Air quality monitoring for Exposure assessment

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Talk

- How useful are current air quality networks for exposure assessment (EA) for epidemiological studies?
- Challenges of EA for selected epidemiological study designs
- Limit to ambient concentrations and not touch on personal exposure (Mark Nieuwenhuijsen later today)

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Epidemiological studies

- Short-term exposure
  - Time series studies
  - Temporal variation
  - Hours to days time scale
- Long-term exposure
  - Cohort studies, cross-sectional studies
  - Spatial variation
  - Year(s)

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Challenges exposure assessment

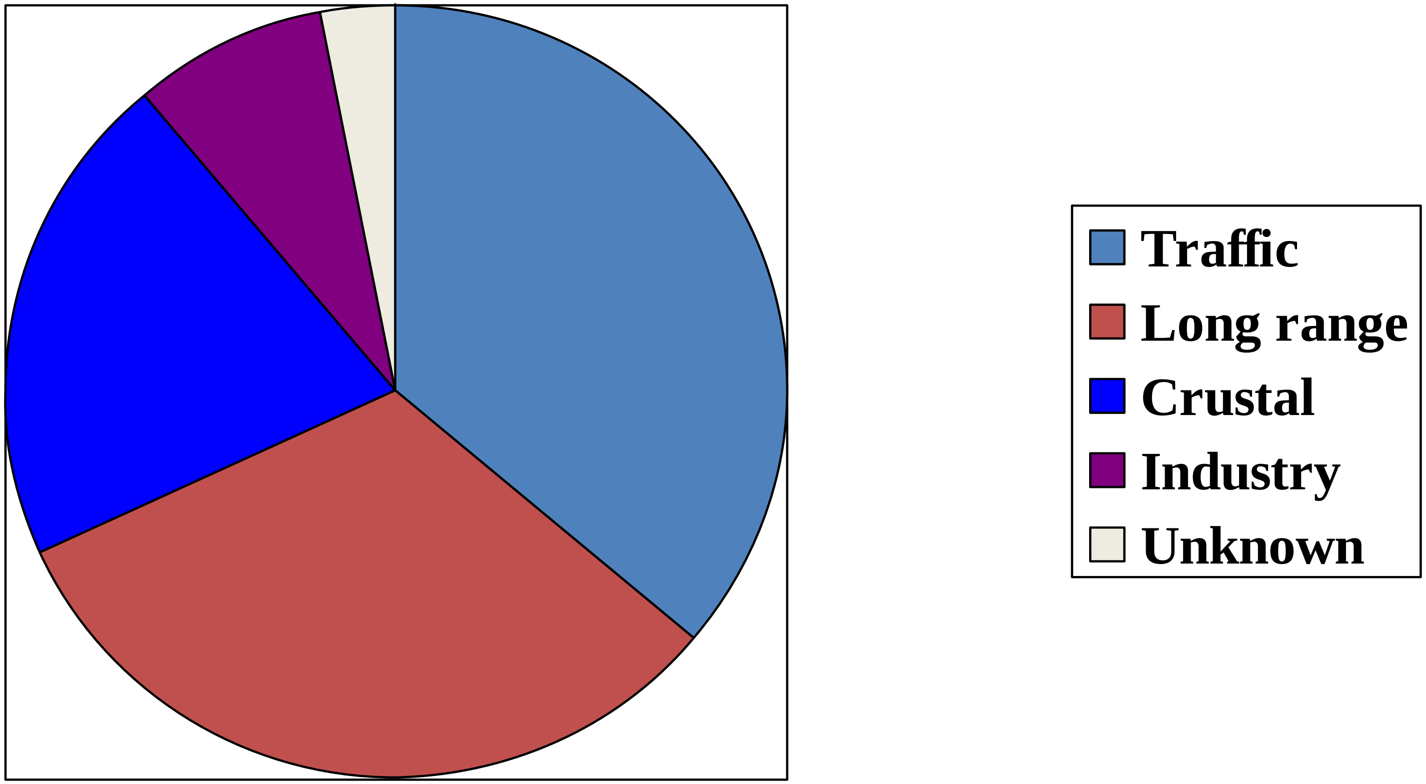
- Short-term: long complete daily series of pollutant concentrations

- Long-term: annual average concentrations for a large number of locations (e.g. homes) in space

Where do relevant traffic exposures occur?

- **Everywhere**, as traffic emissions affect urban background
- **Major roads**, if your home, workplace, school or day care center are located there
- **Participation in traffic**

Contribution of sources to PM2.5 in Erfurt



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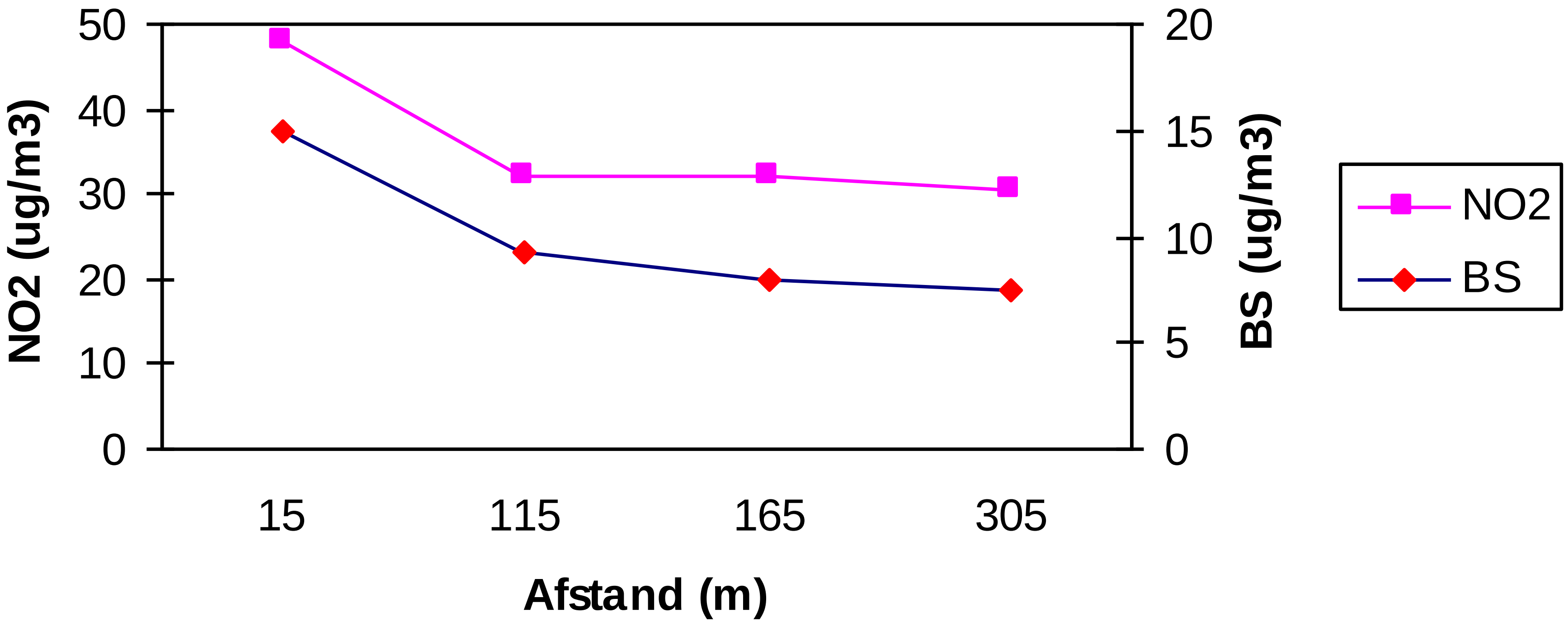
NO2 and soot decrease with distance to a freeway



