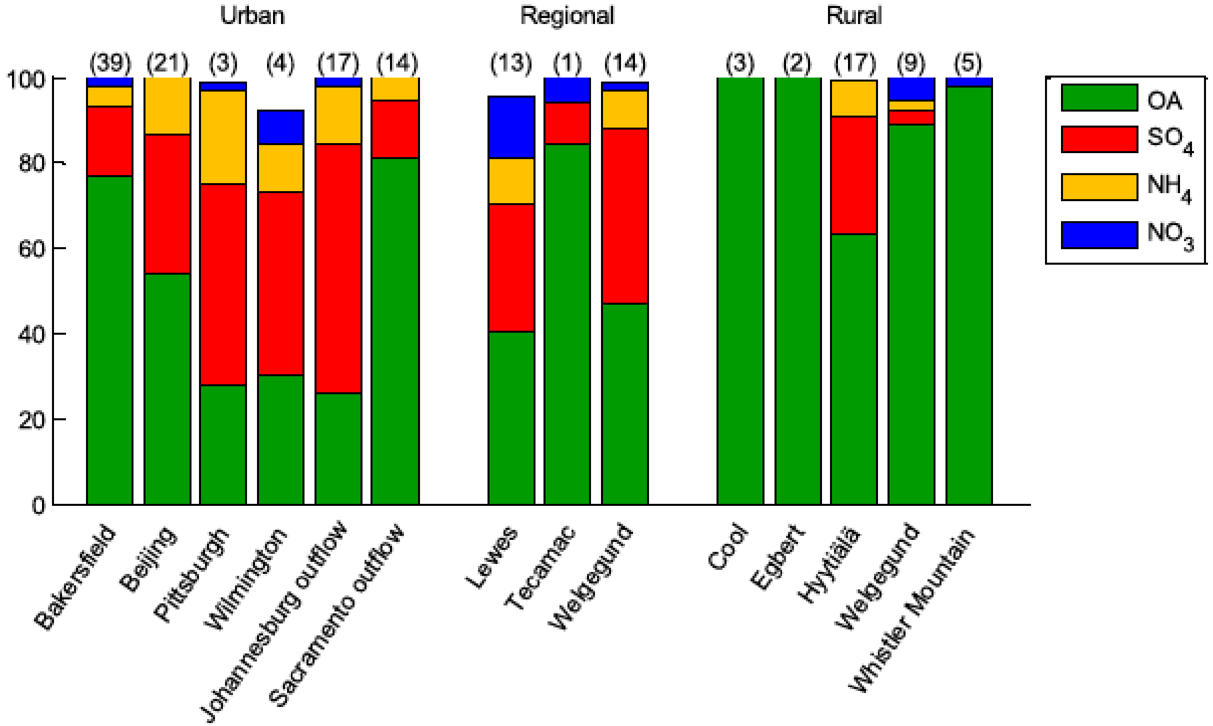
Key compounds for initial clustering

Sulfuric acid
Ammonia
Amines
Oxidized organics
Iodic acid (marine, Arctic)

Key compounds for the growth

Oxidized organics
+ other vapors above
Considerable variability from one location to another





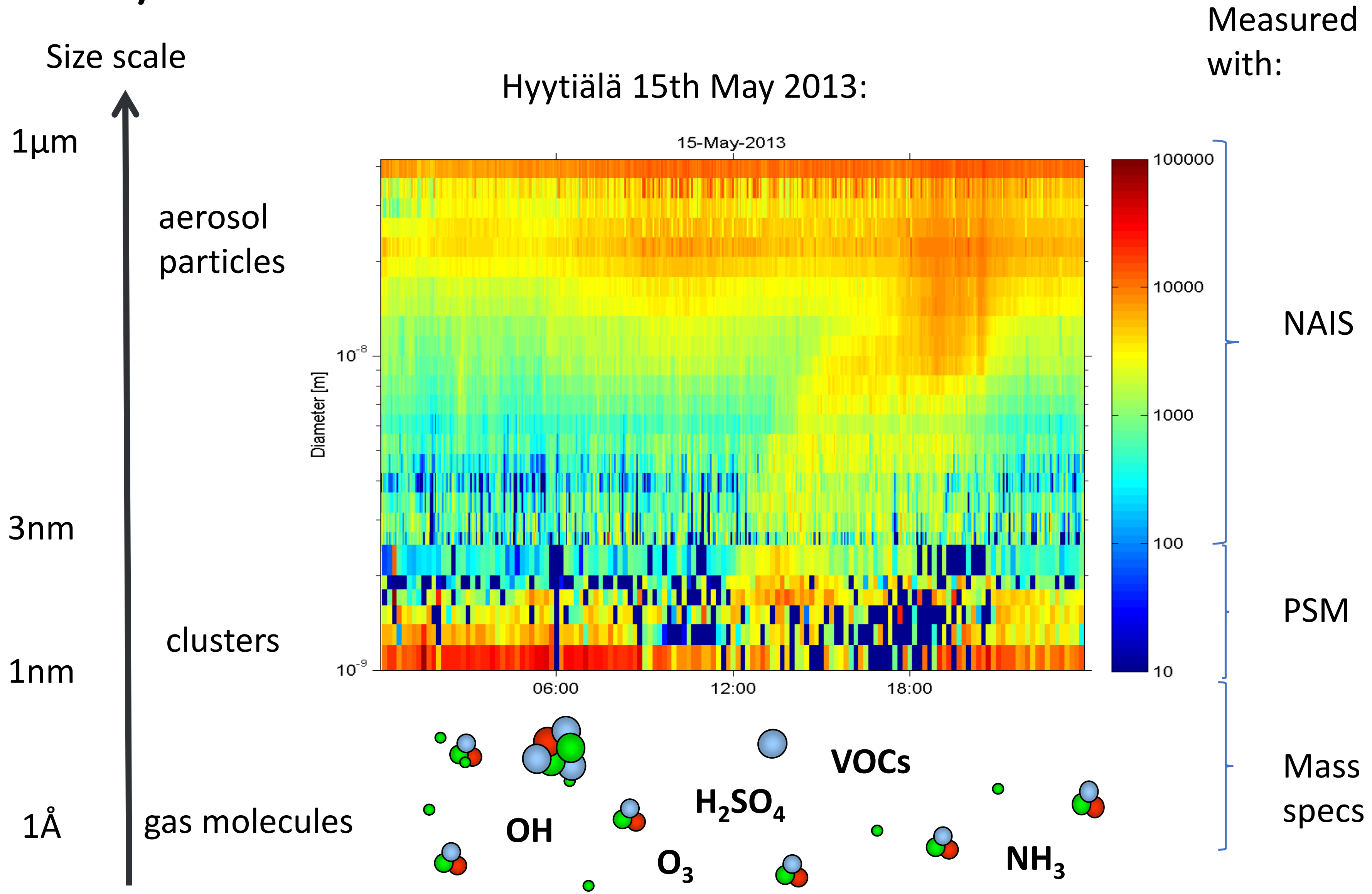
Different vapors responsible for growth as a function of size.

Ehn et al. (2014) Nature

Different vapors responsible for the growth in different environments.

Kerminen et al. (2018) Environ. Res. Lett.

In order to distinguish different processes contributing to the number concentration below 10 nm, we need complementary instrumentation



Slide courtesy of Katrianne Lehtipalo

New technologies for reaching the sizes of nucleating clusters

Spin-off companies

Size scale

1µm

aerosol particles

3nm

clusters

1nm

1Å

gas molecules

Method

Aerosol measurements

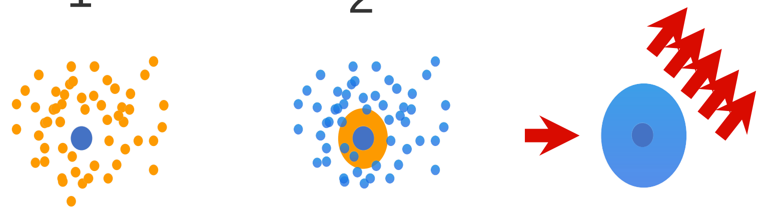
Gas measurements

Key instruments

The Particle Size Magnifier (PSM)

1

2

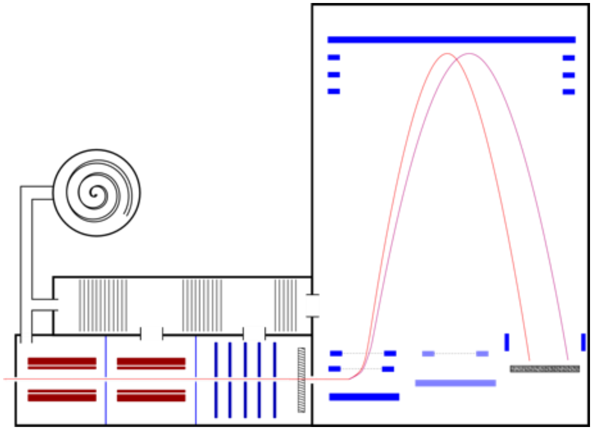


Diethylene glycol

Water / n-butanol

Optical detection

AIRMODUS



The (CI-) APi-TOF

KÄRSA

Atmospheric Chemistry and Physics

Traffic-originated nanocluster emission exceeds H_2SO_4-driven photochemical new particle formation in an urban area

Miska Olin[1], Heino Kuuluvainen[1], Minna Aurela[2], Joni Kalliokoski[1], Niina Kuittinen[1], Mia Isotalo[1], Hilkka J. Timonen[2], Jarkko V. Niemi[3], Topi Rönkkö[1], and Miikka Dal Maso[1]

Atmos. Chem. Phys., 20, 1–13, 2020
https://doi.org/10.5194/acp-20-1-2020

Atmospheric Chemistry and Physics

A phenomenology of new particle formation (NPF) at 13 European sites

Dimitrios Bousiotis[1], Francis D. Pope[1], David C. S. Beddows[1], Manuel Dall'Osto[2], Andreas Massling[3], Jakob Klenø Nøjgaard[3,4], Claus Nordstrøm[3], Jarkko V. Niemi[5], Harri Portin[5], Tuukka Petäjä[6], Noemi Perez[7], Andrés Alastuey[7], Xavier Querol[7], Giorgos Kouvarakis[8], Nikos Mihalopoulos[8], Stergios Vratolis[9], Konstantinos Eleftheriadis[9], Alfred Wiedensohler[10], Kay Weinhold[10], Maik Merkel[10], Thomas Tuch[10], and Roy M. Harrison[1,11]

Atmos. Chem. Phys., 21, 11905–11925, 2021
https://doi.org/10.5194/acp-21-11905-2021

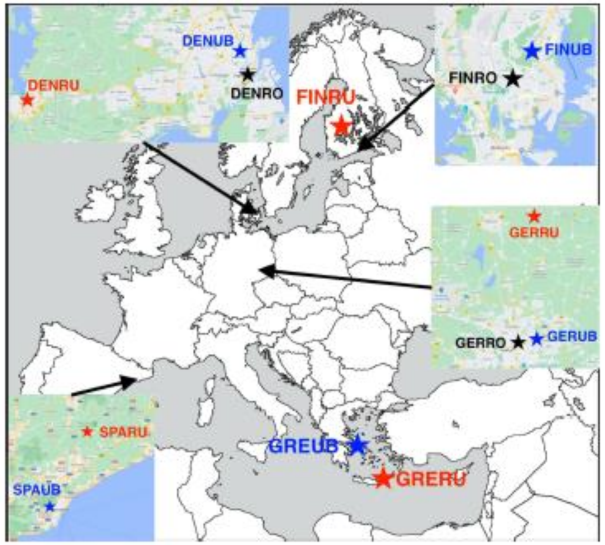


Figure 1. Map of the areas of study (map by © Google Maps).

