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Air Pollution in Cities

Part 2: smart innovations in air pollution research and policy

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Global Sustainability Summer School
Santa Fe Institute
July, 2016

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Smart innovations in air pollution research and policy

(aim is still to recognize complexity and evaluate health-promoting urban strategies)

- Brief overview of tools in air pollution research and regulation
- Three examples of how mobile phones can be used in air pollution research:
  - 2 examples on improving exposure assessments
  - 1 example on citizen engagement and behaviour change

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Tools: why do we monitor air pollution?

Epidemiologic studies

Compliance of standards

Information to the public

Identification of highly hazardous jobs or tasks

performance or effectiveness of emission control equipment

Understand chemical and physical properties of atmospheric pollution

Apportion chemical constituents to their sources

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Example: Fixed monitoring stations

Parc Jordi Girona - Barcelona

- *regulatory purposes (statutory monitoring networks)*
- *Long or medium-term exposures, low spatial resolution*

Pl. Gal.la Placídia - Barcelona

Cost substantial, each instrument from $6000 to $80 000 + maintenance and calibration + infrastructure

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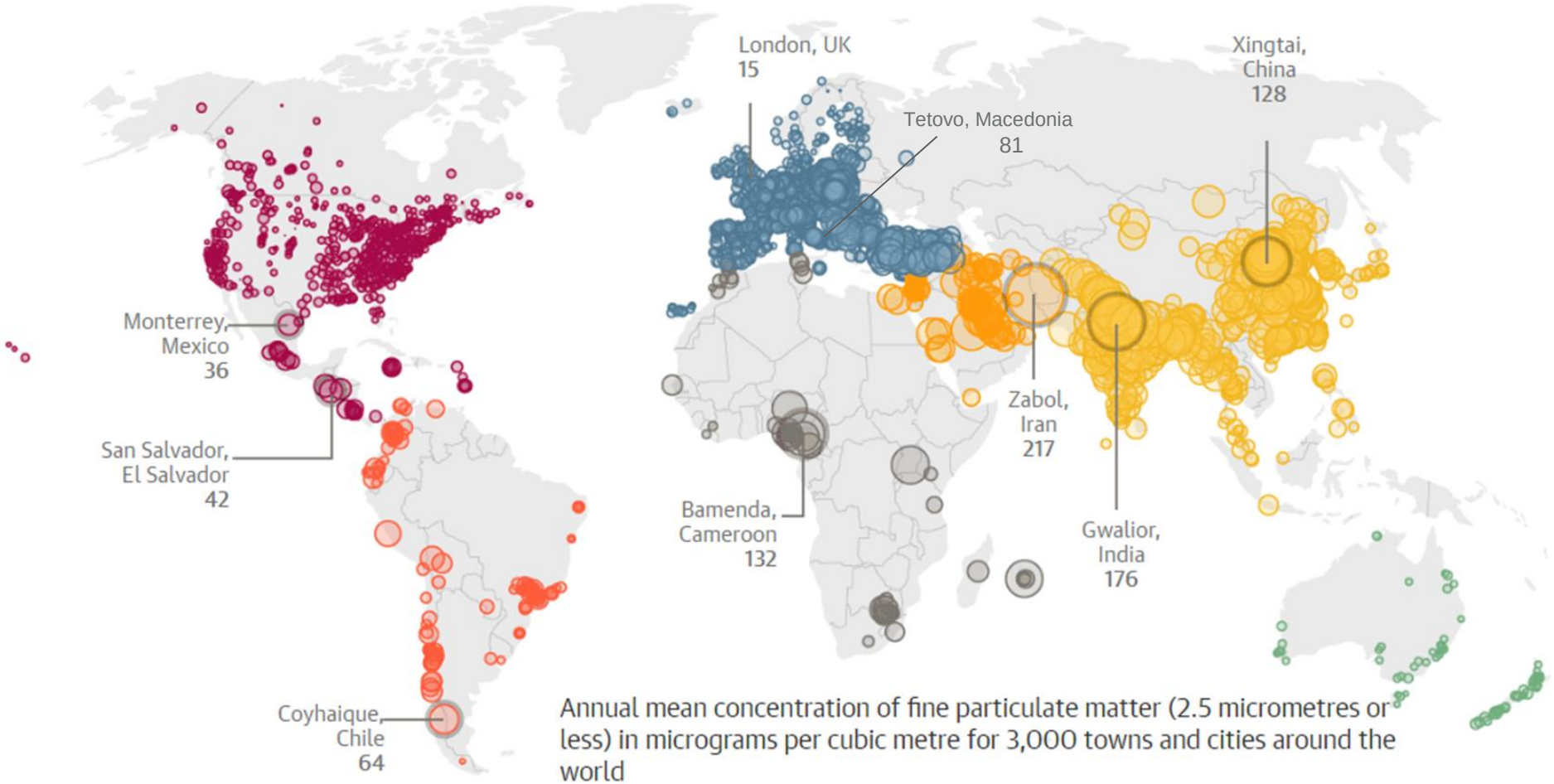
Air Pollution in Cities Around the World



Annual mean concentration of fine particulate matter (2.5 micrometres or less) in micrograms per cubic metre for 3,000 towns and cities around the world

Source: WHO, 2016; TG, 2016

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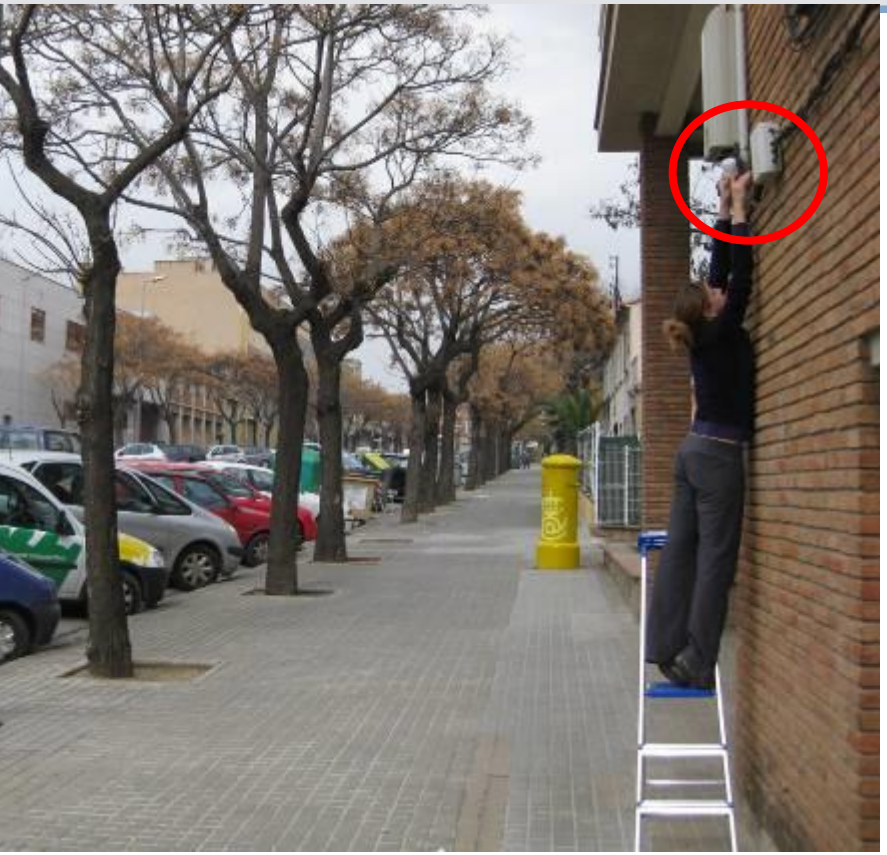
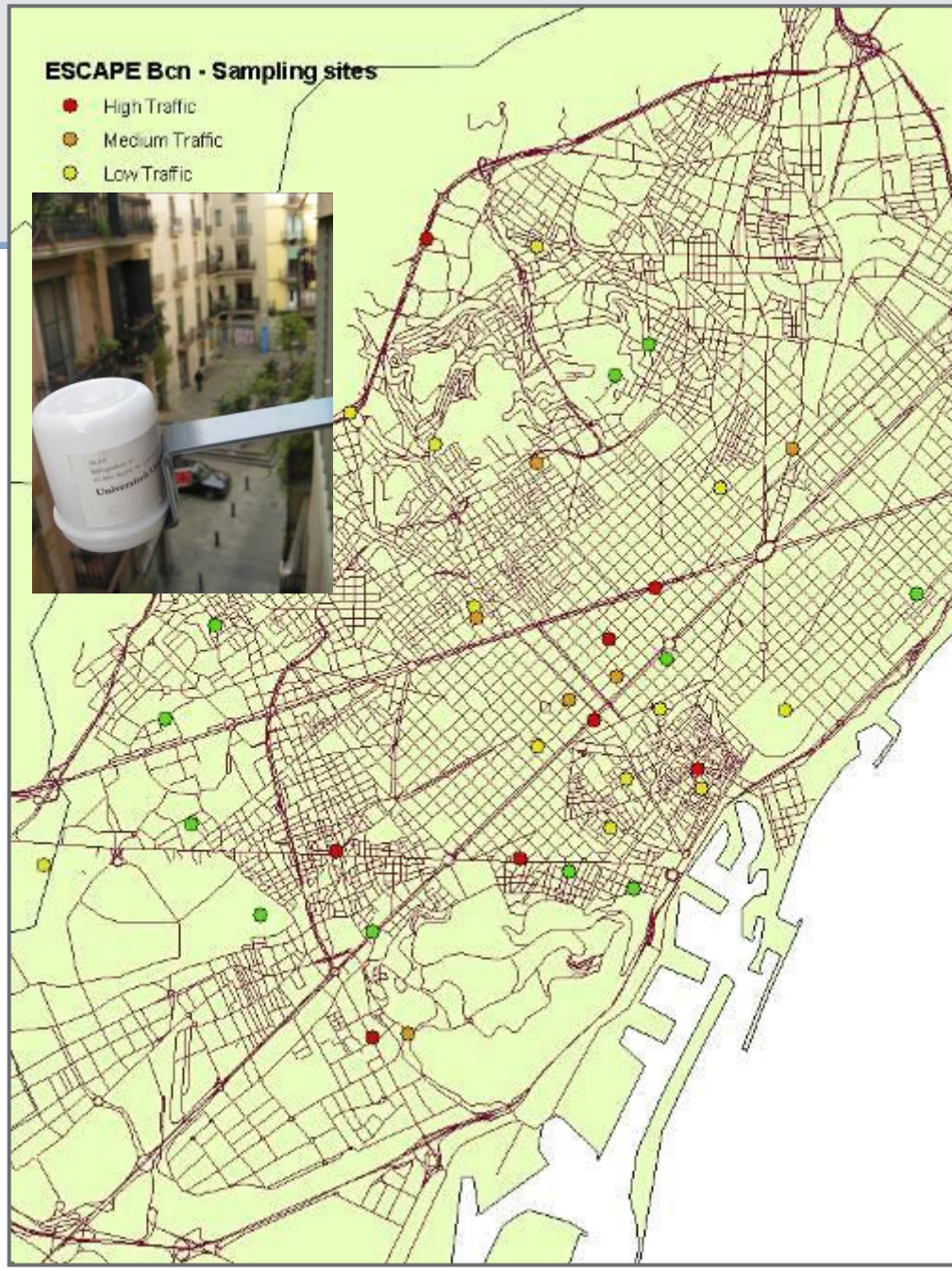
Example: long term exposures at finer spatial scale



Monitoring campaign (mobile) at multiple location across the city



Atmospheric Environment 64 (2013) 287–295

Contents lists available at SciVerse ScienceDirect

Atmospheric Environment

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

Personal, indoor and outdoor air pollution levels among pregnant women

Anna Schembari [a,b,c,d,*], Margarita Triguero-Mas [a,b,c,d], Audrey de Nazelle [a,b,c], Payam Dadvand [a,b,c], Martine Vrijheid [a,b,c], Marta Cirach [a,b,c], David Martinez [a,b,c], Francesc Figueras [e], Xavier Querol [f], Xavier Basagaña [a,b,c], Marloes Eeftens [g], Kees Meliefste [g], Mark J. Nieuwenhuijsen [a,b,c]

Example medium-term measurements: Personal exposures of pregnant women

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Personal, indoor and outdoor measurement

Pregnant women in Barcelona (Schembari et al. 2013)