Line		*n*	Vehicle interior Av.	Sampling station Av.
Tramway	T27	14	279	71
	T12	17	244	68
	T21	10	111	42
	T19	13	110	36
	T18	10	71	41
Bus, circular	B41	23	236	71
	B33	13	179	60
	B44	34	149	48
	B45	15	80	47
Bus, radial	B192	15	134	46
	B85	9	116	44
	B67	10	98	40
	B31	10	97	37
	B53	8	90	35
Sum		201	155	52

Table 10 PM_{10} concentrations ($\mu g \cdot m^{-3}$) inside vehicles for all the lines examined during the study in Munich, Germany (*ca.* 4-h rides), compared with the averages from the three closest to the examined lines outdoor sampling stations (3-h average). *After Praml and Schierl (2000).*

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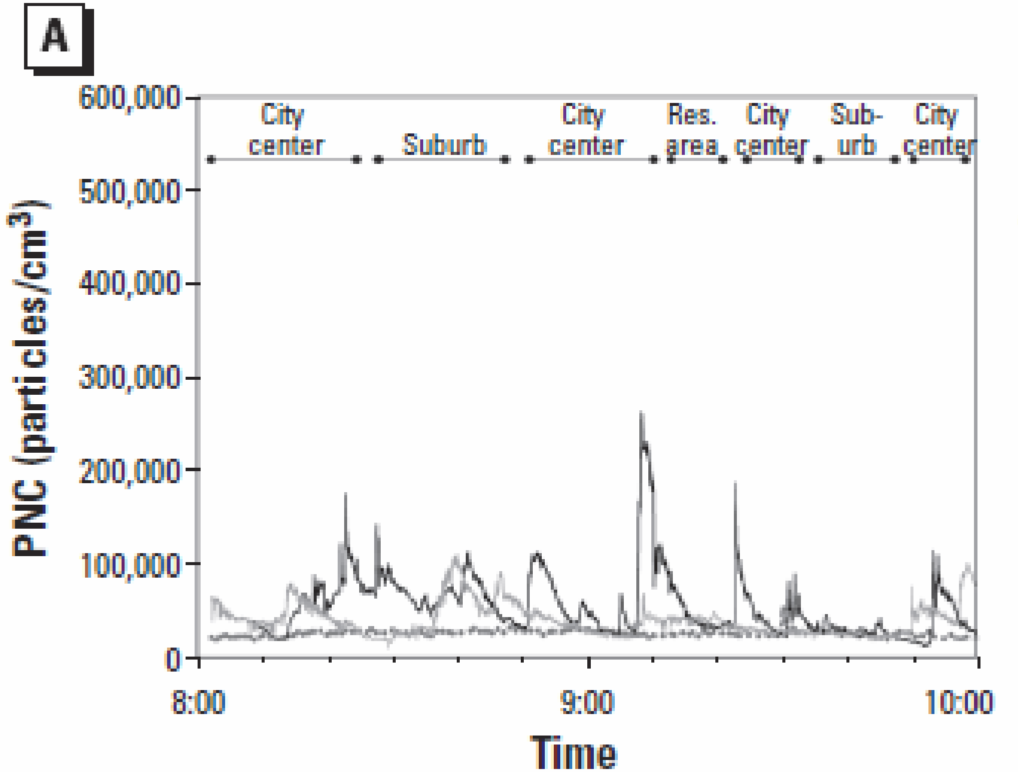

Figure 2. PNCs. (*A*) Bus sampling day, 22 January 2008. Black, diesel bus; gray, electric bus; dotted line, urban background. The diesel bus left and arrived about 15 min later than the electric bus. To facilitate geographical comparison, the time of the diesel bus is shifted 15 min earlier. (*B*) Car sampling day, 18 March 2008. Black, diesel car; gray, gasoline-fueled car; dotted line, urban background. (*C*) Bicycle sampling day, 10 June 2008. Black, high-traffic route; gray, low-traffic route; dotted line, urban background. Res., residential.

Commuting exposures. Zuurbier, 2010 EHP

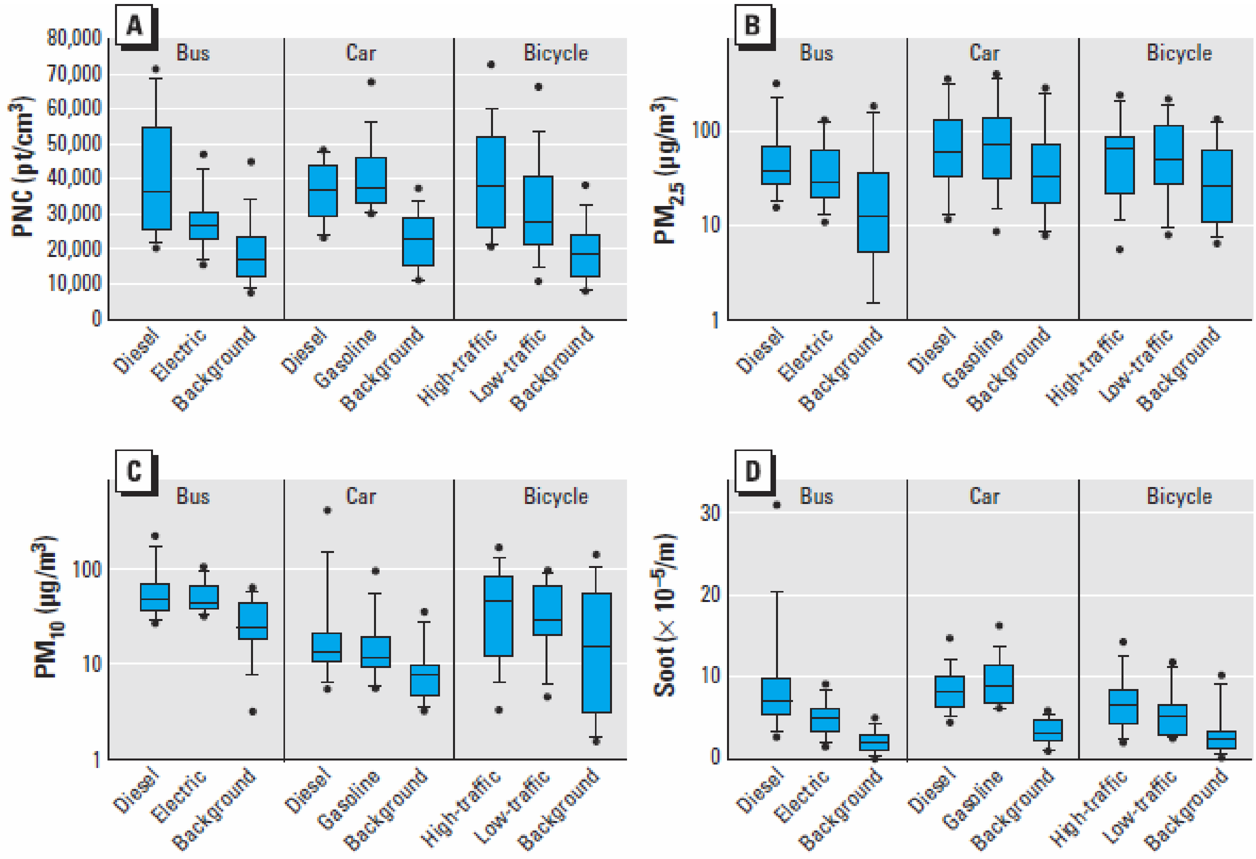

Figure 4. Exposures in modes of transport and at the urban background location on corresponding sampling days. (*A*) Two-hour average PNCs (particles/cm^3). Two-hour average $PM_{2.5}$ (*B*), PM_{10} (*C*), and soot (*D*; fraction of PM_{10}). Box-and-whisker plots indicate lower and upper quartiles (box), median (line), 10–90th percentiles (whiskers), and minimum and maximum values (circles).

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Networks

- Temporally rich (daily, often continuous)
- Spatially sparse (few sites per city)
- Often long series, historically consistent
- Multiple pollutants
- Criteria pollutants
- Exposure oriented?

