European Network on New Sensing Technologies for Air Pollution Control and Environmental Sustainability - *EuNetAir*

COST Action TD1105

2nd International Workshop *EuNetAir* on

New Sensing Technologies for Indoor and Outdoor Air Quality Control

ENEA - Brindisi Research Center, Brindisi, Italy, 25 - 26 March 2014

Participatory Air Quality Sensing

Speaker
Affiliation Logo

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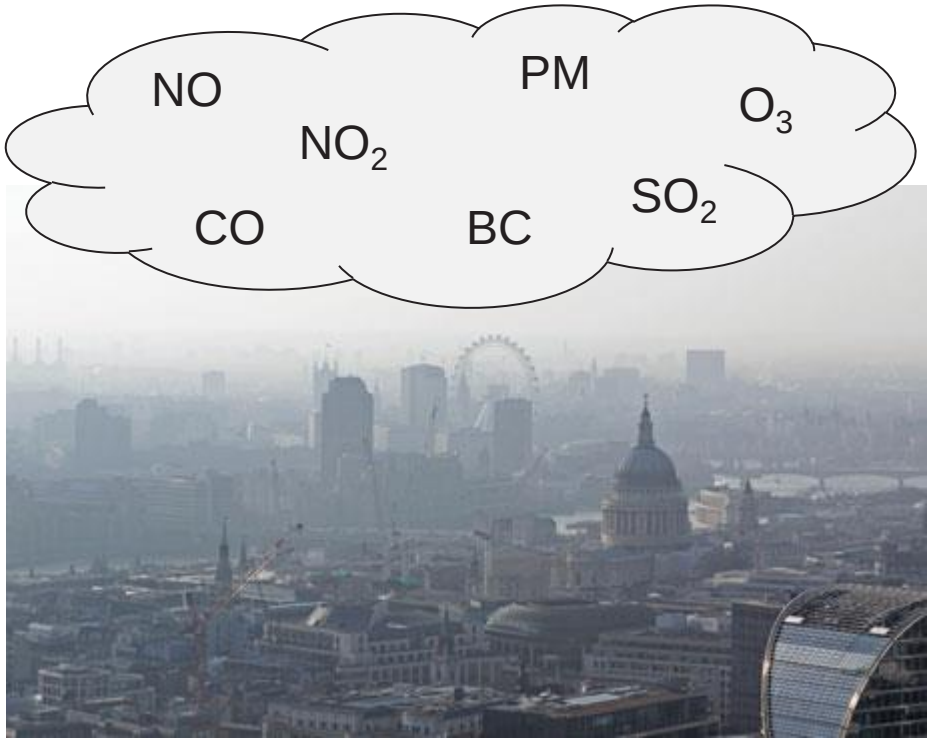
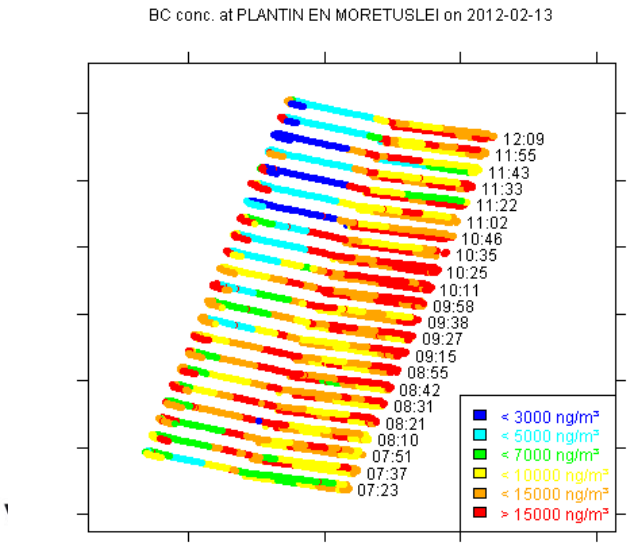
Outline

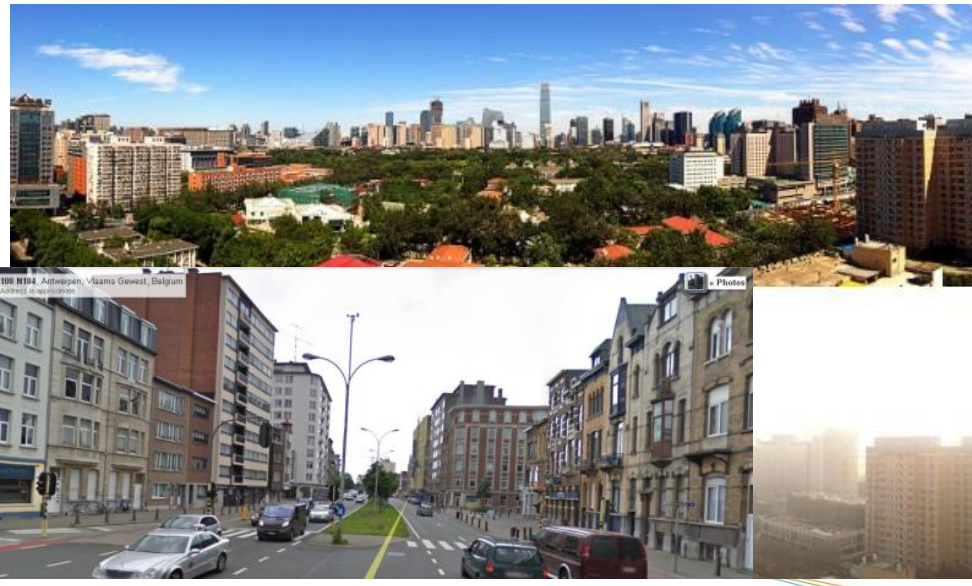
- Participatory Air Quality Monitoring
  - What?
    - Collective action
    - Stakeholders collaboratively define:
      - Evaluation issues
      - Collect and analyse data
      - Take action
    - Large scale deployment
    - Low-cost sensing technologies
  - Why
    - High-resolution characterization of the air quality
    - Exposue assessment at community level
    - Preventive health (activity planning)
    - …