Pollutants	Measurement (N)	Geometric Mean (GSD)	Min - Max
PM2.5	Personal (53)	24.1 (1.5)	9.9 - 63.9
μg m^{-3}	Indoor (54)	20.6 (1.6)	6.7 - 72.9
	Outdoor (52)	18.0 (1.6)	7.0 - 68.9
NO_x	Personal (65)	61.9 (1.6)	26.8 - 279.3
μg m^{-3}	Indoor (65)	60.6 (1.7)	26.4 - 379.5
	Outdoor (65)	51.6 (1.6)	23.2 - 279.3

Example short-term measurements: Personal exposures in travel environments

Atmospheric Environment 59 (2012) 151–159

Contents lists available at SciVerse ScienceDirect

Atmospheric Environment

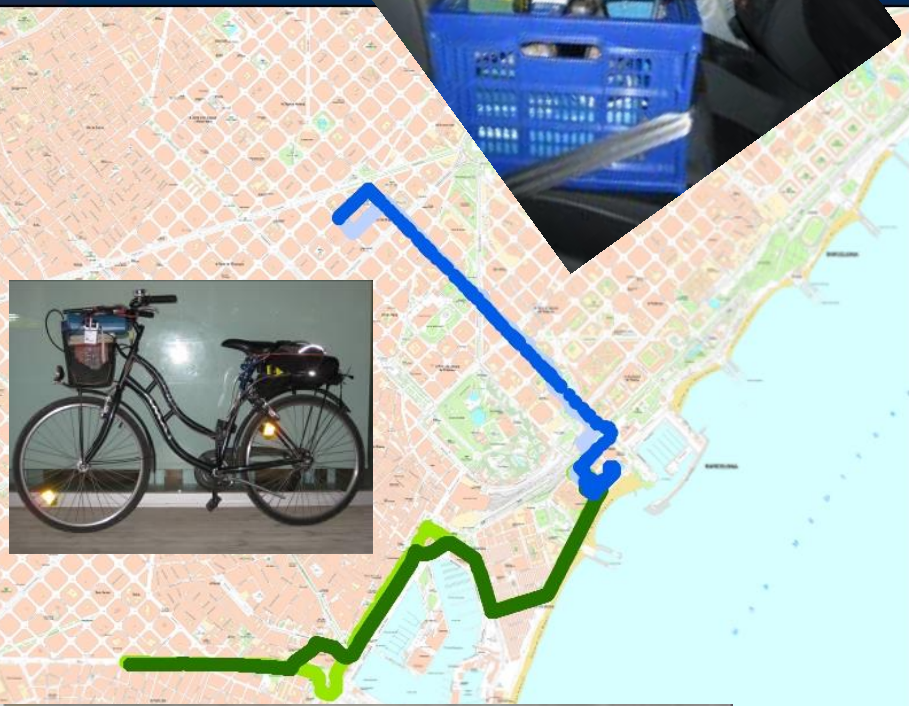
journal homepage: www.elsevier.com/locate/atmosenv

A travel mode comparison of commuters' exposures to air pollutants in Barcelona

Audrey de Nazelle [a,b,c,*,1], Scott Fruin [d,1], Dane Westerdahl [e], David Martinez [a,b,c], Anna Ripoll [f], Nadine Kubesch [a,b,c], Mark Nieuwenhuijsen [a,b,c]

COMMUTERS' EXPOSURES

2 "round trip" routes, each monitored with "pairs of modes"

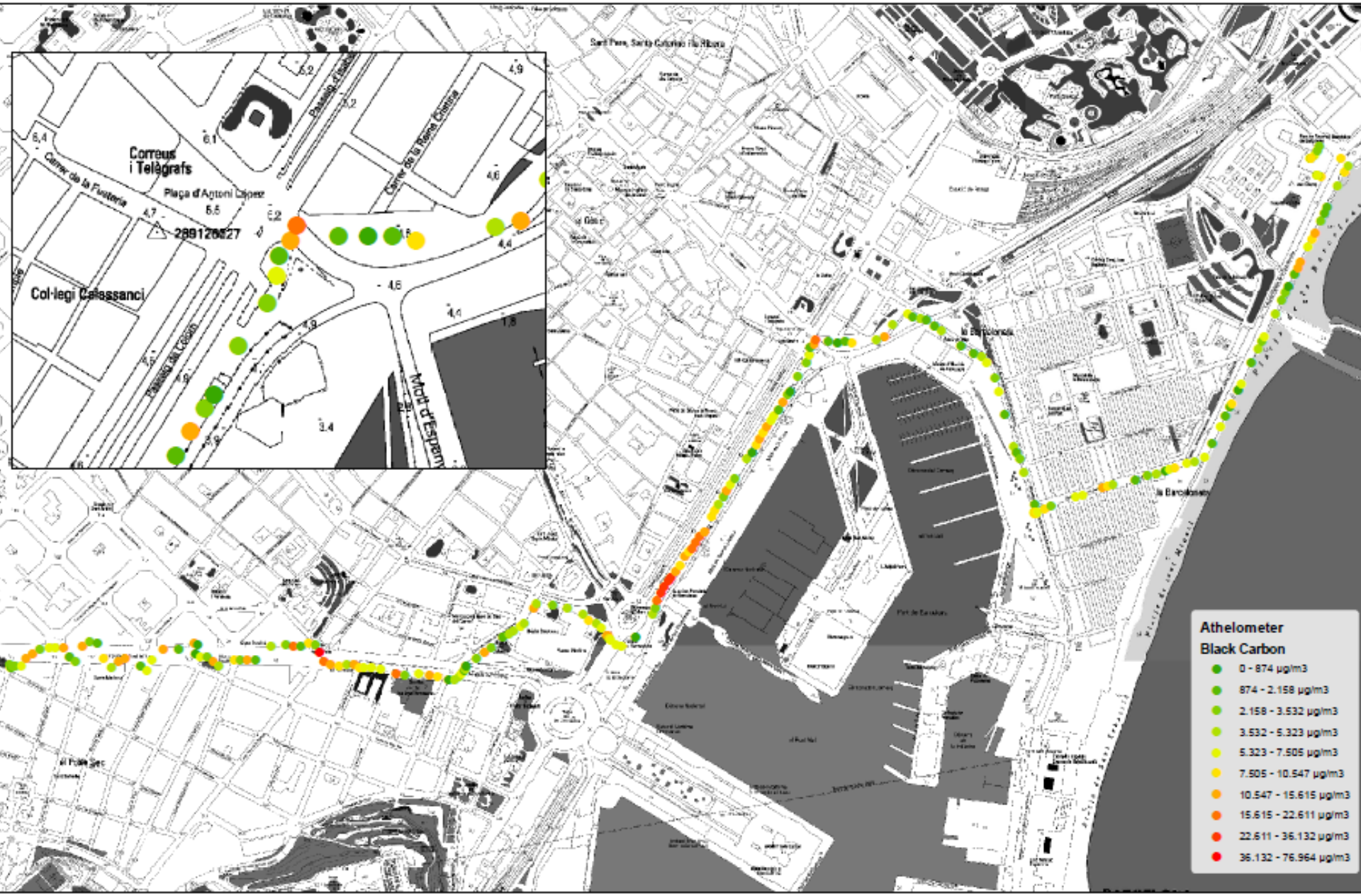


- *CO/CO2*
- *PM2.5*
- *Ultrafine Particles*
- *Black Carbon*
- *Physical*

0 2.

Kilometers

Date: 11th of June
Hour: 9:00 a.m.
Route: From Paral·lel to CREAL
Mode: walking



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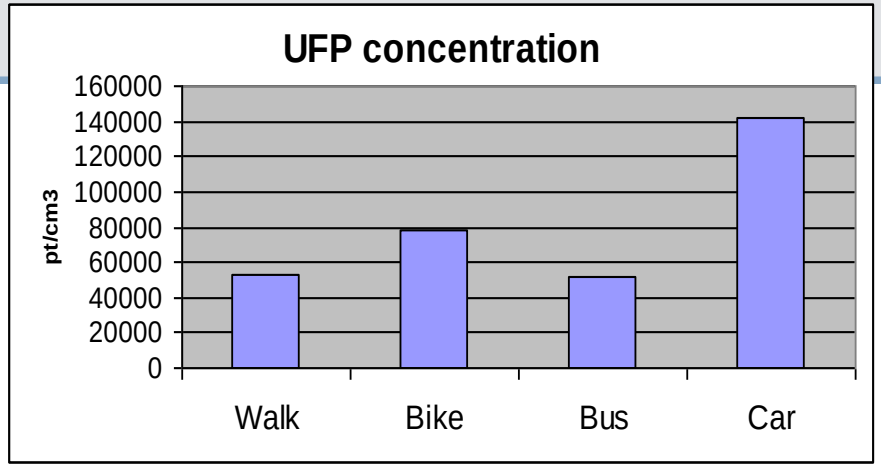
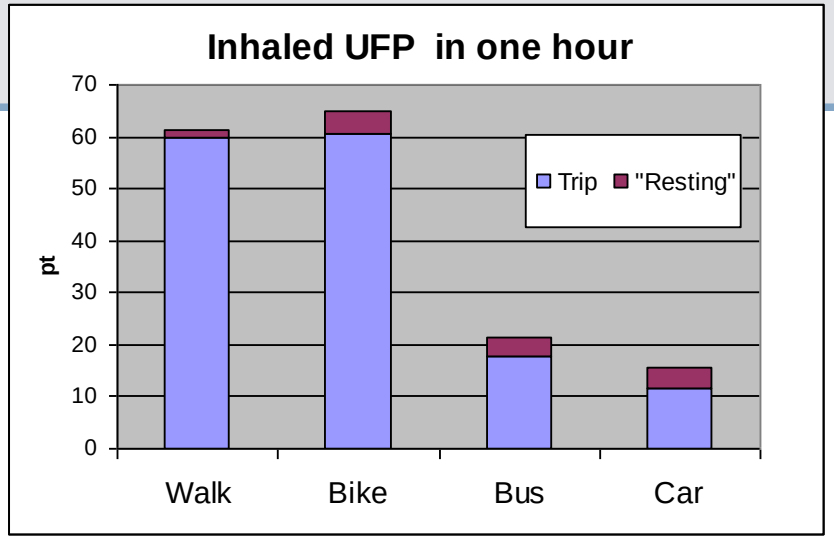
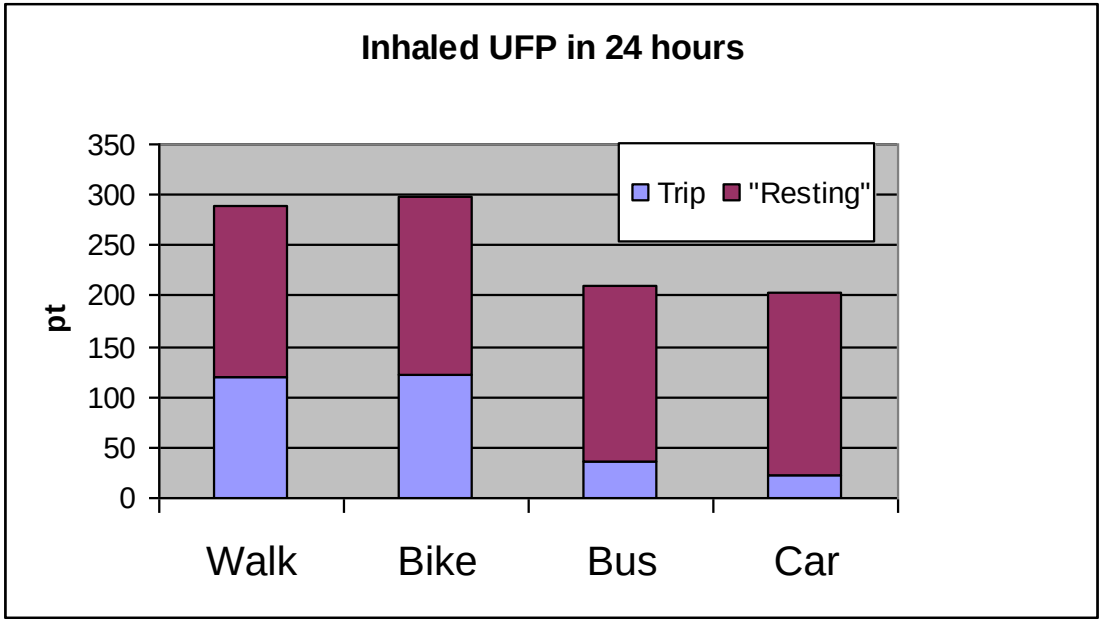
Average concentrations and inhaled doses

de Nazelle et al. 2012 Atmospheric Environment. 59:151-159; 2012





	IR (L/min)	Trip time (min)
Walk	23	49
Bike	37	24
Bus	10	34
Car	10	28



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Low cost sensors

Electrochemical sensors:
CO, NO2, NO.