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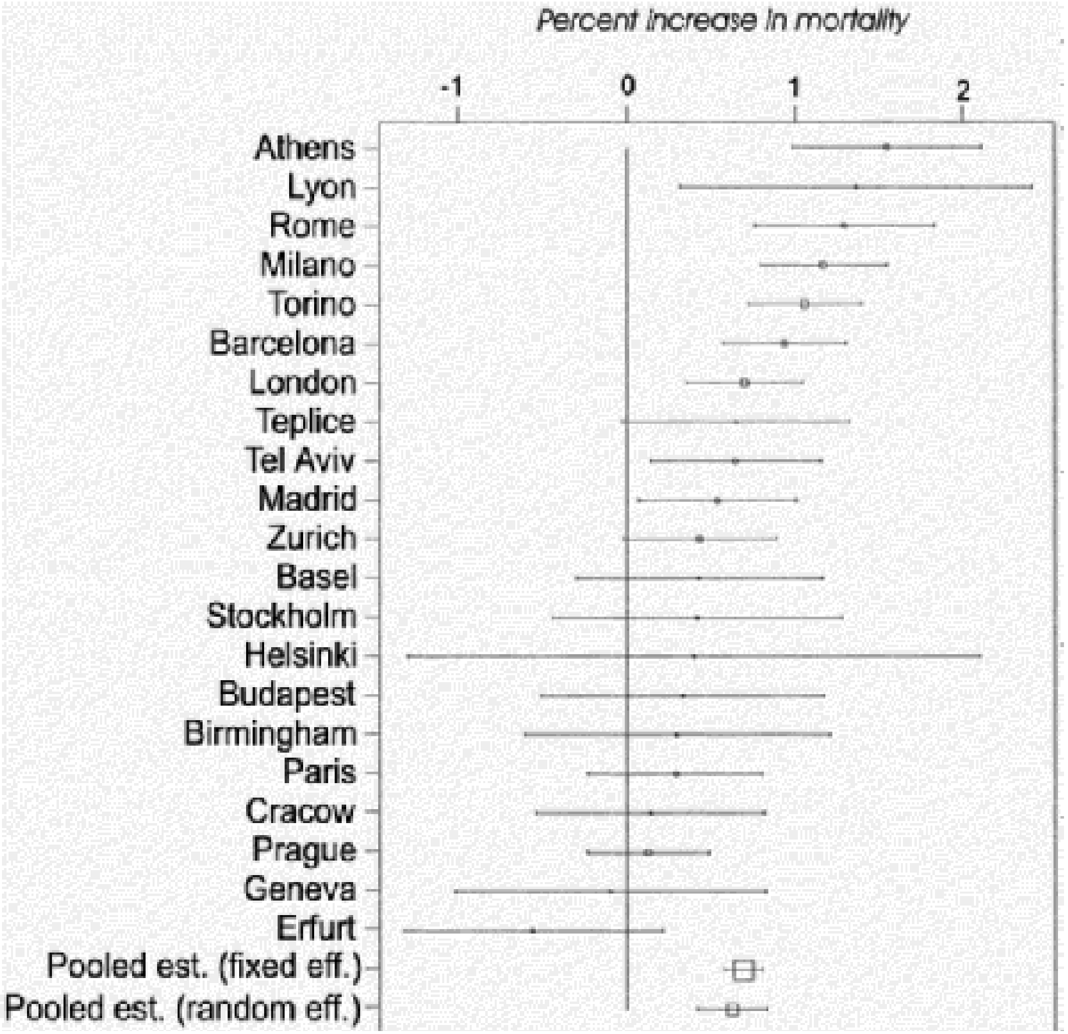
Time series studies

- Most based upon networks
- Variation in time measured at a few sites predicts variations across the city well
- Good correlation with personal exposure



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Issues

- Siting
- Time series length
- Components measured
  - Coarse particles
  - Ultrafine particles
  - Composition of PM (metals, EC, OC, PAH)
- Not appropriate for commuting exposures

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Long-term exposure studies

- Between community studies
  - Expo often one value per city
  - Strong assumption …
  - Between and within city variation
- Within community studies
  - Individual often residential exposure
  - Challenging ….

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Harvard 6 cities study

- Dockery DW, Pope CA, Xu X, Spengler JD, Ware JH, Fay ME, Ferris BG, Speizer FE. N Engl J Med. 1993;329:1753-9.
- Prospective cohort study
- 9,000 subjects living in 6 U.S. cities, followed for 15 years
- Cities varied in long-term concentrations of sulfur oxides and particles
- One monitor per city

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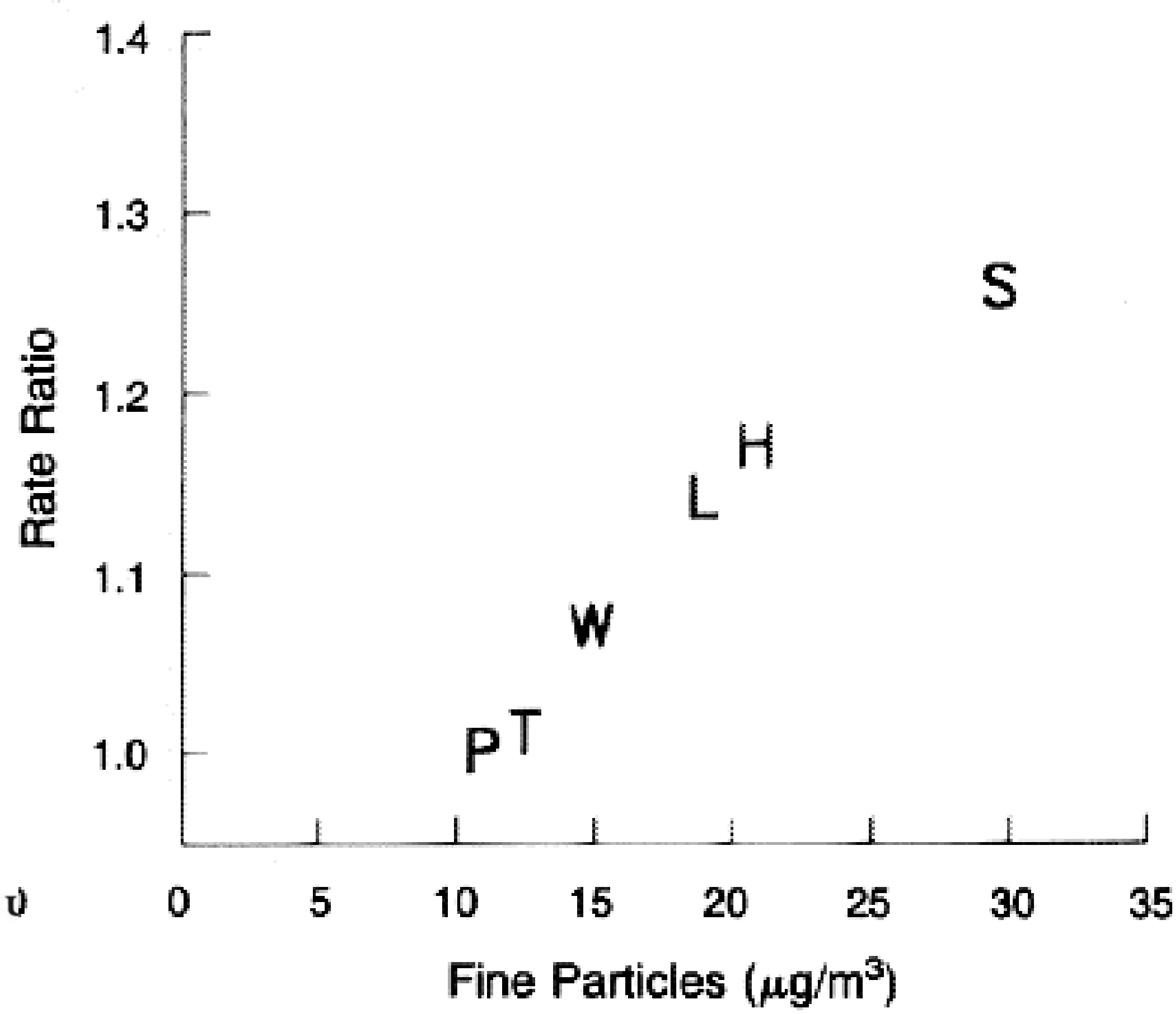
Dockery, NEJM 1993; 329: 1753-9



