The Potential of Mobile Monitoring Campaigns to Assess Long-Term Exposure to Ultrafine Particles

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Overview

- Role of mobile monitoring in assessing long-term average UFP exposure e.g. for epidemiological studies (spatial variation)
- Not other purposes

- Background (UFP, land use regression (LUR))
- Mobile monitoring campaigns
- Merits and limitations

Background UFP

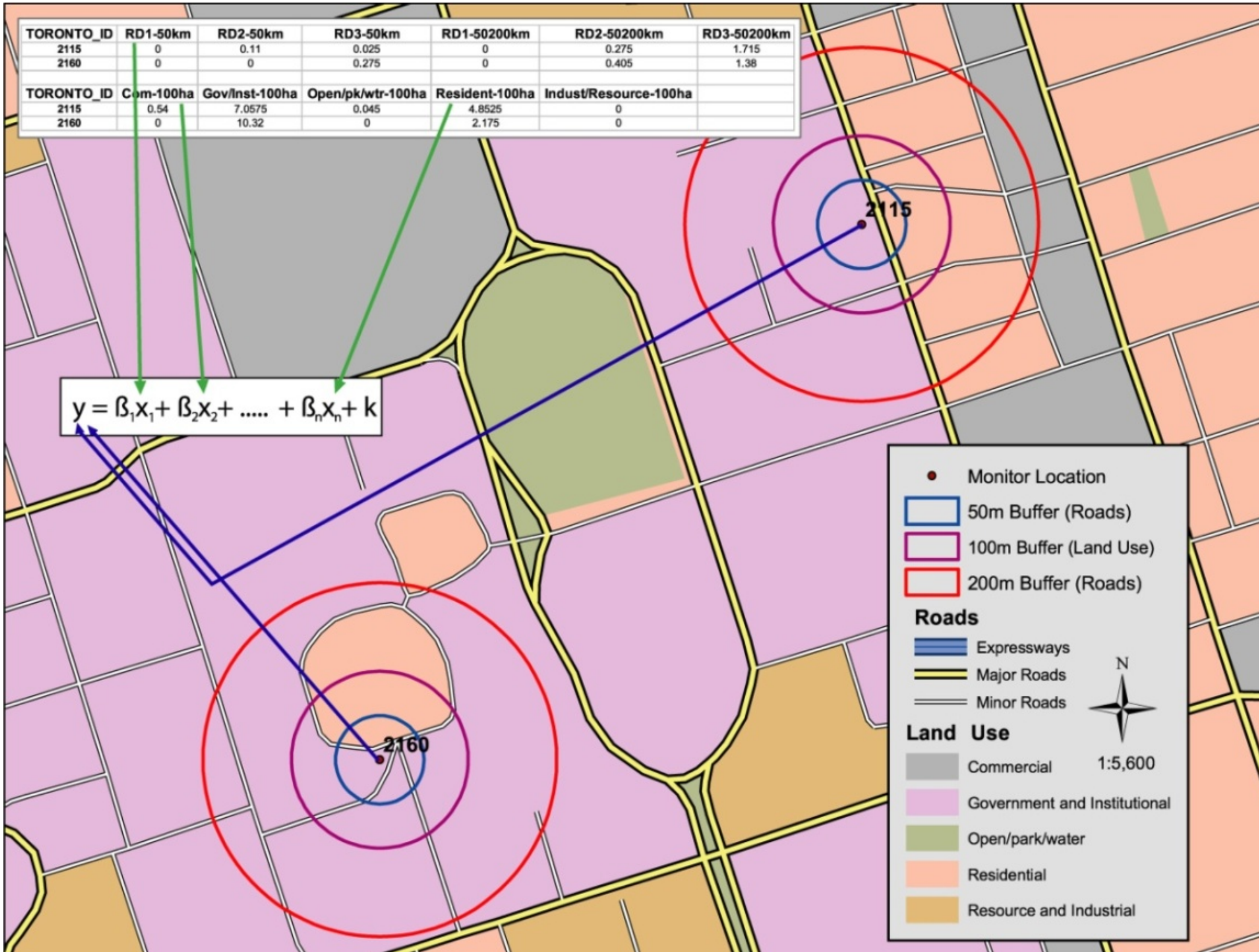
- HEI, 2013 UFP report
- Toxicology: potential health effect
- Epidemiology: somewhat inconsistent results
- No studies on long-term exposure effects
- Exposure assessment main reason
- Challenges of exposure assessment
  - Large small-scale spatial variation
  - Variety of (combustion) sources
  - Monitoring methods
- Only outdoor concentrations, no indoor sources

Assessment UFP spatial variation

- Limited routine monitoring
- Monitoring alone insufficient (large spatial variation versus resolution monitoring)
- Interpolation of measurements (kriging)
- Dispersion modelling (emission factors for UFP)
- Land use regression modelling

Land use regression

- Monitored concentrations at limited number of sites
- Predictor variables near the site (GIS), typically time-invariant
- Development of a (linear) regression model to predict the measured spatial variation