Problems:

- cross-sensitivities with O3
- sensitivity to temperature

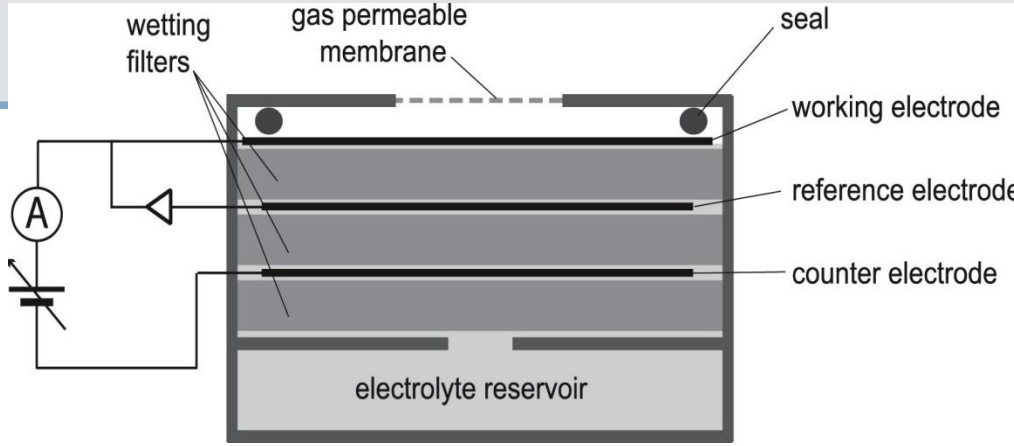
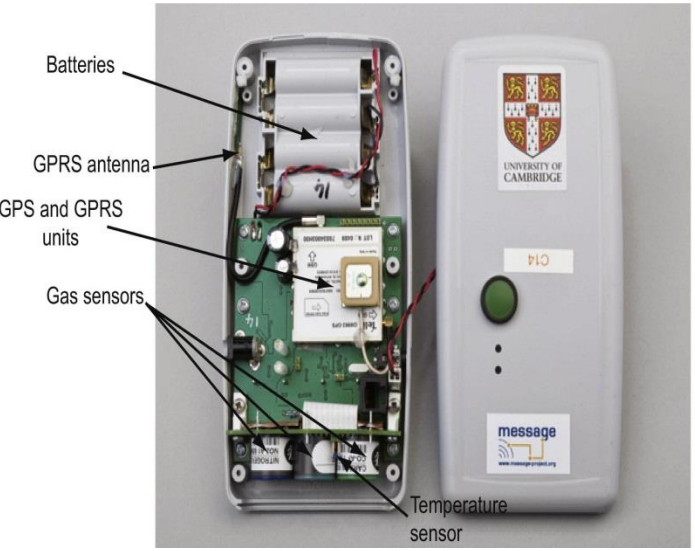


Fig. 1 Schematic of an electrochemical cell of the type used in this study. The gas diffusion barrier is a gas-permeable PTFE membrane used to prevent water and dust ingress to the cell. During operation the working and counter electrodes are maintained with a fixed voltage bias, and the current between them is the output of the sensor



Mead et al. Atmospheric Environment, Volume 70,

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Tools: Why do we model air pollution?

Epidemiologic studies

Compliance of standards

- Unmonitored locations
- Future compliance
- Assessment of future scenarios

Information to the public

- The Air Quality Directive (2008/50/EC) states that *"Member States shall ensure that timely information about actual or predicted exceedances of alert thresholds, and any information threshold is provided to the public."*

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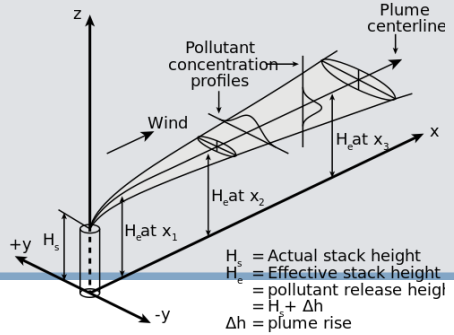
Different types of models



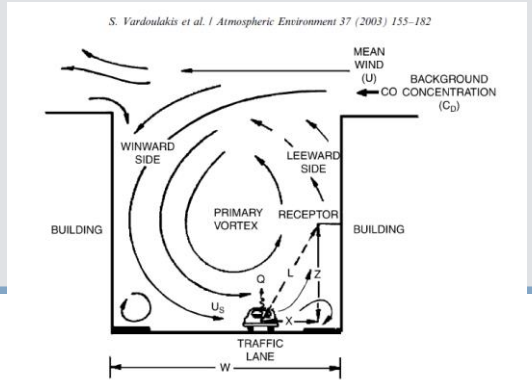
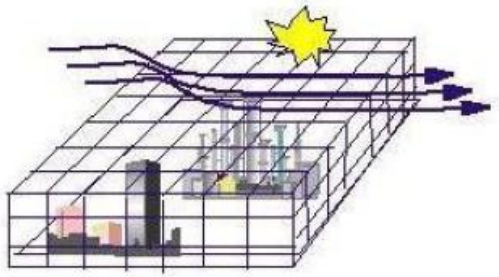
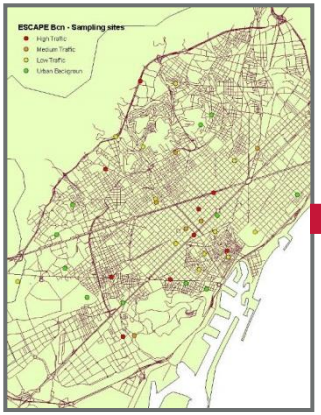
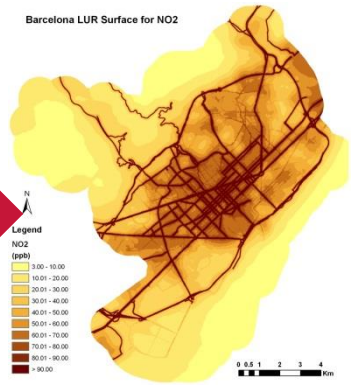


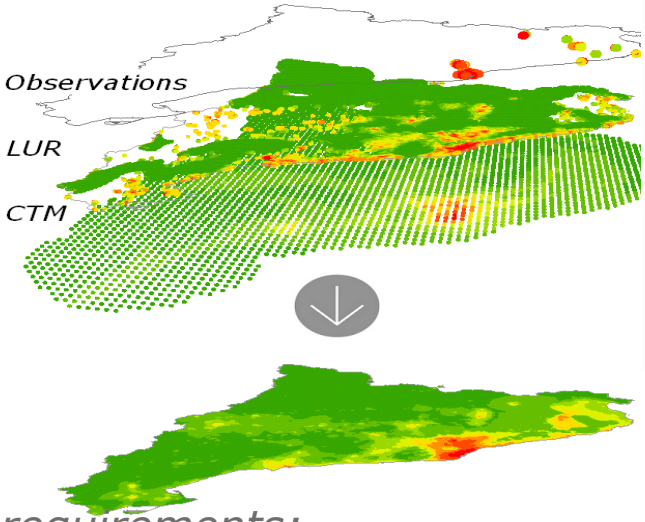
Fig. 1. Pollutant dispersion in a regular street canyon (Dabberdt et al., 1973).

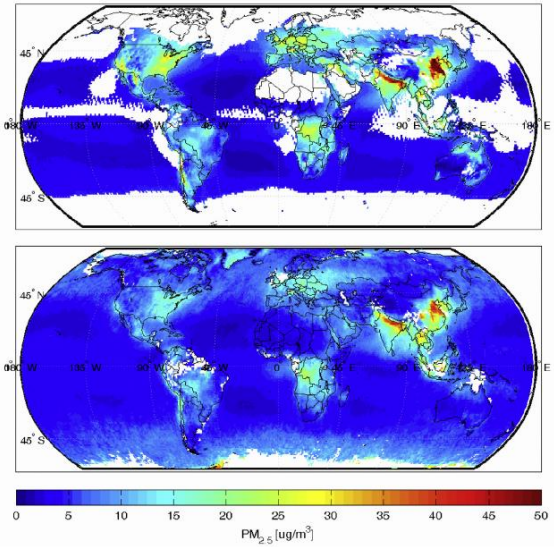
- Dispersion
- Chemical-transport
- Land use regression
- Remote sensing (satellite-based)
- Hybrid











From simple to complex, model requirements:

Emissions inventory
Meteorology
Monitoring data (for model development or for validation)
Numerical solutions to simple to complex equations (ie computer time)

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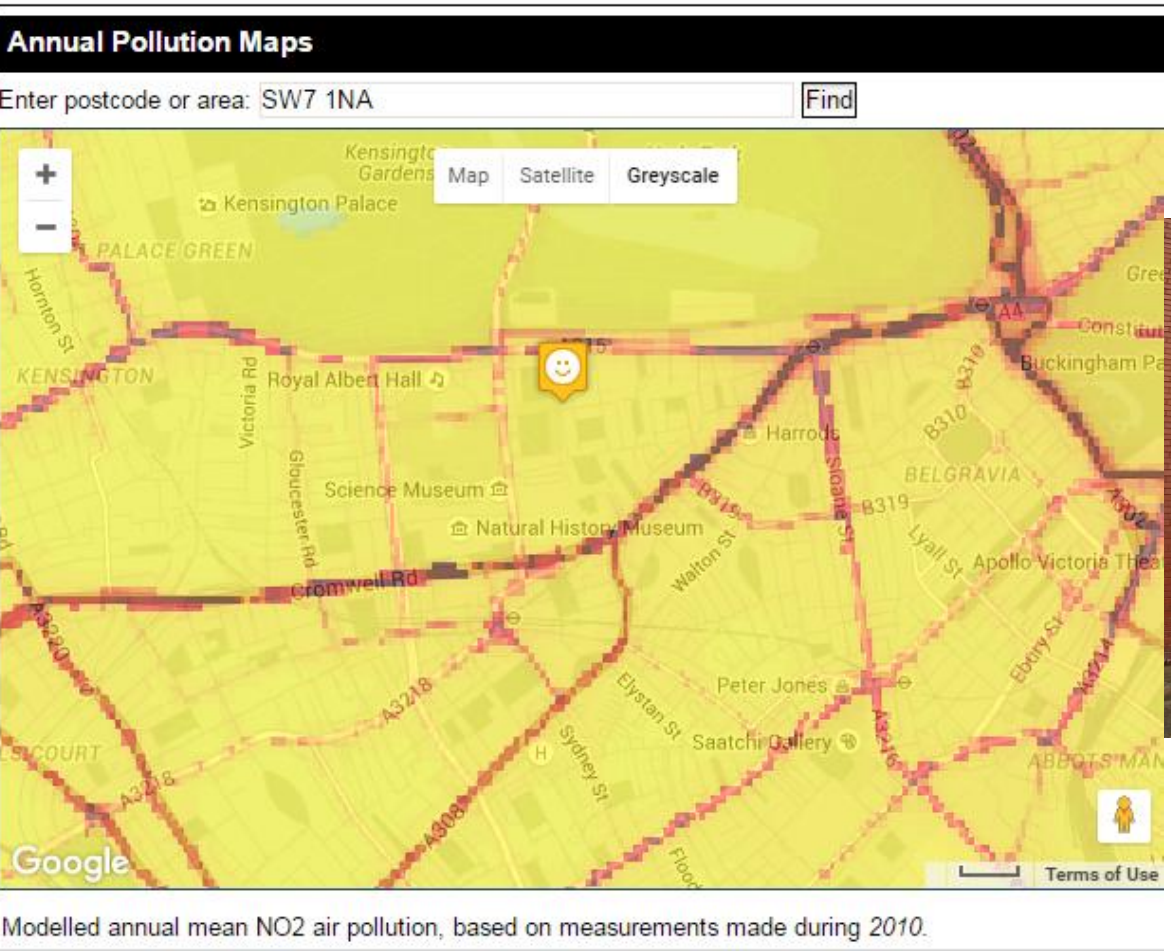
Exposure assessment in epidemiology



Modelled annual mean NO2 air pollution, based on measurements made during *2010*.

