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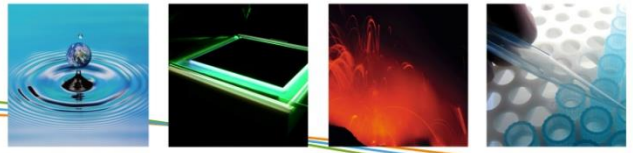


Examples of sensor applications: mobile monitoring of air quality

20/08/2013

COST Action TD1105 EuNetAir

First Scientific Meeting, 4 – 6 December, Rome, Italy

Presentation: Jan Theunis

Research team:

Matteo Reggente

Jan Peters

Martine Van Poppel

Evi Dons

Joris Van den Bossche

Outline

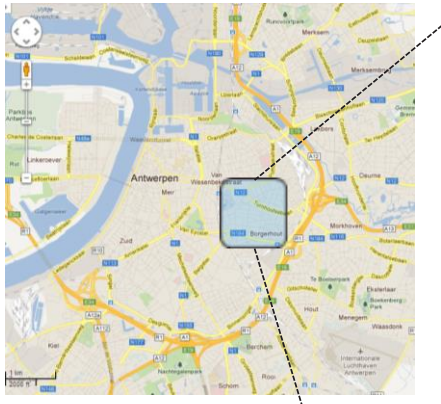
- (Urban) air quality monitoring
- New approaches: focus on exposure and health
- Sensor networks: concept, examples of statistical modelling
- Mobile monitoring
- Participatory monitoring

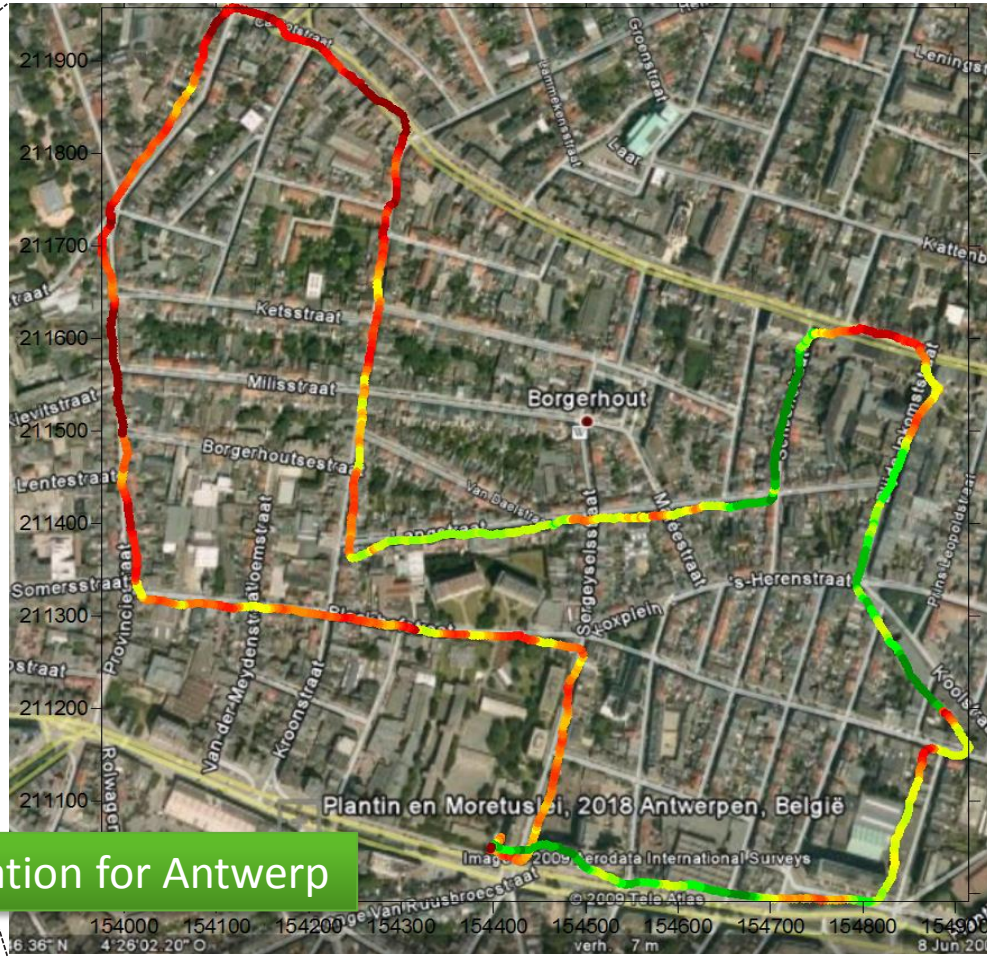
tools and methods

- Sensor array

Air quality monitoring

- Conventional: Reference methods
  - Only regulated components
  - “Correct” but poor spatial coverage





1 Urban air quality station for Antwerp

Air quality is not homogeneous in urban environments!