TORONTO_ID	RD1-50km	RD2-50km	RD3-50km	RD1-50200km	RD2-50200km	RD3-50200km
2115	0	0.11	0.025	0	0.275	1.715
2160	0	0	0.275	0	0.405	1.38

TORONTO_ID	Com-100ha	Gov/Inst-100ha	Open/pk/wtr-100ha	Resident-100ha	Indust/Resource-100ha
2115	0.54	7.0575	0.045	4.8525	0
2160	0	10.32	0	2.175	0

$$y = \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n + k$$

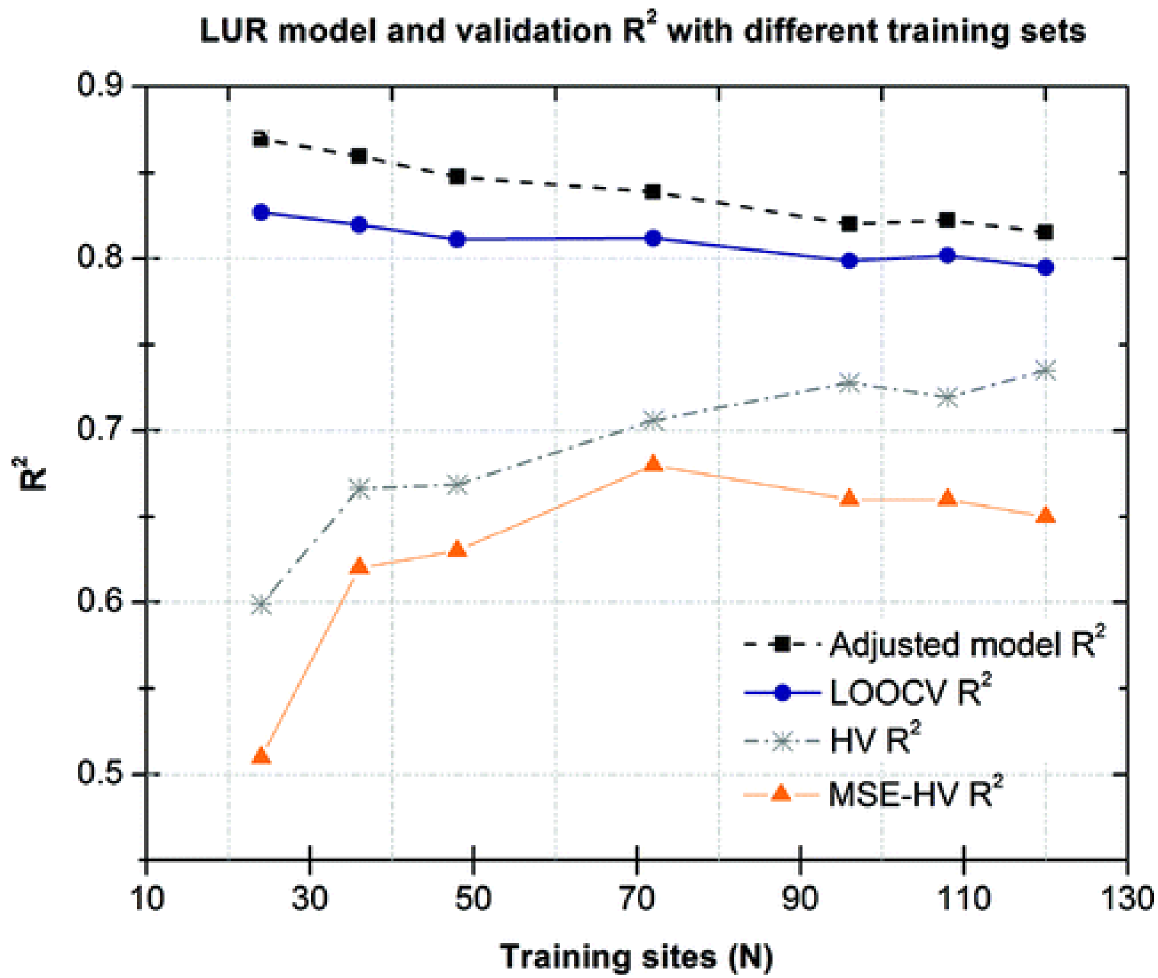
LUR Monitoring campaigns

- Monitoring campaigns for LUR modeling are typically based upon 1-3 repeats of 1-2 weeks duration at 40-100 sites
- All sites simultaneous for NO_2 (passive samplers)
- For PM groups of sites simultaneous (temporal issue)

LUR monitoring and UFP

- Typical approach not practical for UFP
  - Equipment cost
  - Equipment supervision
- -> Mobile campaigns with short supervised monitoring at many sites
- Other reasons for mobile monitoring:
  - Cost-effectiveness
  - Large number of sites improves robustness of models

