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COST Action TD1105

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New Sensing Technologies for Air Quality Monitoring

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HIGH SPATIAL RESOLUTION AIR QUALITY MAPPING USING DATA FROM AN OPPORTUNISTIC MOBILE MONITORING CAMPAIGN

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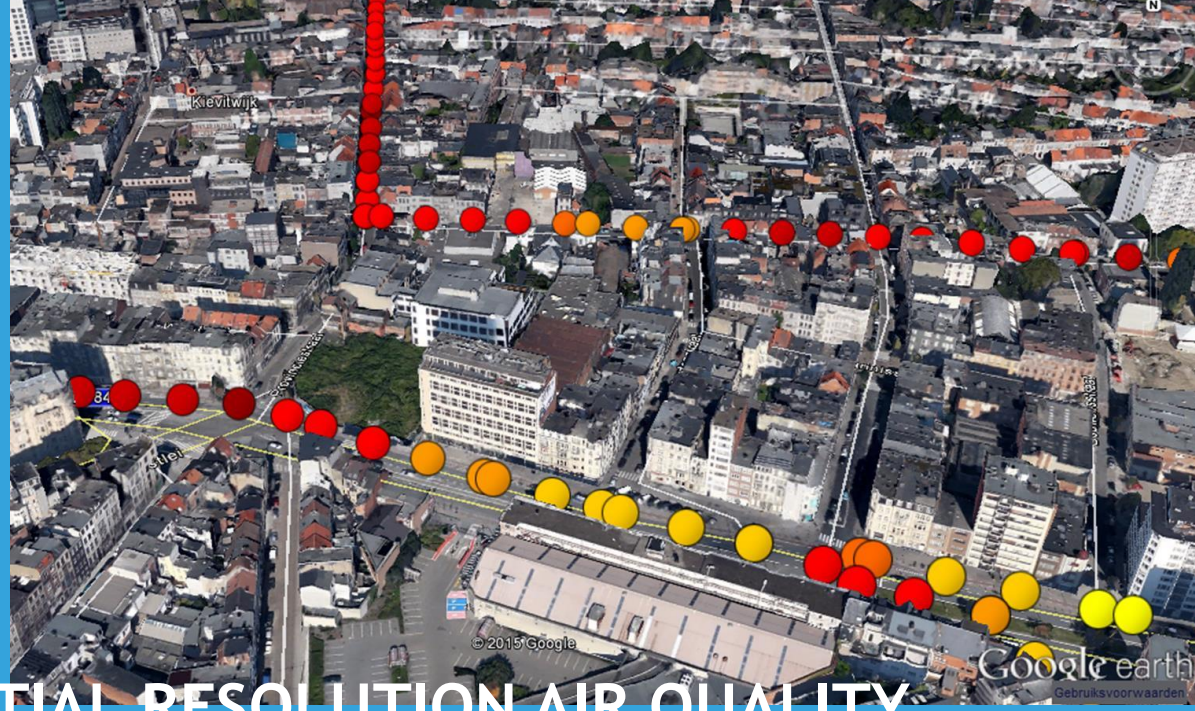

HIGH SPATIAL RESOLUTION AIR QUALITY MAPPING USING DATA FROM AN OPPORTUNISTIC MOBILE MONITORING CAMPAIGN

J. Van den Bossche[1, 2], B. Elen[1], J. Peters[1], D. Botteldooren[3], B. De Baets[2], J. Theunis[1]

J. Van den Bossche, "Towards high spatial resolution air quality mapping: a methodology to assess street-level exposure based on mobile monitoring", Ph.D Thesis, Ghent University, (2016)

MOBILE MONITORING STRATEGIES

Targeted and opportunistic mobile monitoring

- ***targeted mobile monitoring***
  - a coordinated, goal-driven approach in which the mobile measurements are deliberately planned and carried out along predefined tracks and at predefined times with a specific purpose in mind
  - high level of human interaction
  - repeated, controlled sampling

  - ***cycling***
  - ***walking***

Easy to use measurement device to collect mobile BC measurements in a 'cost-effective' way :