Atmospheric Chemistry and Physics

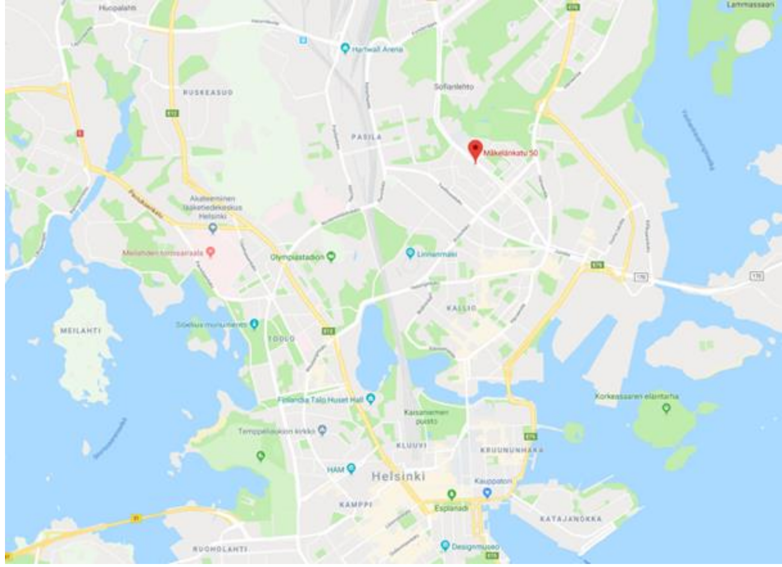
Measurement report: The influence of traffic and new particle formation on the size distribution of 1–800 nm particles in Helsinki – a street canyon and an urban background station comparison

Magdalena Okuljar[1], Heino Kuuluvainen[2], Jenni Kontkanen[1], Olga Garmash[1], Miska Olin[2], Jarkko V. Niemi[3], Hilkka Timonen[4], Juha Kangasluoma[1], Yee Jun Tham[1], Rima Baalbaki[1], Mikko Sipilä[1], Laura Salo[2], Henna Lintusaari[2], Harri Portin[3], Kimmo Teinilä[4], Minna Aurela[4], Miikka Dal Maso[2], Topi Rönkkö[2], Tuukka Petäjä[1], and Pauli Paasonen[1]

Atmos. Chem. Phys., 21, 9931–9953, 2021

Measurements: location

- Mäkelänkatu street canyon in Helsinki
  - 6 lanes, 2 tramlines, 2 rows of trees, 2 pavements
  - Highly trafficked (26 000 vehicles / day)
- Traffic counting and weather station nearby



Measurements: setup

Measurement station:

- Nitrate-ion (NO_3^-)-based chemical-ionization atmospheric-pressure-interface time-of-flight mass spectrometer (CI-APi-TOF-MS) for H_2SO_4 concentration measurement
- PSM+CPC for aerosol number concentration measurement
- DMPS for aerosol particle size distribution measurement
- NO_x and CO_2 concentrations as traffic tracers

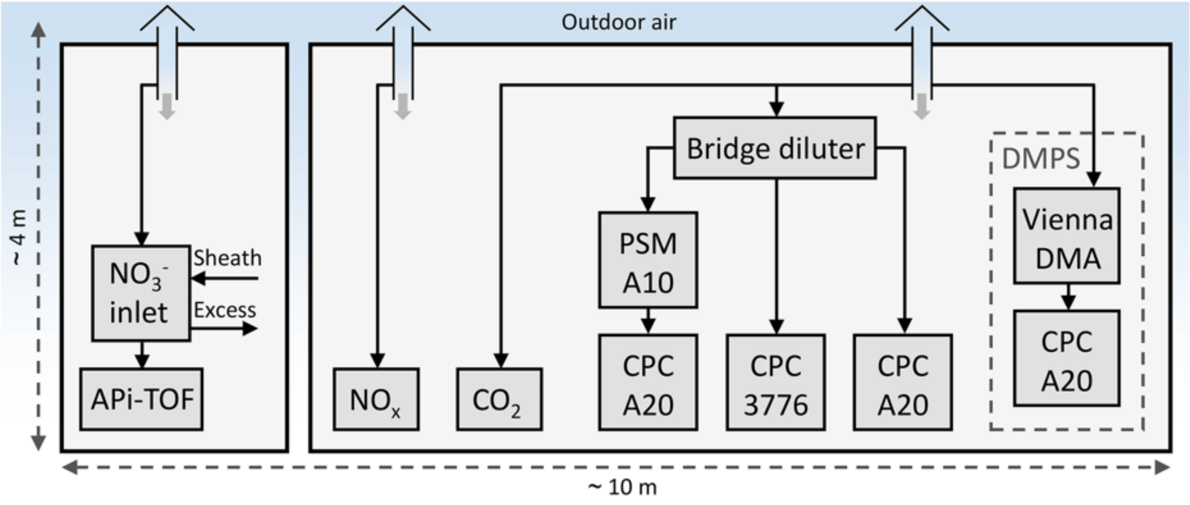
Traffic counting: vehicles/hour in both directions

Weather station: wind velocity and direction, solar irradiance, air temperature, pressure, RH, precipitation

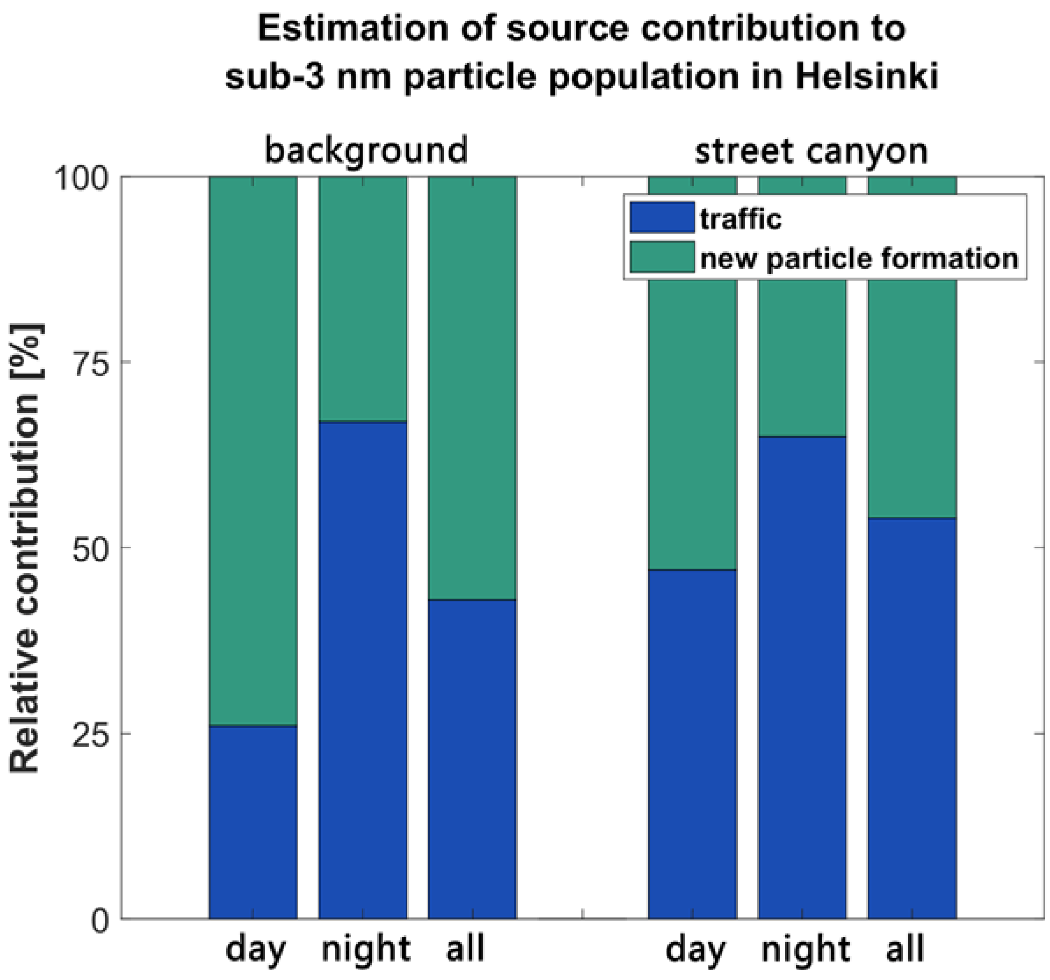
Streetcanyon site

Urban background site 900 m away

CI-APi-TOF

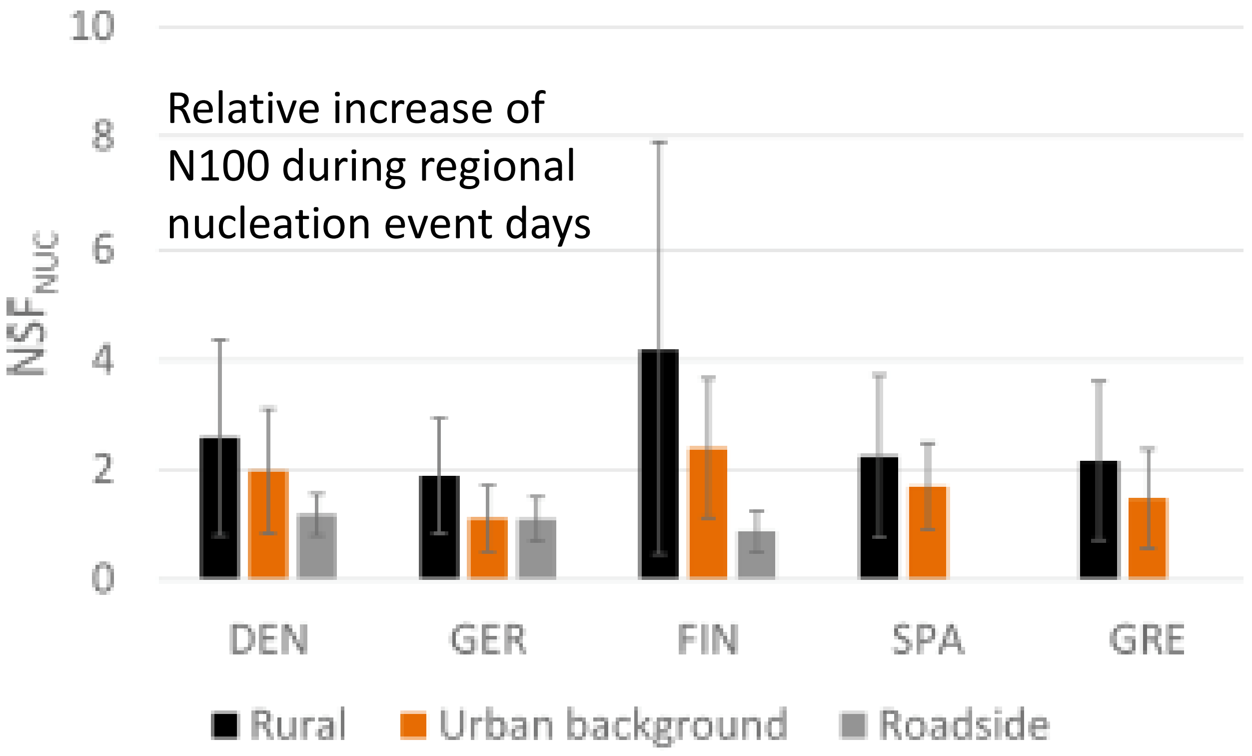


Containers at the measurement station



Okuljar et al. (2021)

Regional and traffic related sub-3 nm particles have on average 50/50 contribution to the aerosol number concentration