The NEW ENGLAND JOURNAL of MEDICINE

SPECIAL ARTICLE

Fine-Particulate Air Pollution and Life Expectancy in the United States

C. Arden Pope III, Ph.D., Majid Ezzati, Ph.D., and Douglas W. Dockery, Sc.D.

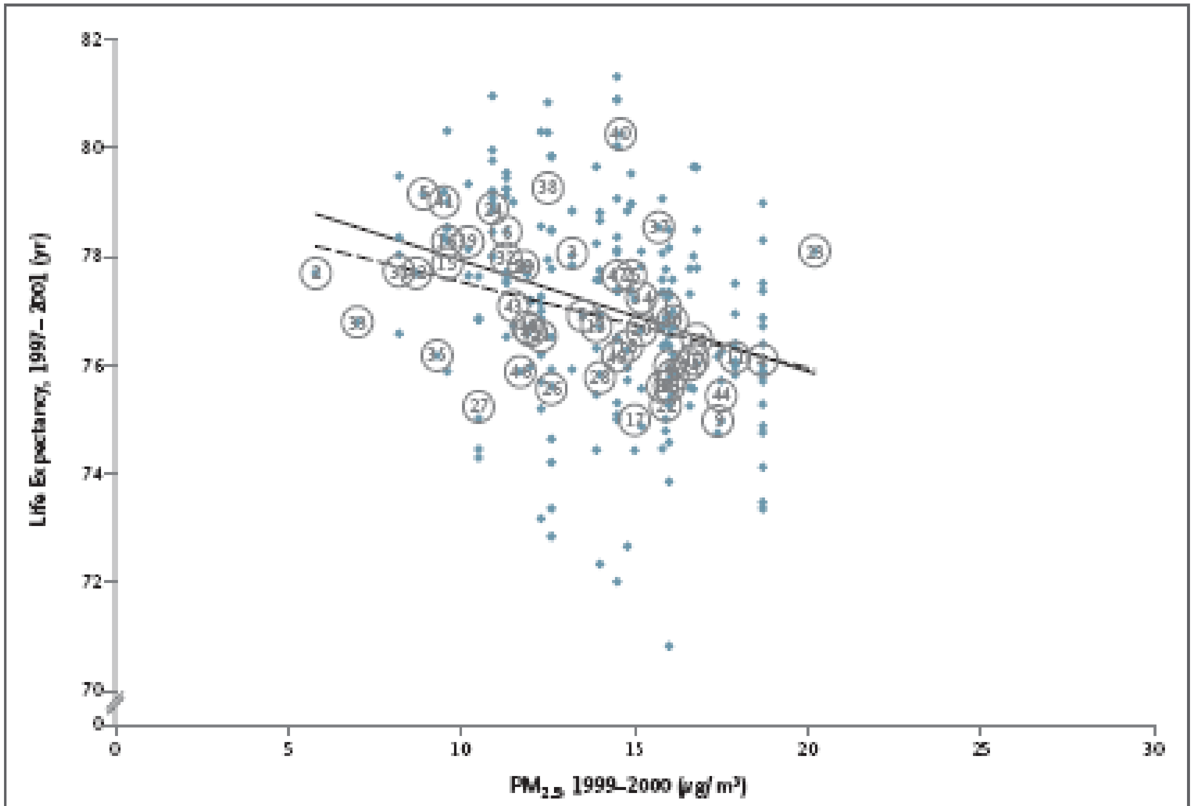


Figure 3. Cross-Sectional Life Expectancies for 1997–2001, Plotted against $PM_{2.5}$ Concentrations for 1999–2000.

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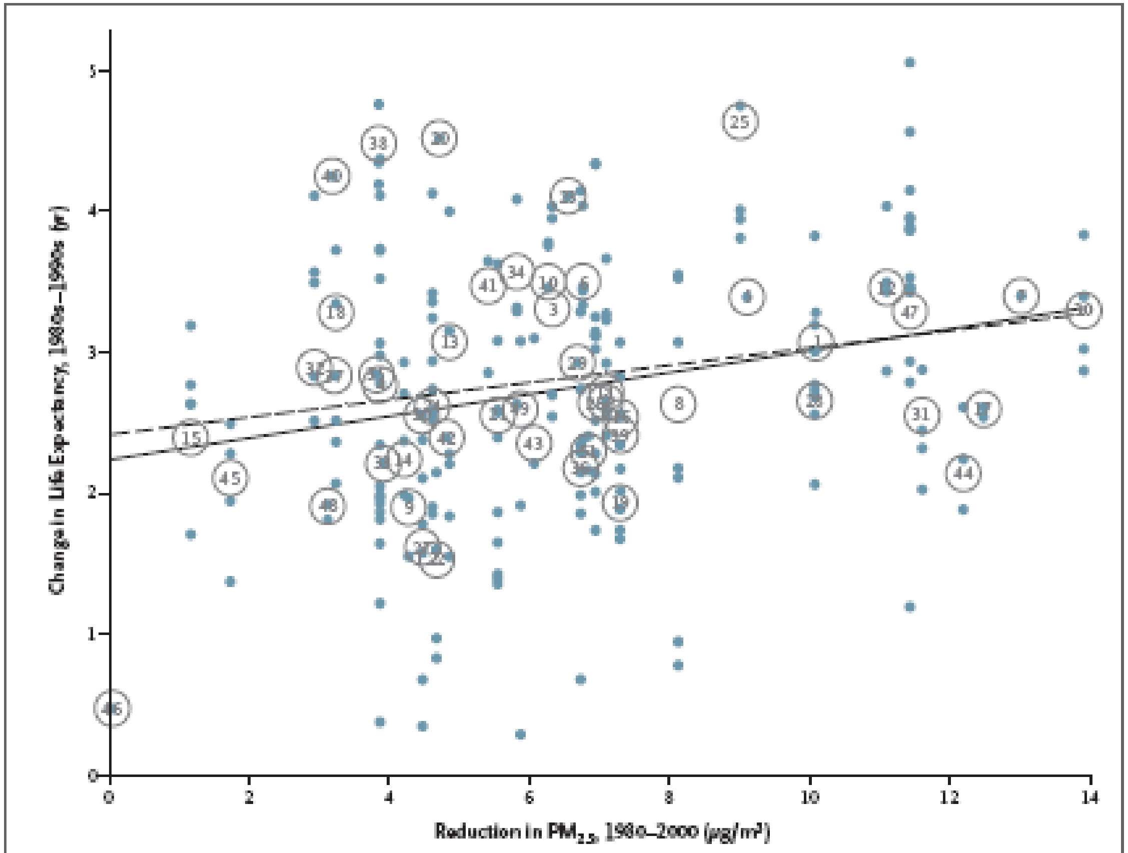

Figure 4. Changes in Life Expectancy for the 1980s–1990s, Plotted against Reductions in $PM_{2.5}$ Concentrations for 1980–2000.