GPS and microAeth AE-51

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TARGETED MOBILE MONITORING

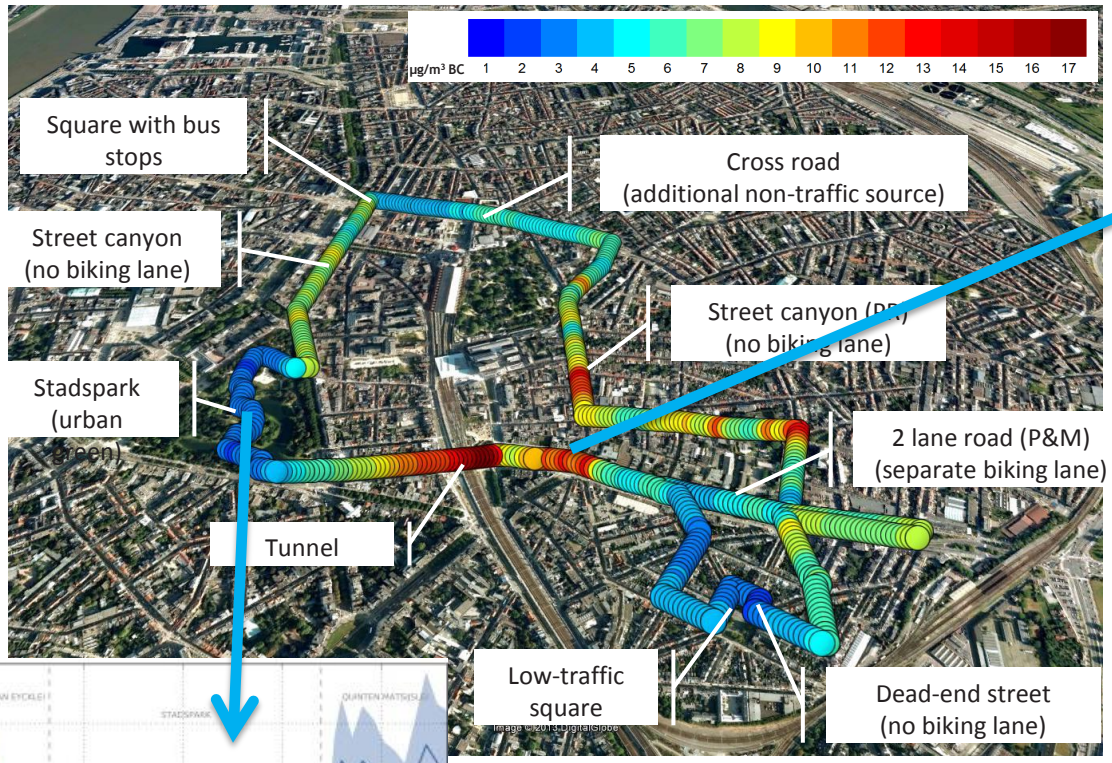
Case study in Antwerp

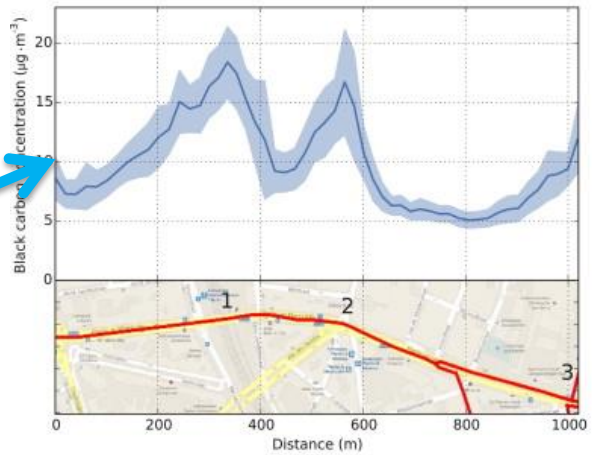
Contents lists available at ScienceDirect
Atmospheric Environment
journal homepage: www.elsevier.com/locate/atmosenv

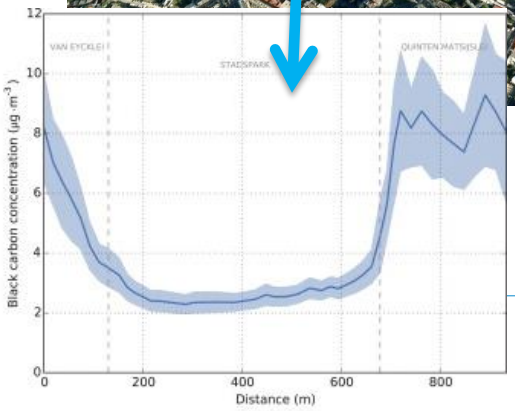
Cyclist exposure to UFP and BC on urban routes in Antwerp, Belgium

Jan Peters [a,*], Joris Van den Bossche [a,b], Matteo Reggente [a], Martine Van Poppel [a], Bernard De Baets [b], Jan Theunis [a]

[a] VITO – Flemish Institute for Technological Research, 2400 Mol, Belgium
[b] KERMIT, Dept. of Mathematical Modelling, Statistics and Bioinformatics, Faculty of Bioscience Engineering, Ghent University, 9000 Ghent, Belgium







- large gradients over short distances, differences up to a factor of 10 in BC concentrations
- mobile monitoring suitable for mapping urban air quality at a high spatial resolution.

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TARGETED MOBILE MONITORING

Method development and validation

Contents lists available at ScienceDirect

Atmospheric Environment

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

Mobile monitoring for mapping spatial variation in urban air quality: Development and validation of a methodology based on an extensive dataset

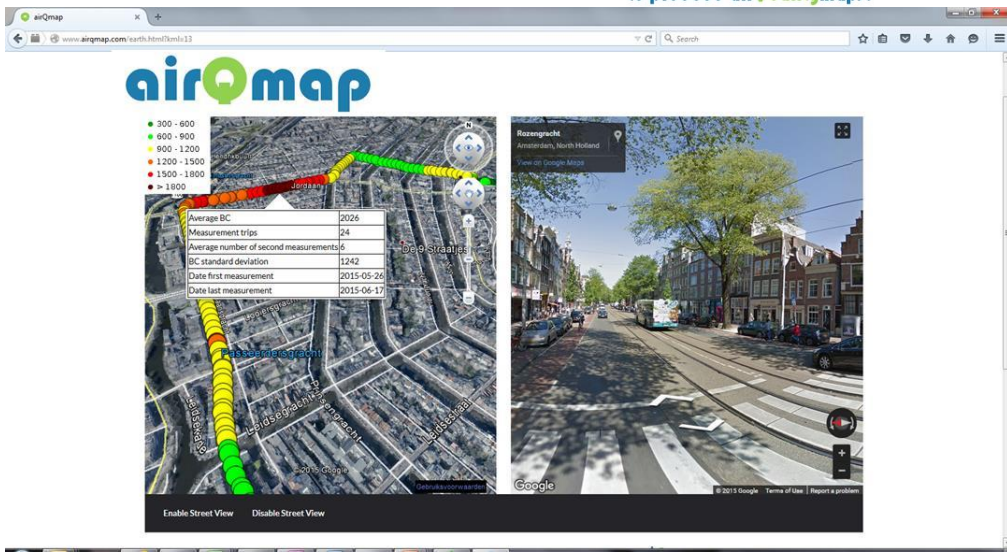
Joris Van den Bossche [a, b, *], Jan Peters [a], Jan Verwaeren [b], Dick Botteldooren [c], Jan Theunis [a], Bernard De Baets [b]