New approaches: focus on exposure and health

- health-relevance versus regulation
- exposure in different micro-environments
- detailed data – high spatio-temporal resolution

Sensor Networks	Mobile Monitoring	Participatory Monitoring

Stationary	**Low cost sensing devices**	
	Targeted	***Opportunistic***
Mobile	**High range portable monitors**	
	Targeted	***Opportunistic***
	Low cost sensing devices	
	Targeted	***Opportunistic***

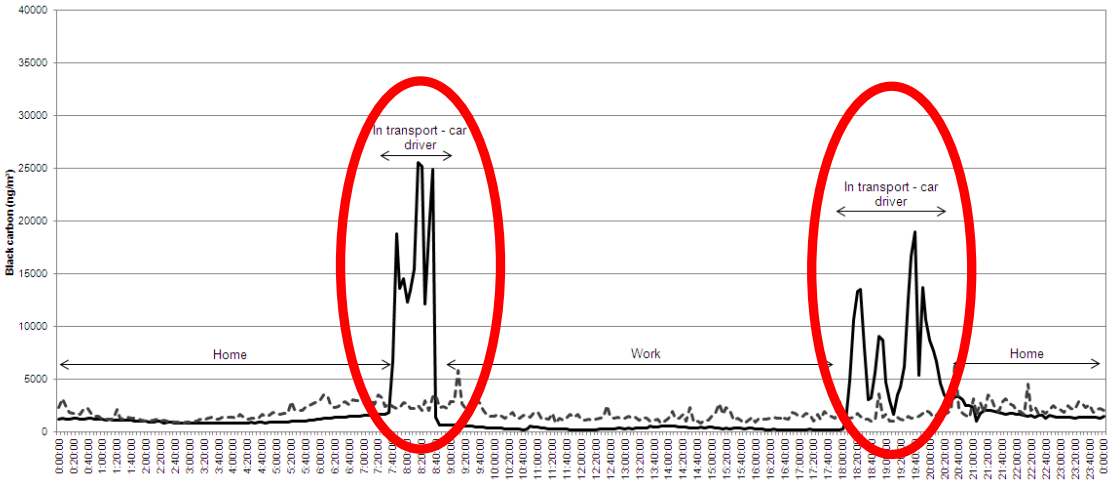
Mobile air quality monitoring : why ?

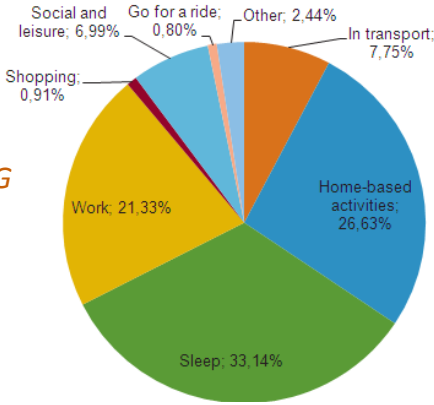
- Objectives :
  - Obtain spatially and temporally resolved data on air quality
- Applications :
  - Personal exposure monitoring
    - *Berghmans P, Bleux N, Int Panis L, Mishra V, Torfs R, Van Poppel M, 2009. Exposure assessment of a cyclist to PM10 and ultrafine particles. Science of The Total Environment, Volume 407, Issue 4, 1286-1298*
  - Hot-spot identification: mapping in urban and industrial environments to assess impact of local sources
  - High resolution mapping in urban environment
  - Data acquisition for model calibration

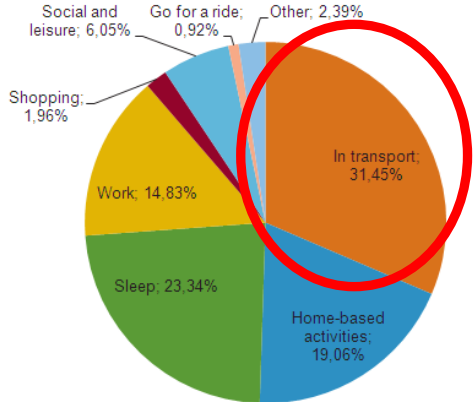
Dynamic exposure assessment: personal exposure monitoring