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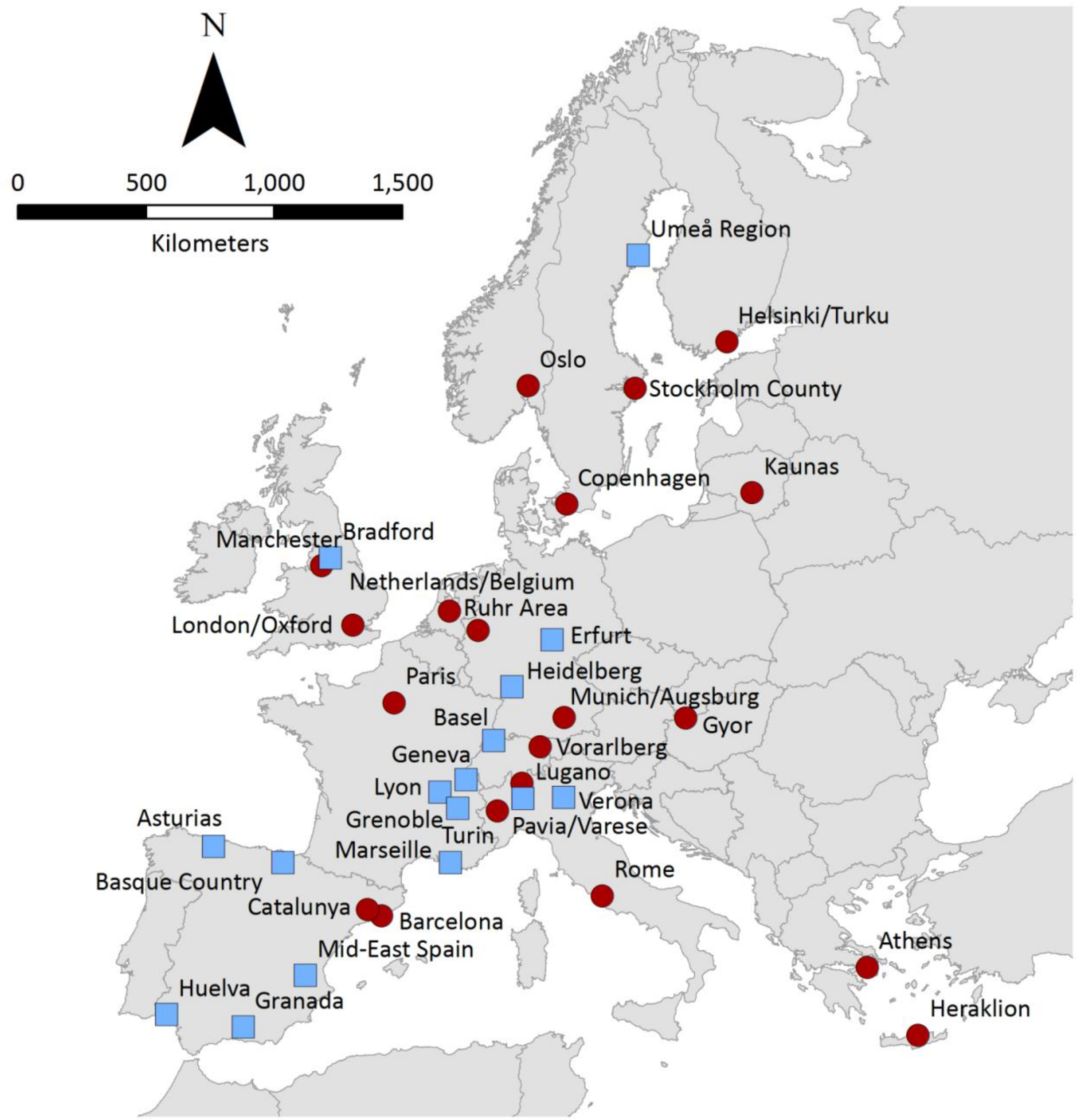
Within study area variation, ESCAPE study



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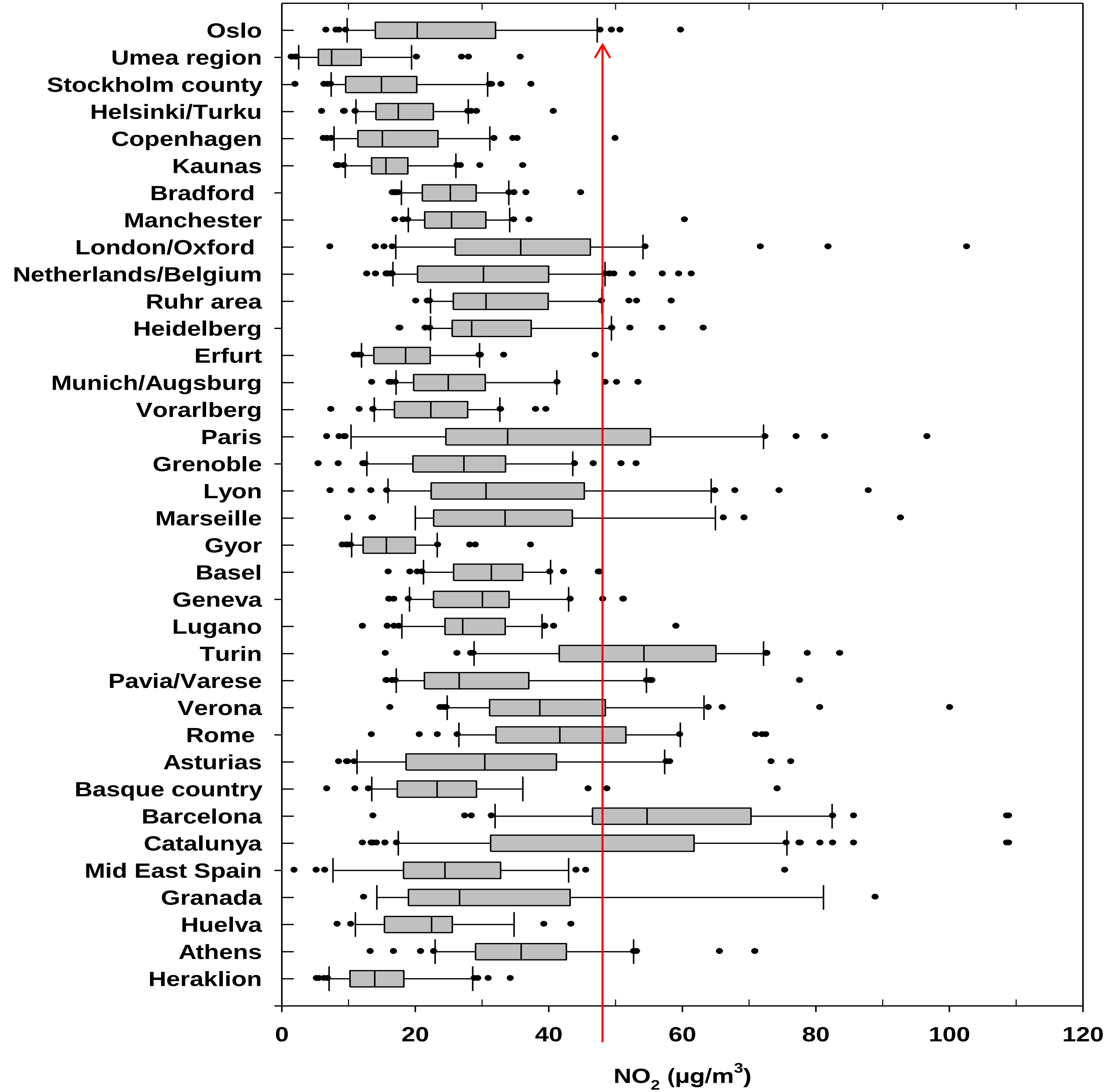
Oslo
Umea region
Stockholm county
Helsinki/Turku
Copenhagen
Kaunas
Bradford
Manchester
London/Oxford
Netherlands/Belgium
Ruhr area
Heidelberg
Erfurt
Munich/Augsburg
Vorarlberg
Paris
Grenoble
Lyon
Marseille
Gyor
Basel
Geneva
Lugano
Turin
Pavia/Varese
Verona
Rome
Asturias
Basque country
Barcelona
Catalunya
Mid East Spain
Granada
Huelva
Athens
Heraklion
0
20
40
60
80
100
120
NO$_2$ (µg/m^3)