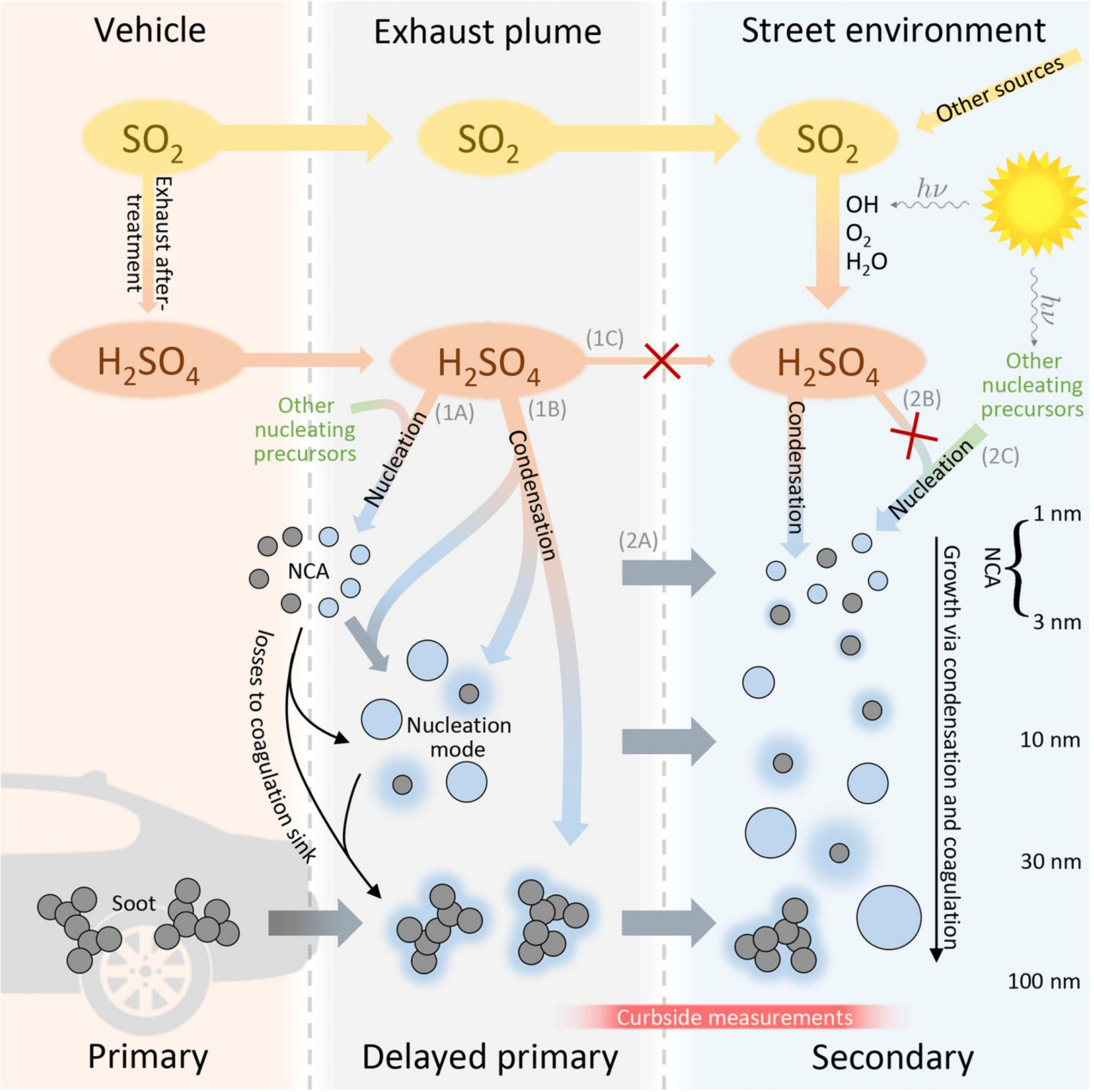
Bousiotis et al. (2021)

Regional formation can double the sub-100 nm concentrations during event days.

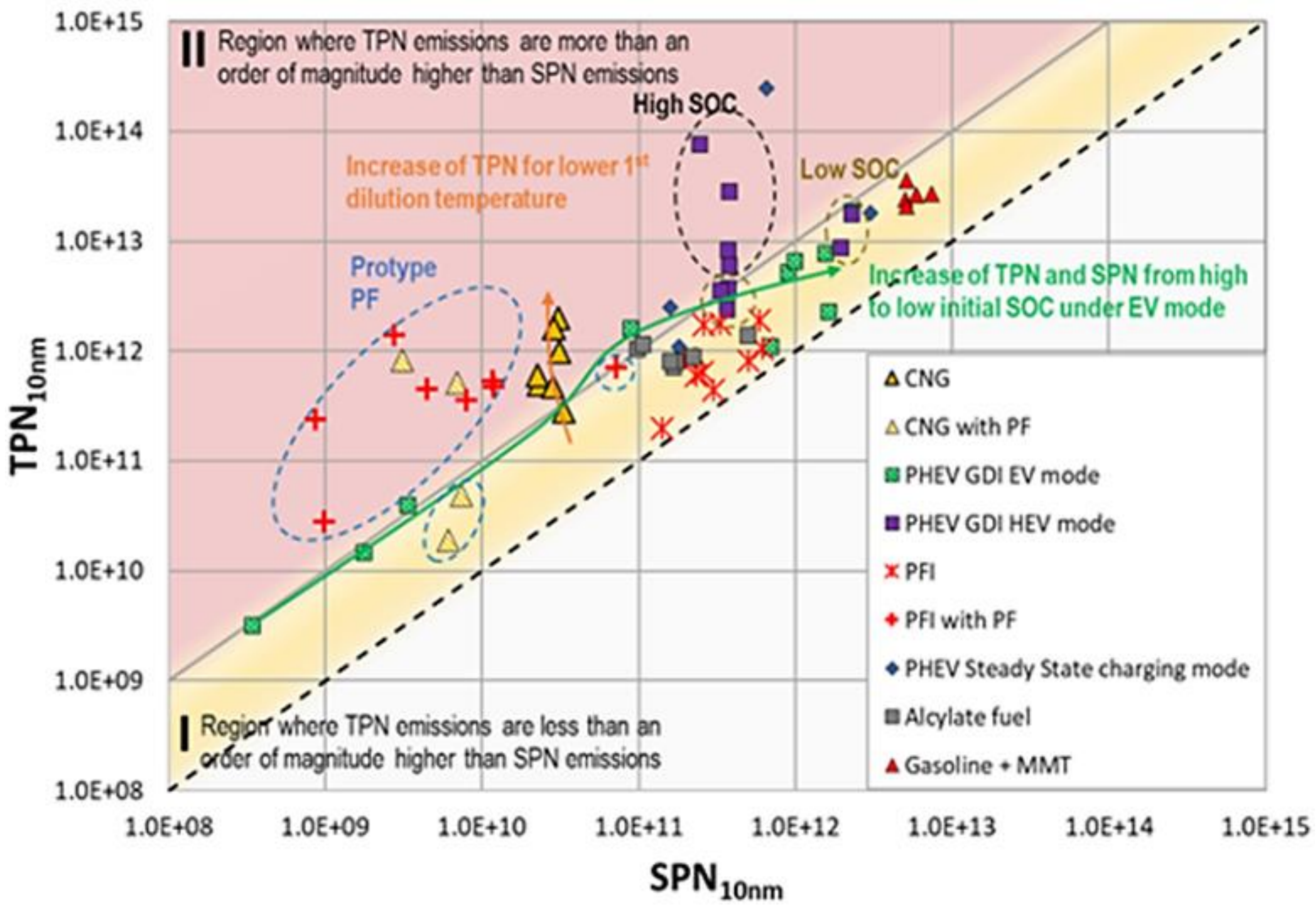
Differentiation between traffic-related and regional formation is challenging.

Both photochemistry and traffic emission have an influence

- Primary emitted H_2SO_4 goes to particles
- Vehicles emit SO_2 which converts to H_2SO_4 photochemically = *secondary* H_2SO_4
- Secondary H_2SO_4 is not the main source for the traffic-originated nanoparticles
- Aerosol number emissions in real atmosphere requires comprehensive instrumentation
- Aerosol number size distribution and aerosol number concentration need to be measured down to 1-3 nm sizes close to traffic
- A rough calculation:
  68% of H_2SO_4 and 85% of nanoaerosols originate from traffic at Mäkelänkatu at noontime



Fresh exhaust particles vs solid particles only



Some vehicles with new technologies produce real-world relevant particle number emissions more than an order of magnitude higher than their solid particle emissions

Samaras, Z.C., Andersson, J., Bergmann, A., Hausberger, S., Toumasatos, Z., Keskinen, J., Haisch, C., Kontses, A., Ntziachristos, L., Landl, L., Mamakos, A., Bainschab, M .: Measuring Automotive Exhaust Particles Down to 10 nm, SAE Technical Paper 2020-01-2209, 2020.

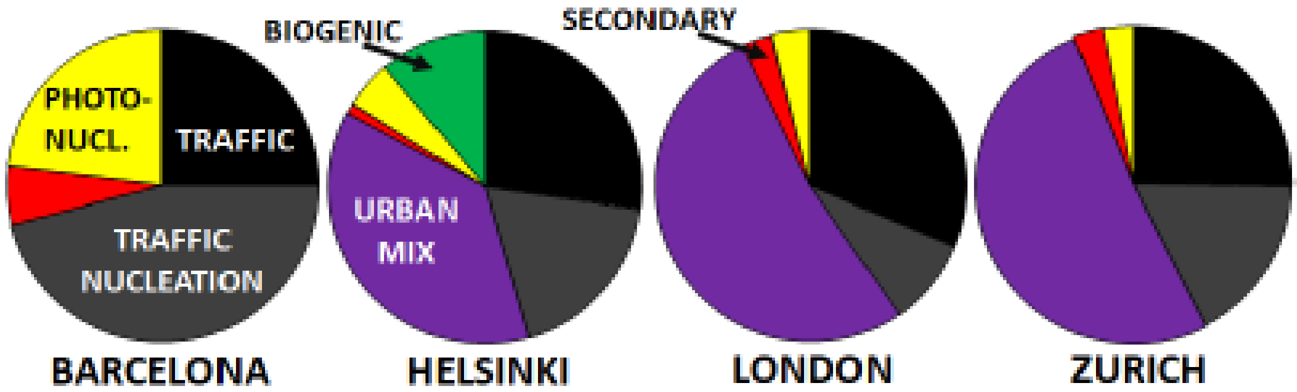
Research Infrastructures Services Reinforcing Air Quality Monitoring Capacities in European Urban & Industrial AreaS (RI-URBANS)

Co-coord: Xavier Querol, CSIC, Barcelona
Co-coord: Tuukka Petäjä, UHEL, Helsinki

25 European partners

8 MEUR budget
4 year RIA project
2021-2025

2018	% Population exposed to levels exceeding: EU AQ Standards	% Population exposed to levels exceeding: WHO AQGs	% AQMNs recording Levels exceeding: EU AQ Standards	% AQMNs recording Levels exceeding: WHO AQGs
PM2,5	4%	74%	4%	70%
NO_2	4%	4%	8%	8%
BaP	15%	75%	27%	83%
O_3	34%	99%	41%	96%



Source apportionment of particle number size distribution in urban background and traffic stations in four European cities

Ioar Rivas[a,*], David C.S. Beddows[b], Fulvio Amato[c], David C. Green[a], Leena Järvi[d,e], Christoph Hueglin[f], Cristina Reche[c], Hilkka Timonen[g], Gary W. Fuller[a], Jarkko V. Niemi[h], Noemí Pérez[c], Minna Aurela[g], Philip K. Hopke[i], Andrés Alastuey[c], Markku Kulmala[d], Roy M. Harrison[b,j], Xavier Querol[c], Frank J. Kelly[a]

Environment International 135 (2020) 105345

European Commission | HORIZON 2020

- ACTRIS = network of harmonized aerosols, trace gases and clouds observations in Europe
    - Mainly remote / background environments
- Air quality monitoring networks (AQMN) aerosol observations in urban environment