- Portable instrument
- Micro-aethalometer AE51
  - Black carbon

- Electronic diary







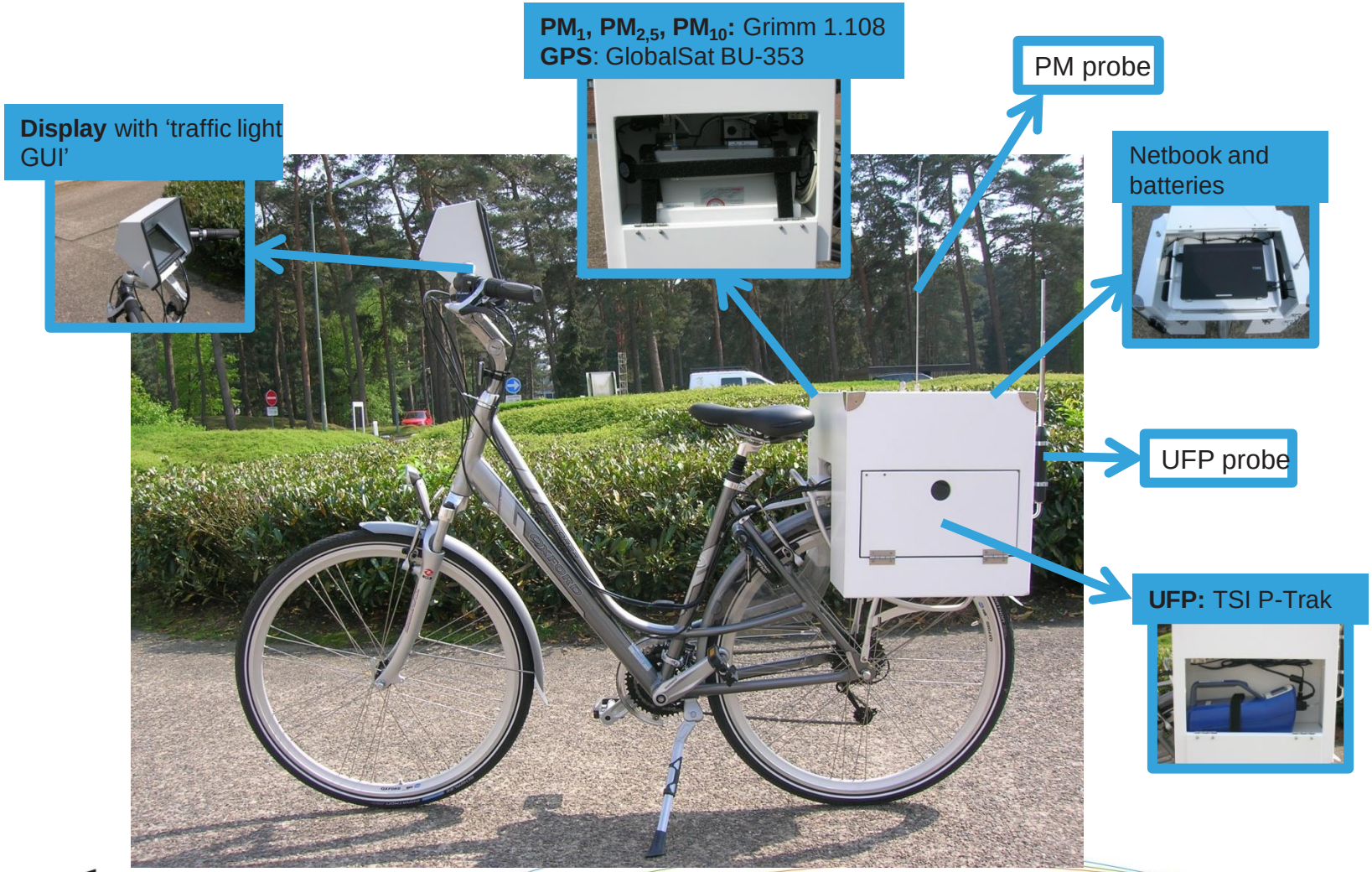
Average proportion of time spent on activities (left) and corresponding proportion of black carbon exposure per activity (right)

Dons E, Int Panis L, Van Poppel M, Theunis J, Willems H, Torfs R, Wets G (2011), Impact of time-activity patterns on personal exposure to black carbon, Atmospheric Environment, Volume 45, Issue 21, July 2011, p. 3594-3602,

Dons, E., Int Panis, L., Van Poppel, M., Theunis, J., & Wets, G. (2012). Personal exposure to Black Carbon in transport microenvironments. Atmospheric Environment 55, 392-398.