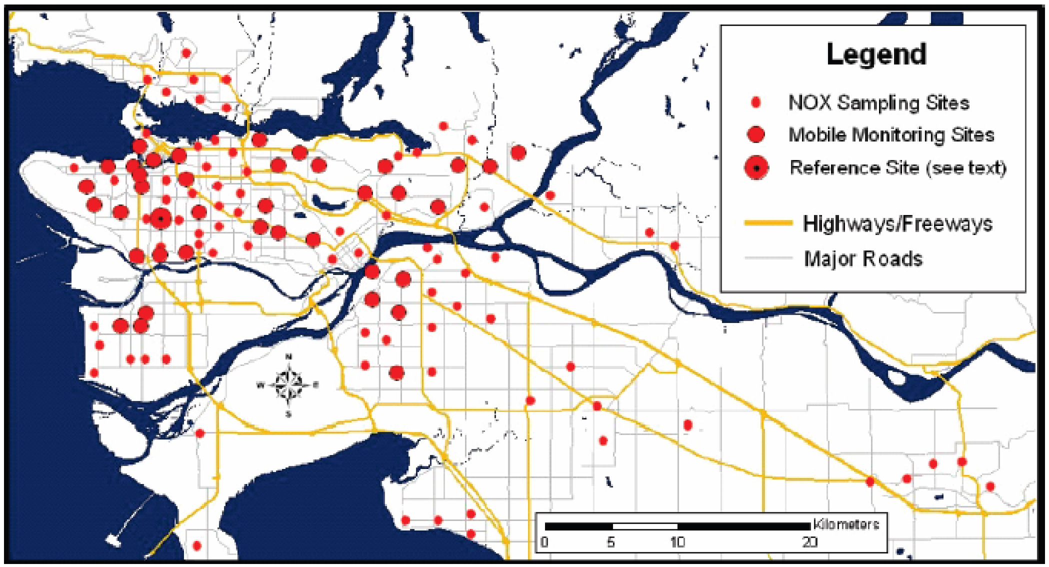
More sites lead to more robust LUR models. Wang, EST2012

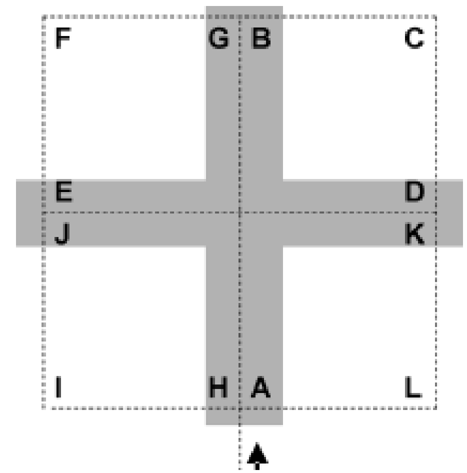


Mobile Monitoring of Particle Light Absorption Coefficient in an Urban Area as a Basis for Land Use Regression

Environ. Sci. Technol. 2009, 43, 4672–4678

TIMOTHY LARSON,
SARAH B. HENDERSON, AND
MICHAEL BRAUER*





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- 39 intersections
- 8 days, peak afternoon
- Conventional car
- Model R^2 54-72%

Land Use Regression Model for Ultrafine Particles in Amsterdam

Environ. Sci. Technol. **2011**, *45*, 622–628

GERARD HOEK,[*,†] ROB BEELEN,[†]
GERARD KOS,[‡] MARIEKE DIJKEMA,[§]
SASKIA C VAN DER ZEE,[§]
PAUL H FISCHER,[∥] AND
BERT BRUNEKREEF[†,⊥]

- 50 sites in Amsterdam
- 1-week measurements façade
- CPC3022a
- 1 home per week
- Reference site

Environ. Sci. Technol. **2011,** *45,* 622–628

TABLE 2. Land Use Regression Model for Particle Number Concentration (cm^{-3})

	regression coefficient[a]	standard error
intercept	14491	(3165)
product T.I. and inverse distance squared	29523	(3795)
address density, 300 m	10266	(3839)
port, 3000 m	6059	(3421)

[a] regression slopes multiplied by the difference between the 10th and 90th percentile for each of the three predictors (1102, 2653, and 4 149 780), intercept directly from model. The R^2 of the model was 0.67 (adjusted R^2 = 0.65). T.I. is traffic intensity.

Estimation of ultrafine particle concentrations at near-highway residences using data from local and central monitors

Christina H. Fuller [a,b,*], Doug Brugge [c], Paige L. Williams [d], Murray A. Mittleman [e,f], John L. Durant [g], John D. Spengler [a]

Atmospheric Environment 57 (2012) 257–265

- Boston area
- 18 homes
- 1-3 weeks monitoring
- WCPC 3781
- Reference sites

Covariate	Model 4: SPH and MAC sites	
	% Change	95% CI
$\log(UFP_{SPH})$[a]	0.4	0.1, 0.8
$\log(UFP_{MAC})$[a]	6	6, 7
Distance to highway		
>1000 m (ref)	–	–
100–400 m	34	–0.7, 81
<100 m	77	25, 149
Wind speed (m s^{-1})	–6	–7, –4
Wind direction		
Southeast (ref)	–	–
West	8	1, 14
Northwest	–6	–12, –0.4
East	–27	–31, –23
Traffic volume (veh h^{-1})		
<5340 (ref)	–	–
5340–8630	12	7, 18
>8630	6	–0.5, 13
Precipitation (yes/no)	–8	–12, –4
Hour (sine)	–14	–16, –12
Hour (cosine)	–8	–11, –4
AIC	3886	