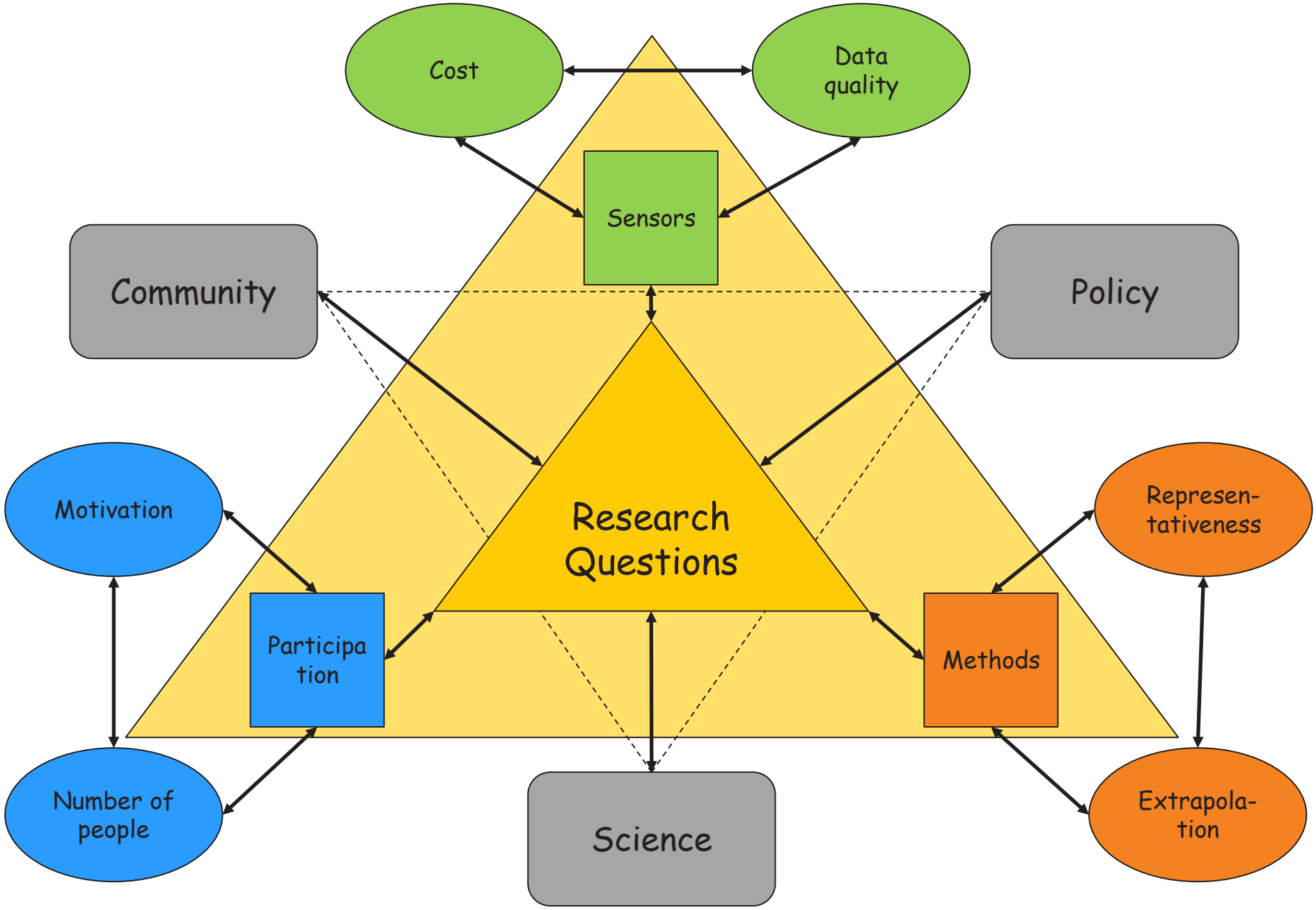
Outline

- Participatory Air Quality Sensing
- Urban air quality
  - pollutant concentrations
  - local sources - traffic
  - dynamic environment
  - spatio-temporal pattern
- 3 projects







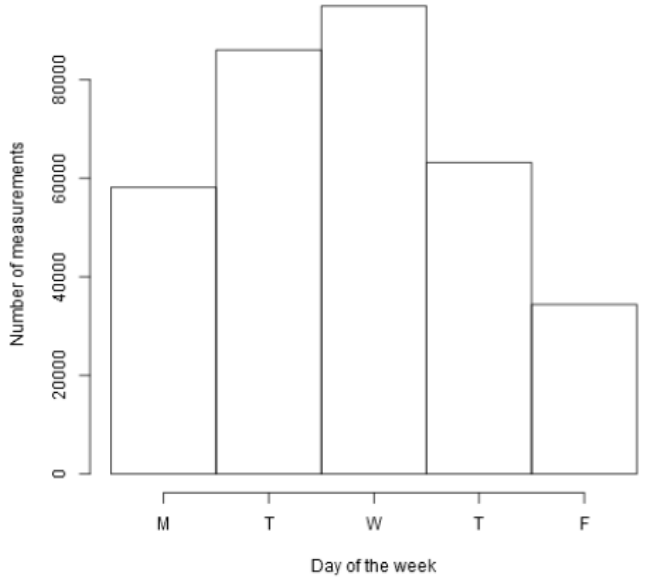

Cost
Data quality
Sensors
Community
Policy
Motivation
Research Questions
Represen-tativeness
Participa tion
Methods
Number of people
Science
Extrapola-tion

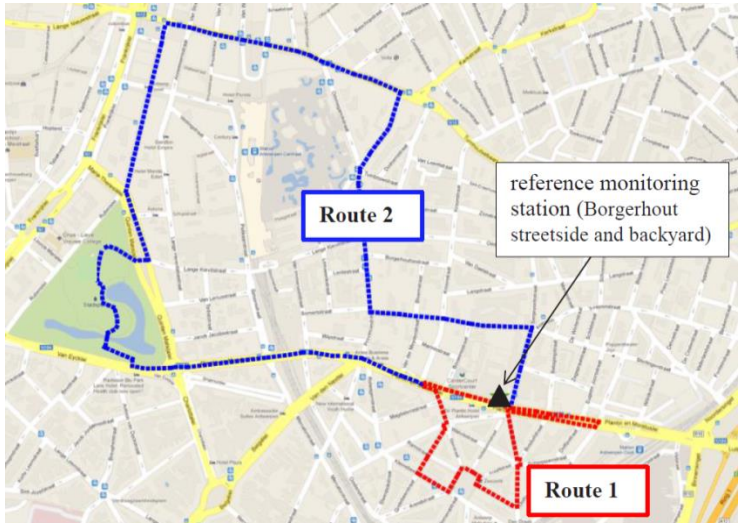
Case 1: mobile monitoring

- Research questions:
  - Mapping of the air quality in urban micro-environments
  - Variability of hot-spots
  - Data coverage and data processing
- Sensors:
  - Aeroflex VITO (Elen et. al., Sensors 13(1), 221-240)
    - Micro-aethalometer
    - P-Trak

Case 1: mobile monitoring

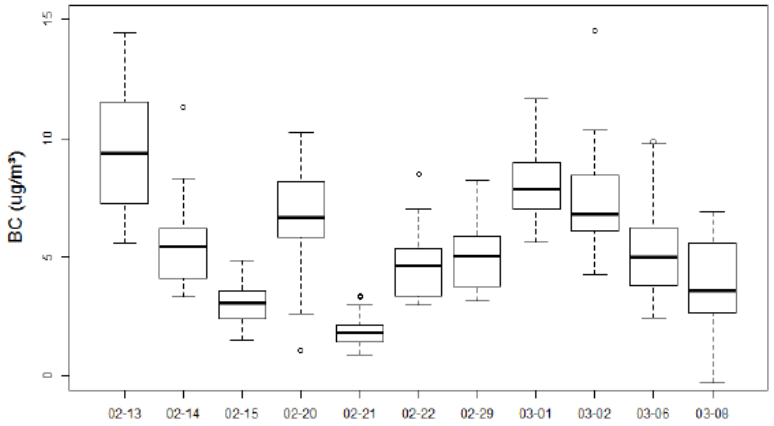
- Research questions: mapping of the air quality in urban micro-environment
- Sensors: Aeroflex VITO
- Methods: mobile monitoring
  - Confined area, limited nr streets
  - Targetted in space and time