RI-URBANS integrates these two domains

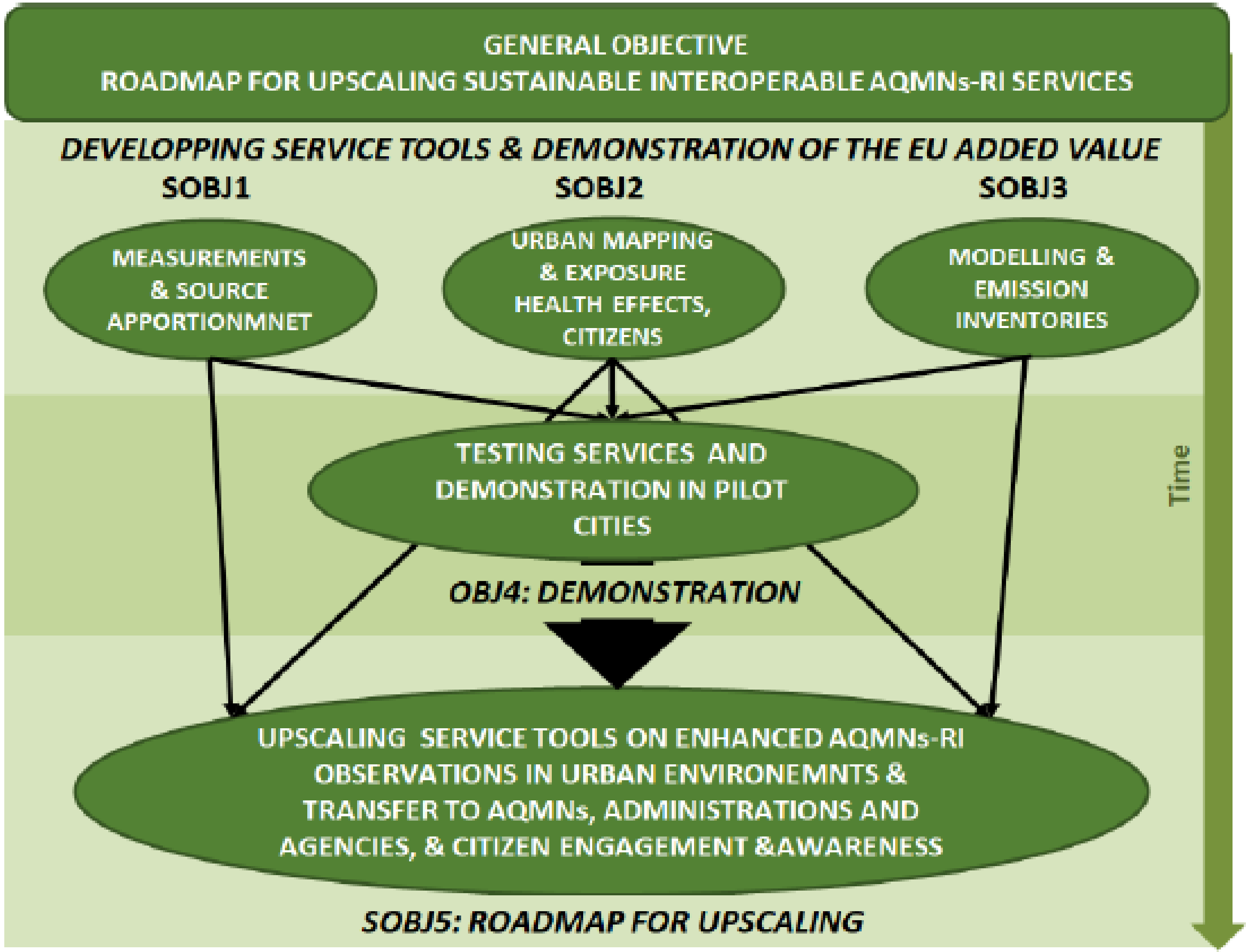


Figure 1.4: RI-URBANS' objective and specific objectives (SOBJ).

RI-URBANS and the European Green Deal

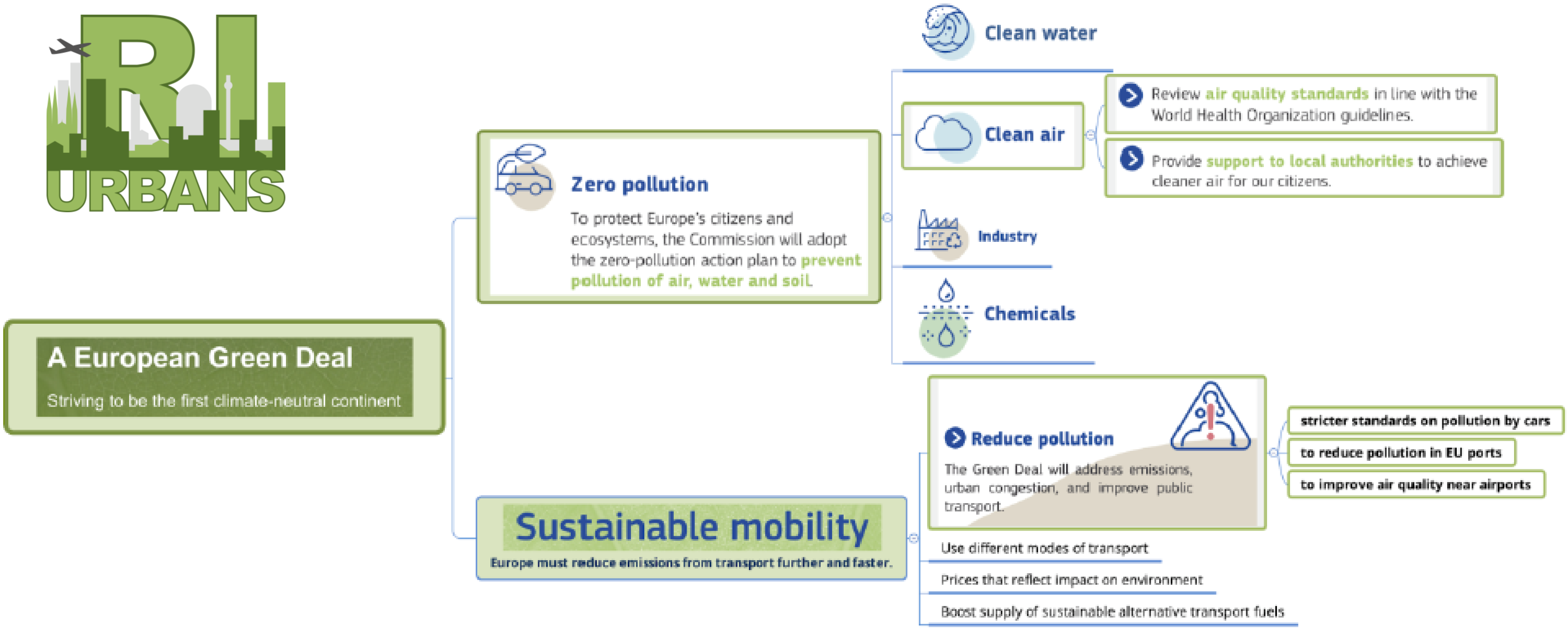


Figure 1.5: *Relationship with Green Deal Policy areas and challenges.*

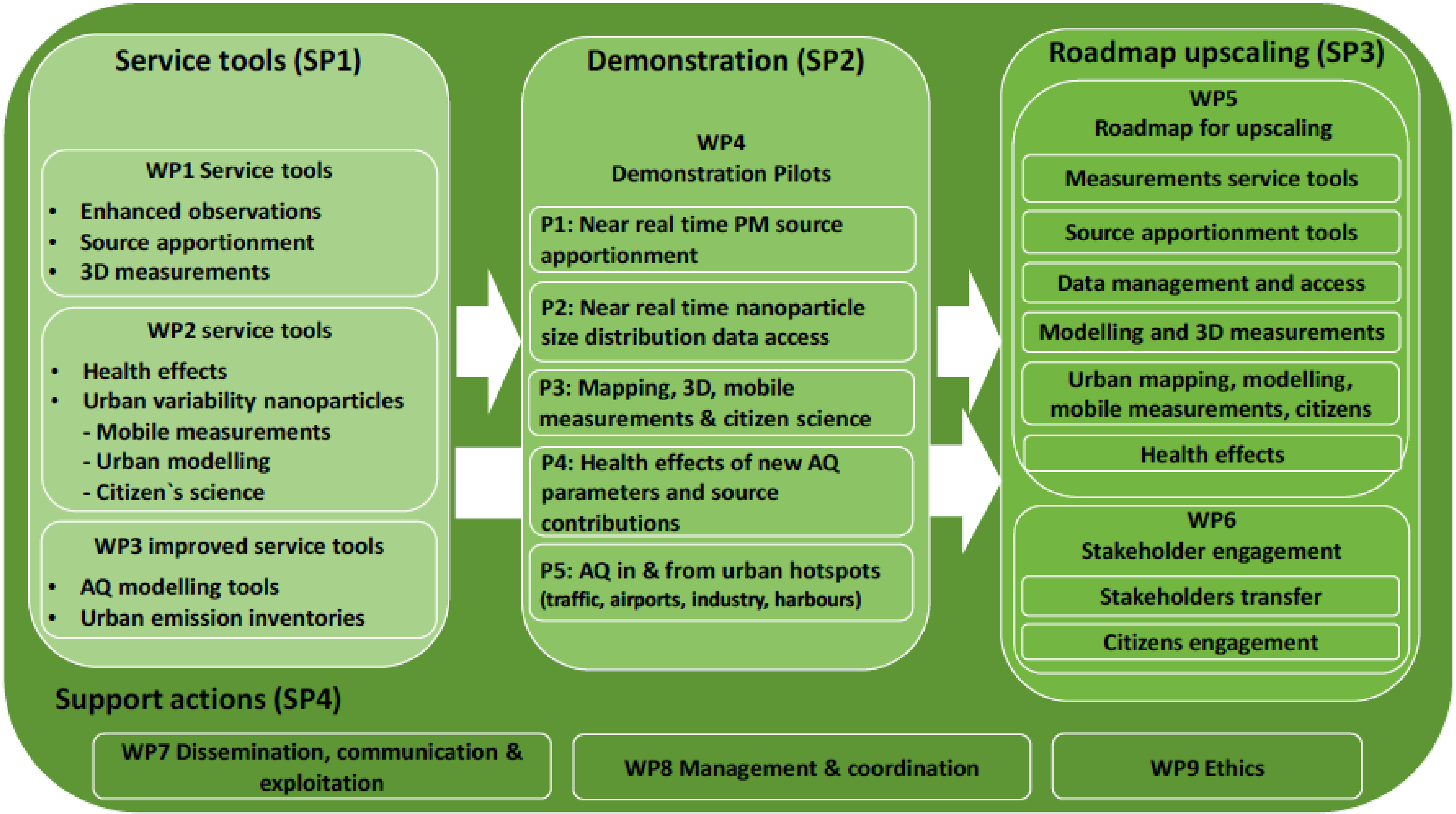
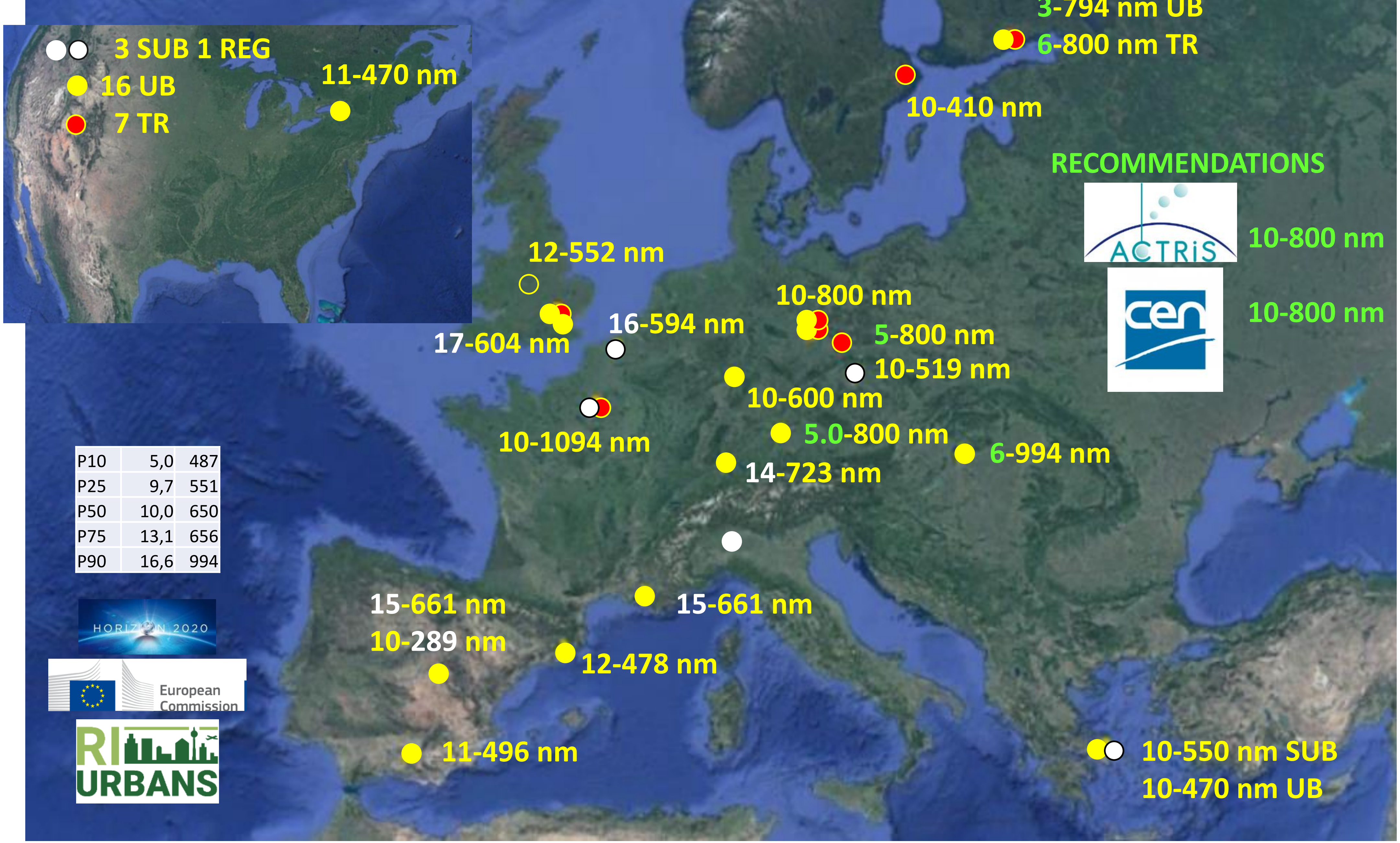