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Spatial distribution of ultrafine particles in urban settings: A land use regression model

Marcela Rivera [a,b,c,*], Xavier Basagaña [a,b], Inmaculada Aguilera [a,b,d], David Agis [a,b], Laura Bouso
Maria Foraster [a,b,c,d], Mercedes Medina-Ramón [a], Jorge Pey [e], Nino Künzli [f,g], Gerard Hoek [h]

Atmospheric Environment 54 (2012) 657–666

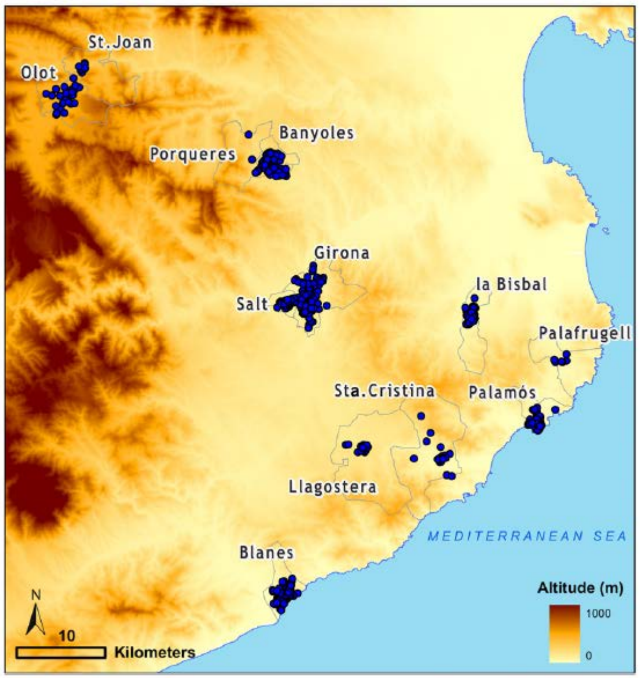

Fig. 1. Monitoring locations. Points represent monitoring locations.

- 644 sites sidewalk
- 15 minutes monitoring
- Daytime, no rush hour
- Single measurement
- PTRAK
- NO_X routine site for temporal variation

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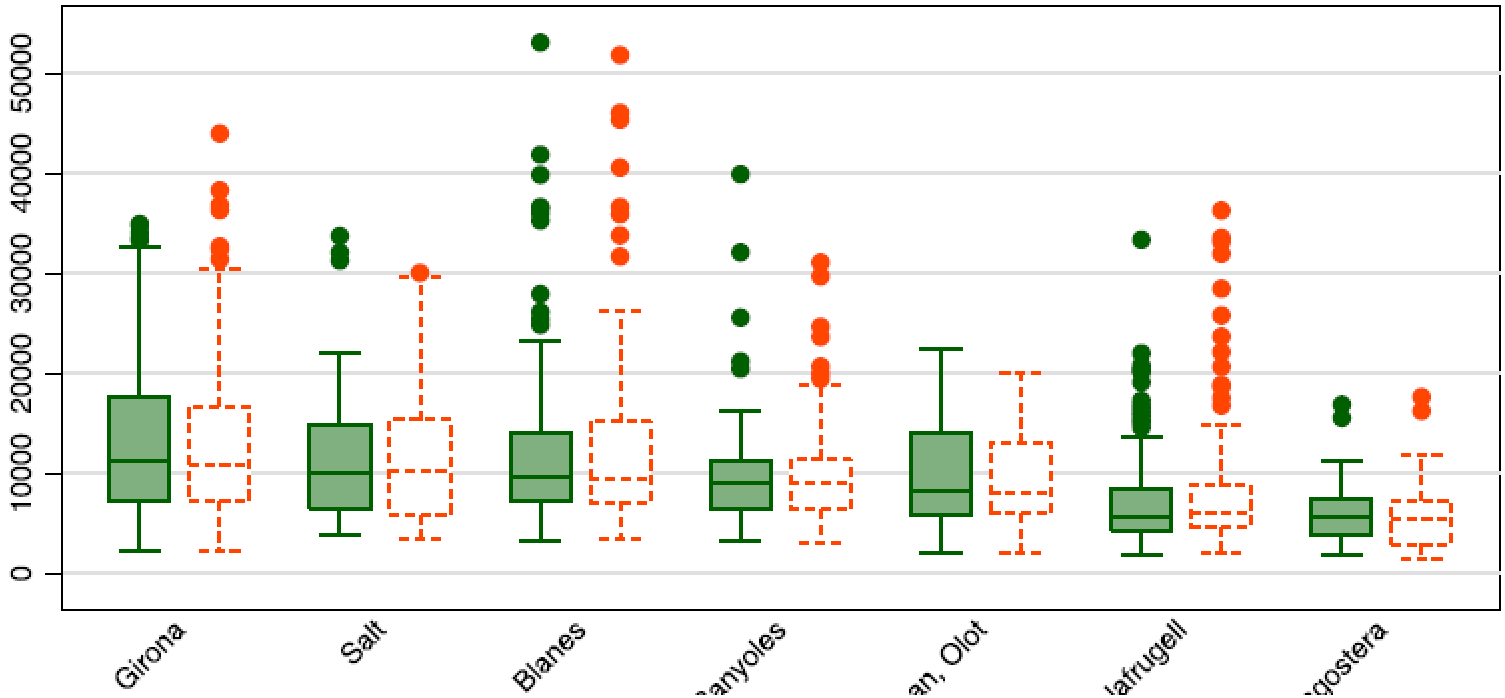