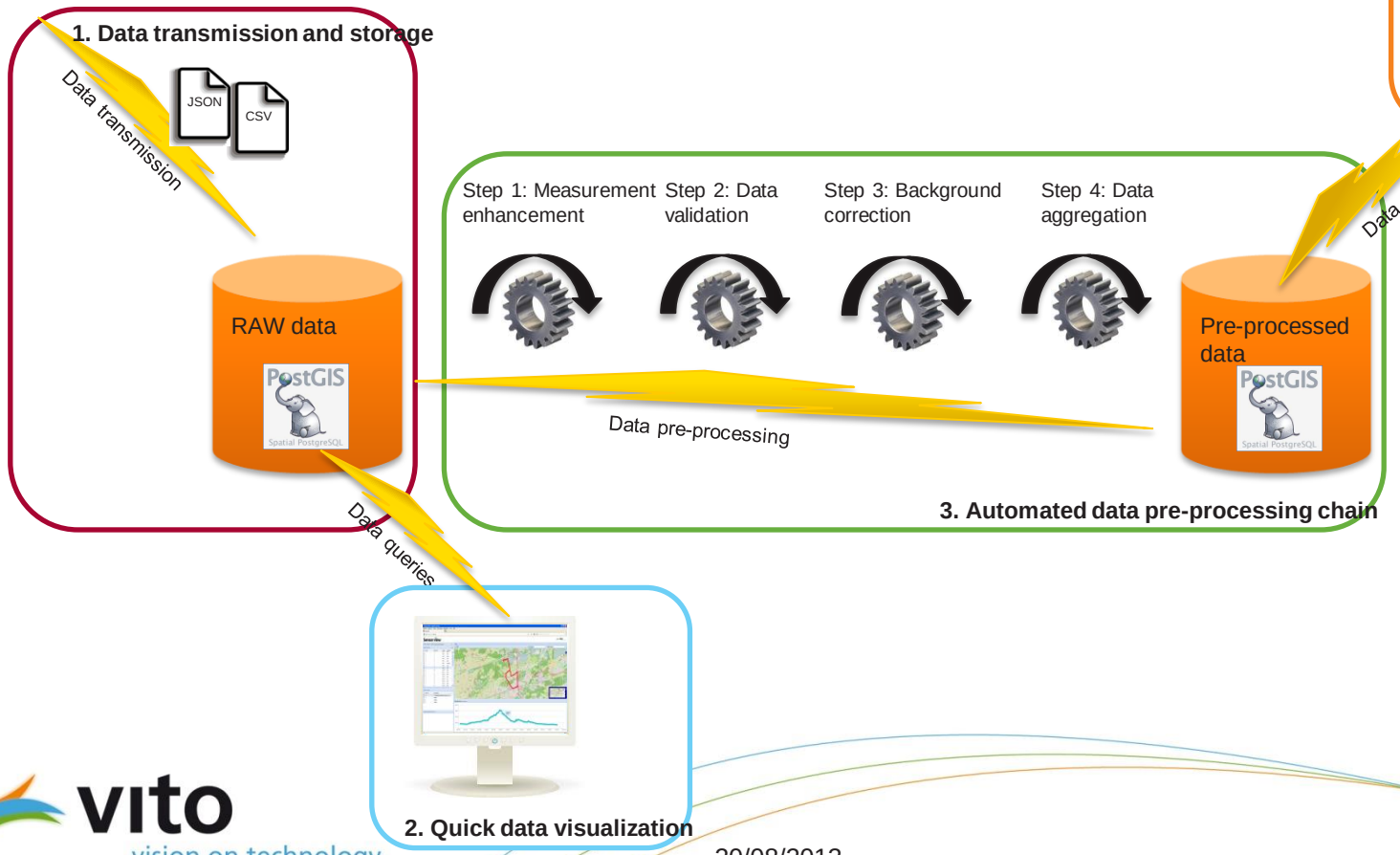
Bart Elen, Jan Peters, Martine Van Poppel, Nico Bleux, Jan Theunis, Matteo Reggente, Arnout Standaert (submitted 2012) The Aeroflex: a bicycle for mobile air quality measurements, submitted to Sensors