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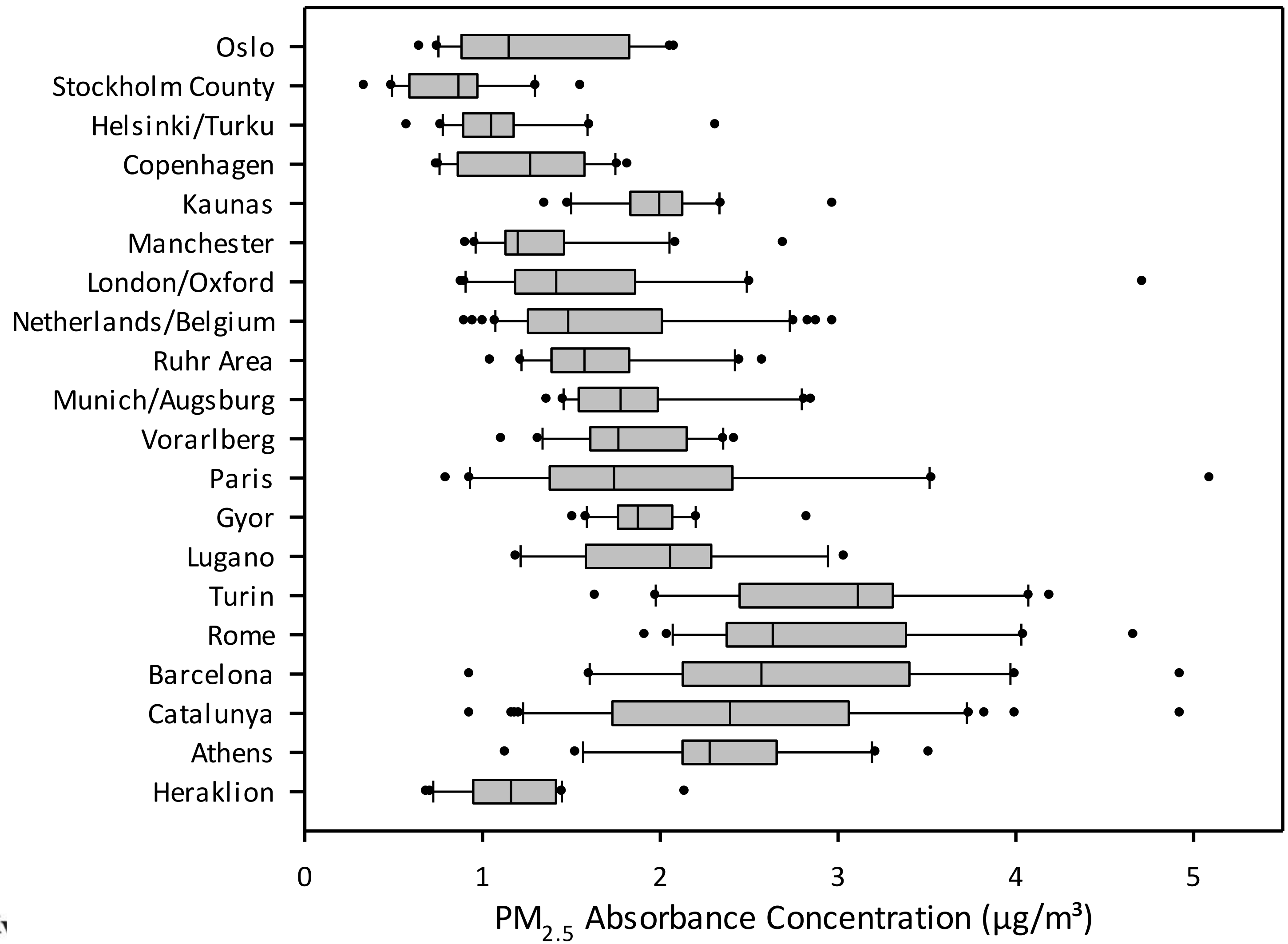

Oslo
Stockholm County
Helsinki/Turku
Copenhagen
Kaunas
Manchester
London/Oxford
Netherlands/Belgium
Ruhr Area
Munich/Augsburg
Vorarlberg
Paris
Gyor
Lugano
Turin
Rome
Barcelona
Catalunya
Athens
Heraklion
0
1
2
3
4
5
PM2.5 Absorbance Concentration (µg/m³)

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Role of network monitoring

- Typically several 100-s and 100-s addresses
- Nearest station not attractive
- Interpolation of measurements
- Basis for land use regression models

Interpolation of measurements

Ambient Air Pollution and Atherosclerosis in Los Angeles

Nino Künzli, Michael Jerrett, Wendy J. Mack, Bernardo Beckerman, Laurie LaBree, Frank Gilliland, Duncan Thomas, John Peters, and Howard N. Hodis

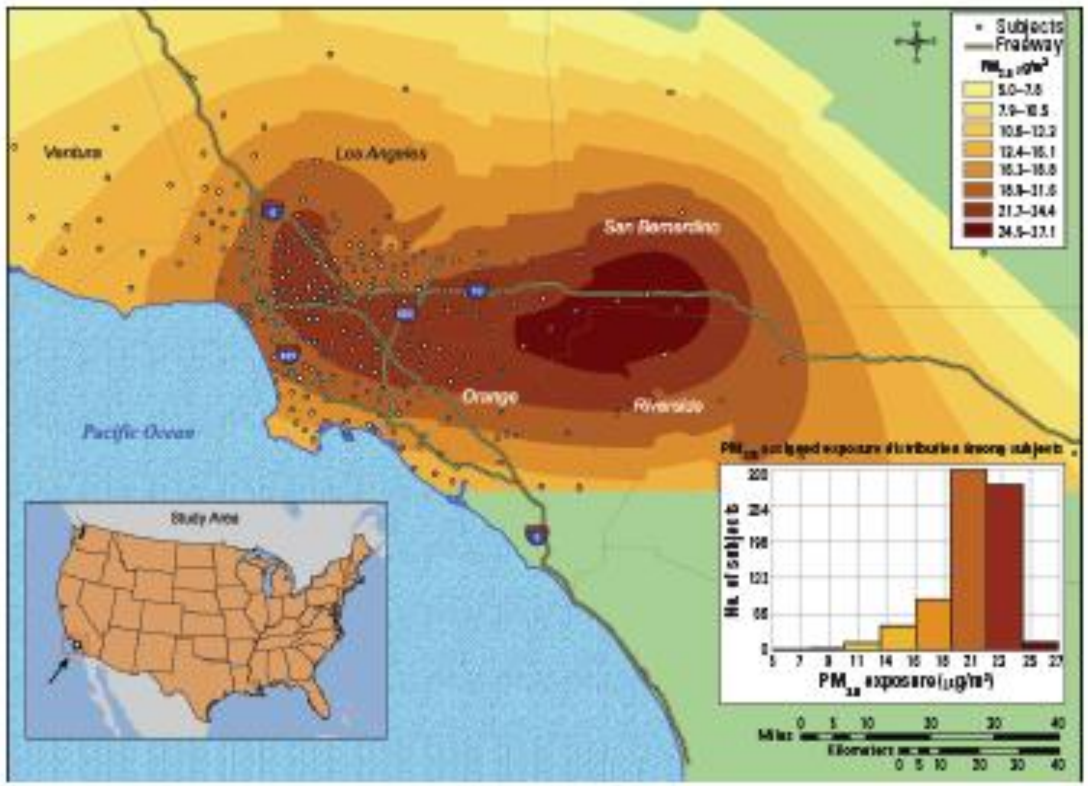

Figure 1. ZIP code locations of the study population geocoded on the $PM_{2.5}$ surface, modeled with 2000 $PM_{2.5}$ data, and distribution of individually assigned concentrations.

Background

$$Y = \beta_1 X_1 + \beta_2 X_2 + ... + \beta_n X_n + c$$

- Land use regression (LUR) models have become popular to explain the spatial variation of air pollution concentrations.