People move around

- Exposure measurement error

reduces the power of a study, making it more likely that real associations are not detected.

- Time spent in traffic:
  - Onset of myocardial infarctions (Peters et al., 2013)
  - Sub-clinical effects (Adar et al., 2007; McCreanor et al., 2007; Strak et al., 2009; Weichenthal et al., 2011, Kubesch et al., 2014a,b)

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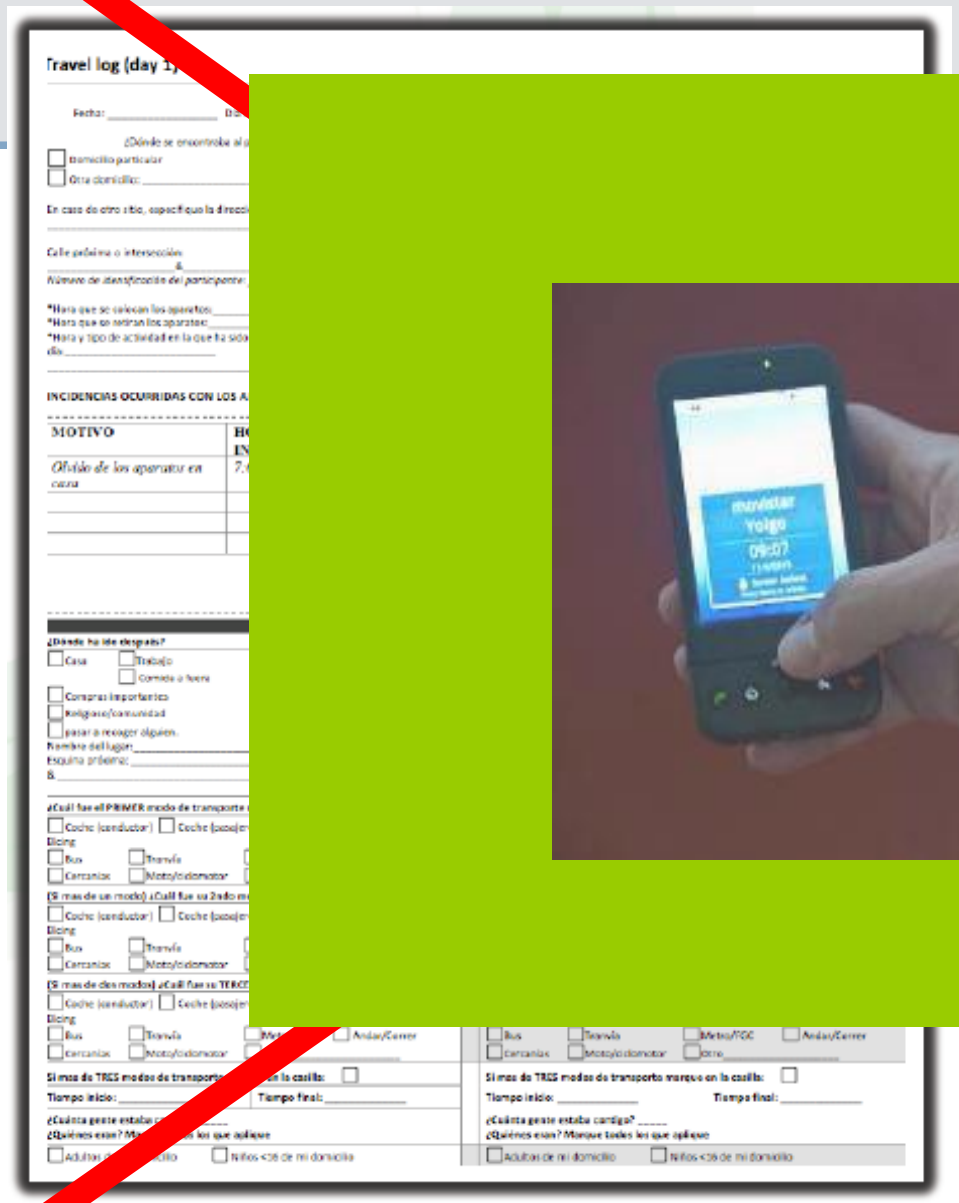
Accounting for activity patterns?



EXAMPLE 1: SMART PHONES FOR EXPOSURE ASSESSMENT

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Smart phone study: Activity patterns & air pollution

Aim: *Test novel ubiquitous sensing technology to assess activity patterns and air pollution exposure*

Methods:

36 volunteers equipped with 3 activity measurement devices including novel smart phone technology CalFit and reporting daily travel activity during 5 days

Contents lists available at SciVerse ScienceDirect

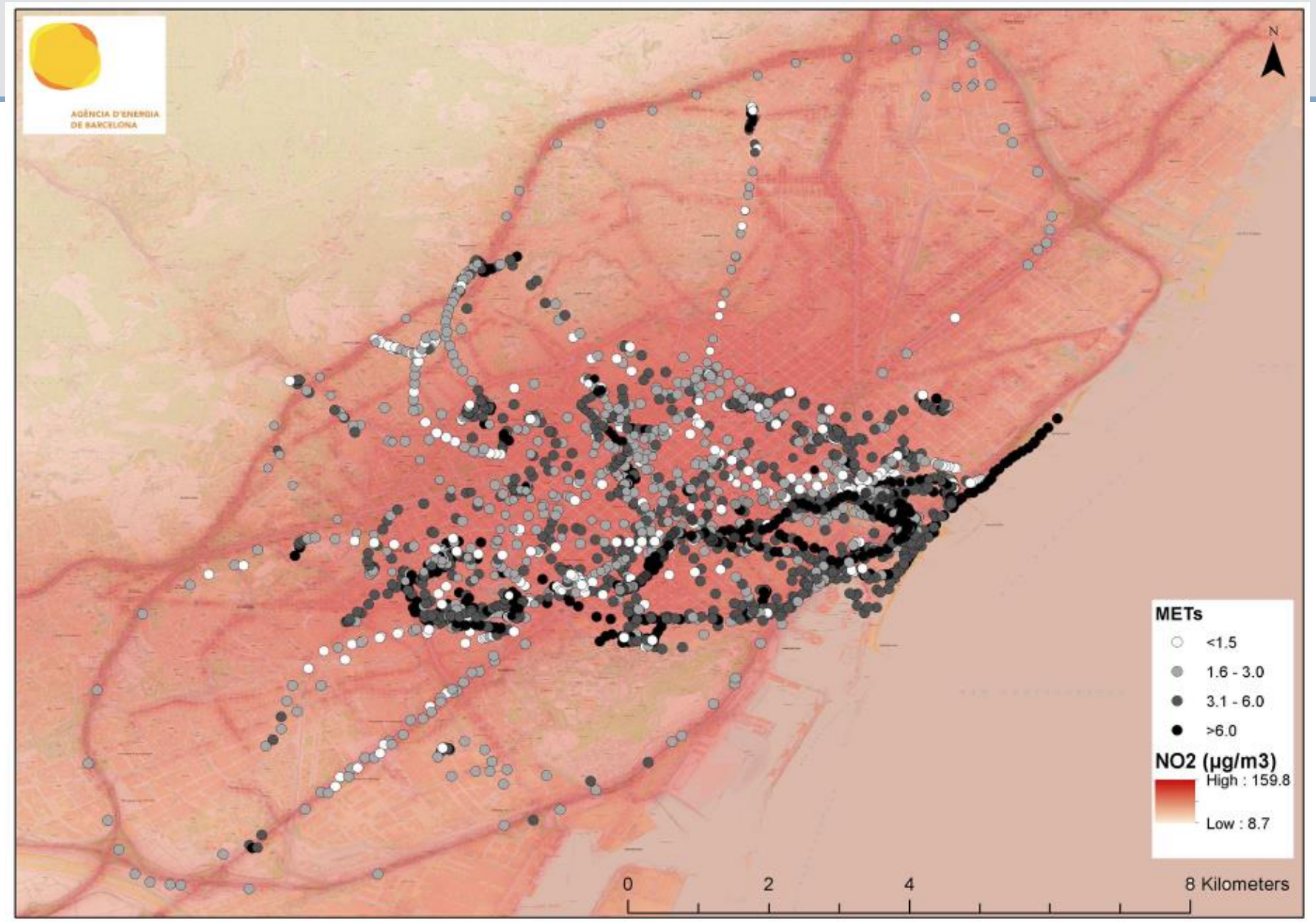
Environmental Pollution

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

Improving estimates of air pollution exposure through ubiquitous sensing technologies

Audrey de Nazelle [a,b,c,d,*,1], Edmund Seto [e], David Donaire-Gonzalez [b,c,d,f], Michelle Mendez [b,c,d,g], Jaume Matamala [b,c,d], Mark J. Nieuwenhuijsen [b,c,d], Michael Jerrett [e]

GPS tracking and physical activity for 1 workday for each volunteer + air pollution map (NO2)



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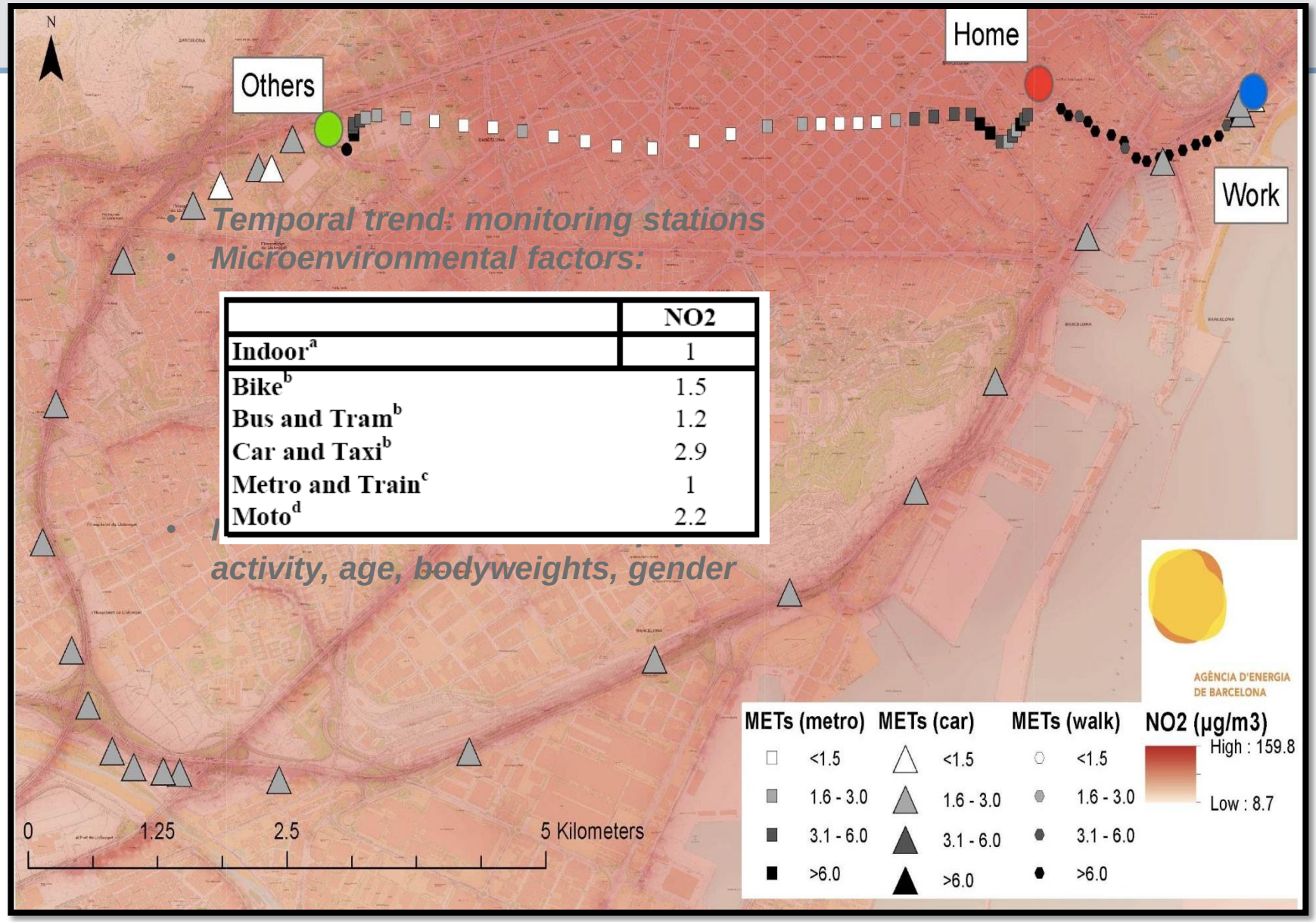
One day's activity of one participant