Aeroflex – Air Quality Bike



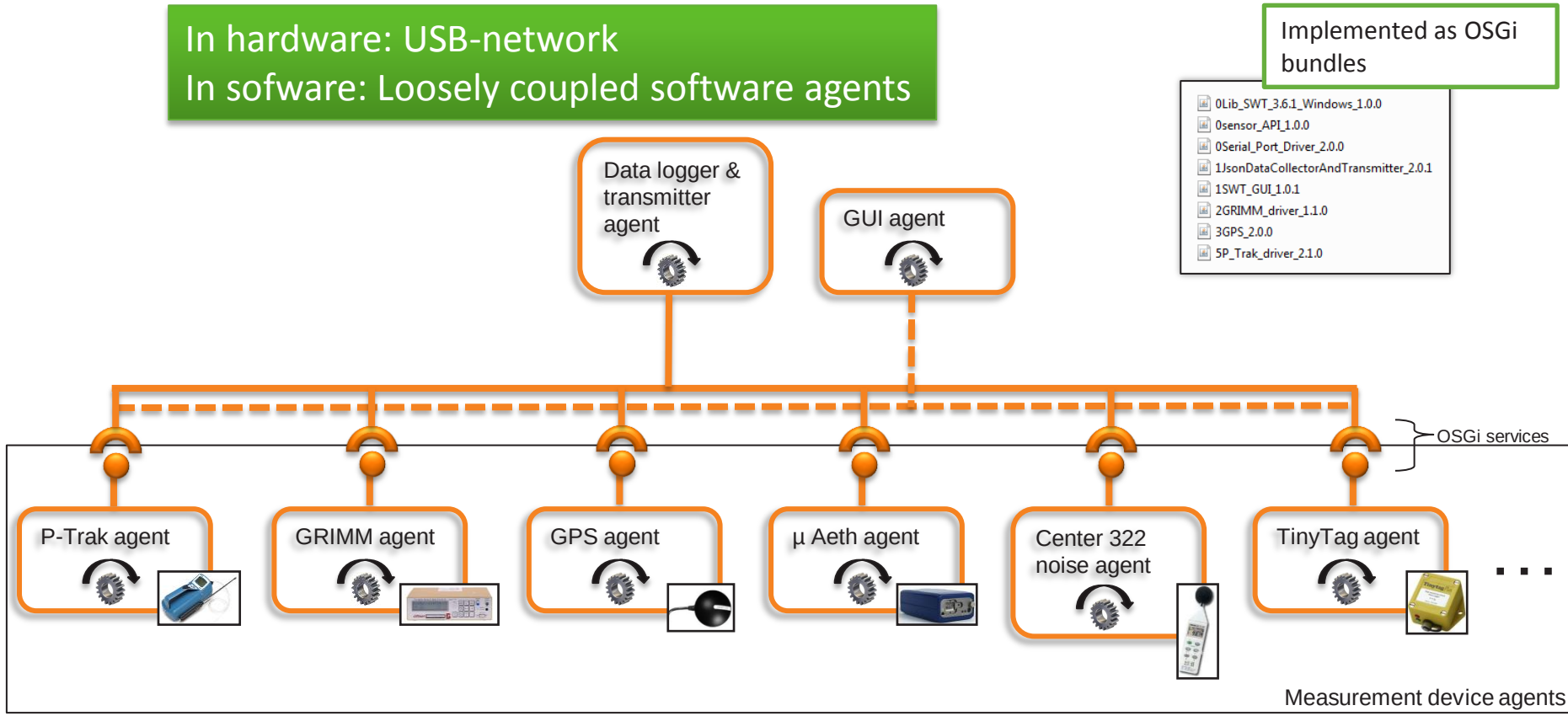
Aeroflex Data Infrastructure - Overview

collect **lots** of mobile measurements
-> requires automated data processing



Aeroflex Data Infrastructure – Need for adaptability

» Must be ready to adapt set of measurement devices:

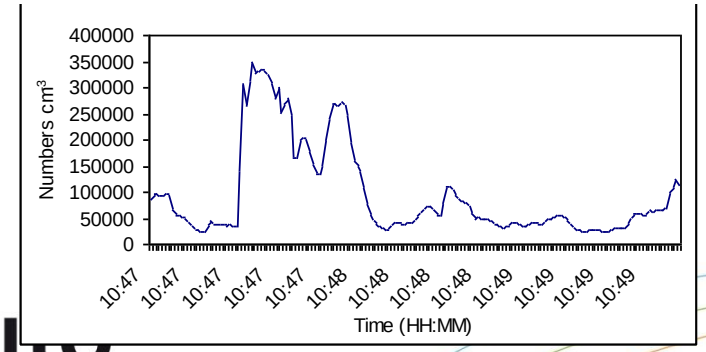


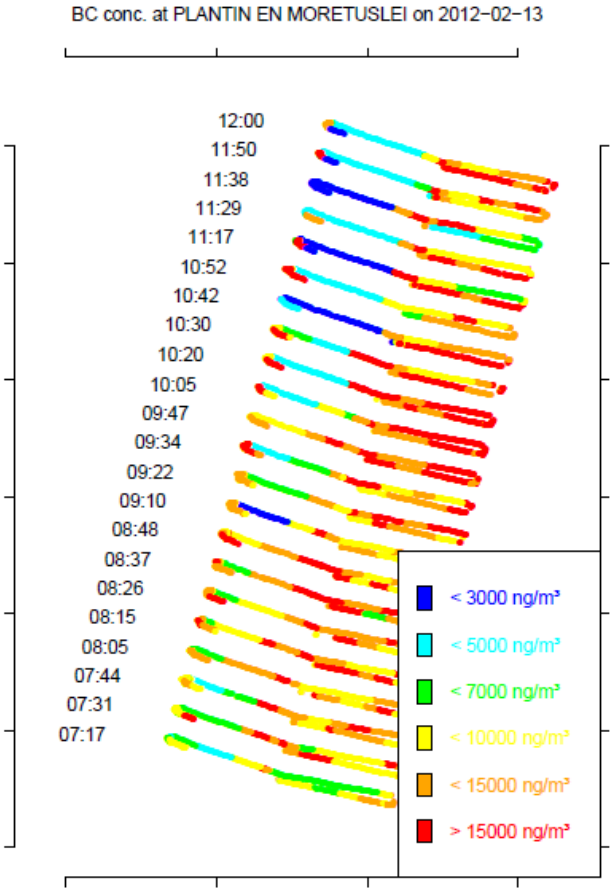
Mobile monitoring: methodology

Jan Peters, Jan Theunis, Martine Van Poppel, Patrick Berghmans, Monitoring PM10 and ultrafine particles in urban environments using mobile measurements, accepted for publication in Aerosol and Air Quality Research

- Spatio-temporal data
  - $L = \{\text{time, location, air quality}\}$
  - Single run: snap shot - Highly influenced by traffic discontinuity and short term incidents
  - Spatio-temporal series of measurements
    - Fixed route
    - Repeated measurements + data aggregation
    - Background correction