- data processing to increase representativity
  - using trimmed mean to deal with extreme events
  - background normalisation
- About 40 repeated measurement runs to map the BC concentrations at 50 m resolution with 25% uncertainty
- About 10 repeated measurement runs for 50 % uncertainty

airqmap

do-it-yourself airQualitymapping

a powerful platform
for people without air quality expertise
to produce airQualitymaps.



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MOBILE MONITORING STRATEGIES

Targeted and opportunistic mobile monitoring

- *targeted mobile monitoring*
  - a coordinated, goal-driven approach in which the mobile measurements are deliberately planned and carried out along predefined tracks and at predefined times with a specific purpose in mind
  - high level of human interaction
  - repeated, controlled sampling

- ***opportunistic mobile monitoring***
  - data collection making use of existing carriers to move measurement devices around
    - public transport, commuters, postmen, taxi drivers, parking wardens, …
  - differing degree of human interaction
  - repeated structure (same routes, same time frame) versus unstructured
  - no control over the specific location and time of the measurements → BIAS !

Contents lists available at ScienceDirect
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OPPORTUNISTIC MOBILE MONITORING

City wardens in Antwerp

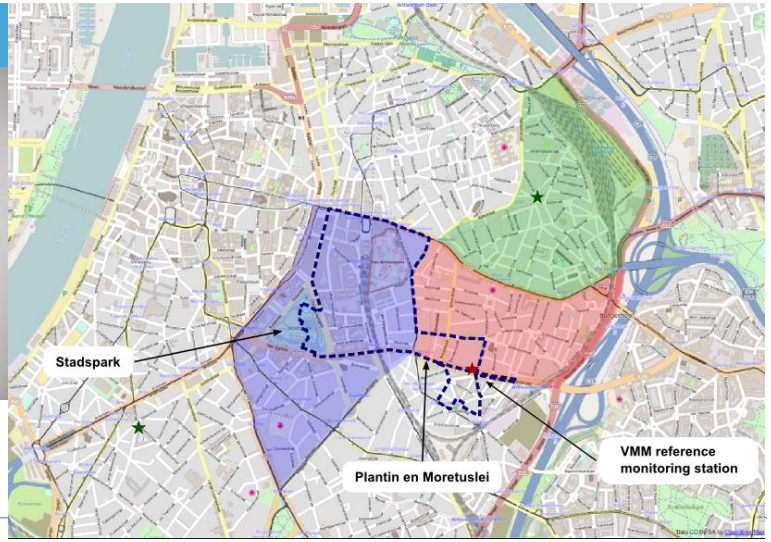
Opportunistic mobile air pollution monitoring: A case study with city wardens in Antwerp

Joris Van den Bossche [a, b, *], Jan Theunis [a], Bart Elen [a], Jan Peters [a], Dick Botteldooren [c], Bernard De Baets [b]

[a] VITO – Flemish Institute for Technological Research, 2400 Mol, Belgium
[b] KERMIT, Dept. of Mathematical Modelling, Statistics and Bioinformatics, Faculty of Bioscience Engineering, Ghent University, 9000 Ghent, Belgium
[c] INTEC, Dept. of Information Technology, Faculty of Engineering and Architecture, Ghent University, 9000 Ghent, Belgium

- Case study with city wardens in Antwerp, Belgium,
  during a one-year period (from July 2012 until June 2013)
  - unstructured → data collection is unevenly spread in space and/or time
  - 393 hours of raw 1 second second measurements (459 hours of measurements before filtering for GPS quality) spread over 110 days
  - Most of the measurements were done between 10 am and 16 pm during working days.
- Data analysis:
  - spatial aggregation (50 m segments), trimmed mean, background normalization

3 teams of 'City Guards' measuring air quality during one year



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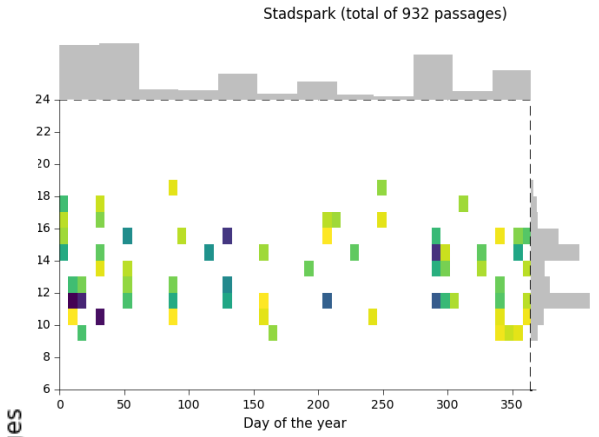
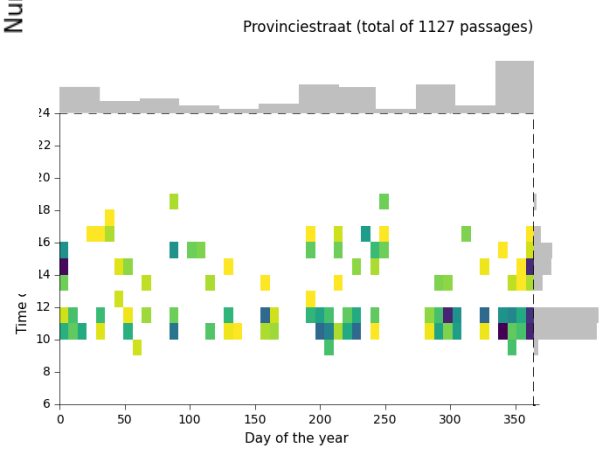
OPPORTUNISTIC MOBILE MONITORING : ANTWERP CITY WARDENS