	NO2
Indoor[a]	1
Bike[b]	1.5
Bus and Tram[b]	1.2
Car and Taxi[b]	2.9
Metro and Train[c]	1
Moto[d]	2.2

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Travel microenvironments, air pollution, and health

Travel microenvironments

(Barcelona sample, de Nazelle et al. 2013):

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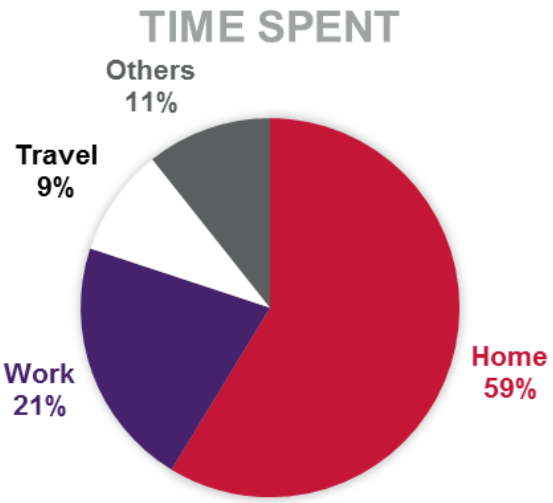
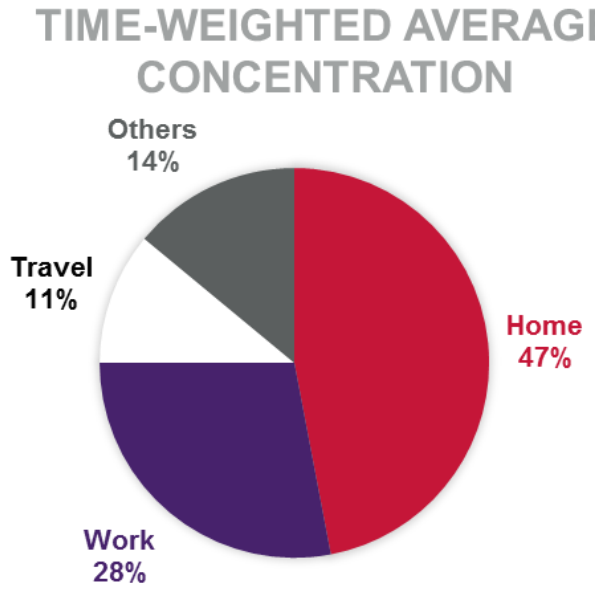
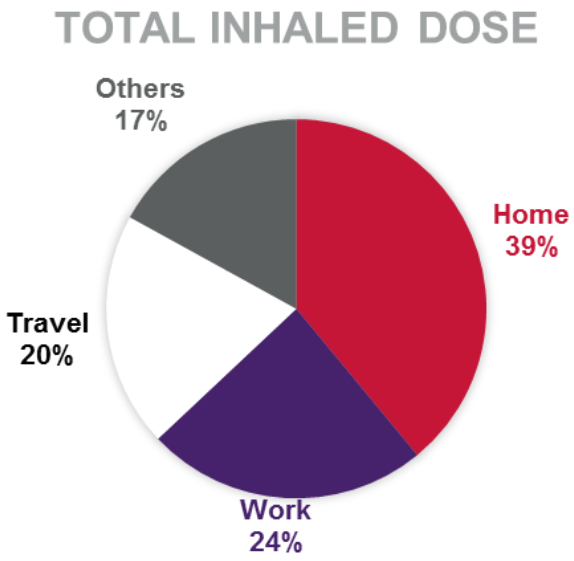
Next step: 174 participants (big data !)







Juan Pablo Orjuela's MSc thesis 2014

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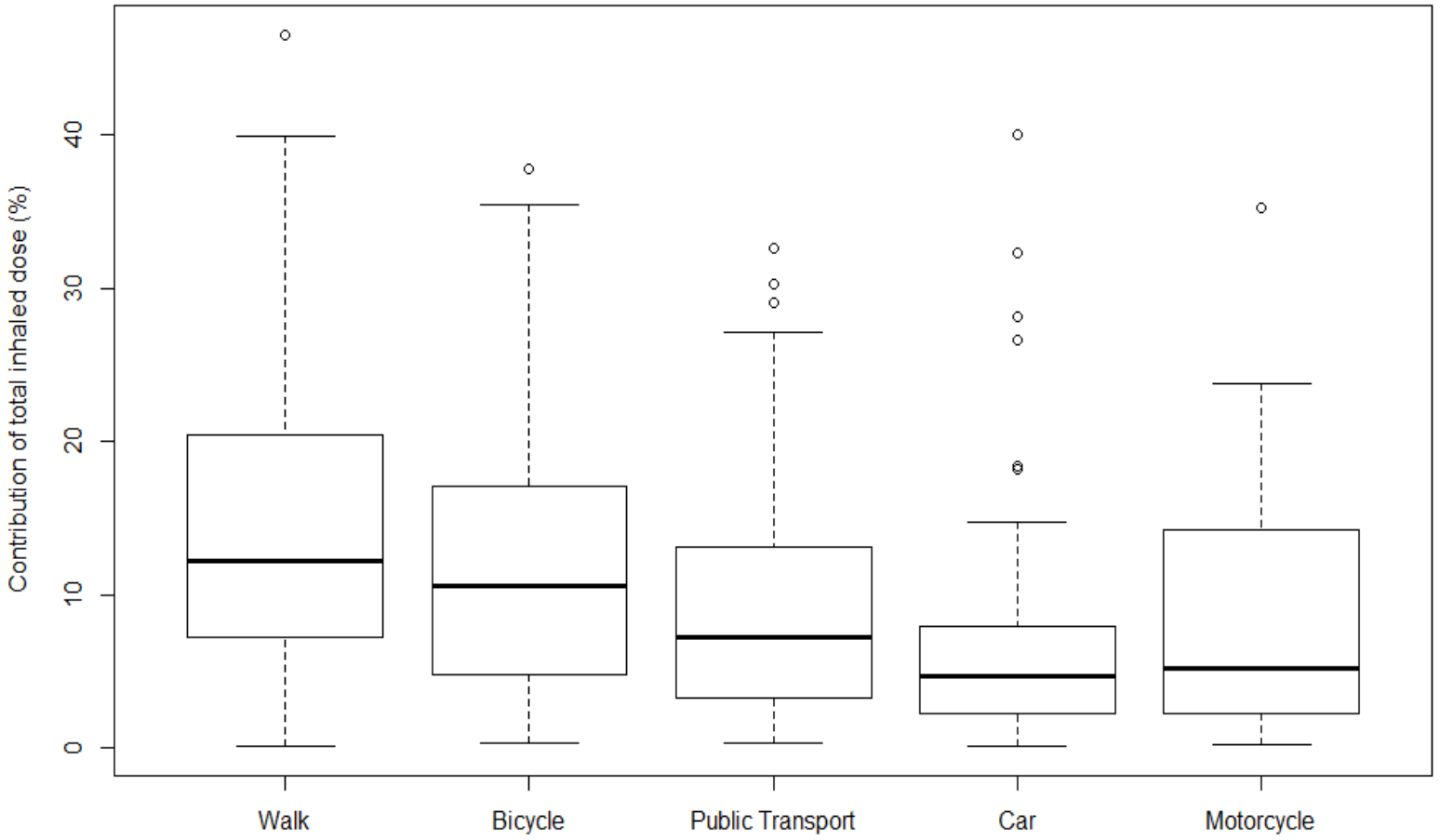
Percent contribution to inhaled dose by mode (for individuals who used that mode)



Juan Pablo Orjuela's MSc thesis

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Comparing home-based vs activity (ie phone) –based exposure assignment

	NO_2 (μgm^{-3})	$PM_{2.5}$ (μgm^{-3})
Home based exposure	56.5	24.6
Activity based exposure	67.8	30

EXAMPLE 2: CELL PHONE DATA FROM TELECOM COMPANIES

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Telecom company-provided cell phone usage data

Data provided by Telecom Italia for 7 Italian cities

- Geo-referenced 15-minute mobile phone data (calls, SMS, internet connections, March-April 2015) – aggregated on a grid
- Census data

Roma, Milano, Napoli, Bari, Torino, Venezia, Palermo

Collaborators: Markus Schläpfer(Santa Fe Institute), Juan Pablo Orjuela (CEP PhD student)

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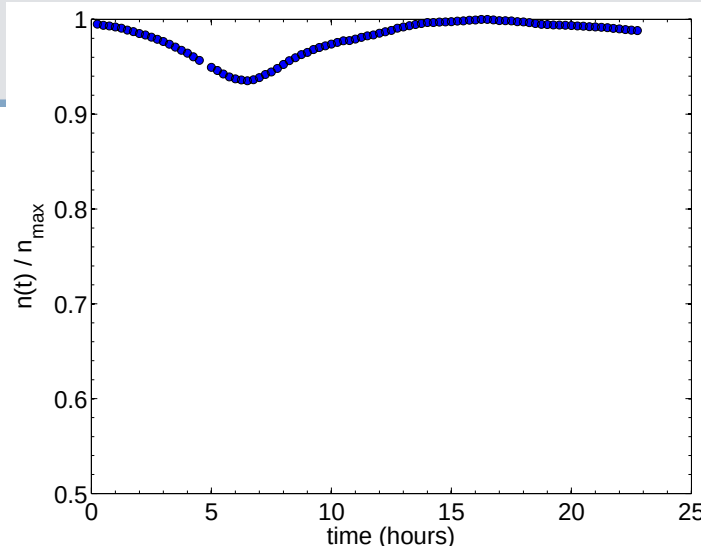
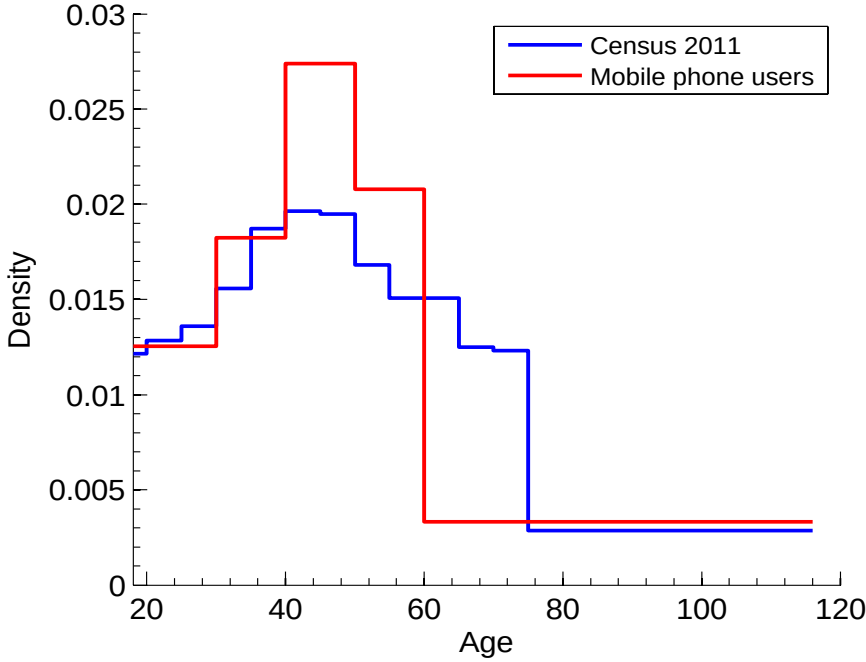
Telecom Italia data

- *Data set includes ~ 8 million callers and covers ~ 40% of the total population in each urban region.*
- *Numbers stay approximately constant across the different time intervals*



Distribution of mobile phone users according to different age groups (18+) and comparison with the 2011 Census