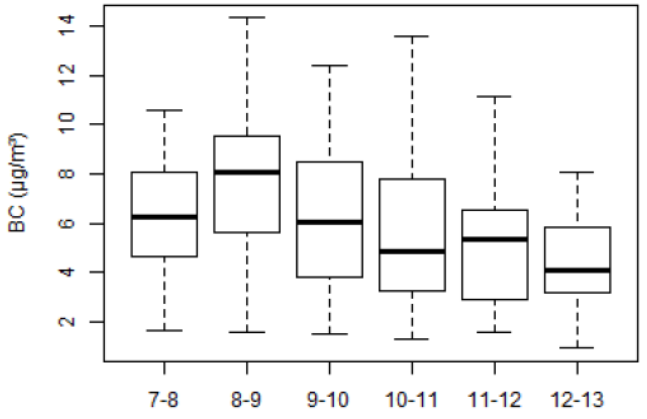




Case 1: mobile monitoring

- Research questions: mapping of the air quality in urban micro-environment
- Sensors: Aeroflex VITO
- Methods: mobile monitoring in limited number of streets
- Participation: no citizen participation
- Results:
  - Temporal variability:





Case 1: mobile monitoring

- Research questions: mapping of the air quality in urban micro-environment
- Sensors: Aeroflex VITO
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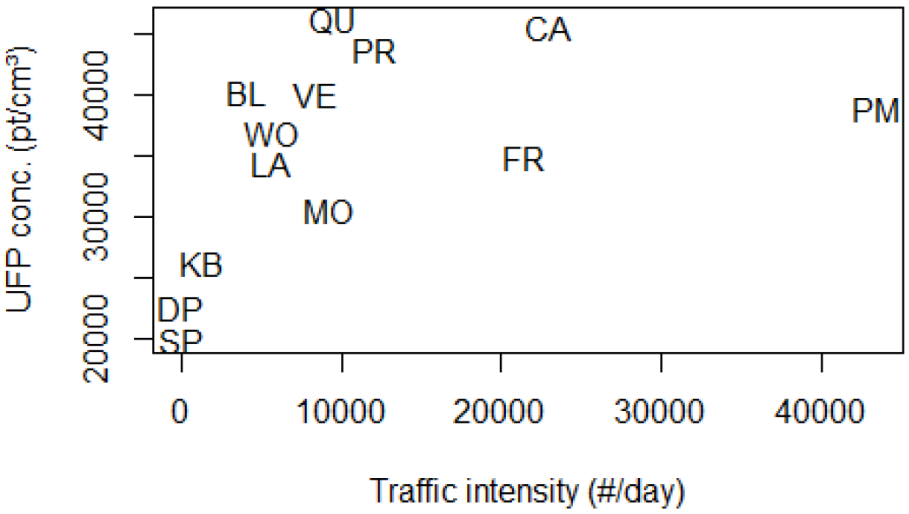
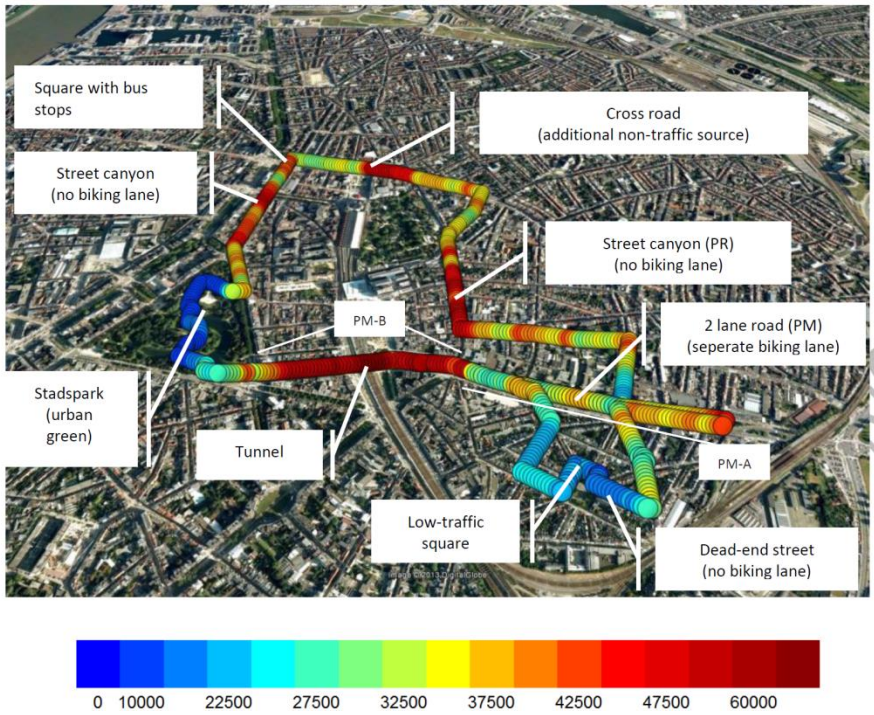
- Participation: no citizen participation
- Results:
  - Spatial variability:



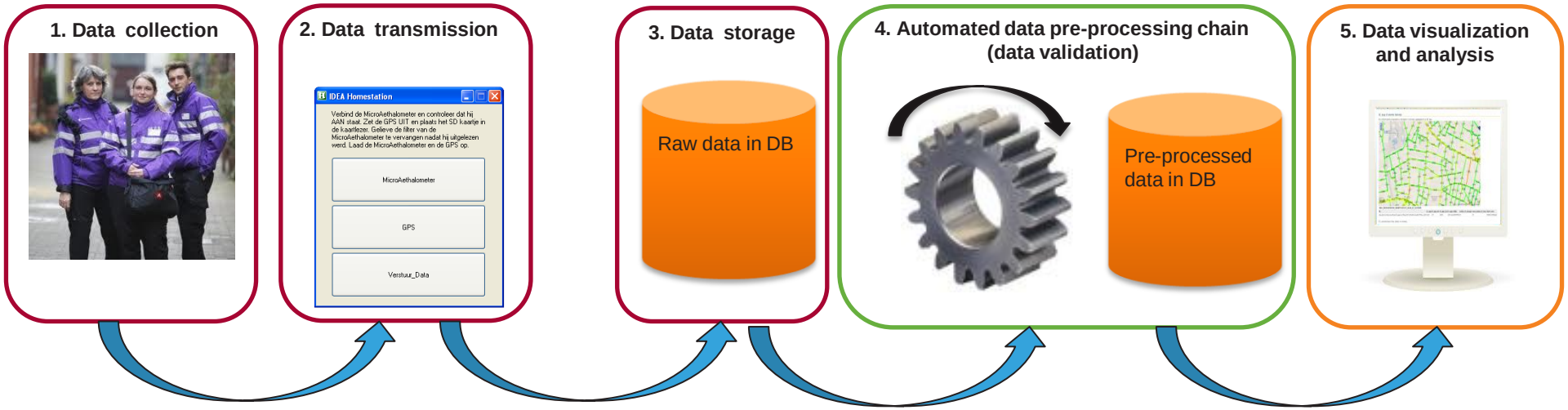


Case 1: mobile monitoring

- Research questions: mapping of the air quality in urban micro-environment
- Sensors: Aeroflex VITO
- Methods: mobile monitoring in limited number of streets
- Participation: no citizen participation
- Conclusion:
  - Feasibility of mapping at high (temporal) and spatial resolution
  - Effects of traffic dynamics, street morphology, distance to traffic
  - Suitable for individual exposure monitoring, strong effect of peak concentrations at cross-roads and in tunnels
- Challenges:
  - Methodological issues setting up mobile monitoring campaigns
  - Data coverage in space and time
  - Data validation