Land use regression model for ln (ultrafine particles −659.2): Core model. $N = 644$.

Core model	Coef.	$P > t$	[95%	CI]	R_A^2
					0.36
Heavy, light and motorcy. veh in 24 h (veh/9726)	0.433	<0.001	0.35	0.52	
Area of high density residential land within 1000 m (m^2/1930508)	0.355	<0.001	0.20	0.51	
Distance to intersection of two major roads (m/904)	−0.21	<0.001	−0.28	−0.13	
Household density within 100 m (number/184)	0.144	0.008	0.04	0.25	
Constant	8.679	<0.001	8.56	8.79	

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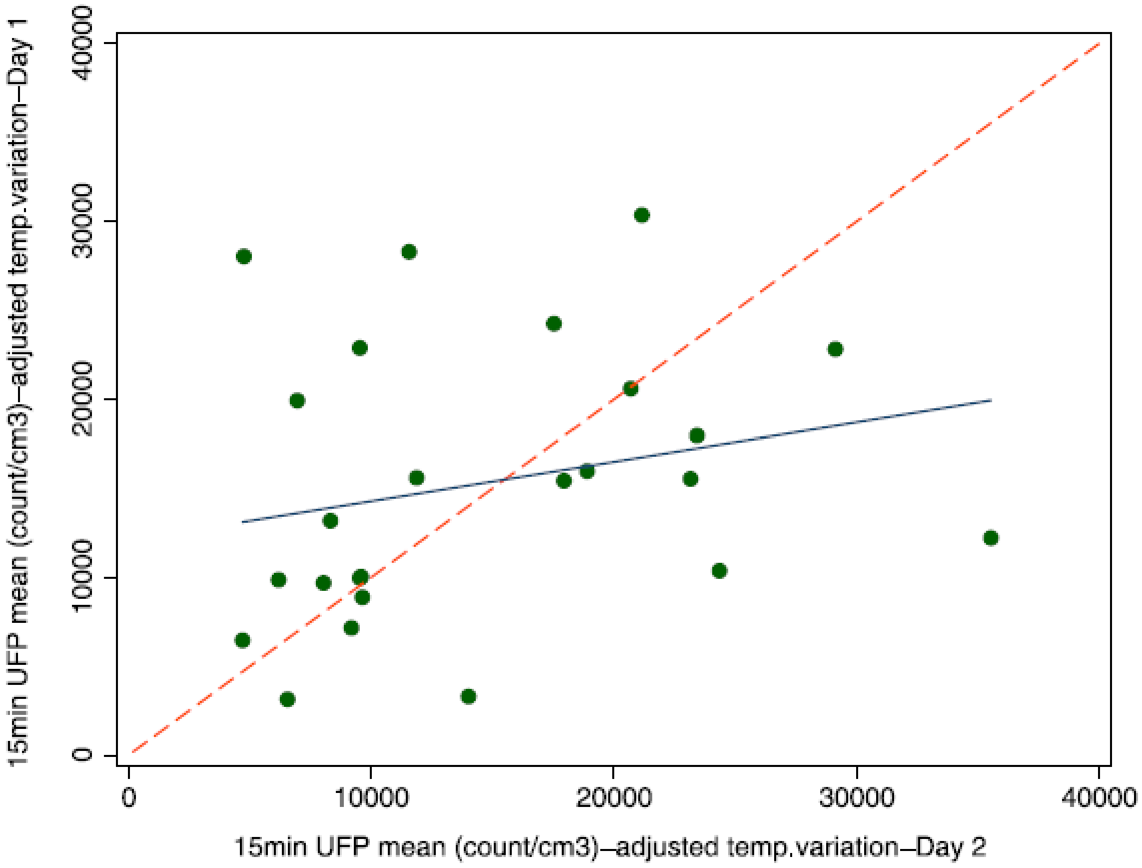
Repeated measurements at 25 sites



Model for these 25 sites:

- Single 47%
- Average two 72%

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A Land Use Regression Model for Ultrafine Particles in Vancouver, Canada