Figure 1.9: *Strategic Pillars (SP1-4) and Work Packages (WP1-9) in RI-URBANS.*

Pilot cities

Athens
Barcelona
Birmingham
Bucharest
Helsinki
Milan
Paris
Rotterdam – Amsterdam
Zurich

UFP-PSD Low and high size detection limits



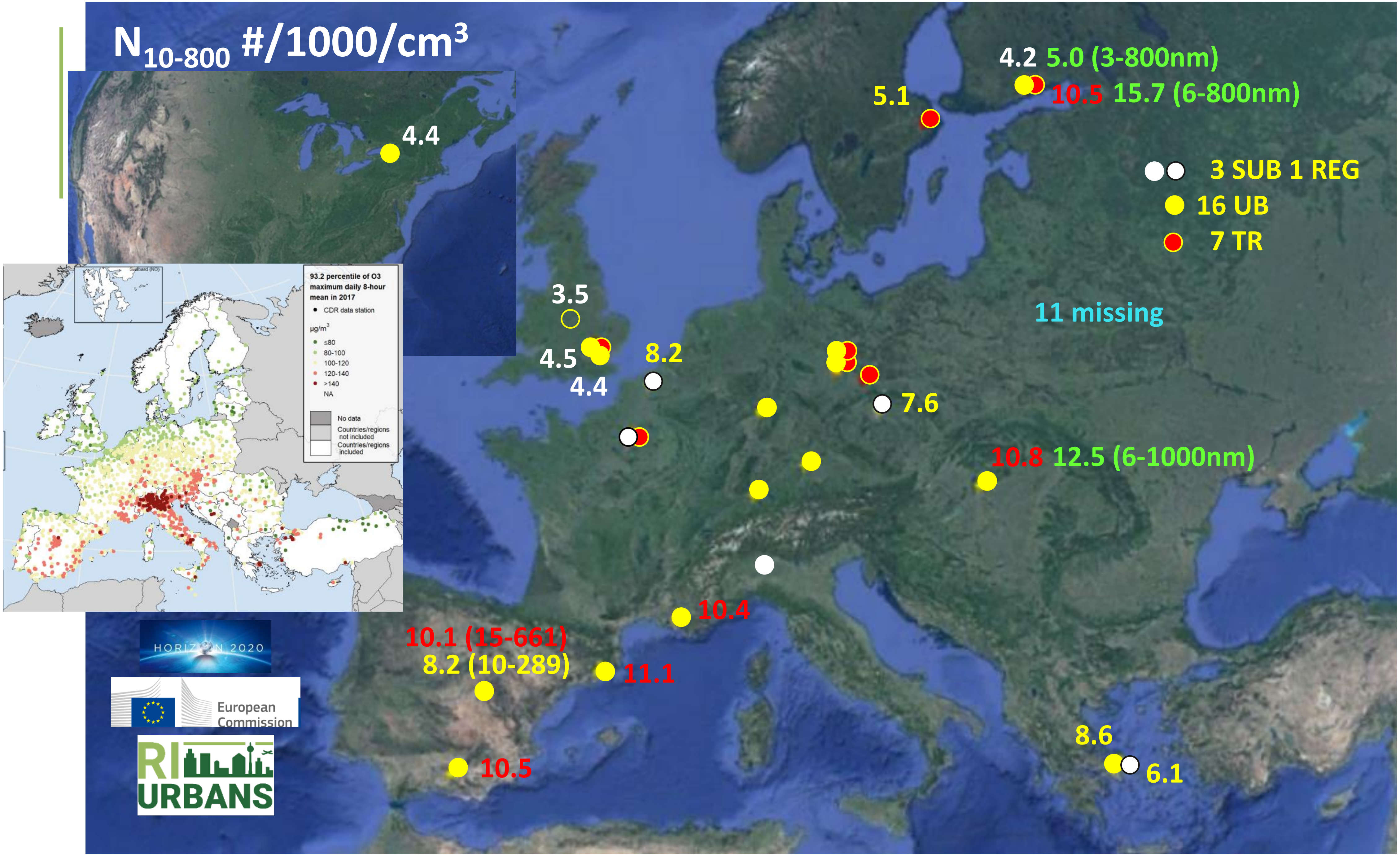
P10	5,0	487
P25	9,7	551
P50	10,0	650
P75	13,1	656
P90	16,6	994

HORIZON 2020

European Commission

RI URBANS

N_{10-800} #/1000/cm^3



HORIZON 2020

European Commission

RI URBANS

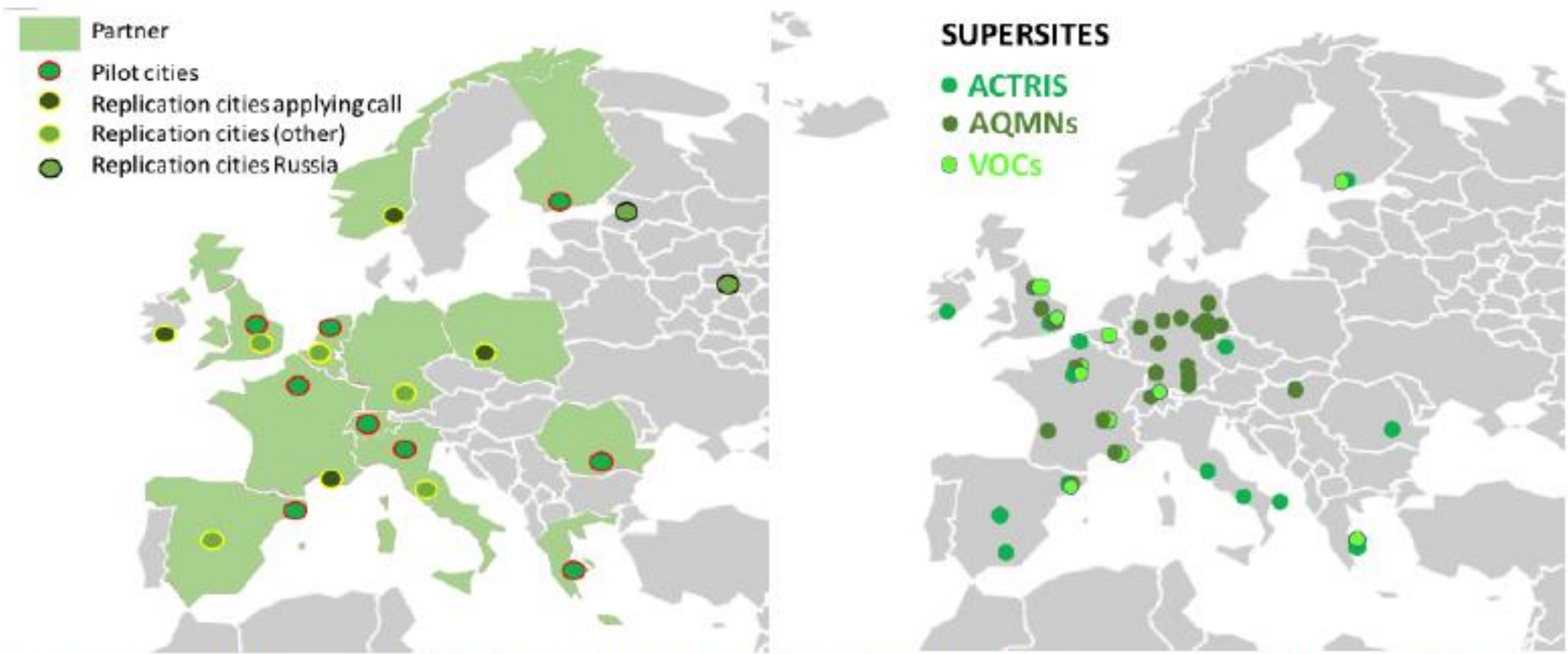


Figure 1.7: Left: *Partners and pilot cities in RI-URBANS.* ***Right:*** *ACTRIS-RI and AQMNs supersites available in urban areas with measurements of nanoparticles, PM chemistry, BC, and in a few cases VOCs.*

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				
P3 - T4.3 - Urban fine scale mapping			x	x			x	x	
P4 - T4.4 - Novel health indicators	x	x							x
P5 - T4.5 - Pollution hotspots				x		x		x	

The pilot cities are (* indicates participation in ATMO-ACCESS to attract international contributions and involvement of SMEs for innovative AQ solutions):

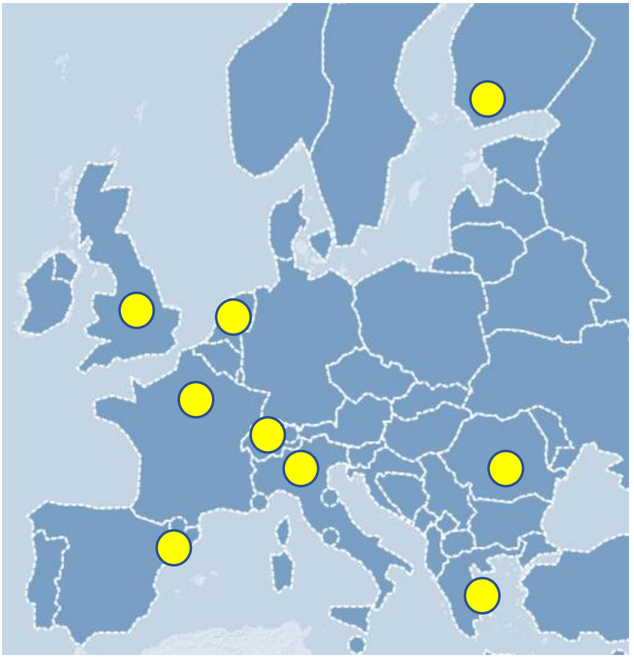
+ PAUL –project (same call, same phase) related to GHG observations

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

RI-URBANS has 5 pilots for testing and demonstrating services:

- **Near-Real Time (NRT) aerosol source apportionment** of carbonaceous aerosols (T4.1) and **NRT aerosol number size distribution data** (T4.2)
- **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)
- quantifying emission sources in/near urban areas (with intense traffic and/or industries) and identifying contribution of **hotspots** to air pollutant exposure (T4.5).

+ synthesis of outcomes of pilot studies (T4.6).



Pilot 4.1: Near-real time aerosol source apportionment of carbonaceous aerosols

- Lead: Jean-Eudes Petit, CNRS (email: jean-eudes.petit@lsce.ipsl.fr) ; Hilkka Timonen, FMI (email: hilkka.timonen@fmi.fi)
- Implementation of near-realtime source apportionment tool (from T1.2) at pilot stations.
- Participants: FORTH, NOA, UHEL, EMPA, PSI, CNRS, CNR, FMI
- **Expected outputs:**
  - Automatic transfer of data (organic aerosols matrices and aethalometer BC concentrations) to ACTRIS DC.
  - Tracers and contributions of primary sources such as traffic, wood burning, and cooking (depending on measurement site) near real-time
  - Quantification of the SOA fraction

Instruments for NRT-SA

Timeseries, contribution, diurnal variation, mass spectra for:

ACSM

Chemical composition of PM1

Organics
Sulfate
Nitrate
Ammonium
Chloride

Online factorization (T1.2)

HOA
BBOA
OOAs
..

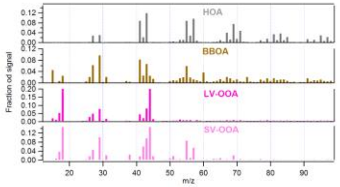


Fig. 7. Mass spectra in fraction of signal of PMF factors, LV-OOA, SV-OOA, BBOA and HOA.