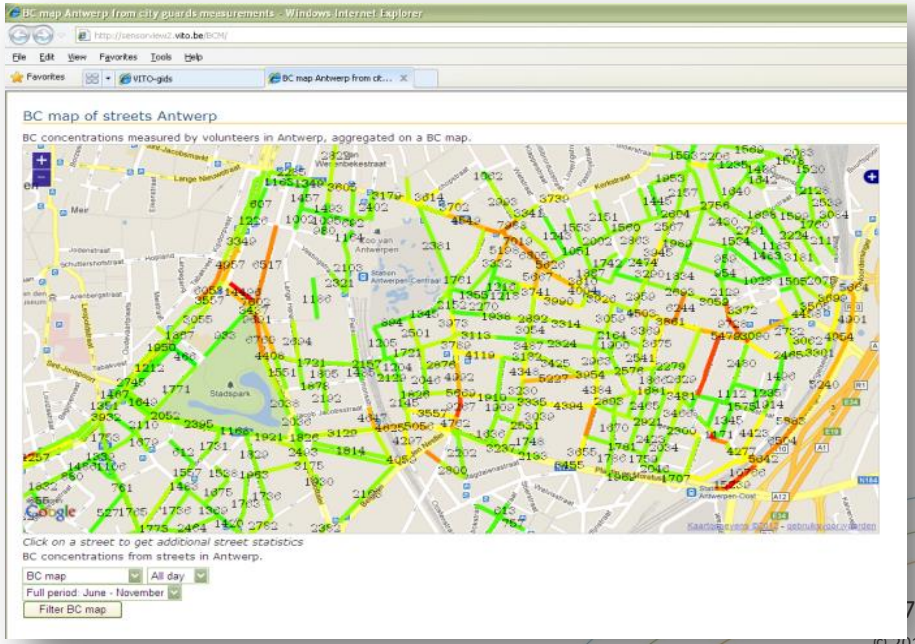
Case 2: City Guards

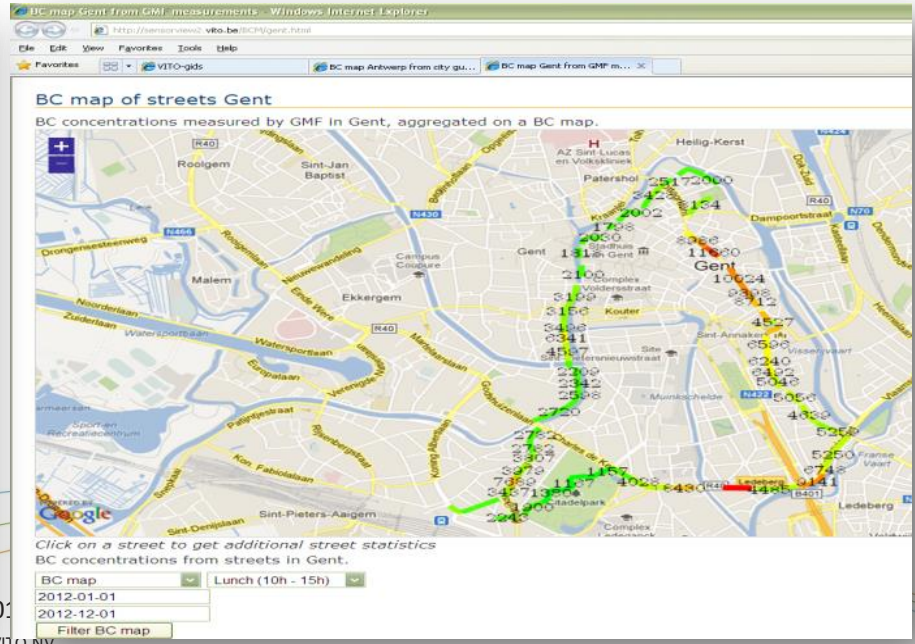
- Research question: mapping of black carbon in urban environment by city personnel
- Sensors: black carbon mapper



Case 2: City Guards

- Research question: mapping of black carbon in urban environment by city personnel
- Sensors: black carbon mapper
- Methods: mobile monitoring (opportunistic – targetted)
- Participation: city authority, interest group
- Results:



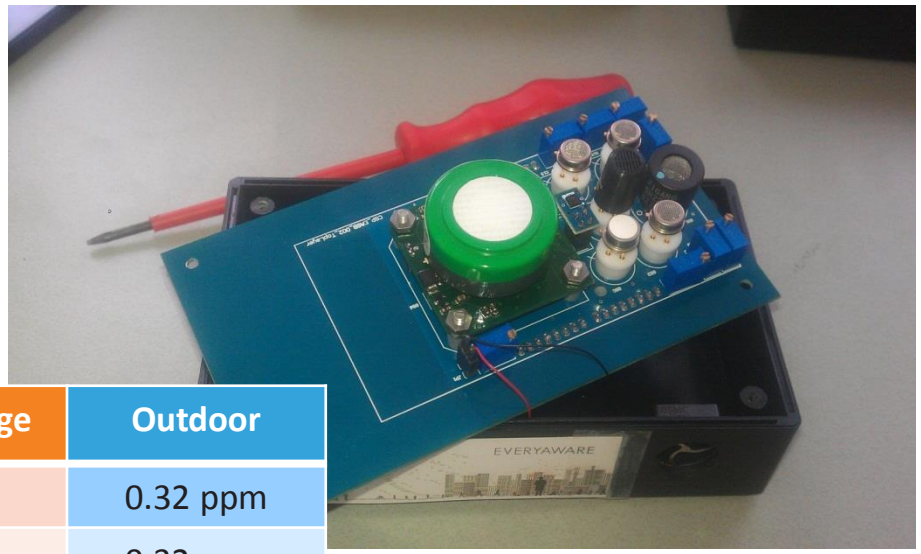


Case 2: City Guards

- Research question: mapping of black carbon in urban environment by city personnel
- Sensors: black carbon mapper
- Methods: mobile monitoring (oportunistic – targetted)
- Participation: city authority, interest group
- Results
- Conclusion:
- The Black Carbon Mapper allows to map the BC exposure of pedestrians and bikers in urban environments on the street level at a feasible cost by cooperating with city personnel and volunteers.