Sampling bias





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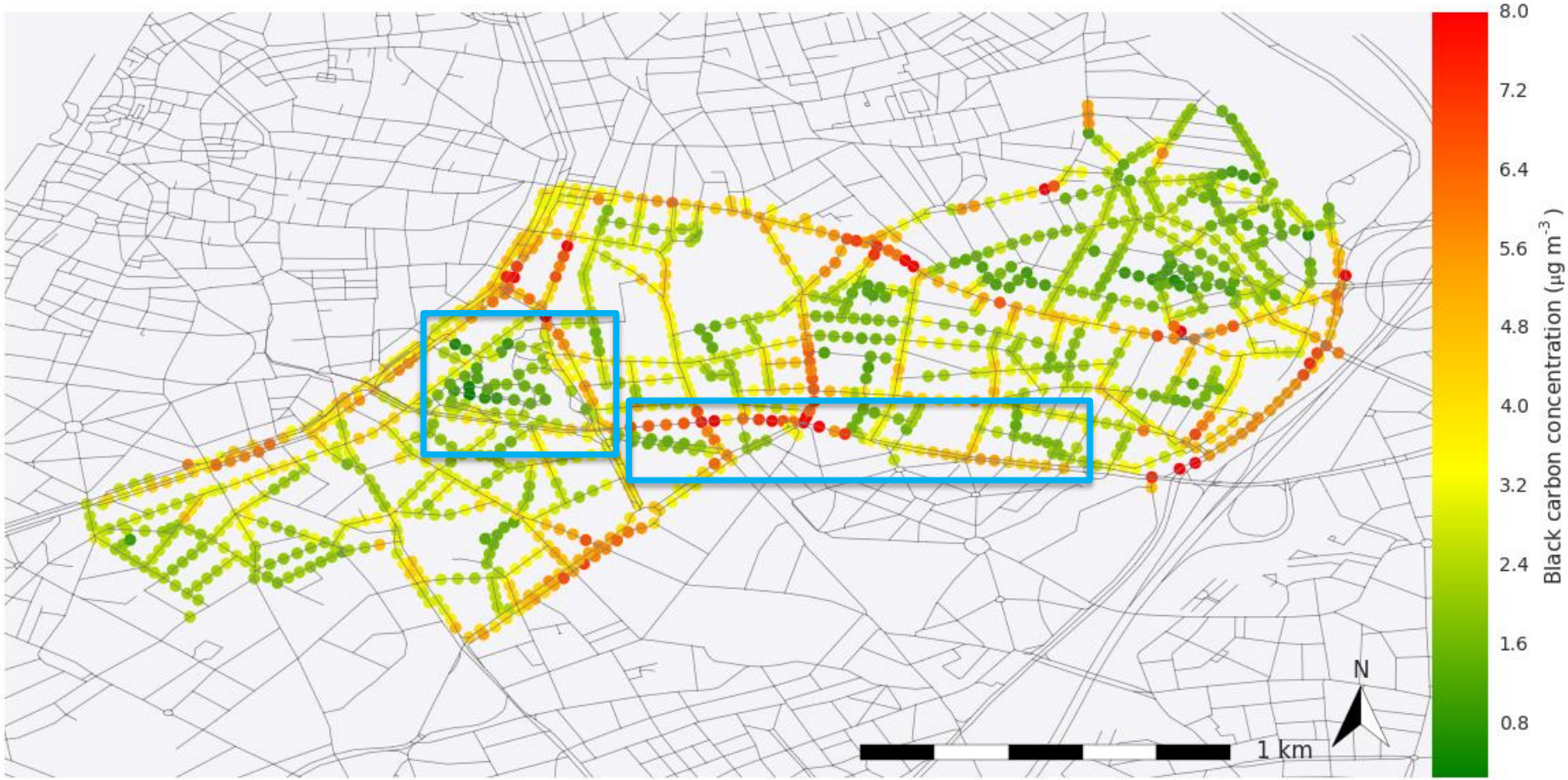
OPPORTUNISTIC MOBILE MONITORING : ANTWERP CITY WARDENS