Aethalometer

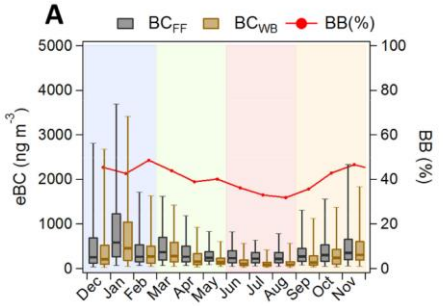
Absorption

BC

Online apportionment (T1.2)

BC_{ff}

BC_{wb}



Timeline of work

- **Implementation** of the necessary data transfer tools at **pilot sites** during **2022 - ongoing**

- ECAC tools for online data acquisition and generation

- ECAC procedure installed on Igor

→ Contact : jean-eudes.petit@lsce.ipsl.fr

- Connected to Windows/Linux computer
- Python, InfluxDB, Grafana installed
- ECAC scripts installed & set up

→ Contact : muellert@tropos.de

- NextCloud desktop client installed on every computers

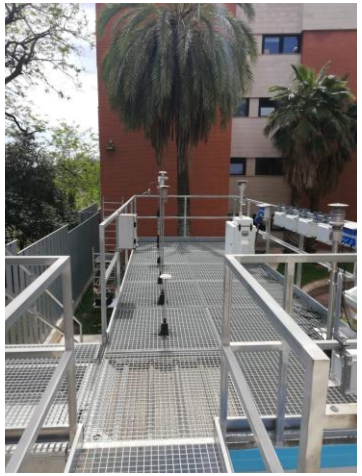
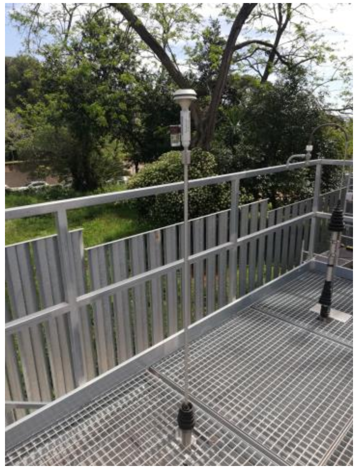
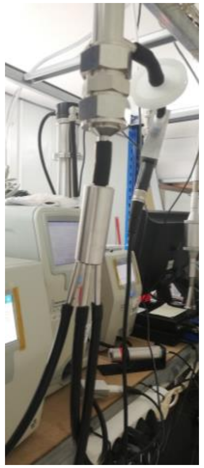
→ Contact : nicolas.pascal@univ-lille.fr

-> Data from each site in real-time to the server for NRT-SA

WP4.2 Near Real Time (NRT) data provision of nanoparticles and their size distributions

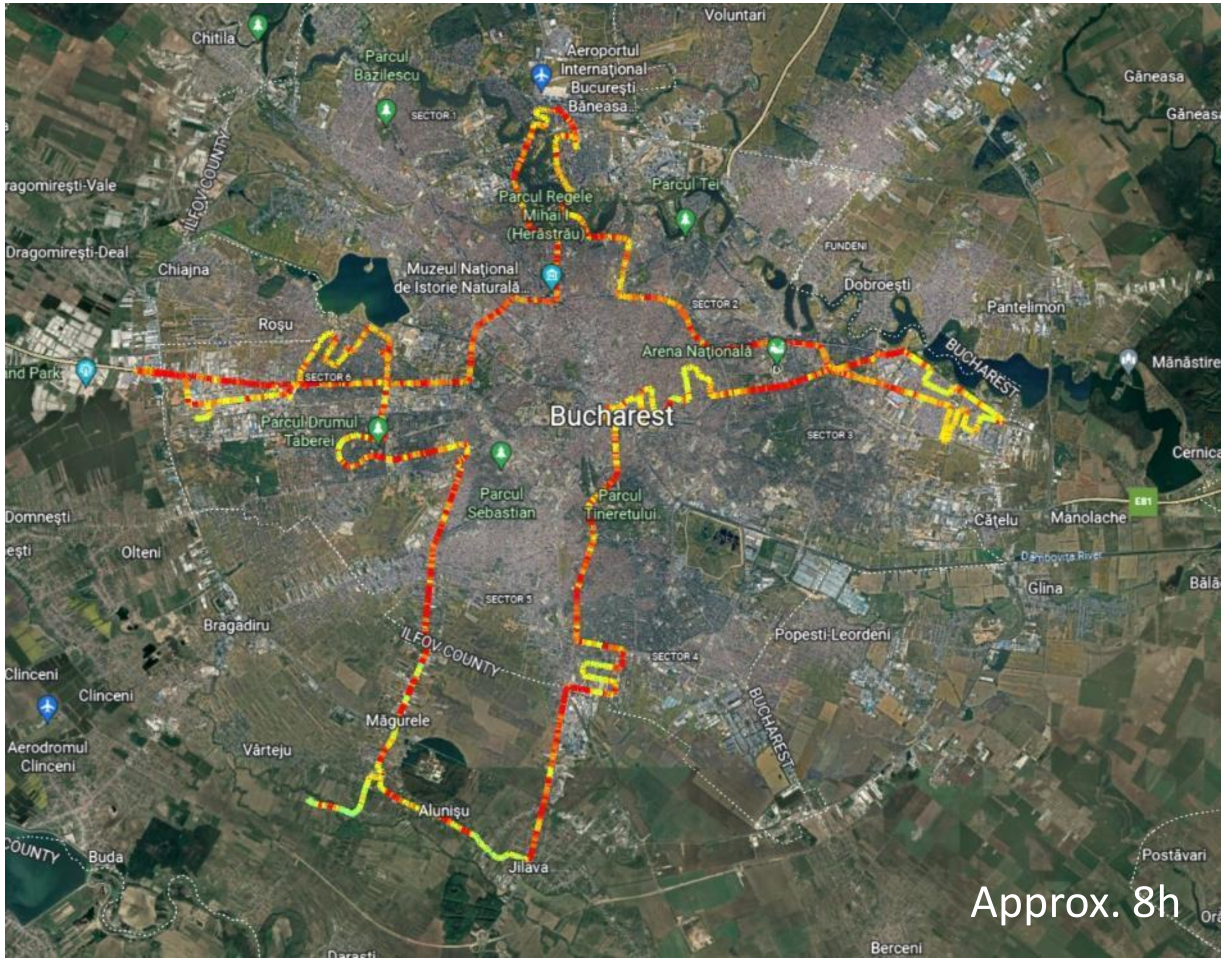
- This provides:
  - (i) a base from which changes in measurement procedure can be carried out.
  - (ii) A platform onto which the other work packages can trial their improvements.

Birmingham, Helsinki, Barcelona

Pilot 3 + 5 (mapping + hot spots) Bucharest

- **Route**
  - Approx. 8h (8:30-17:00), including rush hours
  - Main traffic roads
  - Residential areas
  - Industrial and commercial areas
- **Model:** ESCAPE Land Use Regression models + RLUR tool +QGIS
  - Road segments: ~250 m; midpoint coordinates
  - Dependent variables: average concentration of pollutant per road segment (UFP, PM10, PM2.5, PM1)
  - GIS predictors variables: Corine CLC2018 Land use (industry, urban, green) in buffers of 100, 500, 1000 si 5000 m, traffic variables (including traffic intensity and road lengts variables) in buffers from 50 to 5000 m, and population density in buffers from 100 to 5000 m.



Pollution hot spot in Bucharest

CET Vest power plant

Operating since 1972

The installed electrical power: 436.25 MW
Thermal power: 1196 Gcal/h
5 steam turbines, with a total capacity of 310 MW
Operates on natural gas or fuel oil
Highest tower: 250 m
Modernized (automation) in 2020

The 2nd largest industrial polluter for PMs, NOx and CO, and the 3rd for CO_2 in Bucharest

Source: National Agency for Environmental Protection

Rotterdam pilot

- Mobile monitoring using a dedicated car (Google airview)
- Mobile monitoring with citizens (with VITO)
- Existing low cost sensor measurements (with DCMR, RIVM: de Luchtclub Rotterdam focussed on PM2.5)
- Existing monitoring (DCMR, RIVM)

Device	Pollutants	Operating
GPS	Location	Google Ji-BOx
EPC	**Ultrafine Particles**	**Google Ji-BOx**
AE33	**Black Carbon**	**Google Ji-BOx**
DRX DustTrack	PM2,5	Manual
LiCOr	CO_2	Google Ji-BOx
MiniDisc	Ultrafine Particles	Manual
2BTech	NO_x	Google Ji-BOx
Aerodyne	NO_2	Google Ji-BOx

Mobile monitoring with a car + by bike with citizens

Both dedicated routes and opportunistic sampling

The Birmingham project

- Measurements will cover a part of Selly Oak, a heavily populated area located south of the University of Birmingham, which houses approximately 10,000 students.
- Apart from local residential emissions, the area is also affected by many other sources of pollution (incl. train station, road traffic, etc.).
- A dense network of stationary and mobile low-cost sensors will be deployed in an area of less than 1 km^2 for 1 month.

- **Measurements**
- Stationary measurements of size resolved PM at 5 - 10 sites will be deployed in public buildings (University or council owned buildings, churches etc.)
- Mobile measurements of size resolved PM will also be conducted by citizen student scientists. With monitors placed with GPS devices in backpacks.
- Comparison of time-resolved exposures on canal bank and roadside routes from University to city centre using portable sensors for PM, NO_2, CO and SO_2.
- Size resolved PM measurements will be achieved using Alphasense OPC-N3 sensors, with a size resolution of 0.36 to 40 µm, with a 10-second resolution.
- OPC measurements will be complicated by ultrafine PM numbers measured by Discmini devices.
- The Birmingham Air Quality Supersite (BAQS) will be used to calibrate sensors throughout the campaigns.

OPC-N3 sensors
Cost approx. €250
PM size range measured 0.36 – 40 µm

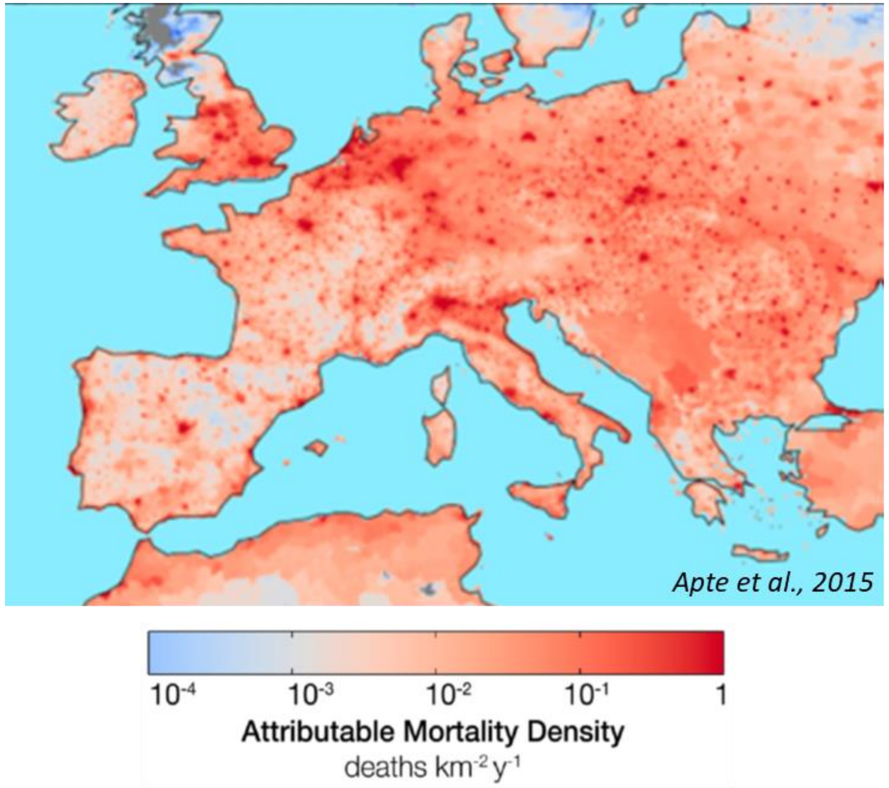
- **Data Analysis**
- Measurement area will be mapped using the combination of static and mobile measurements.
- Spatial and temporal mapping will be compared to modelled output from the high resolution (10 m) ADMS model.
- The effect of local pollution sources, alongside wider urban and regional sources will be studied.
- The evolution and significance of these sources with distance will be explored along with the effect of meteorological conditions and the temporal variation.
- Size resolved PM distributions will allow for source apportionment following Bousiotis et al. (2022) and Bousiotis et al. (2022).