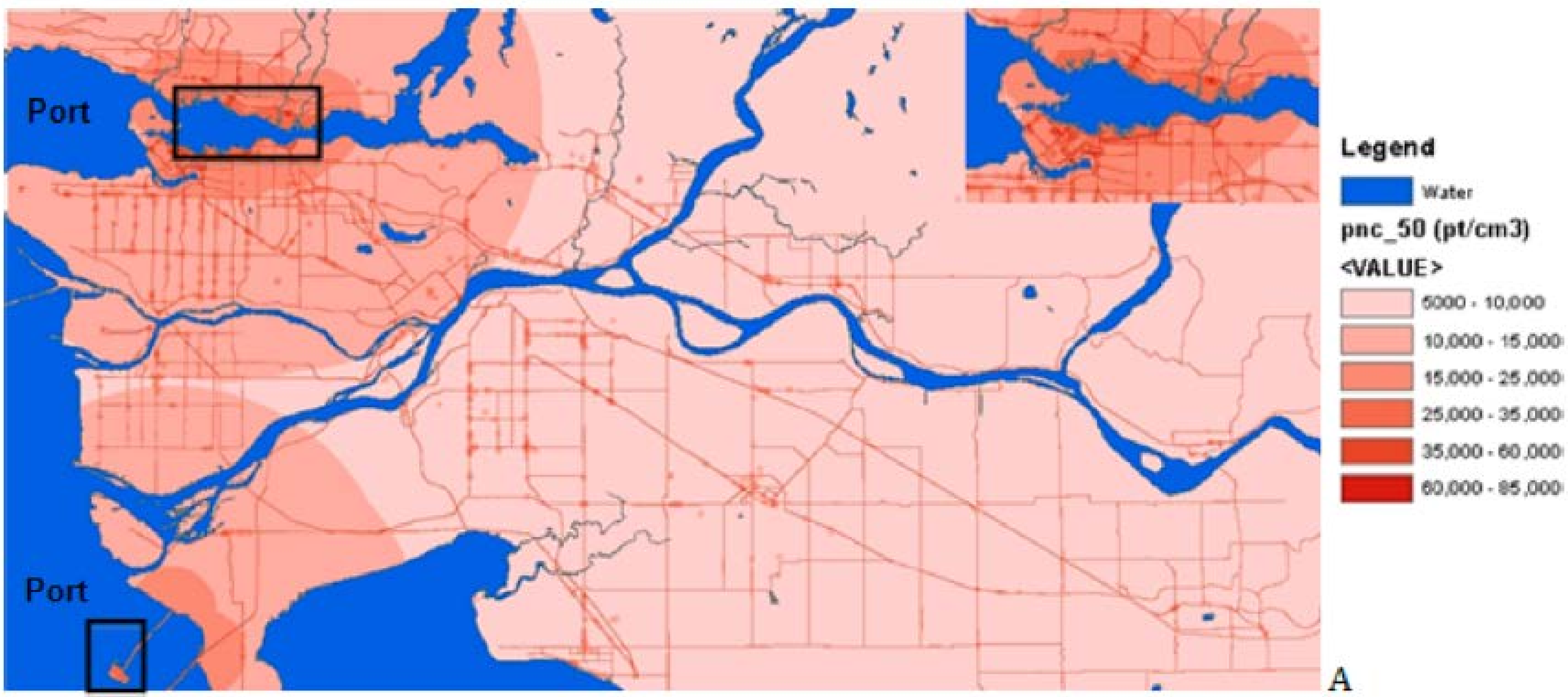
Rebecca C. Abernethy,[†] Ryan W. Allen,[‡] Ian G. McKendry,[§] and Michael Brauer[*,†]

Environ. Sci. Technol. 2013, 47, 5217–5225

- 80 sites
- Single measurement
- 60 minutes per site
- Median and 90th percentile
- Four reference sites to correct for temporal variation

Table 2. LUR Models Developed for PNC in Greater Vancouver[a]

model	concentration metric	traffic variable type	buffer type	variables	coefficients (SE) (pt/cm^3 or ln-pt/cm^3)	partial R^2 model R^2
1	PNC_{50}	road length	circular	truck route length (50 m buffer)	150800 (25200)	0.36
				distance to port (ln km)	−3000 (900)	0.10
				fast food site density (200 m buffer)	3700 (1700)	0.05
				intercept	17700 (2500)	**model 0.48**