Case 3: EveryAware

- Research questions: Air quality monitoring by citizens
- Sensors:
- Hardware sensor box
  - Commercially available sensors
  - 8 gas sensors
  - Specifications and tests:

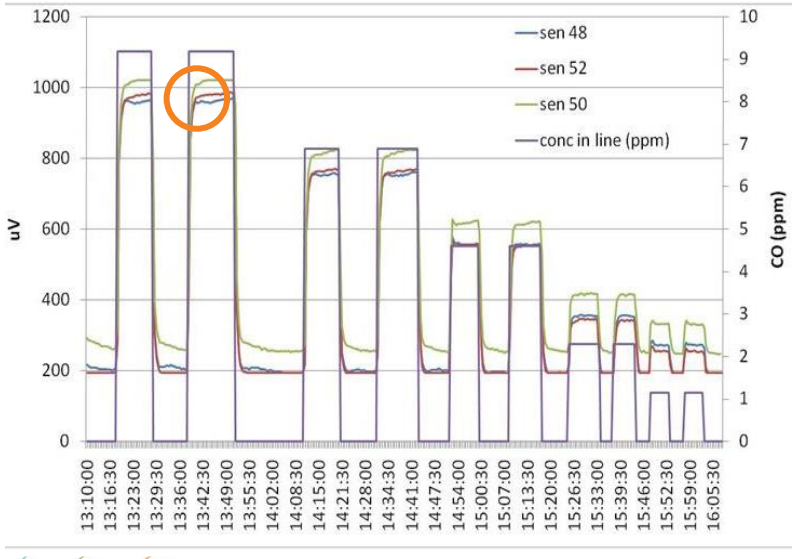


	Parameter	Dynamic range	Outdoor
Alphasense CO-BF	CO		0.32 ppm
e2v MiCS-5521	CO	1 – 1000 ppm	0.32 ppm
e2v MiCS-5525	CO	1 – 1000 ppm	0.32 ppm
Figaro TGS 2201 (dual)	CO NOx	10 – 1000 ppm 0.1 – 10 ppm	0.32 ppm 30 ppb
e2v MiCS-2710	NO2	0.05 – 5 ppm	30 ppb
e2v MiCS-2610	O3	10 – 1000 ppb	0 - 70 ppb
Applied Sensors AS-MLV	VOC		

Case 3: EveryAware

- Sensors:
- Hardware
  - Commercially available sensors
  - 8 gas sensors
  - Specifications and tests:
    - At lower end of the sensor measurement range
    - Response times: minute(s)

from laboratory tests



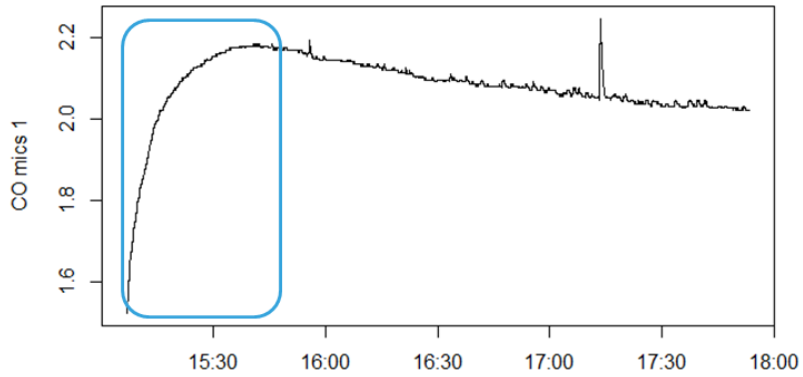
Case 3: EveryAware

- Sensors:
- Hardware
  - Commercially available sensors
  - 8 gas sensors
  - Specifications and tests:
    - At lower end of the sensor measurement range
    - Response times: minute(s)
    - Sensitivity from outdoor tests at traffic location: moderate

	Reference monitors				
Sensors	CO	NO	NO_2	O_3	BC
Alphasense CO-BF	0.52 (0.16)	0.41 (0.11)	0.34 (0.11)	-0.32 (0.14)	0.35 (0.13)
e2v MiCS-5521 CO	0.31 (0.04)	0.32 (0.04)	0.34 (0.04)	-0.09 (0.11)	0.41 (0.02)
e2v MiCS-5525 CO	0.60 (0.02)	0.51 (0.05)	0.56 (0.05)	-0.71 (0.05)	0.55 (0.06)
Figaro TGS 2201 CO	0.25 (0.02)	0.32 (0.01)	0.17 (0.00)	-0.48 (0.01)	0.38 (0.01)
Figaro TGS 2201 NOx	-0.78 (0.01)	-0.40 (0.06)	-0.24 (0.05)	0.47 (0.05)	-0.47 (0.06)
e2v MiCS-2710 NO_2	-0.58 (0.02)	-0.40 (0.06)	-0.31 (0.08)	0.64 (0.07)	-0.49 (0.06)
e2v MiCS-2610 O_3	-0.67 (0.06)	-0.56 (0.02)	-0.55 (0.05)	0.83 (0.07)	-0.62 (0.03)
Applied Sensors AS-MLV VOC	0.63 (0.02)	0.43 (0.17)	0.53 (0.15)	-0.44 (0.26)	0.45 (0.19)

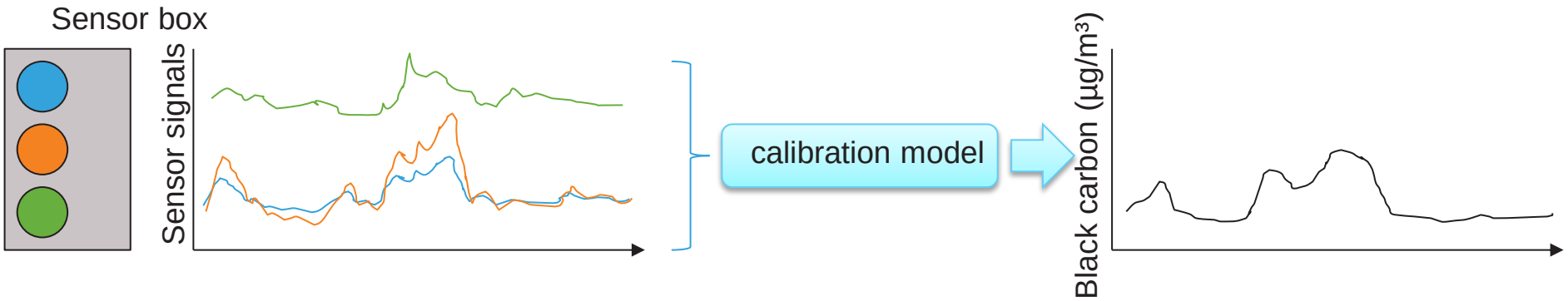
Case 3: EveryAware

- Sensors:
- Hardware
  - Commercially available sensors
  - 8 gas sensors
  - Specifications and tests:
    - At lower end of the sensor measurement range
    - Response times: minute(s)
    - Sensitivity at traffic location: moderate
    - I