Bousiotis et al. (2021) Assessing the sources of particles at an urban background site using both regulatory instruments and low-cost sensors–a comparative study. *Atmospheric Measurement Techniques*, *14*(6), pp.4139-4155. https://doi.org/10.5194/amt-14-4139-2021

Bousiotis et al. (2022). A study on the performance of low-cost sensors for source apportionment at an urban background site. Atmospheric Measurement Techniques Discussions, pp.1-40. https://doi.org/10.5194/amt-2022-84

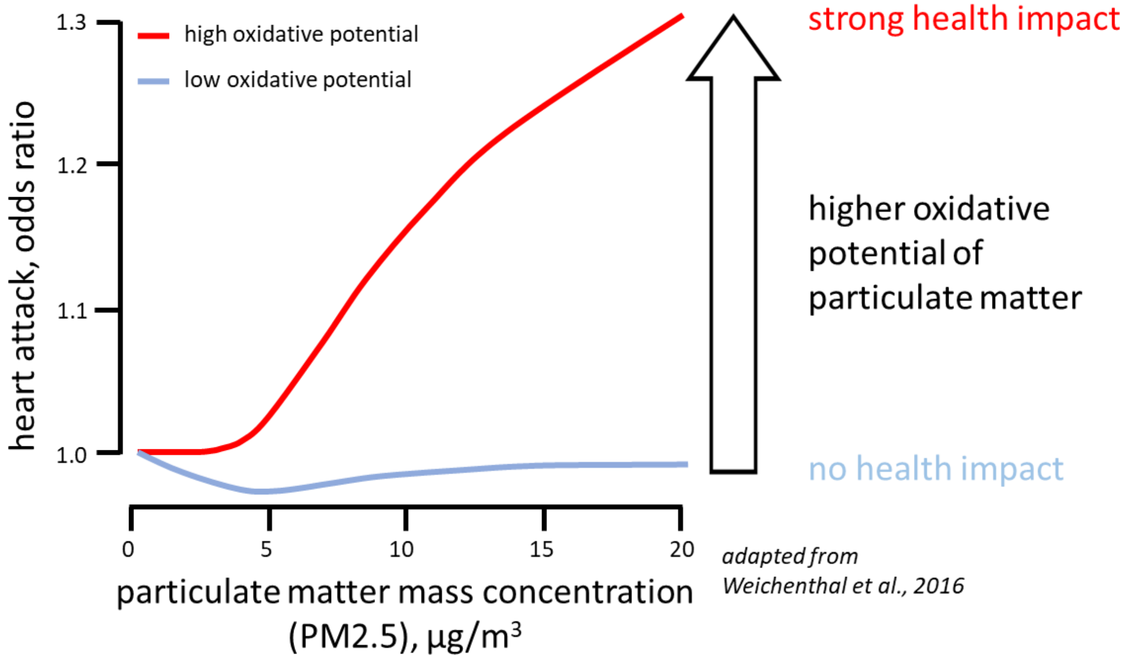
Pilot 43: Health exploring health effects of PM

Health impacts estimated based on **particulate matter (PM) mass concentration**.

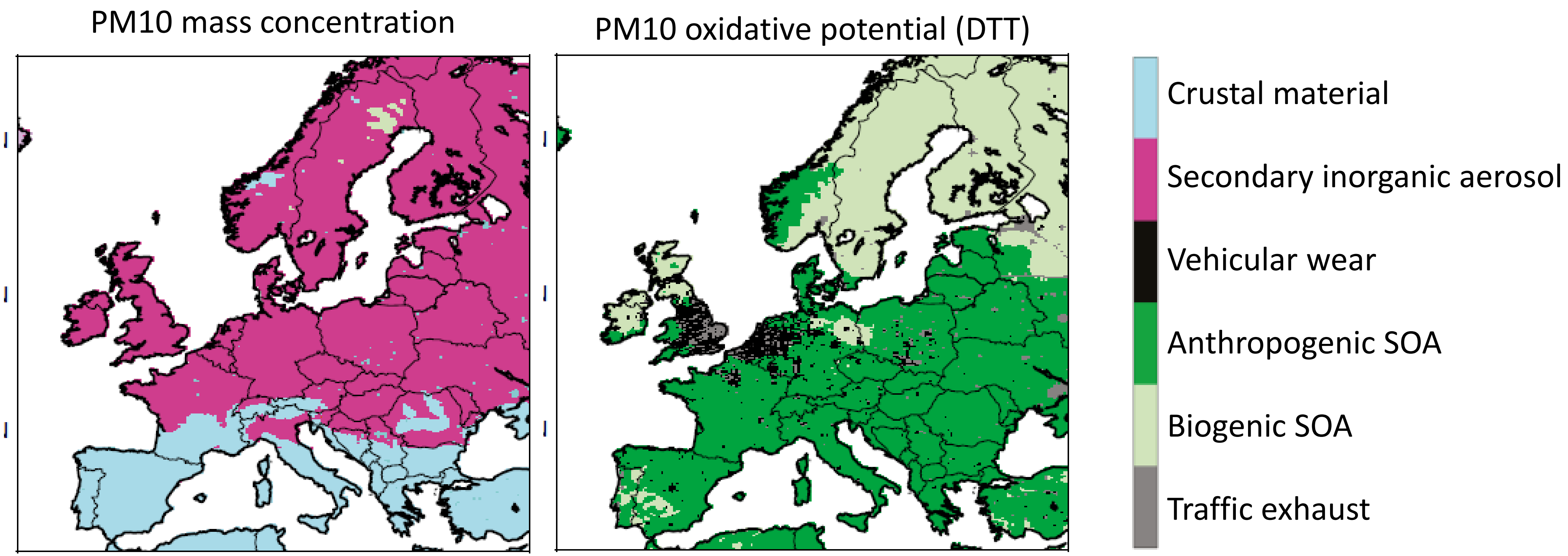


Particulate matter's oxidative potential (OP):

- PM's capacity to oxidize molecules by producing reactive oxygen species
- PM's OP depends on chemical composition of PM.
- What are the emission sources controlling PM's OP?



PM10 sources driving mass concentration and oxidative potential



Daellenbach et al., 2020

Health indicators - Study locations

+ PARIS !

Athens

Barcelona

Zurich

Sampling of PM10 and PM2.5 started in January-April 2022, extended for 1 year period

Samples obtained at all cities will be analysed by the same institutes

Mortality data will be available for Athens, Barcelona and Paris

Pilot 4: Health effects of novel AQ metrics and their source contributions, including PM components and nanoparticles

1. Improved evaluation of health effects in epidemiologic time series studies

- Using long-term offline and online data:
  PM10 mass, PM2.5 mass, nanoparticles, organic + elemental/black carbon, trace elements, other constituents, oxidative potential.

2. Evaluation of the drivers of PM's oxidative potential

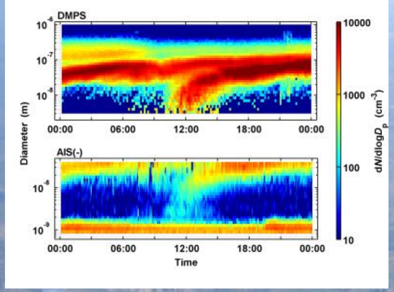
- 24h-resolution, filter-based (1 year) – PM10 vs PM2.5
  Water-soluble ions, trace metals, OC/EC, WSOC, sugars and polyols, other organic tracers, offline AMS, offline EESI, oxidative potential
- 1h-resolution, short-term, online instrumentation (months) - mostly fine PM:
  OA (ACSM), BC (Aethalometer), trace elements (Xact), online oxidative potential (sources from T4.1).

RI-URBANS annual meeting

October 19 – 20 , 2022 in Barcelona (hybrid)

- Urban air quality
- Data compilation
- New observations and technologies
- RI-URBANS pilots
- Upscaling to new cities
- Interactions with the city air quality monitoring authorities

Contact:
tuukka.petaja@helsinki.fi or xavier.querol@idaea.csic.es



Main message:

1) **Commitment to comprehensive and continuous environmental observations**

2) **Continuous method development (instrumentation, models)**

3) **Active and open collaboration across various boundaries**

4) **Willingness to tackle and solve grand challenges together**

SMEAR II station
(boreal) 1995 -

Contact:
Prof. Tuukka Petäjä, University of Helsinki
tuukka.petaja@helsinki.fi
+358 50 41 55 278

Vipuvoimaa EU:lta 2014–2020

Euroopan unioni
Euroopan aluekehitysrahasto

European Commission

Support from Academy of Finland, European Commission, Regional Council of Lapland, Helsinki-Uusimaa Regional Council, and Business Finland are gratefully acknowledged.

Prof. Tuukka Petäjä

- Full Professor of experimental atmospheric sciences
- Vice director of INAR institute
- Head of Aerosol laboratory, Head of SMEAR research infrastructure
- Pan Eurasian Experiment (PEEX) Science director
- over 500 peer reviewed publications, 20 in Nature or Science
- H-factor 75, total number of citations over 22 500
- Vaisala award for development of scientific instrumentation for nanoparticles and trace gases
- Thompson Reuters Highly Cited scientist since 2014
- Science and Technology in Society Future Leader, New York Academy of Sciences
- Member of International Eurasian Academy of Sciences
- Research areas: 1) Aerosol-cloud interactions, 2) Development of mass spectrometric methods for atmospheric aerosols and trace gases; 3) Measurement techniques, aerosol particles; 4) Long-term and field campaigns; 5) Aerosol-cloud-climate-biosphere interactions;
- Cumulative personal research funding 10.0 M EUR, as a PI or co-PI 40 MEUR

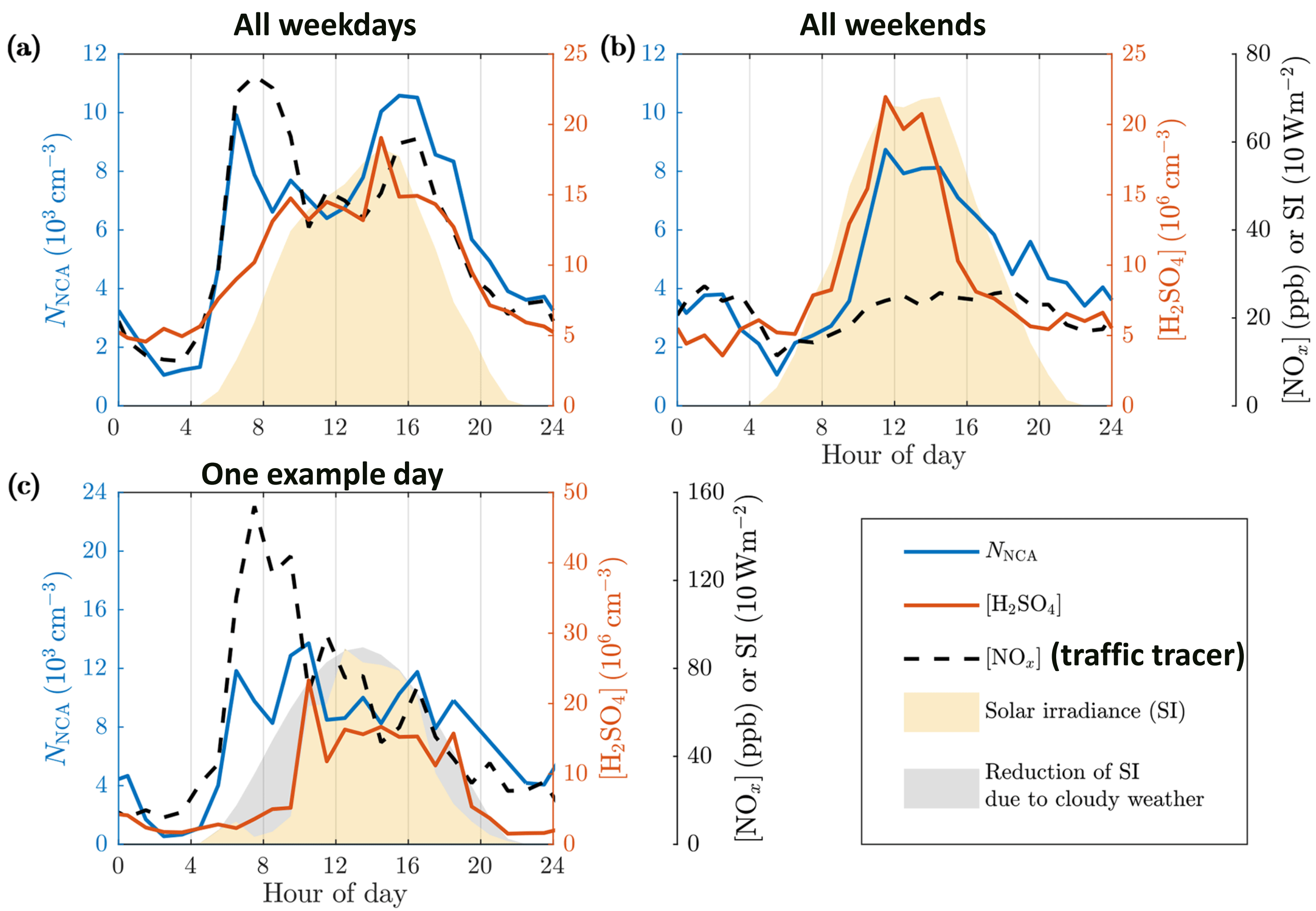
WP4: Pilots in 9 cities

- Overall, the 5 pilots are organised in 9 urban areas, representing a **variety of conditions** (climate zone, size of the urban area, presence of hot spots such as industrial areas, harbours, airports, roadsides).
- At least 3 cities involved in each pilot, where some STs are already implemented in one of the cities, and the others will replicate, in such a way that all cities will replicate at least one STs in the pilot.