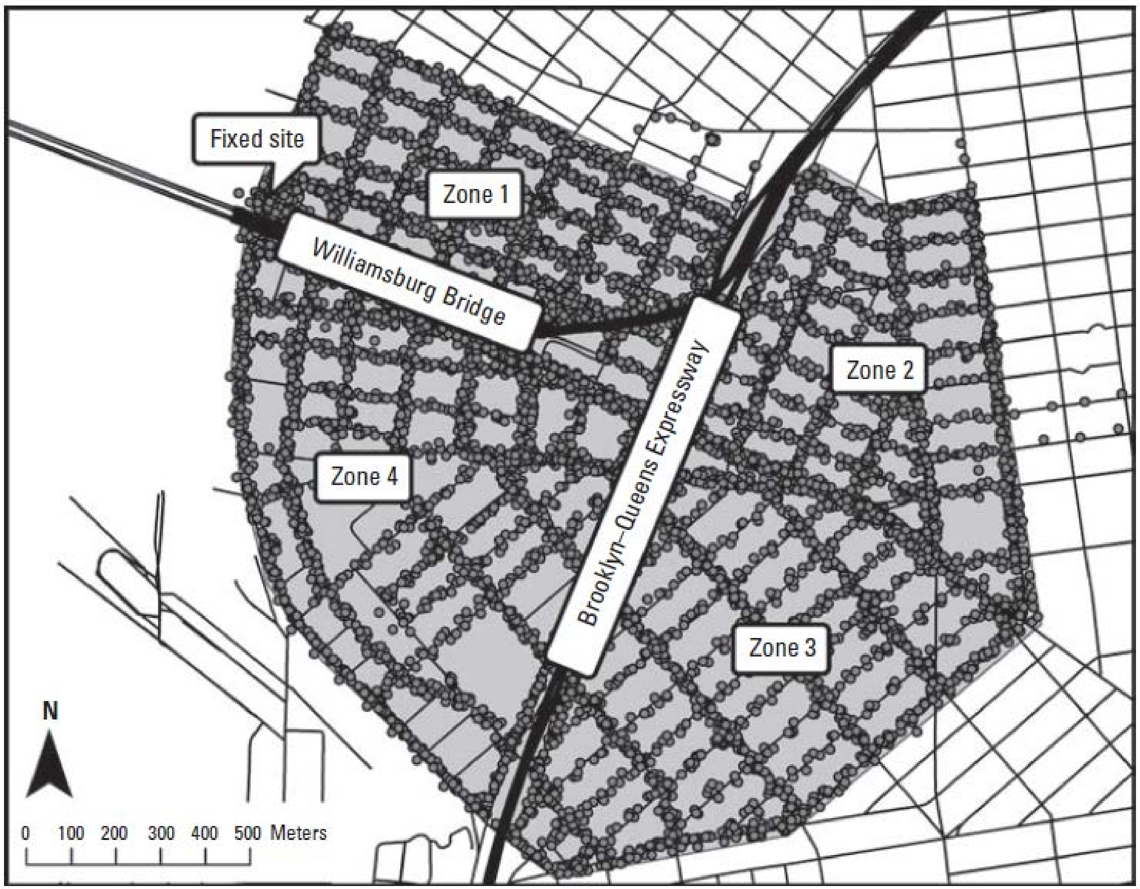
Klompmaker STOTEN 2015: MUSIC study.

- Amsterdam and Rotterdam
- 160 sites, 30 minutes per site
- Three repeats per site (season)
- Traffic and background sites each route
- Single UFP reference site + routine NO_2 + weather
- On-road mobile monitoring -> electric car

Modeling Spatial Patterns of Traffic-Related Air Pollutants in Complex Urban Terrain

Leonard M. Zwack,[1] Christopher J. Paciorek,[2,3] John D. Spengler,[1] and Jonathan I. Levy[1,4]

Environmental Health Perspectives • VOLUME 119 | NUMBER 6 | June 2011



- Walking routes (3 hr)
- 3 weeks
- CPC3781
- model R^2 0.24-0.32
- Meteo + distance to main roads

LUR models from UFP mobile and short-term sampling campaigns

Reference	Location	Design	Model type	Model R^2
Zwack, 2011	Brooklyn, NY	Mobile monitoring along fixed walking routes (~3 hour per route)	Spatiotemporal	0.22-0.32
Rivera, 2012	Girona, Spain	Single 15-minute measurement at 644 sites.	Spatial	0.36
			Spatiotemporal	0.51
Abernethy, 2013[7]	Vancouver, Canada	Single 60-minute measurement at 80 sites.	Spatial	0.29–0.53
Saraswat, 2013[6]	New Delhi, India	Single 1-3 hour measurement at 39 sites.	Spatiotemporal	0.23-0.28
Patton, 2014[10]	Somerville, MA	Mobile monitoring car driving on 43 days (3-6 hr per day)	Spatiotemporal	0.41- 0.43
Ragettli, 2014[19]	Basel, Switzerland	Three 20-minute measurements at 60 sites	Spatiotemporal	0.58- 0.68*
Sabaliauskas, 2015	Toronto, Canada	Mobile monitoring walking, 112 road segments. Three days summer 2008	Spatial	0.72
Weichental, 2015	Toronto, Canada	Mobile monitoring three cars, 405 road segments, three weeks	Spatial	0.67
Montagnge, submitted	Amsterdam, Rotterdam	Three 30-minutes measurements at 161 sites	Spatial	0.33-0.42
			Spatiotemporal	0.39

Why low explained variance?