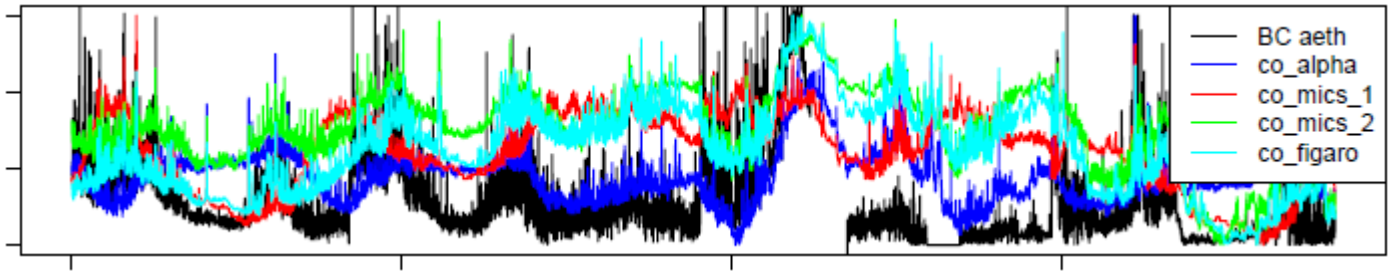
Case 3: EveryAware

- Single sensor response is meaningless (absolute values)
- Sensor response has to be “translated” into air parameter concentration
- “translation process” by calibration procedure
  - Not for single sensors
  - For sensor array (e-nose) (complex mixture) → integrated target



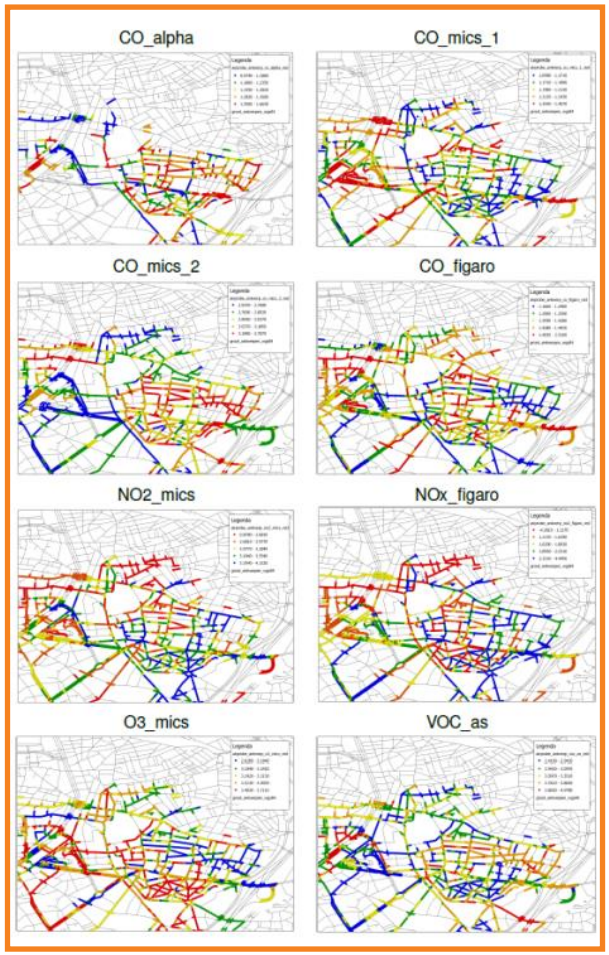
Case 3: EveryAware

- Sensor box calibration :
  - model relationship between output of the sensor array and a pollutant concentration ⇨ black carbon (BC)



  - Stationary and mobile measurements for two weeks with sensor boxes and reference BC instrument
  - ANN model on rescaled data (“city specific”)
- Calibration model:
  - Good performance on stationary data (cross-validation) – $R^2 > 0.8$
  - Lower performance on mobile data (fully independent validation) $R^2 < 0.4$

Case 3: EveryAware



calibration model

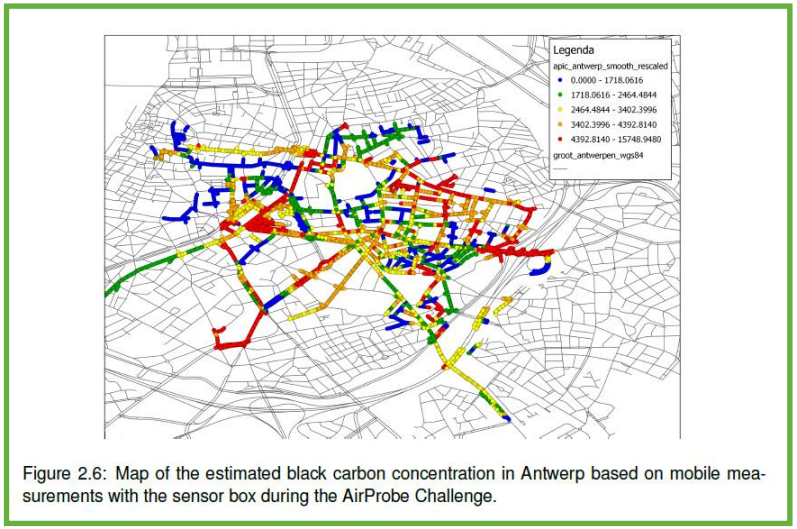
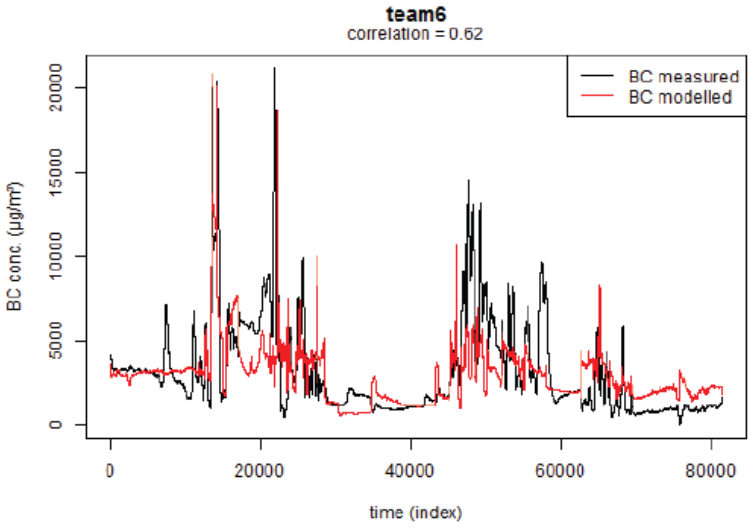
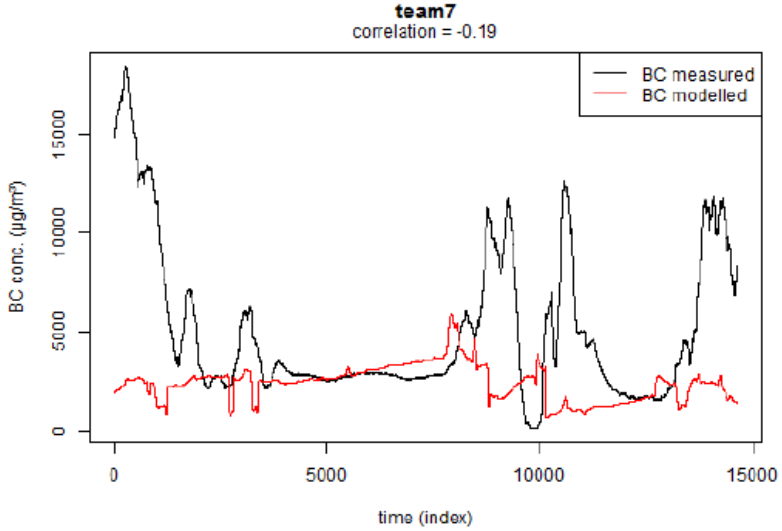


Figure 2.6: Map of the estimated black carbon concentration in Antwerp based on mobile measurements with the sensor box during the AirProbe Challenge.