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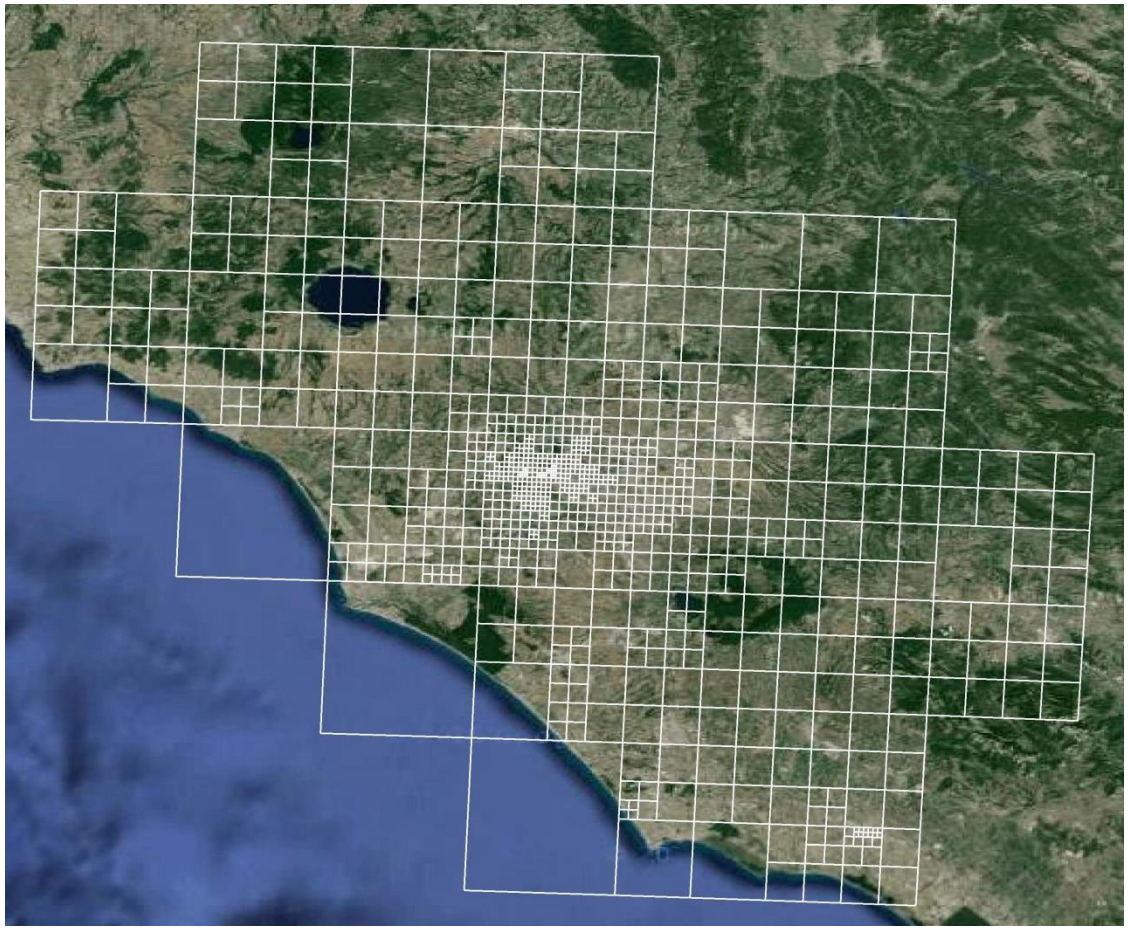
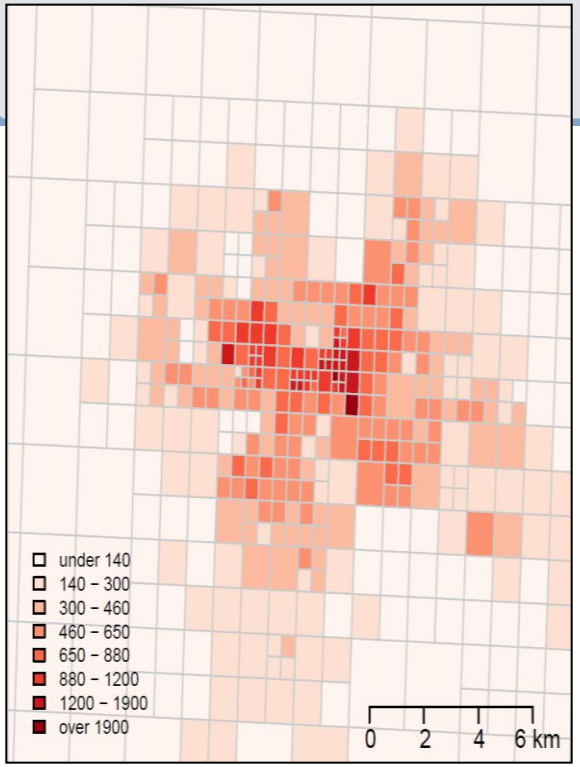
Mobile phone data - Spatial aggregation

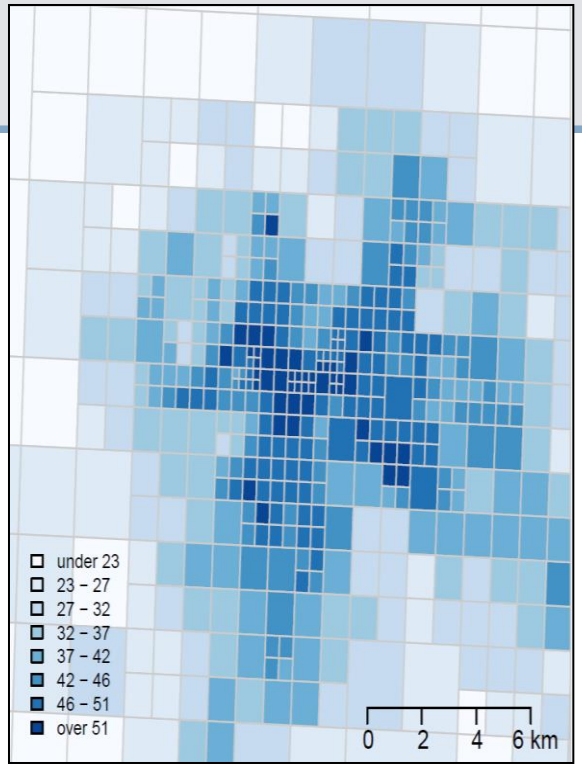
Grid structure (Rome)



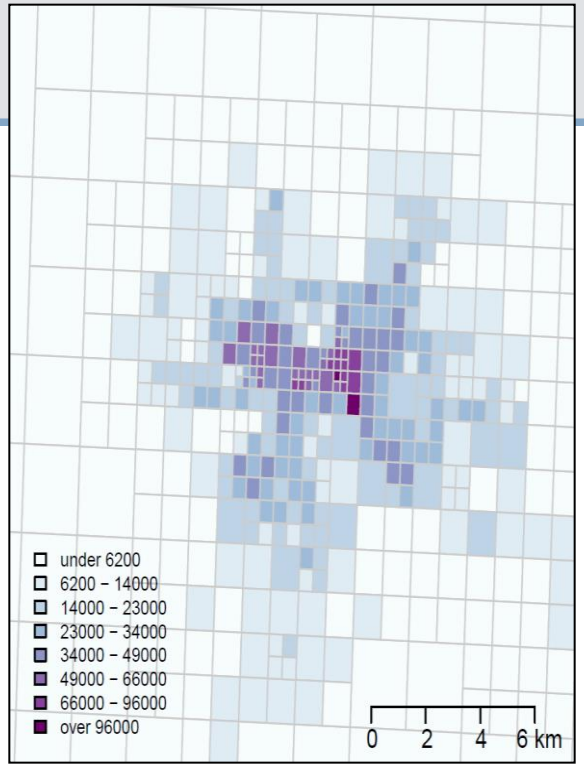
Example Rome exposure assessment



(a) cell-phone based activity data



(b) NO2 concentrations (Europe-wide LUR, Vienneau et al. 2013 Environ Sci Technol 47, 13555-13564)



(c) resulting activity based exposure for a random day at 9am, normalized for cell area

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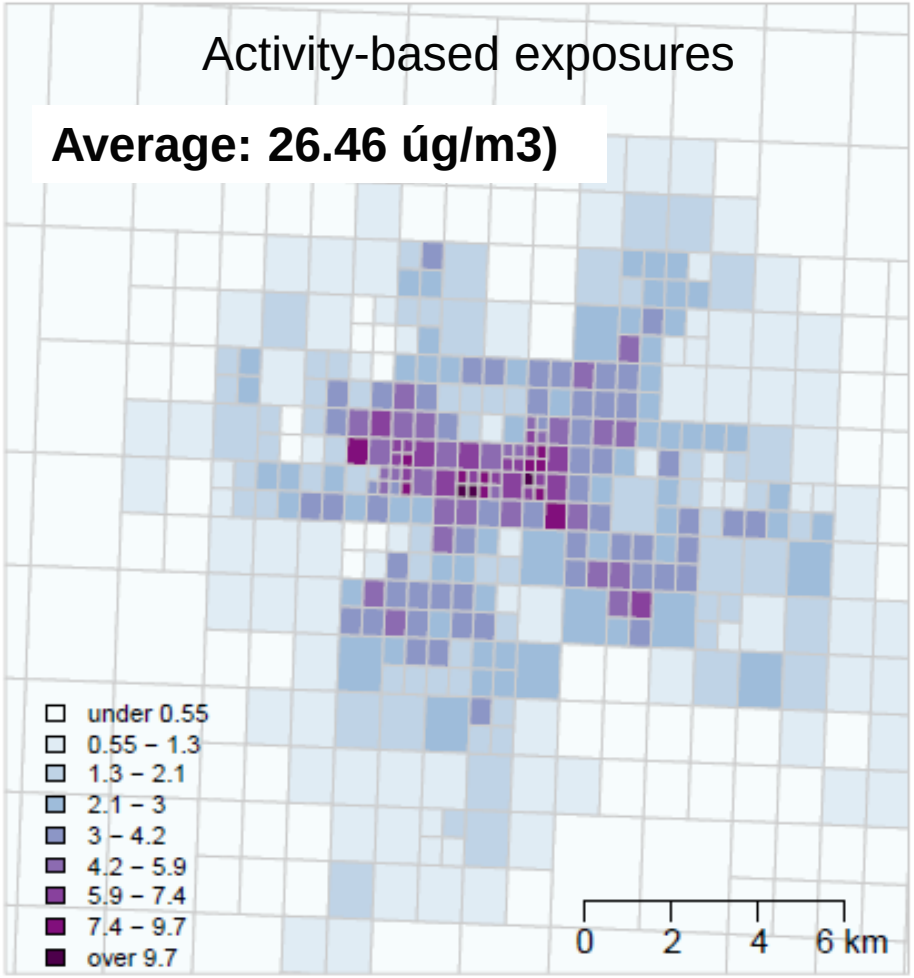
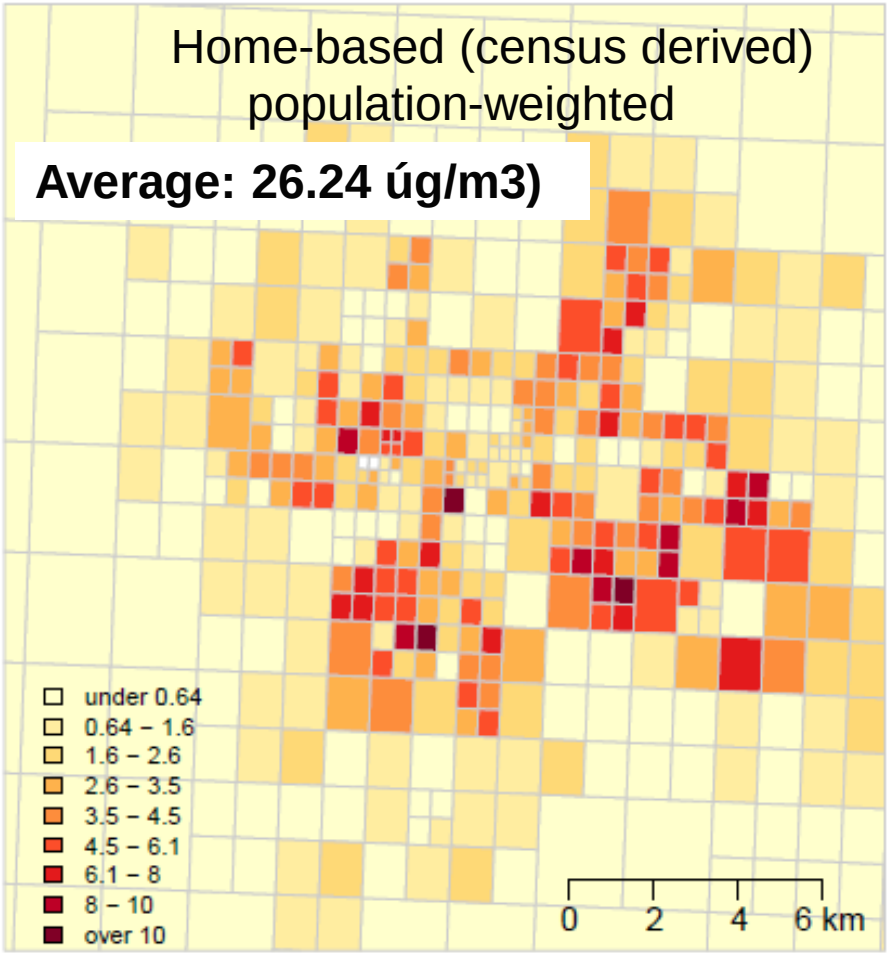
Home vs activity-based exposures: contributions from different areas in central Rome