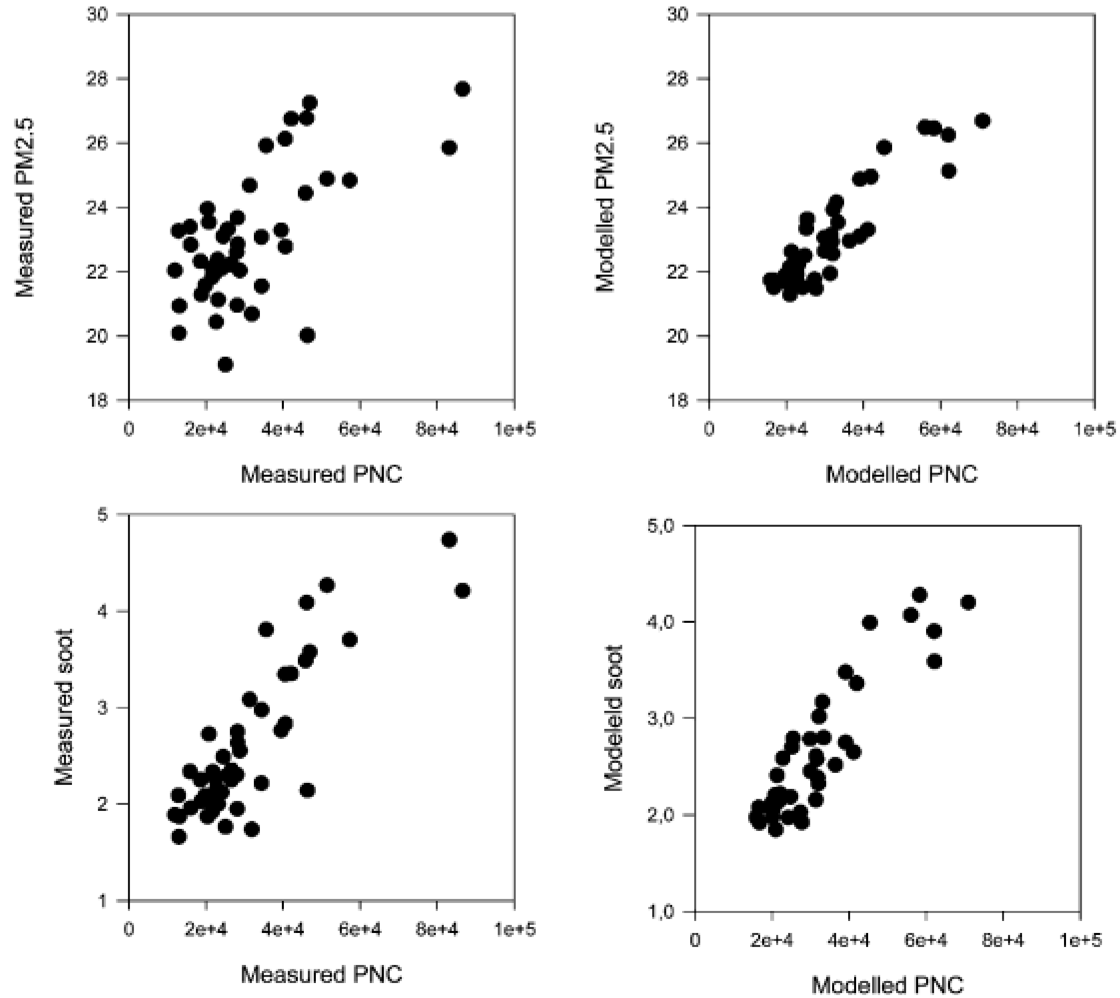
Klompmaker, STOTEN 2015:
Within to between site concentration variance ratios

Project	Duration	Repeat		Time corr.	No time corr.
MUSIC	30 minutes	3	UFP	2.17	2.21
RUPIOH	24 hour	3	UFP	0.31	0.50
MUSiC	30 minutes	3	BC	2.44	3.25
VE^{3}SPA	96 hour	6	BC	0.69	2.55
ESCAPE	14 days	3	BC	0.09	0.39

Low explained variance

- Much larger temporal variation in concentration data than in longer duration campaigns
- Not accounted for by reference site
- Consequences?
- Measurement error in dependent variable
  - Low model R^2 Unbiased regression coefficients -> correct and robust model

Amsterdam UFP, BC and $PM_{2.5}$ spatial patterns. EST 2011.



Pearson correlations between measured PNC with measured PM2.5, soot, and coarse was 0.66, 0.85, and 0.47,

... correlations between modeled PNC with modeled PM2.5, soot, and coarse was

Merits

- Promising tool for UFP
- Large number of locations -> robustness model and diverse sources
- Cost-effective
- Not exclusively for traffic
  - Amsterdam + Vancouver model: port
  - Vancouver model: fats food restaurants
  - Toronto model: airport
- Spatiotemporal models can be developed
- Other applications (Brantley et al, 2014)

Limitations and challenges

- More validation needed with external data to test robustness
- Temporal variation
  - Reference site
  - Route design
  - Repeats
- Often daytime concentrations on weekdays…
- Mobile versus **short-term** campaigns (local exhaust)
- Translation of on-road mobile to residential exposures

Limitations and challenges

- LUR model development (# sites, predictors, not too empirical)
- Pollution metric (mean, median, ...)

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