Results



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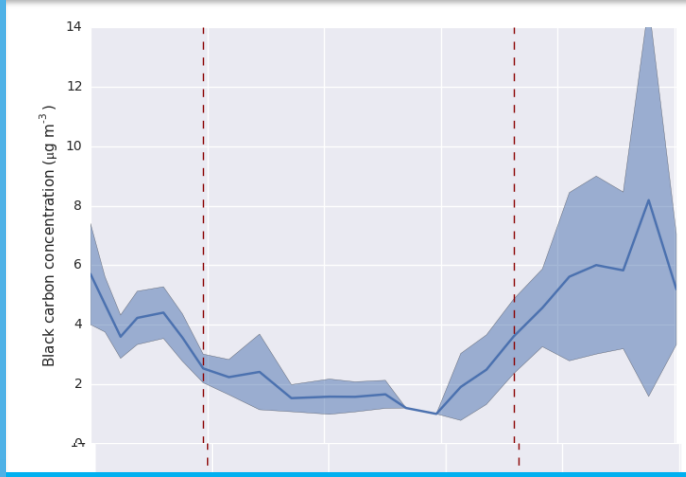
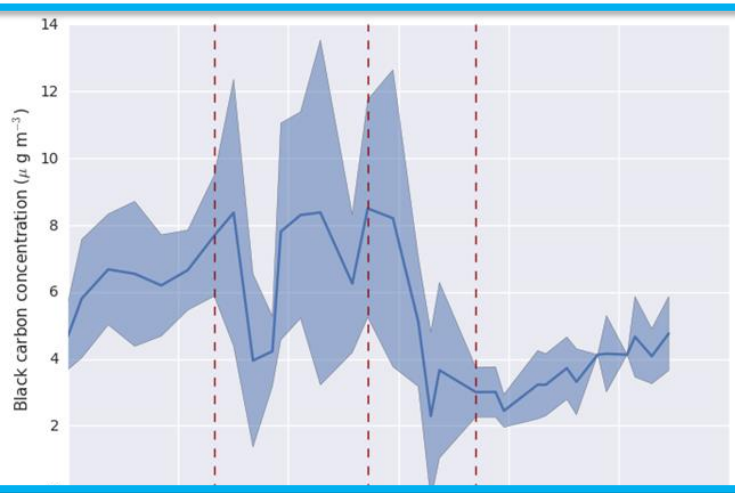
OPPORTUNISTIC MOBILE MONITORING : ANTWERP CITY WARDENS