UFP number concentration Provinciestraat during a single passage



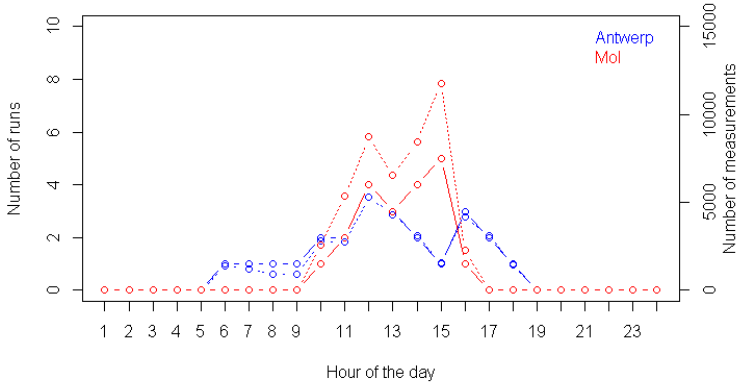


Spatio-temporal series

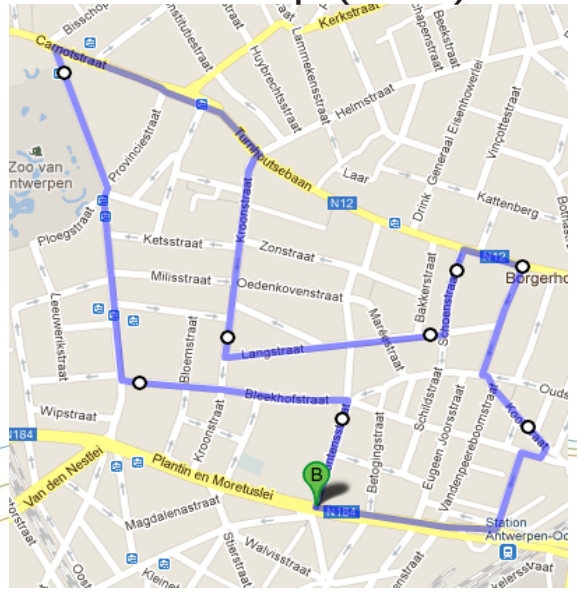
Repeated measurements: one morning

Case study

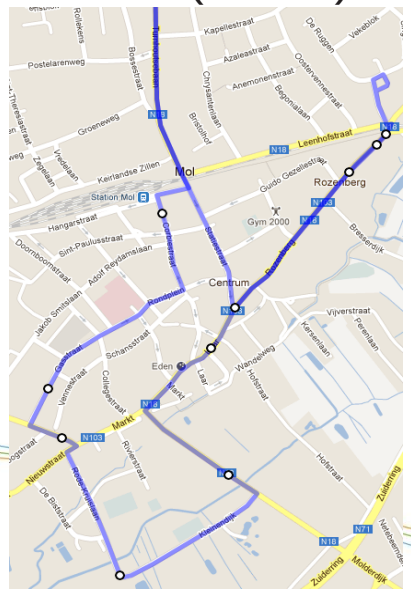
- Two locations: **Antwerp** (medium-sized city, 480 000 inhabitants, 985 inhabitants km-2) and **Mol** (provincial town, 34 000 inhabitants, 300 inhabitants km-2)
- Fixed route at both study sites :
  - 24 runs in Antwerp, 8 dates in the period between March 16 and April 8, 2009
  - 20 runs in Mol, 10 measurement dates between April 7 and April 23, 2010
  - Measurement times



Antwerp (5 km)



Mol (10 km)



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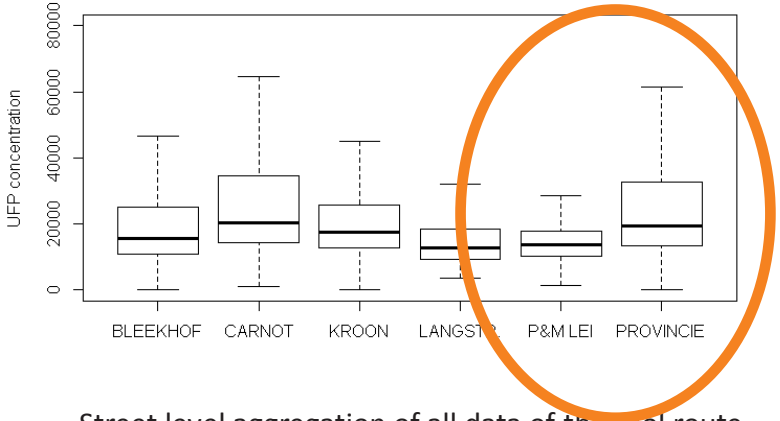
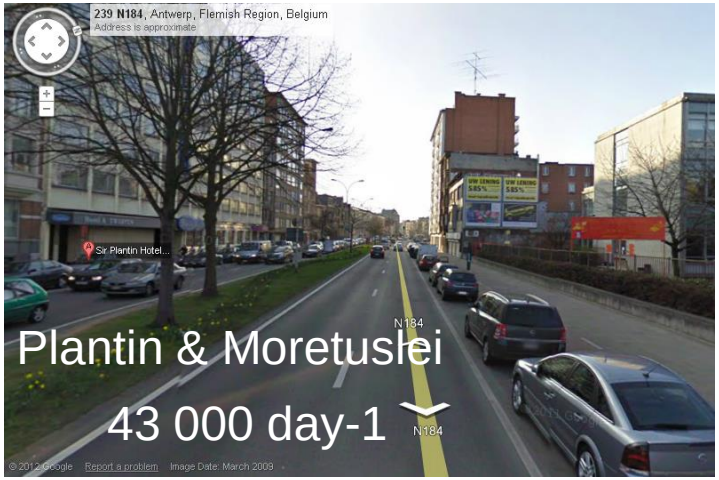
Methodology : street level aggregation

- Exponential decay
- Distance Aeroflex – traffic important
- → Restrictions for use of Aeroflex : measurements are representative in the first place for the pollutant concentrations that cyclists are exposed to.