Advantage:
1.Relatively simple input
2.Low cost

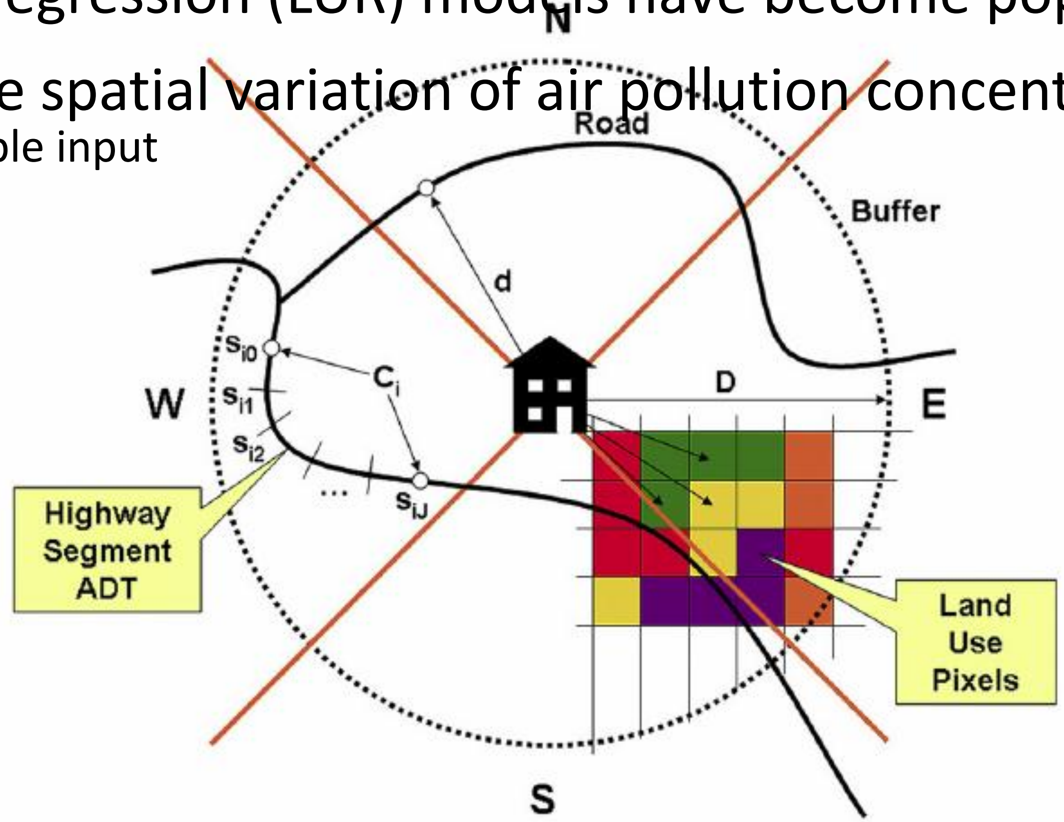

Fig. 1. Traffic volume and land use components of model for estimating residential NO_2 levels calculated within buffer of radius "D" (dotted black line) surrounding residence. Within this buffer, traffic volume component uses state-provided average daily traffic (ADT) counts on curve segment "C_i" of roadways (thick black lines) subdivided into 50-m roadway sub-segments "s_{ij}". Distance from residence to roadway segment is "d". Land use categories, shown as color-coded "pixels," enter model as area in hectares of each category within a buffer. Also shown are axes (orange lines) dividing the buffer into four directional quadrants (i.e., north, east, south and west of residence).

Skene et al., 2010 AE

model did not change. The final LUR model included the following predictor variables: area of low density residential land in a 300 m buffer, traffic intensity in a 200 m buffer, industry in a 1000 m buffer and population density in a 100 m buffer in addition to the interpolated regional background (see Appendix A for a more detailed explanation). Cross-validation of this LUR model using the leave-one out method resulted in a R^2 value of 87% and Root Mean Squared Error (RMSE) of 4.3 $\mu g\ m^{-3}$.

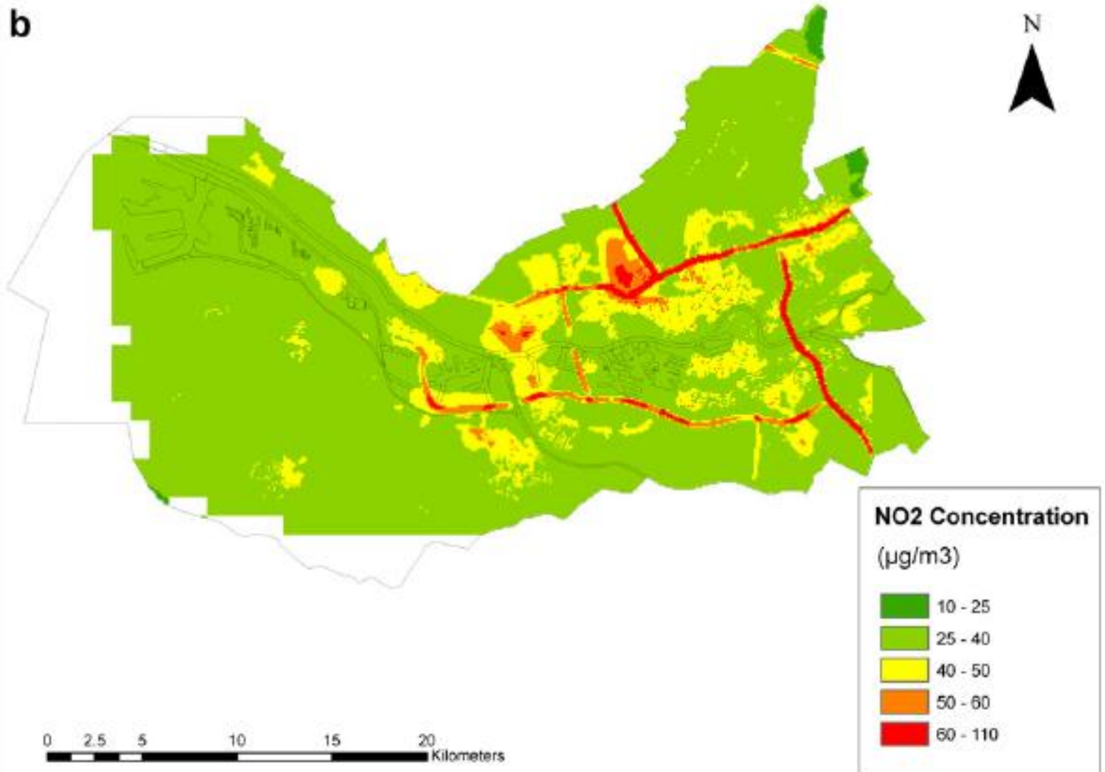

Fig. 3. Maps of the Rijnmond area with estimated NO_2 concentrations (in $\mu g\ m^{-3}$) using the URBIS dispersion model (a) and the LUR model (b) (Fig. 1 shows a map of The Netherlands with the location of the Rijnmond area and the city of Rotterdam).

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

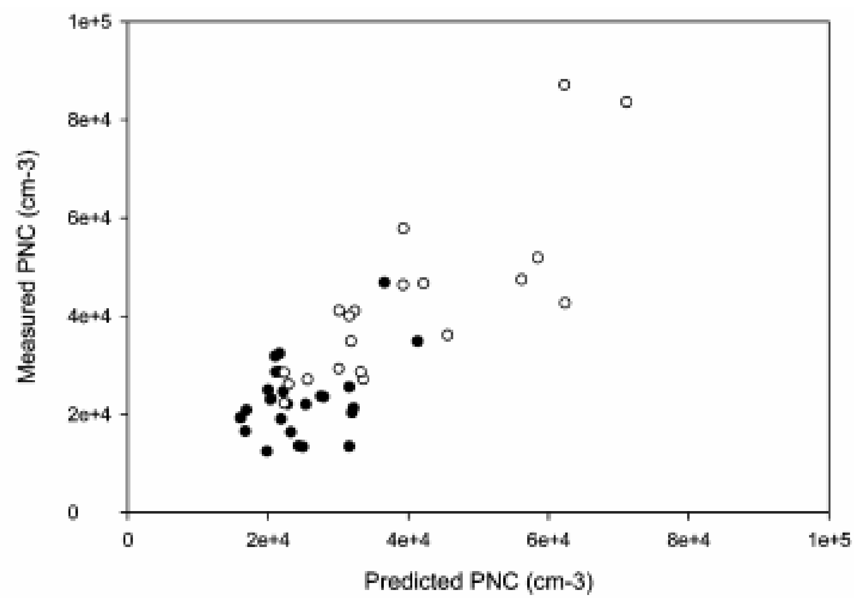
Land Use Regression Model for Ultrafine Particles in Amsterdam

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

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.