Case 3: EveryAware

- Calibration model:
  - Good performance on stationary data (cross-validation) – $R^2 > 0.8$
  - Lower performance on mobile data (fully independent validation) $R^2 < 0.4$





- Build-up of uncertainty: sensors in dynamic urban environment, mobile application, calibration model

Case 3: EveryAware

- Methods: mobile measurements with sensor box
  - Repeated measurements !
- Participation:
- Moderate scale (20 sensor boxes per city) – duration of 2 weeks
- Demanding for volunteers:
  - Sensor requirements: heating-up
  - Methodological requirements: repeated measurements in dynamic environment
  - Obtrusive system
  - Future prospects:
    - Sensor development: improved sensitivity, shorter response times, futher miniaturisation
    - Futher automatisation of the system, less obtrusive
  - 18 million measurements

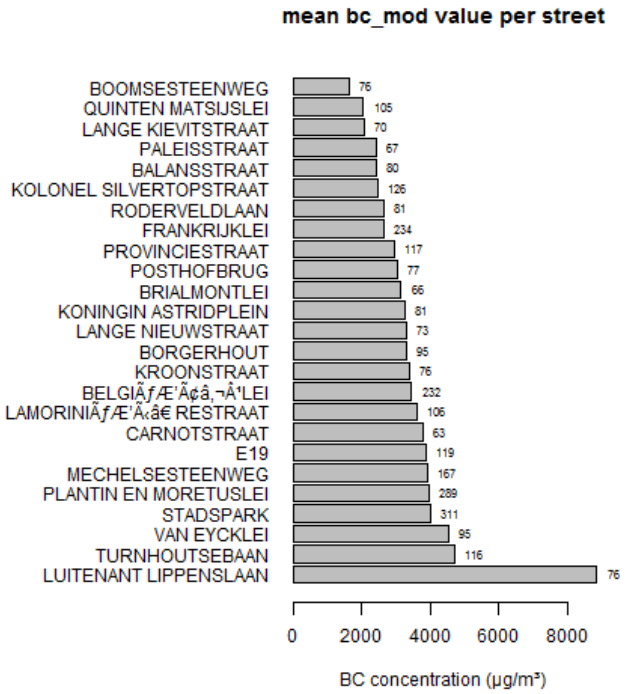
Results

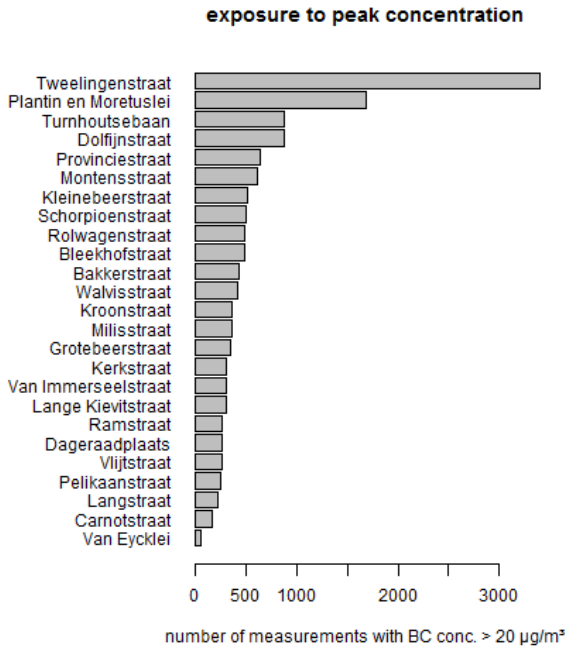
- Data interpretation:
  - Personal data: personal exposure tracking
  - Aggregated data: aggregation of data over all the participants

Personal exposure	Data aggregation
personal statistics on website	Overview stats and maps on website
one sensor box	several sensor boxes
small data sets	large data sets
personal interpretation (events?)	smoothing of events
personal interest	broader community

Results

- Data interpretation:
- Critical steps for data interpretation
  - Data validation
  - Mapping of data points:
    - Map to streets based on closest distance
    - Link street information to air quality measurements

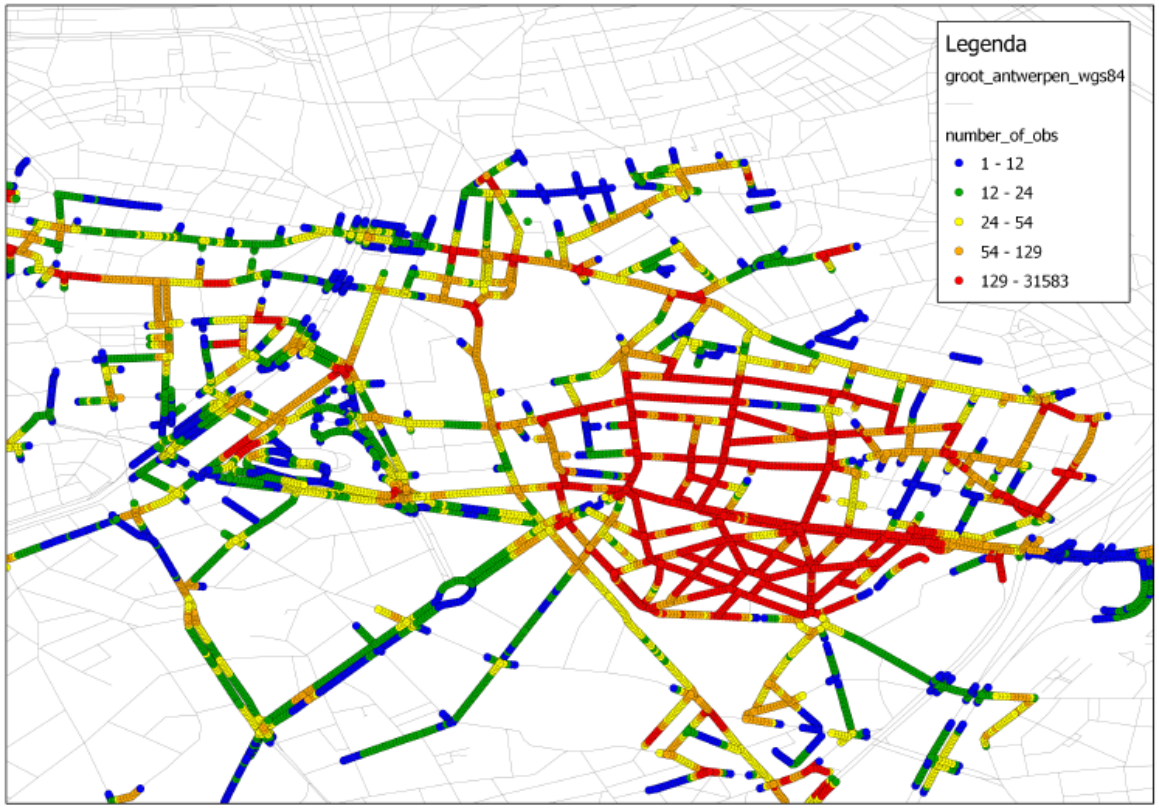




Results

- Data interpretation:
- Critical steps for data interpretation
  - Data validation
  - Mapping of data points
  - Aggregation of data:
    - Integration in time (and space)
    - Smoothing with Gaussian kernel
    - To fixed points (10/20 m distance within streets) - OSM