Street level aggregation of all data of the Mol route (above) and the Antwerp route (below) show significant differences in UFP concentrations between streets

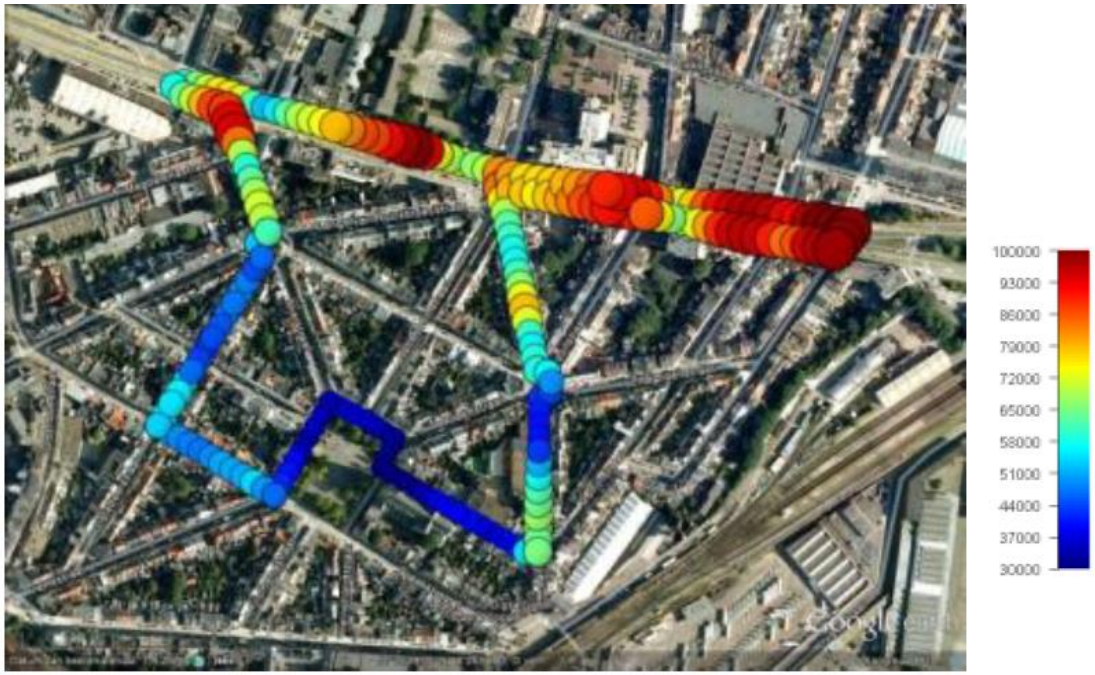


Methodology : repeated measurements

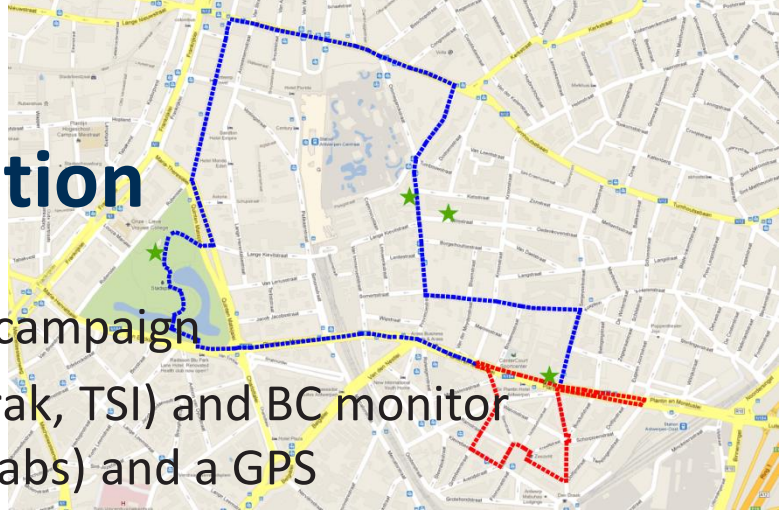
- a limited number of 20 to 24 runs carried out on different days and different times of the day over a period of two to three weeks allows to distinguish streets with higher and lower median concentrations of PM10 and UFP in a significant way.
- strong indications that the same set of measurement runs provides a good quantitative approximation of median UFP and PM10 concentrations for most streets, and that this number could even be reduced

Methodology : traffic discontinuity and short-term incidents

- Data aggregation → representativeness
  - Gaussian kernel smoothing of spatio-temporal data
  - Level out part of the variability that is related to traffic discontinuity and short-term incidents
  - Smooth accumulated data (eg. at traffic light)



Methodology : further validation



- Extensive systematic mobile measurement campaign
  - bike equipped with a portable UFP (P-Trak, TSI) and BC monitor (micro-aethalometer, MicroAeth, AethLabs) and a GPS
  - two fixed routes (ca. 2 and 5 km long)
  - passing by central monitoring station from the Flemish Environmental Agency (VMM) + stationary measurements at 4 locations, including background locations
  - spread over 11 days, ca 138 hours of bike measurements between 7 am and 13 pm, resulting in 256 and 96 repeated runs, respectively. 17 runs of route 1 simultaneous with two bikes.
- Goals:
  - representativity, background correction, extrapolation
- First results will be presented at Monitoring Ambient Air 2012, AAMG - Royal Society of Chemistry, London, 12-13 December 2012.

Participatory monitoring : why ?