Normalized by area and expressed as 1 in 1,000

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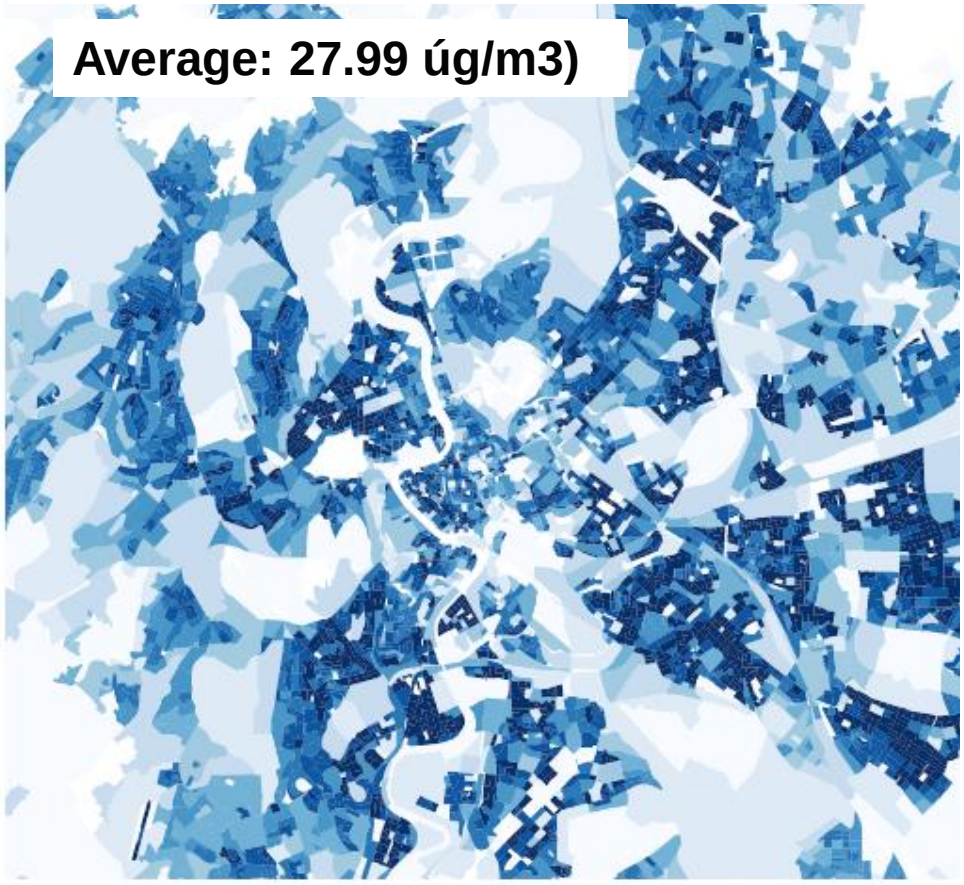
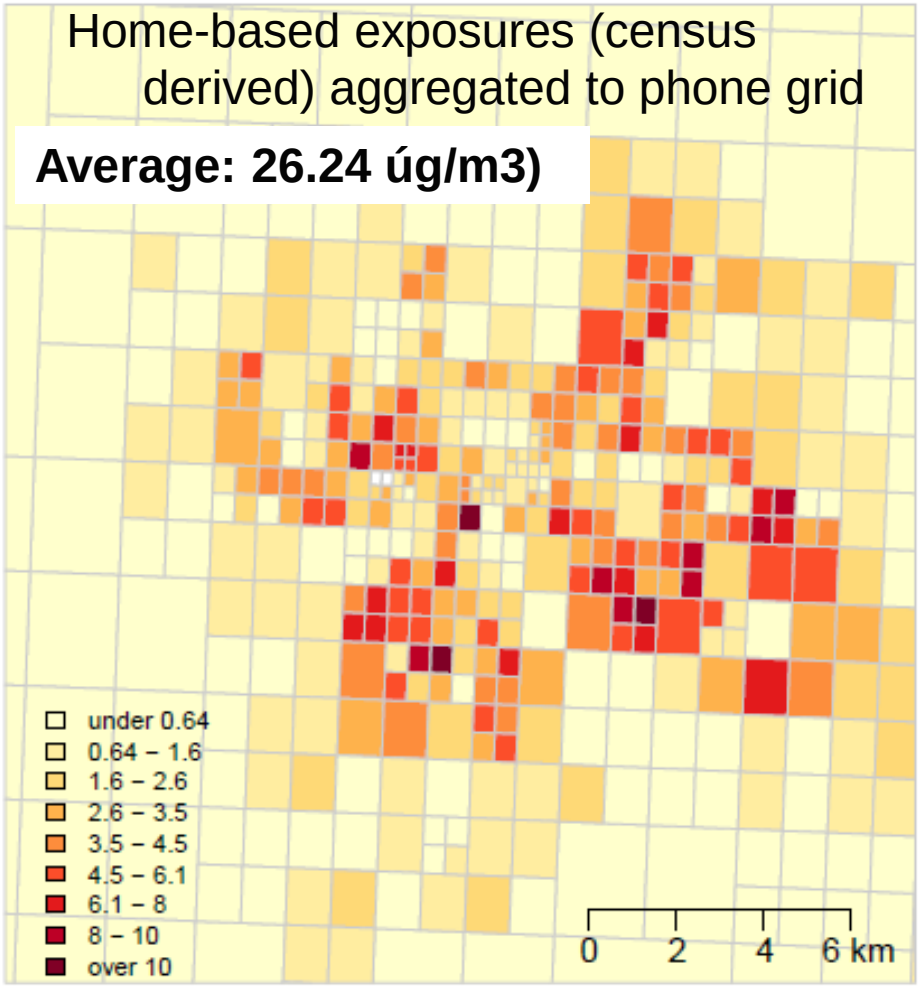
Scale matters

Home-based exposures (census derived) based on census tracks



Home-based exposures (census derived) aggregated to phone grid



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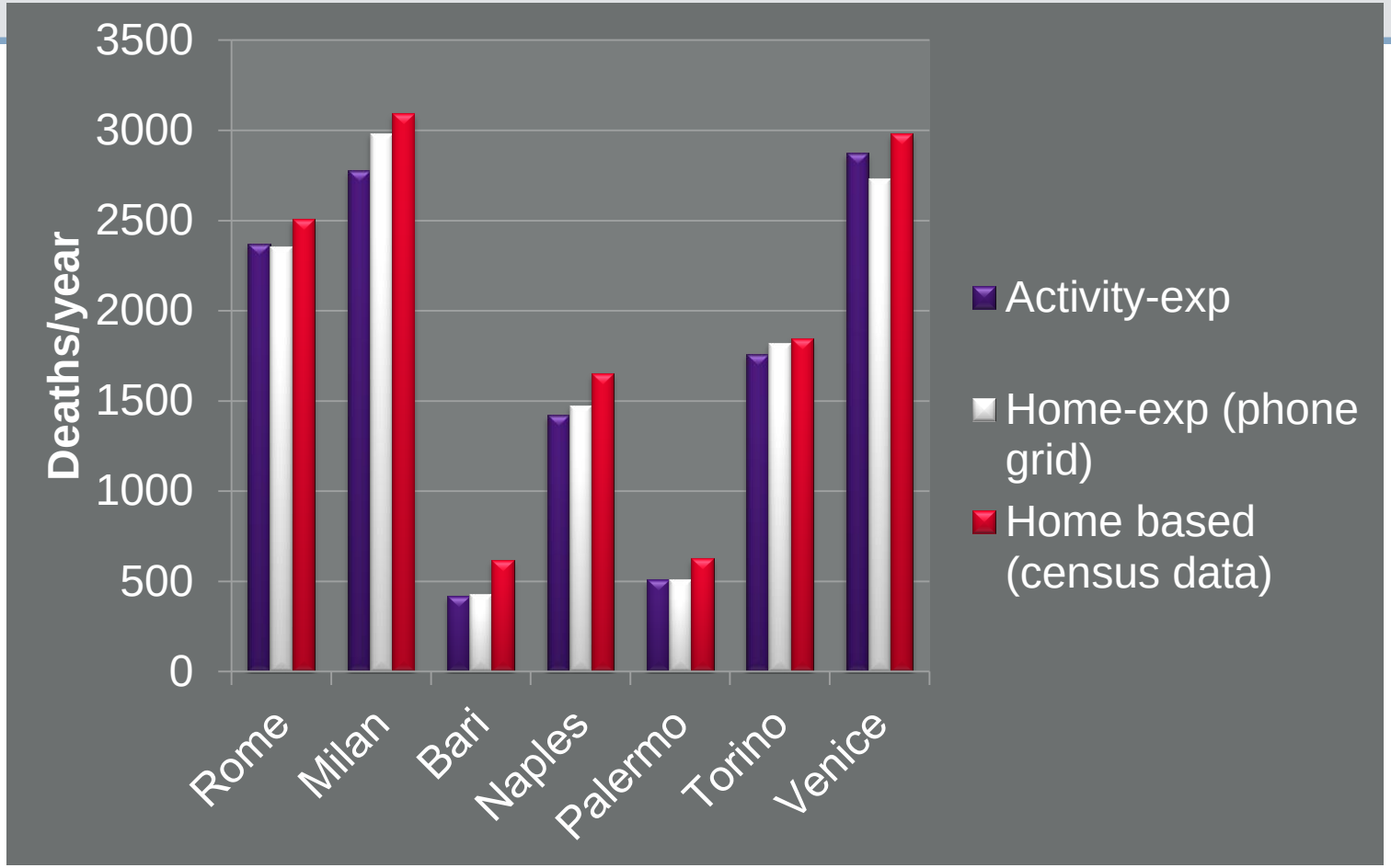
Health outcomes: deaths/year



Activity vs home based (phone grid) % Difference	**1**	**-7**	**-3**	**-4**	**0**	**-3**	**5**

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Conclusion on exposure assessment methods

- Big data from telecom companies:
  - Enable a representation of movements for a very broad population bases.
  - But harder to get individual-based data.
  - Could be useful to identify “hot spots” of activity-based exposures
- Data collected through smart phone apps:
  - Enable detailed information to assess personal exposure assessment
  - But still burdensome and costly

EXAMPLE 3: INFLUENCING BEHAVIOURS USING SMART PHONES

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Citizen engagement - behavioural and attitudinal changes

- Digital health and app-based behavioural interventions are booming research and business areas.
- Unique opportunities offered by digital technologies for a 2-way process of collecting data, reshaping behaviour, and influencing public policies
- Very little exploration of its application to air pollution.