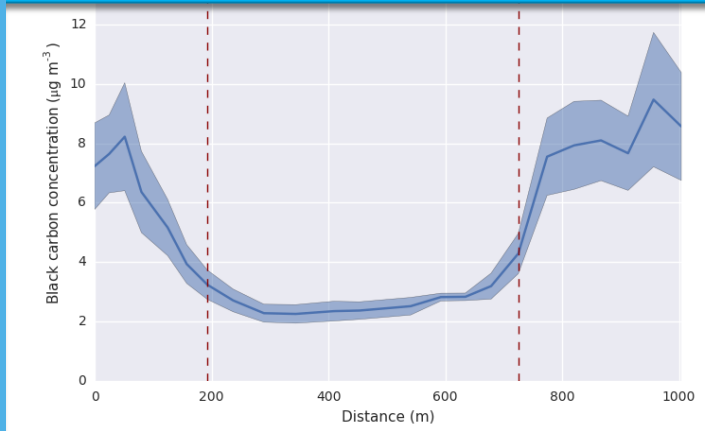
Results

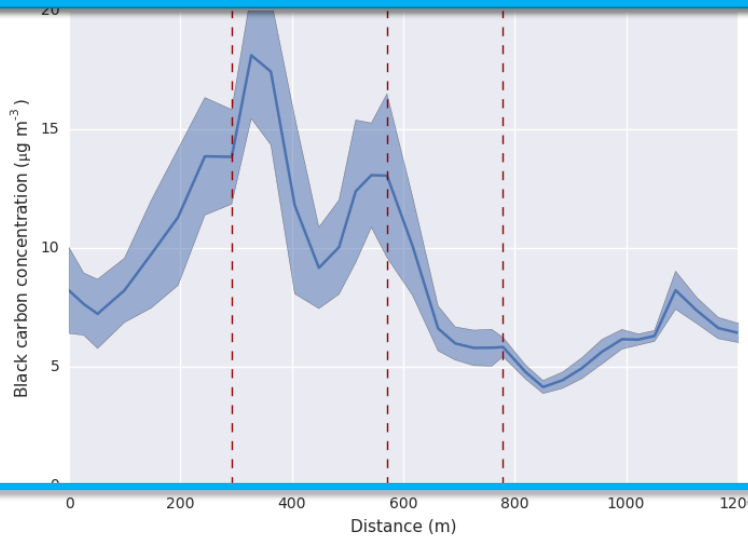
CITY WARDENS





TARGETED MONITORING





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OPPORTUNISTIC MOBILE MONITORING : ANTWERP CITY WARDENS

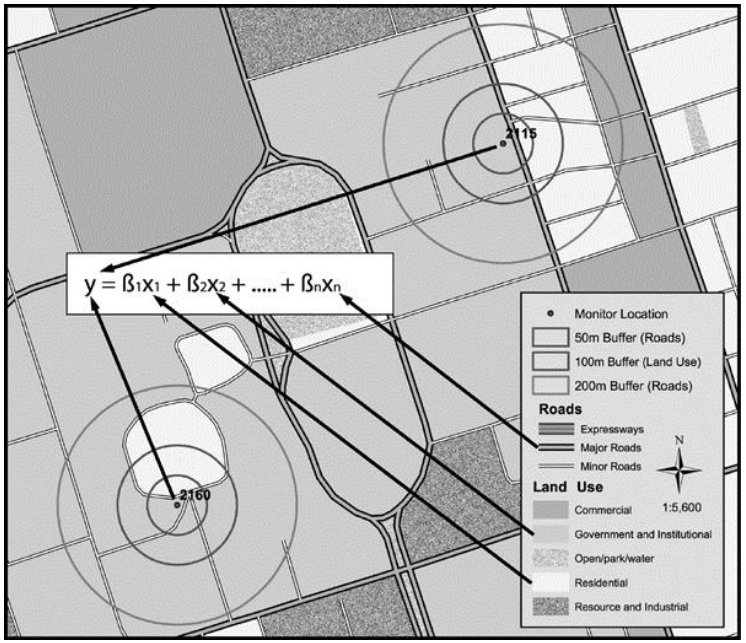
Conclusions

- high spatial coverage in the selected area
- unstructured data collection both in space and time →
  - sampling bias
  - temporal adjustment can partly counteract this bias, but will not fully correct uncertainty associated with temporal variation
- large spatial patterns within the city are clearly captured - identify broad spatial trends and hotspots
- rather large uncertainty at individual locations (50m segments)
- Need for :
  - sufficient data needed to cover both spatial and temporal variability
  - repeated measurements
  - careful processing and interpretation of the results

- *promising approach to monitor urban air quality at a high spatial resolution*
- *potential for participatory monitoring and crowdsourcing approaches based on opportunistic monitoring.*

DEVELOPMENT OF A LUR MODEL BASED ON MOBILE MEASUREMENTS

Inputs and targets



- Predictor variables
  - Road types
  - Land use – land cover
  - Address locations
  - Traffic data (from traffic model)
  - Sky view factor
  - Biking lanes (distance to traffic lanes)
- Transformations
  - Inverse distance, squared inverse distance
  - Interactions (quadratic terms) :
    - traffic * inverse (squared) distance
    - Traffic * sky view factor
- Aggregated concentration level – 50 m segments as dependent variables

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DEVELOPMENT OF A LUR MODEL BASED ON MOBILE MEASUREMENTS

Model building and evaluation

- Linear regression - Support Vector Regression
- Predictor variable selection
  - No selection
  - "Classic" – supervised stepward forward selection
  - LASSO : regularised linear model estimating sparse coefficients
  - Optimal CV : combined forward and backward selection; optimising cross-validation R^2
  - Forward CV : stepwise forward selection based on cross-validation R^2
- Spatial cross-validation
  - For model building : Selecting predictor variables - Tuning hyperparameters
  - For model performance
    - Cross-validation (only parameter estimation)
    - Nested cross-validation (full model rebuilding)

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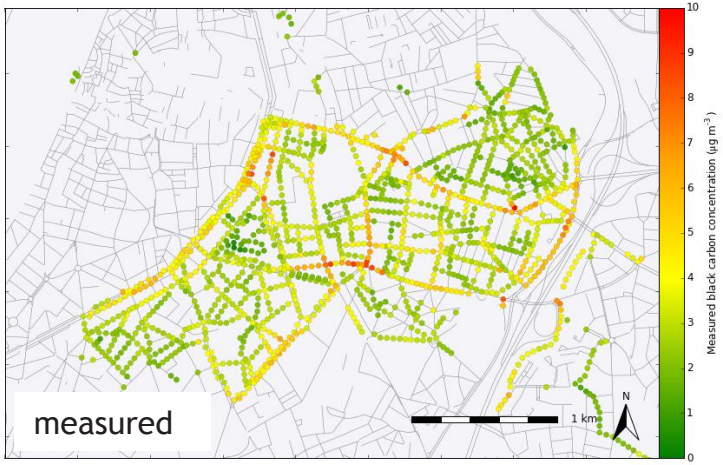
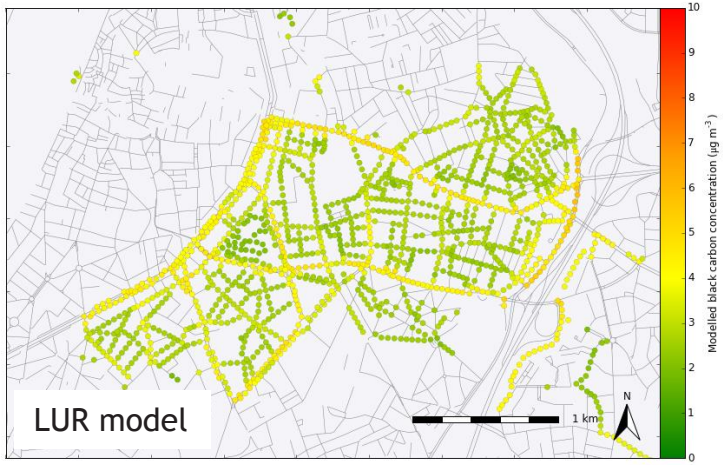
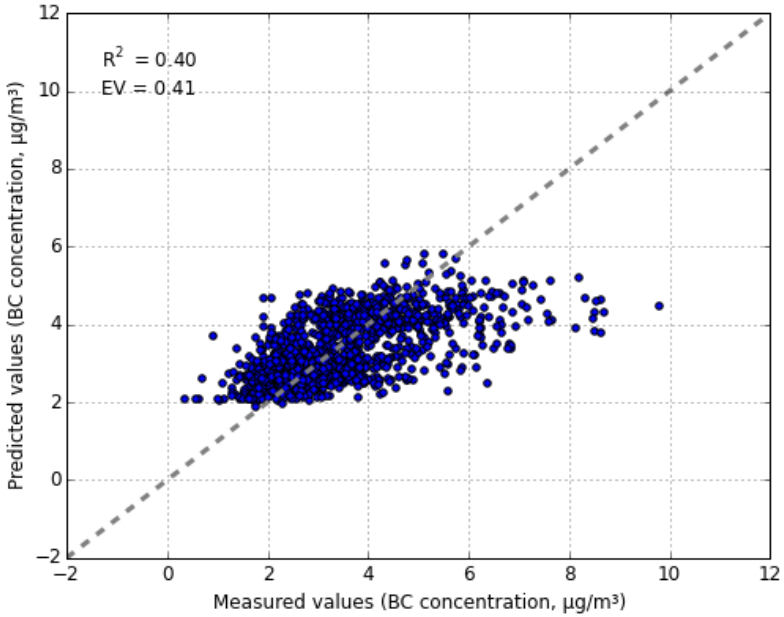
DEVELOPMENT OF A LUR MODEL BASED ON MOBILE MEASUREMENTS