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Why did we not use network data in ESCAPE as basis?

1. Networks not dense enough to assess intra-urban variability
2. Too limited set of components
   a) Soot
   b) Elemental composition of PM
   c) PM10 and PM2.5 -> coarse PM

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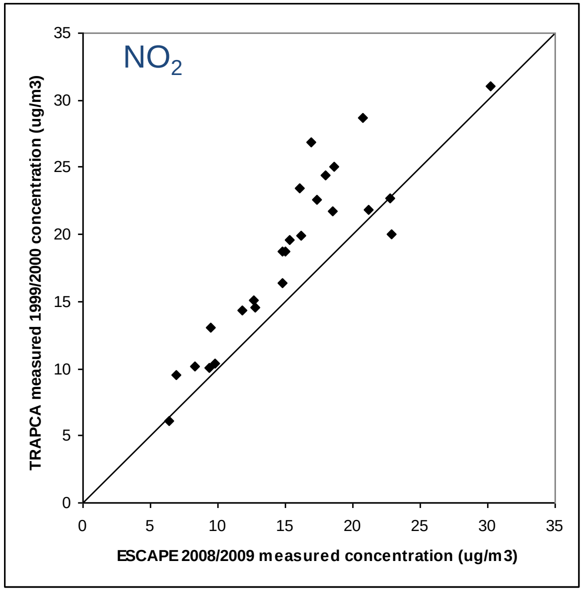
Why did we not use network data in ESCAPE as basis?

3. Differences in monitoring methods across networks (esp. PM)
4. Differences in siting of monitors
5. Location of traffic monitors often does not reflect residential exposures (kerbside vs facade)

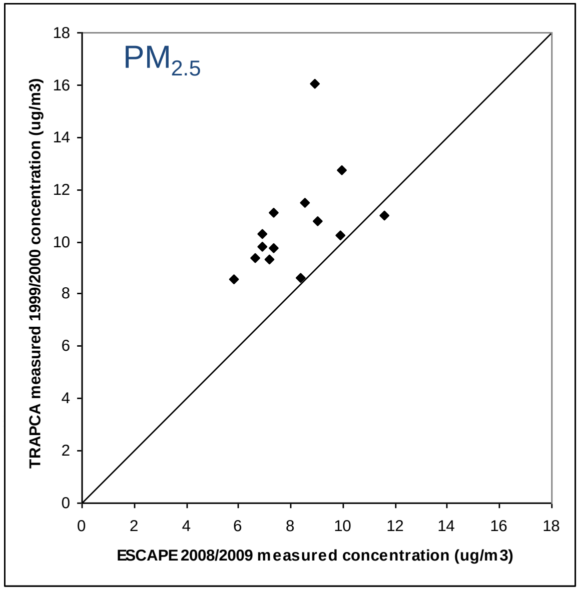
How did we use network

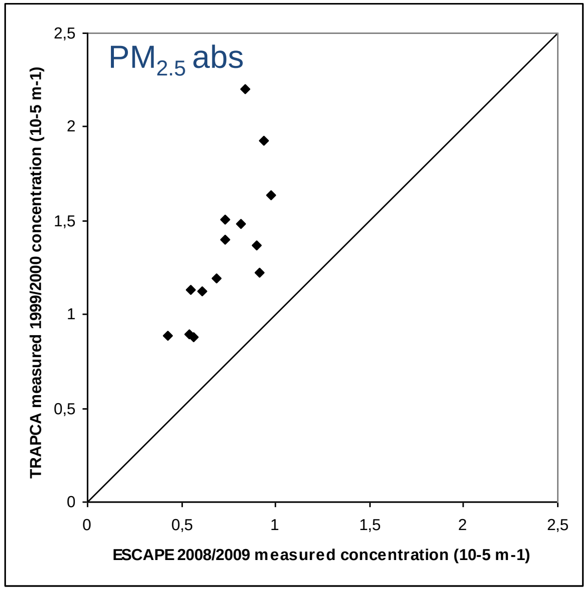
- Co-location (QA-QC)
- Historic trends as we associate *current* measurements with *past* health ....

Correlation between previously measured concentrations and measured ESCAPE concentrations



Stockholm		
	Correlation	***N***
NO_2	0.89	25
$PM_{2.5}$	0.46	14
$PM_{2.5}$ abs	0.75	14





Trend estimation

- Components
- Changes in sites
- Changes in methods

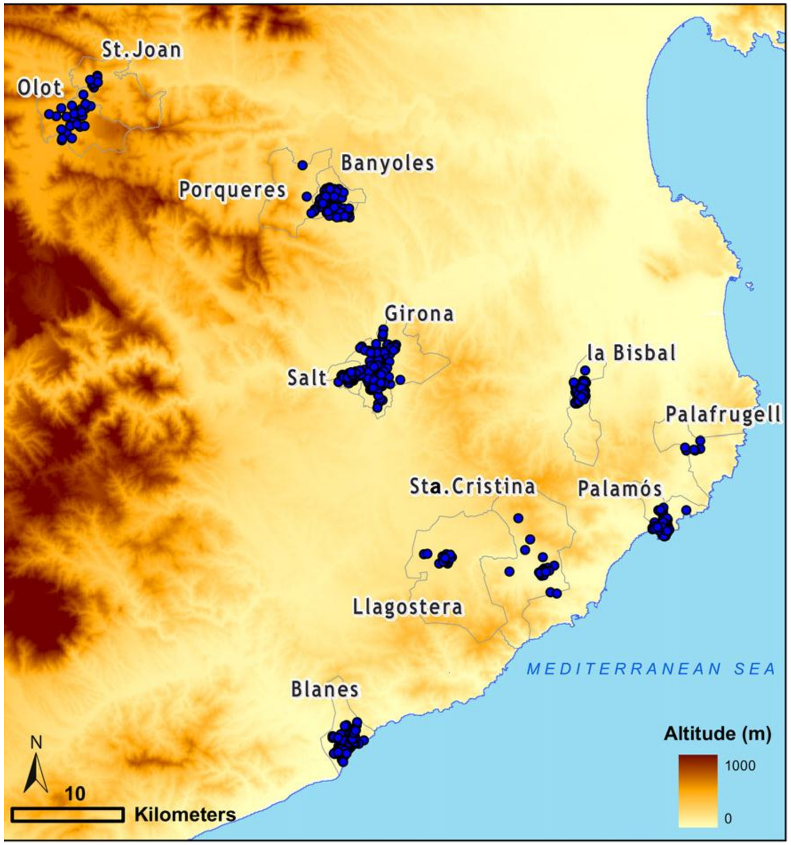
Alternatives

1. Study-specific sampling (mobile campaign)
2. Spatially more dense networks
   a) Passive sampling (NO2)
   b) Simple and cheap sensors
   c) Satelites
3. Multi-component sites (long duration)

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 a,b, Maria Foraster a,b,c,d, Mercedes Medina-Ramón a, Jorge Pey e, Nino Künzli f,g, Gerard Hoek.

- Mobile monitoring campaign
- 644 sites
- 15 minutes per site
- Models explain ~50% of measured variation



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Summary

- Networks have been used extensively in epidemiological studies, esp. time series studies
- Limitations include
  - Spatial density
  - Components (UFP, soot, composition)
  - Consistency