» Mobile monitoring: how to collect enough data

→ Participatory sensing

- » Measurements carried out by volunteers / stakeholders
- » Collaboration scientists – authorities – stakeholders
- » Win-Win situation

• detailed spatial and temporal scale dynamic exposure assessment
• corresponding to people's personal environment and activities
• collaborative efforts to collect large representative datasets for mapping urban environment
• enhance people's understanding of the urban environment
• contribute to collaborative decision-making processes

Participatory monitoring – Portable air quality monitoring devices

UFP: P-trak, MiniDISC, …; BC: micro-aethalometer

User friendly !

BC Mapper

Micro-aethalometer AE51

Portable air quality monitoring kit with **minimal impact** on volunteers

Home station:
- reading out the data
- clock synchronisation
- send data to database
- recharge equipment

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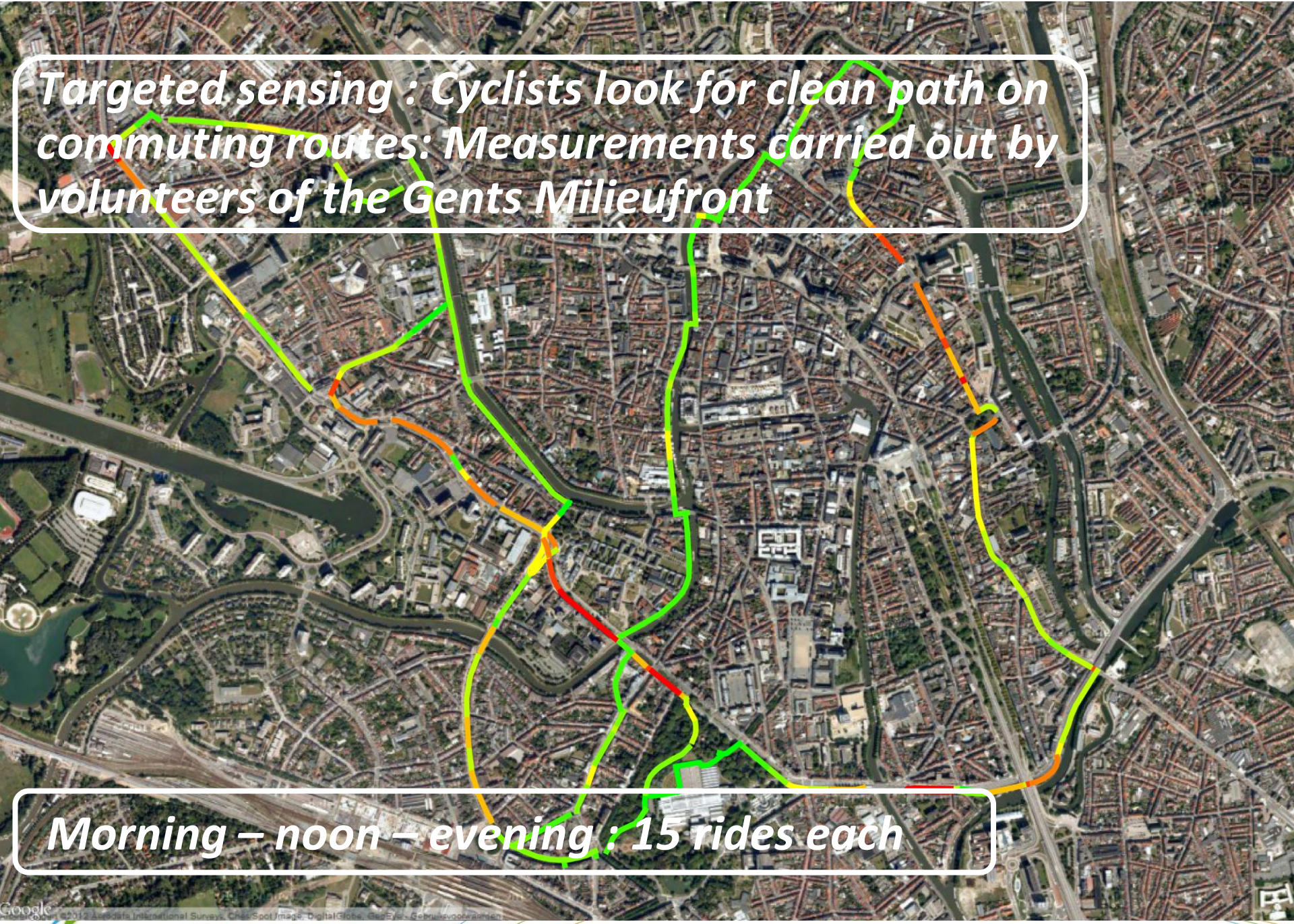

http://sensorview2.vito.be/BCM/gent.html

Participatory sensing – Portable air quality monitoring devices

Opportunistic sensing: City employees monitor air quality during their normal working routine

3 teams of 'City Guards' measuring air quality in Antwerp during 12 months

first 4 and a half months : 1 090 039 second measurements; 302 h of measurements, spread over 53 days; most between 10 am and 16pm during the working week.

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Participatory sensing – Portable air quality monitoring devices

- Challenges:
  - GPS corrections and exact locations
  - Indoor versus outdoor
  - Interferences, e.g. smoking