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				
P3 - T4.3 - Urban fine scale mapping			x	x			x	x	
P4 - T4.4 - Novel health indicators	x	x							x
P5 - T4.5 - Pollution hotspots				x		x		x	

Diurnal variations for weekdays and weekends

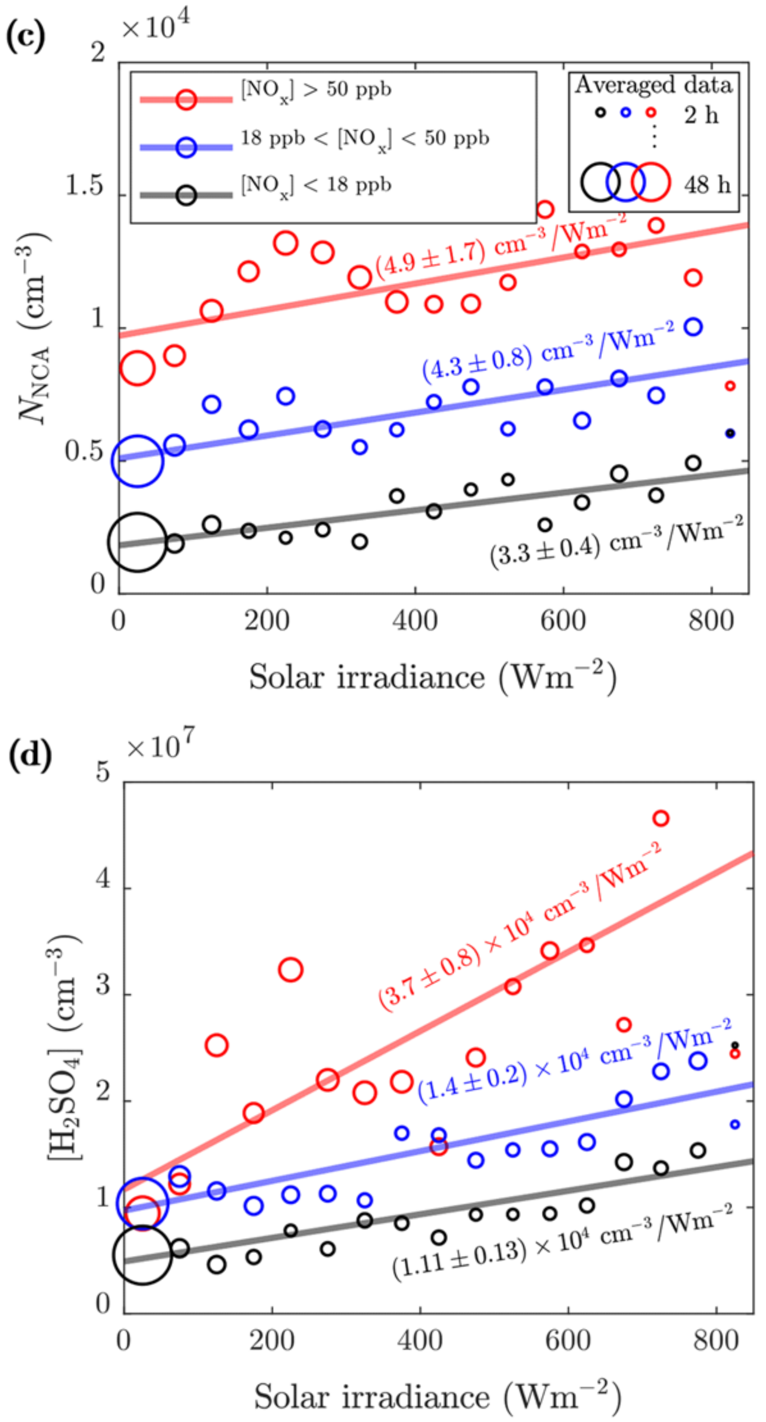
- At least for NCA, they clearly differ
- NCA increased with traffic
  - Also during mornings with no need of radiation
  - And with no need of H_2SO_4
- H_2SO_4 increased with radiation
- Are H_2SO_4 and NCA not connected?
  - Although the correlation plot implied they are



Solar irradiance plots

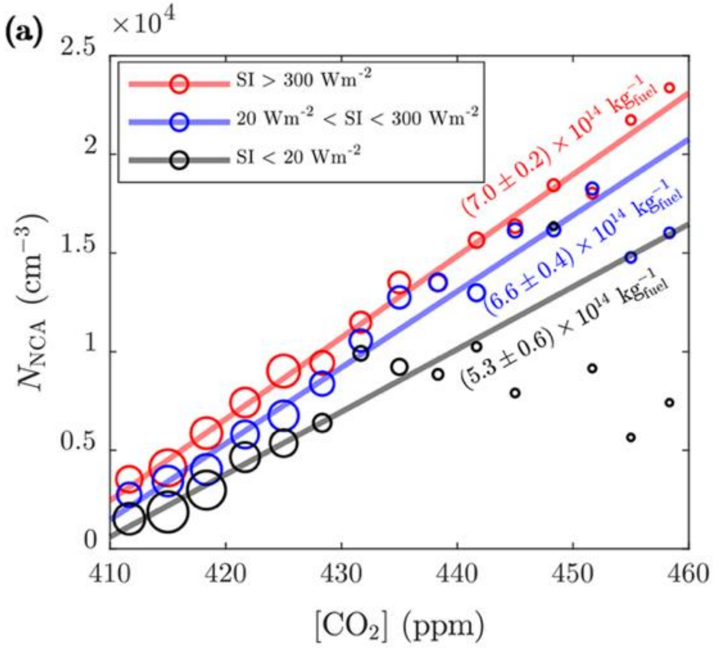
- Separated into three NO_x levels (traffic levels)
- H_2SO_4 and NCA both increase with solar irradiance
- …but the slopes behave differently
  - No clear difference for NCA between the NO_x levels
  - Higher slopes for H_2SO_4 with higher NO_x levels
- Also the intercepts behave differently
  - NCA concentration is high even with zero radiation when the NO_x level is high

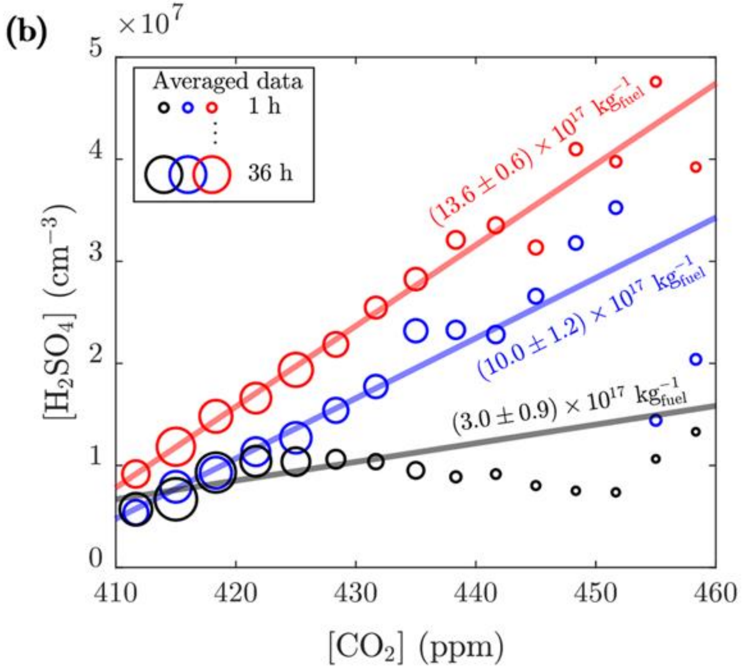
- Conclusions from these plots
  - Traffic and radiation levels influence H_2SO_4 and NCA levels
    - Traffic is the dominant source for NCA
  - Traffic enhances photochemical H_2SO_4 production
    - Not NCA production
  - At least a part of H_2SO_4 and NCA are not connected!



Emission factors

- CO_2 as a traffic tracer due to direct connection to fuel consumption
- Separated into three solar irradiance levels
- NCA has emission factors
  - Already by Rönkkö et al. (2017) and by Hietikko et al. (2018)
  - Vehicles emit NCA
  - The effect of radiation is insignificant
- H_2SO_4 has emission factors
  - Vehicles emit H_2SO_4
  - The emission factors are higher with higher radiation levels
    - Radiation is needed to observe vehicle-emitted H_2SO_4
    - Where does the primary H_2SO_4 ($SO_2 \rightarrow SO_3 \rightarrow H_2SO_4$ in the catalyst) emitted by vehicles disappear?





sensors

MDPI

Fung et al. (2019) Sensors, 20, 182.

Article

Input-Adaptive Proxy for Black Carbon as a Virtual Sensor

Pak Lun Fung [1,*], Martha A. Zaidan [1], Salla Sillanpää [1], Anu Kousa [2], Jarkko V. Niemi [2], Hilkka Timonen [3], Joel Kuula [3], Erkka Saukko [4], Krista Luoma [1], Tuukka Petäjä [1], Sasu Tarkoma [5], Markku Kulmala [1] and Tareq Hussein [1,6,*]

Evaluation of white-box versus black-box machine learning models in estimating ambient black carbon concentration

Pak L. Fung [a,*], Martha A. Zaidan [a,b], Hilkka Timonen [c], Jarkko V. Niemi [d], Anu Kousa [d], Joel Kuula [c], Krista Luoma [a], Sasu Tarkoma [e], Tuukka Petäjä [a], Markku Kulmala [a], Tareq Hussein [a,f,g,**]

Fung et al. (2020) J Aerosol Science

INTERNET OF THINGS AND SENSOR NETWORKS

Toward Massive Scale Air Quality Monitoring

Naser Hossein Motlagh, Eemil Lagerspetz, Petteri Nurmi, Xin Li, Samu Varjonen, Julien Mineraud, Matti Siekkinen, Andrew Rebeiro-Hargrave, Tareq Hussein, Tuukka Petäjä, Markku Kulmala, and Sasu Tarkoma

Motlagh et al. (2020) IEEE Communications

IEEE Sensors Council | IEEE SENSORS JOURNAL

Intelligent Calibration and Virtual Sensing for Integrated Low-Cost Air Quality Sensors

Martha Arbayani Zaidan, *Member, IEEE*, Naser Hossein Motlagh, Pak L. Fung, David Lu, Hilkka Timonen, Joel Kuula, Jarkko V. Niemi, Sasu Tarkoma, *Senior Member, IEEE*, Tuukka Petäjä, Markku Kulmala, and Tareq Hussein

Zaidan et al. (2020) IEEE Sensors

(a) Mäkelänkatu reference station [32]. (b) SMEAR III reference station in Kumpula. (c) Low-cost sensors installed in SMEAR III. (d) Locations of sensing systems.

Spatiotemporal variation and trends of equivalent black carbon in the Helsinki metropolitan area in Finland

Krista Luoma[1], Jarkko V. Niemi[2], Aku Helin[3], Minna Aurela[3], Hilkka Timonen[3], Aki Virkkula[3], Topi Rönkkö[4], Anu Kousa[2], Pak Lun Fung[1], Tareq Hussein[1,5] and Tuukka Petäjä[1]

Luoma et al. (2020) Atmos. Chem. Phys. Discuss.