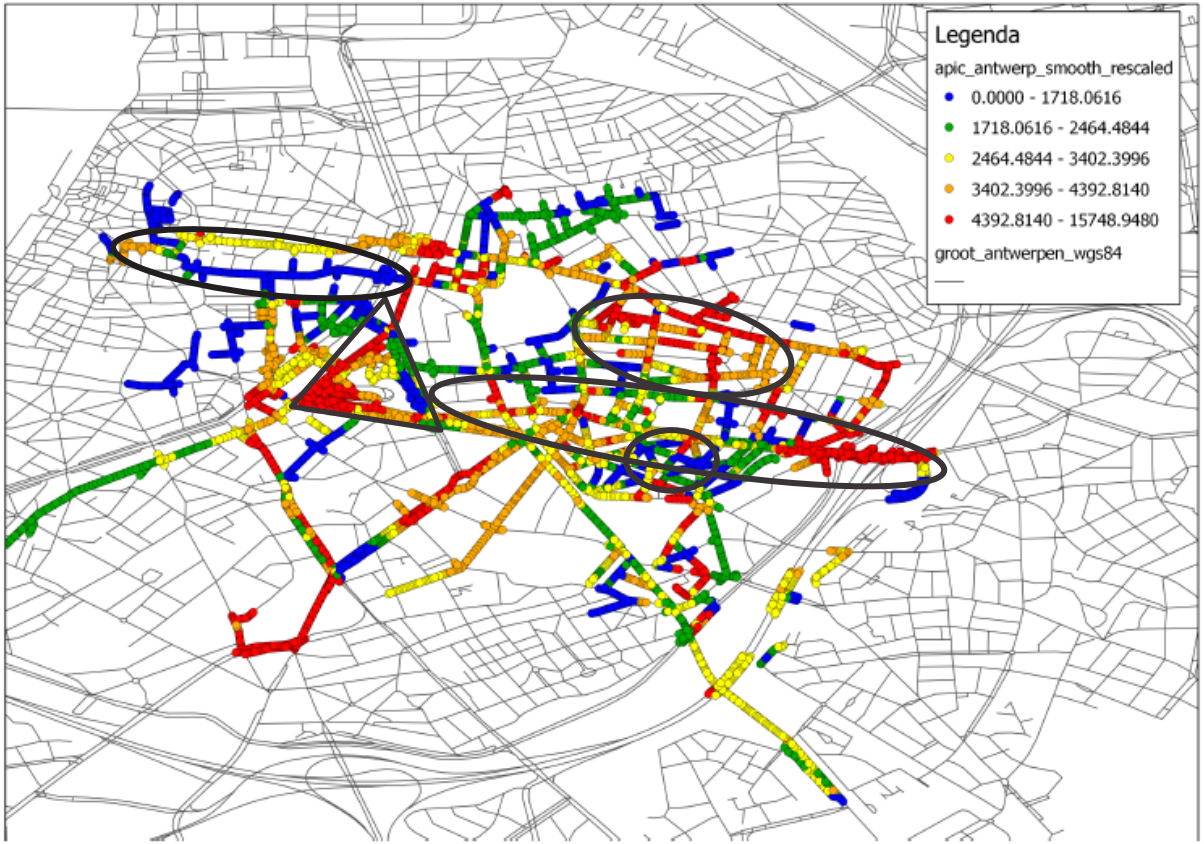
Results



Number of measurements

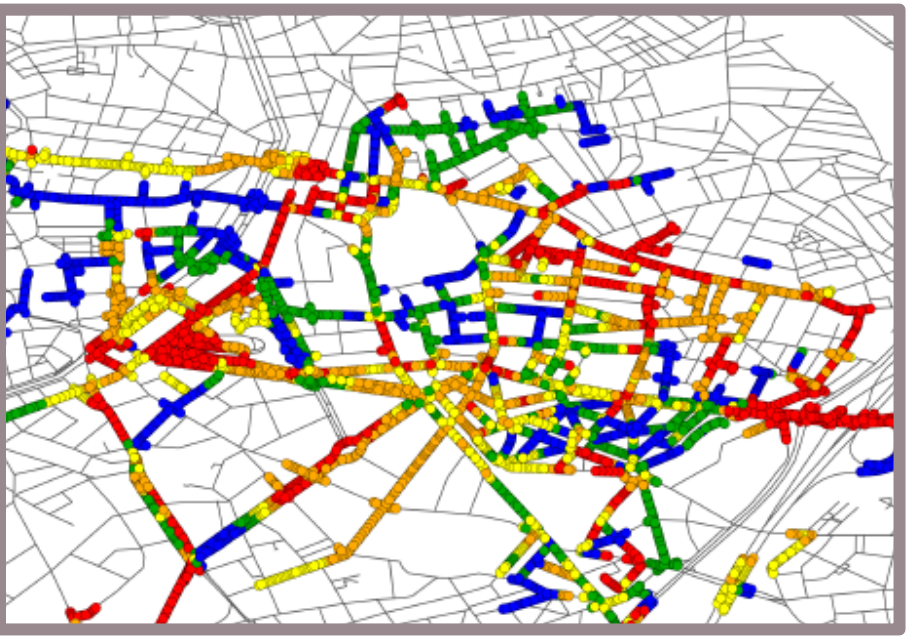
- 20% less than 14 repetitions
- 20% more than 130 repetitions

Results



Black carbon map of Antwerp

Results



Sensor box

Portable 'reference' instrument

\+ : reasonable agreement between streets/squares (relative)
agreement substantially higher than with maps of sensor values

\- : disagreement at urban green
within street variability lower

vito
vision on technology

Conclusions

- Participatory monitoring of a highly dynamic urban environment
  - Our answers to major challenges:
    - Sensor box calibration
      - Sensor array (not just one sensor)
      - Smart combination of sensor responses
      - One target variable of general interest
    - Data collection methods
      - Respect sensor heating-up period
      - Repeated measurements in space and time
    - Data validation (data quality control)
  - Possibilities to map at high resolution from participatory monitoring

References and acknowledgements

- Elen et. al., 2013. The Aeroflex: A Bicycle for Mobile Air Quality Measurements. Sensors 13(1), 221-240.
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- Van Poppel et. al., 2013. Methodology for setup and data processing of mobile air quality measurements to assess the spatial variability of concentrations in urban environments. Environmental Pollution 183, 224-238.
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SEVENTH FRAMEWORK PROGRAMME

cost
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

EuNetAir