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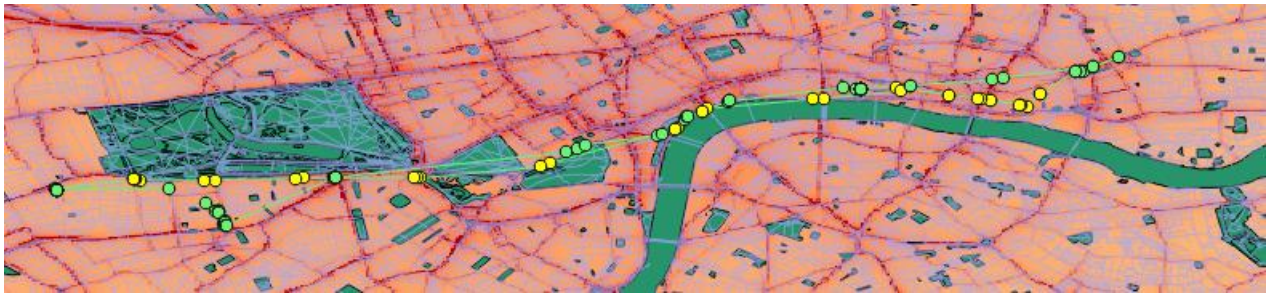
Experiment: Providing personalized feedback on exposures

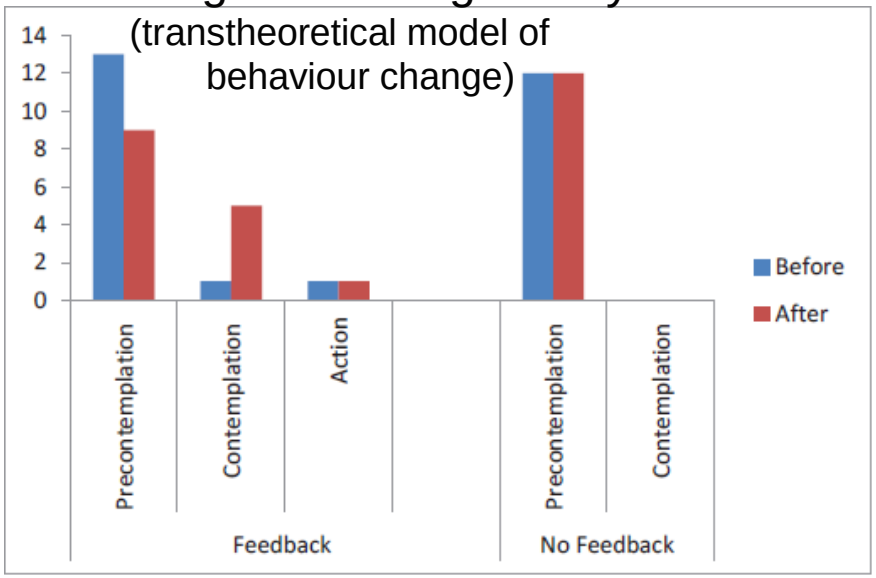
MSc thesis 2014,
Roseline Polle

Your trips on 15/07/2014: Average NO2 exposure = 104 µg/m3



By quiet back streets : ~50% reduction !

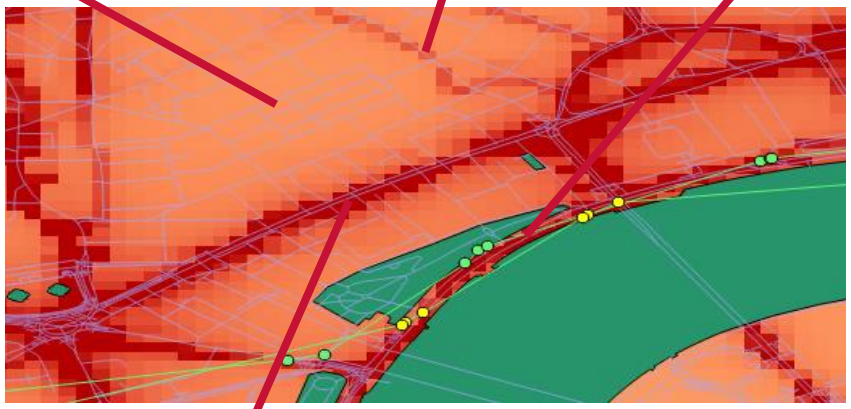
Stages of change analysis
(transtheoretical model of behaviour change)



Walking : ~ 55 µg/m3
Cycling : ~ 65 µg/m3

Walking: ~65 µg/m3
Cycling :~75 µg/m3

Walking : ~90 µg/m3
Cycling : ~110 µg/m3



Walking: ~110µg/m3
Cycling : ~140µg/m3

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Designing apps and sensors for AP engagement

In collaboration with Plume Labs,

- Elissar El-Hage MSc Thesis 2016

How can the Plume Labs app be enhanced to potentially change attitudes or behaviours towards air pollution?

- Testing sensors in Fall 2016 (FSRF-SME engagement grant)

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Mobile phones and air pollution: Conclusion

- Huge potential for data collection, improvement in exposure assessment, citizen and stakeholder engagement...
- Currently trade-offs on type of data available (big data from telecom companies vs research-collected data) – think of purpose
- Issues of privacy and data ownership to deal with to get the best of all worlds
- Big data challenges too

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Challenge questions

The ultimate goal is to help generate “optimal” health-promoting urban strategies– 2 specific challenges within this general framework are:

1.What is the best use of telecom-provided cell phone usage data for air pollution management and research?

2. How would you go about designing a smart phone app to guide people towards more sustainable and healthy behaviours with regards to air pollution?

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Extra slides

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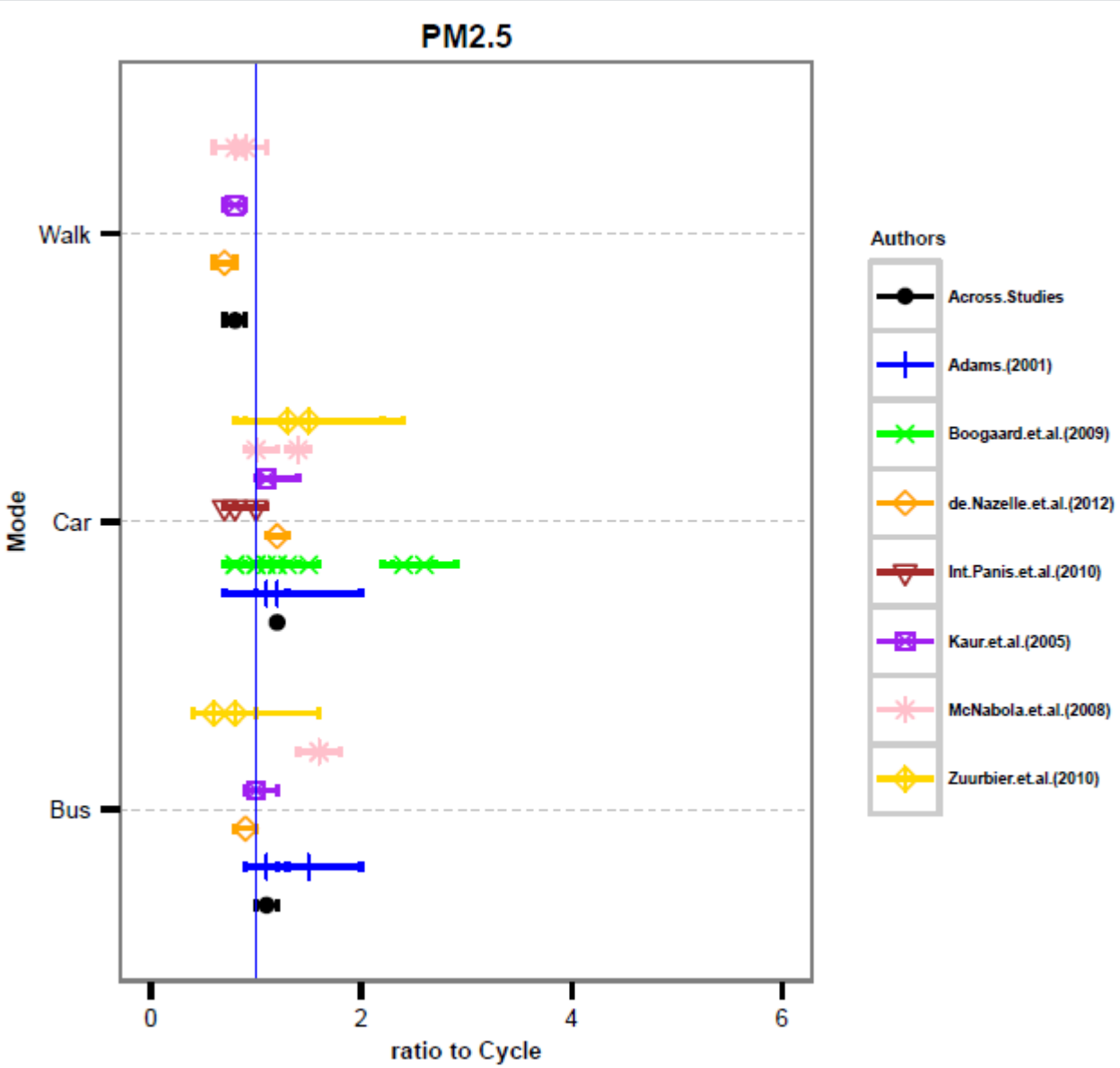
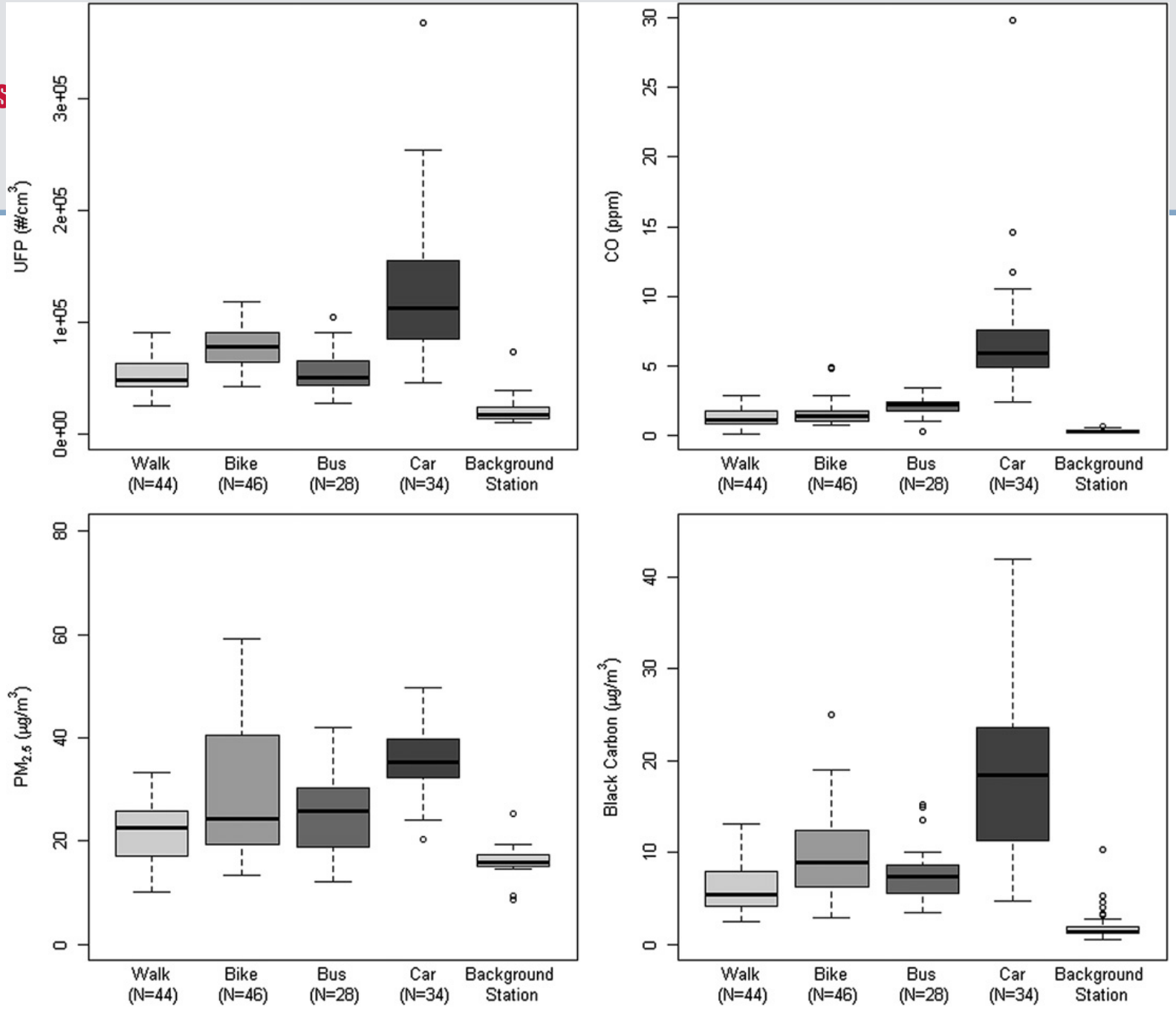
Literature review on exposure contrasts in different modes in Europe:

Modes vs Cycle



Results


UFP (#/cm3)
0e+00
1e+05
2e+05
3e+05
CO (ppm)
0
5
10
15
20
25
30
PM2.5 (µg/m3)
0
20
40
60
80
Black Carbon (µg/m3)
0
10
20
30
40
Walk (N=44)
Bike (N=46)
Bus (N=28)
Car (N=34)
Background Station