overestimating low concentrations
underestimating high concentrations

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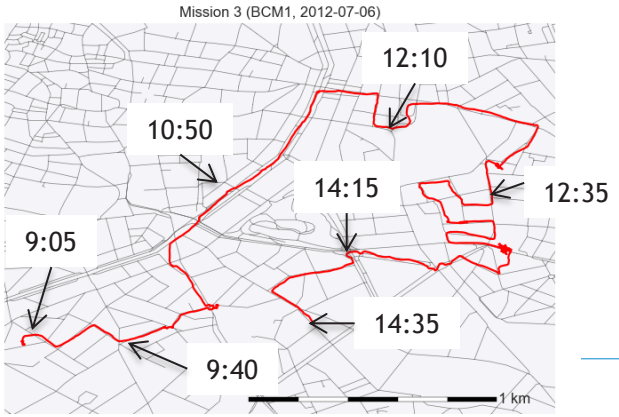
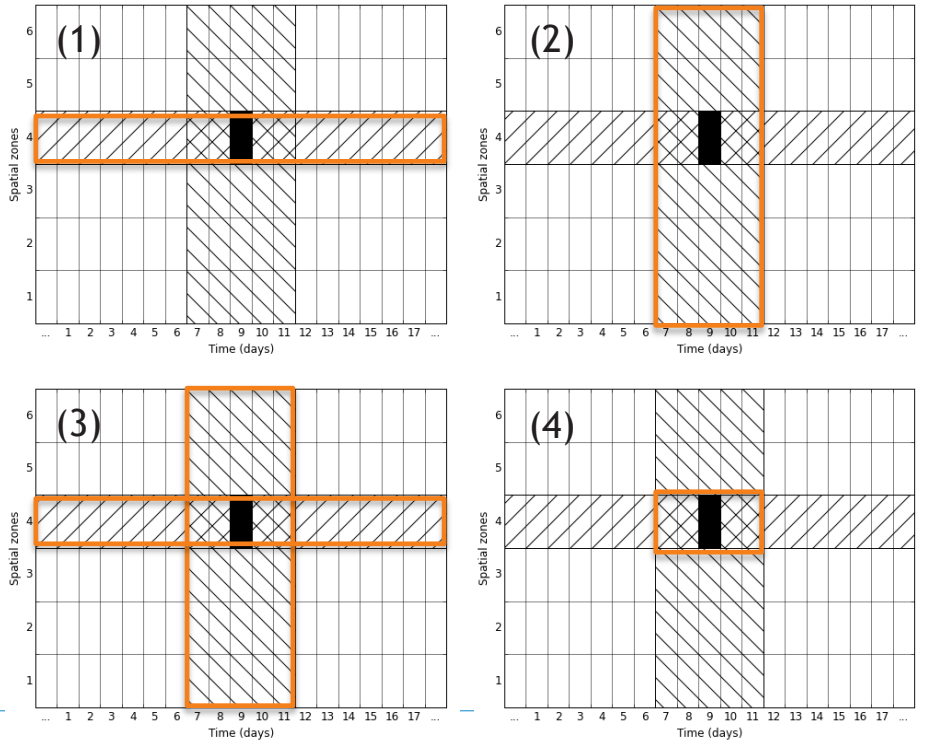
SPATIO-TEMPORAL LUR MODEL TO ASSESS STREET-LEVEL EXPOSURE

Inputs and targets

- Incorporating time-dependent predictor variable : concentrations measured at official central monitoring station (Flemish Environmental Agency)
- use hourly average BC concentrations as target to build model
- 30,099 hourly data points (x,y,t)
- Model validation
  - Spatial cross-validation (1)
  - Temporal cross-validation (2)
  - Spatio-temporal cross-validation (3)
  - Minimal cross-validation (4)
  - Validation using *trips*





SPATIO-TEMPORAL LUR MODEL TO ASSESS STREET-LEVEL EXPOSURE

Evaluation

- Evaluation 50 m segments at hourly level (spatio-temporal unit) : R^2 = 0,08 (EV 0,09)
- Evaluation on spatial level : R^2 = 0,29 (EV 0,34) (*predicted average concentration at specific location)* : comparable to spatial model
- Evaluation on temporal level : R^2 = 0,49 (EV 0,57) (*predicted average daily concentration)*
  - (without
- Evaluation on trip level : predicted average exposure during a trip based on GPS coordinates and spa

Table 11.1: Overview of the evaluation results based on the trips for the different methods and cross-validation schemes.

	R^2	EV	RMSE
Spatio-temporal LUR			
Minimal CV	0.72	0.75	0.9
Spatial CV	0.75	0.75	0.9
Temporal CV	0.58	0.61	1.1
Spatio-temporal CV	0.61	0.61	1.1

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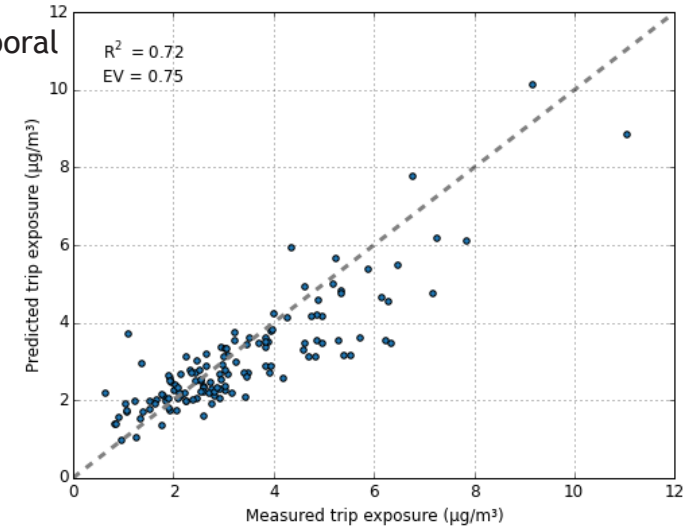
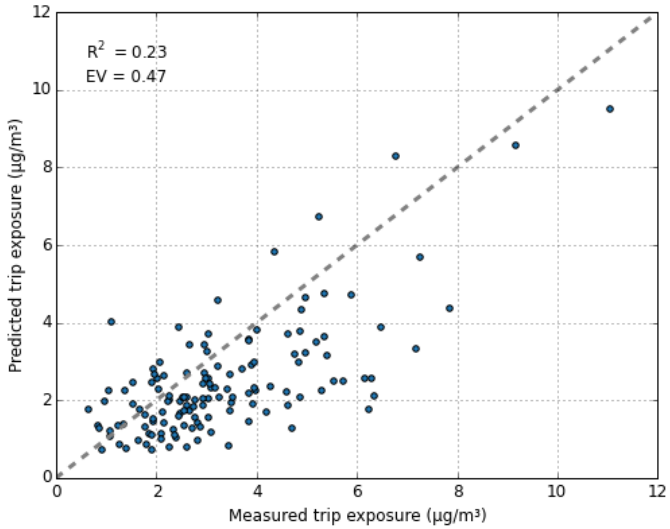
SPATIO-TEMPORAL LUR MODEL : TRIP EXPOSURE PREDICTION

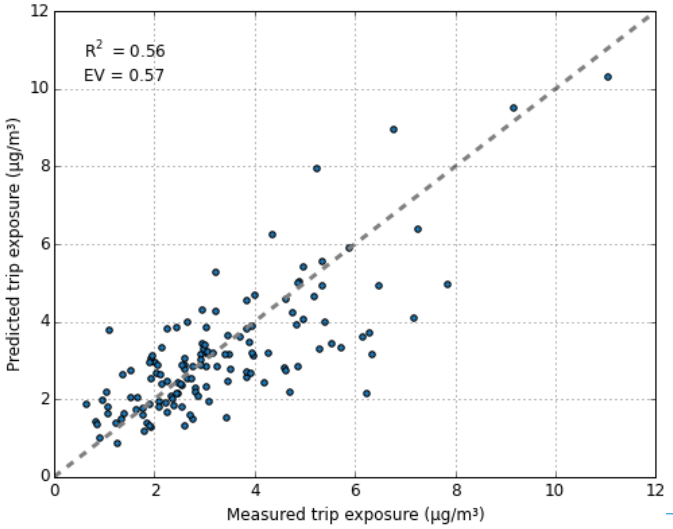
spatio-temporal LUR model



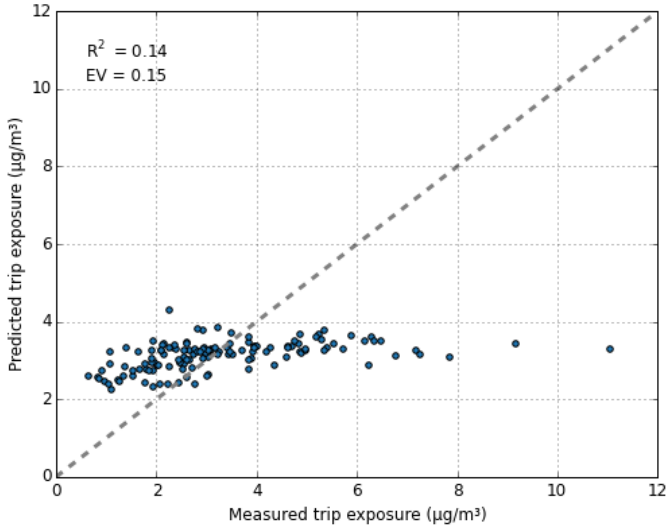
central monitoring station



temporally adjusted spatial LUR model



spatial LUR model



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STREET-LEVEL POLLUTION EXPOSURE MAPS USING DATA FROM AN OPPORTUNISTIC MOBILE MONITORING CAMPAIGN

Conclusions

- Data collected continuously in an unstructured way
- Spatial LUR model
  - Need for more data to improve performance
- Spatiotemporal model
  - Prediction model based on historical data + real-time information from central monitoring station
  - Exposure prediction based solely on GPS track
  - Better exposure prediction than spatial LUR model, temporally adjusted spatial LUR model or central monitoring station
  - Predictive abilities depending on data availabilty :
    - *better than* performance estimated by spatiotemporal cross-validation
    - differentiated map
- Continuously update and improve model based on new data

→ Proof of concept for real-time dynamic pollution map