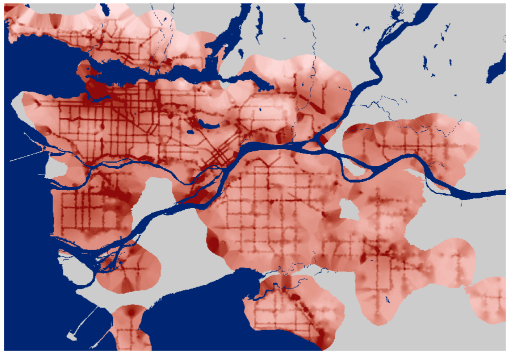
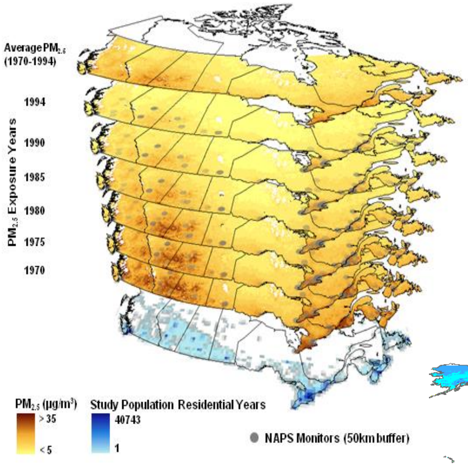
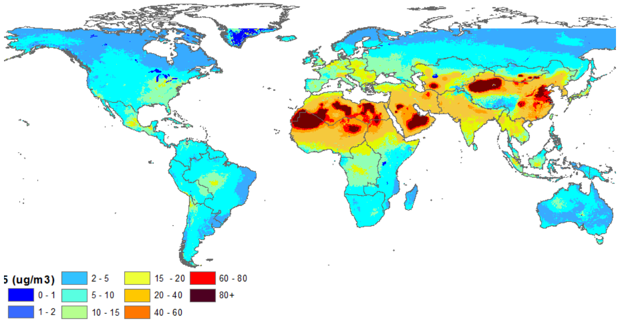
From local to global: Epidemiologic studies of the health impacts of environmental exposures







Michael Brauer

School of Population and Public Health

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

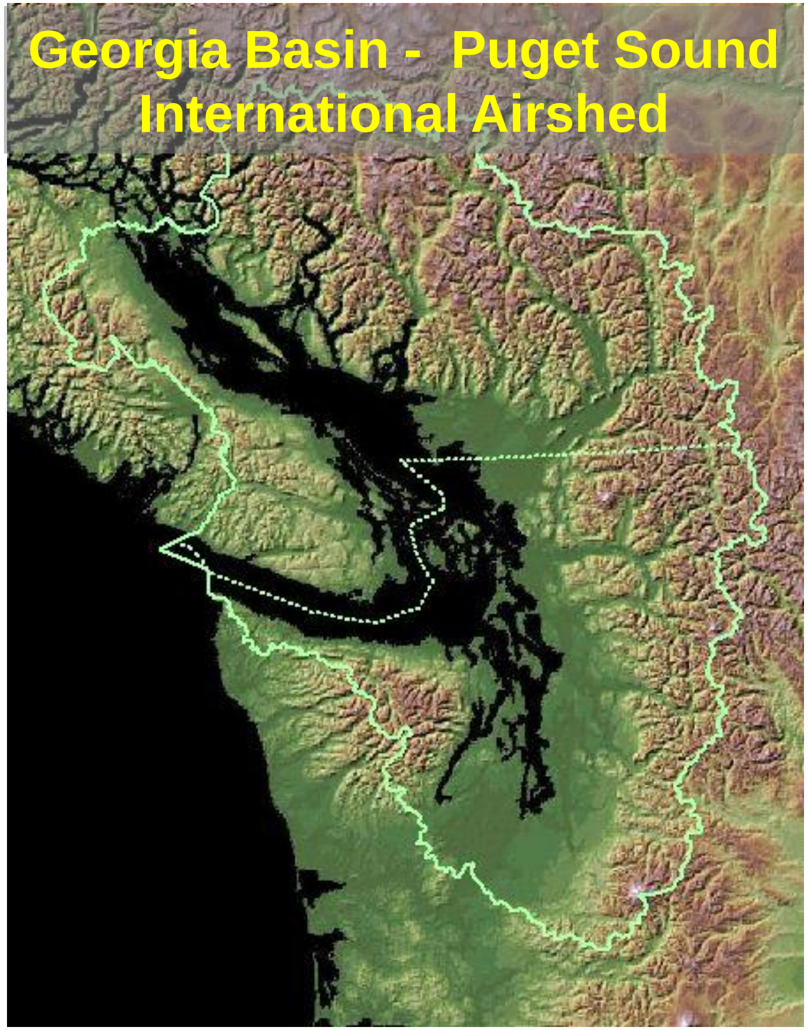
PIMS Big Data in Environmental Science. UBC May 15, 2015

Overview

- Border Air Quality Study (BAQS)
- Canadian Census Health and Environment Cohort (CanCHEC)
- Global Burden of Disease (GBD)

BORDER AIR QUALITY STUDY

Linked environmental and administrative health data to assess the health impacts of exposure to air pollution



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baqs.spph.ubc.ca

University of Victoria

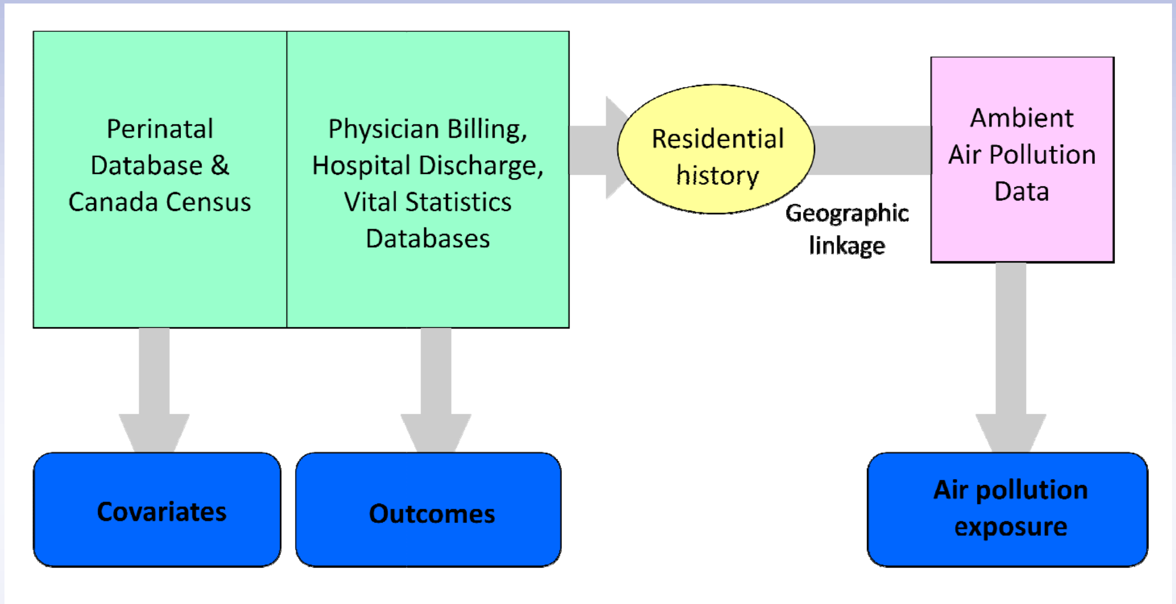
BC Centre for Disease Control

Health Canada Santé Canada

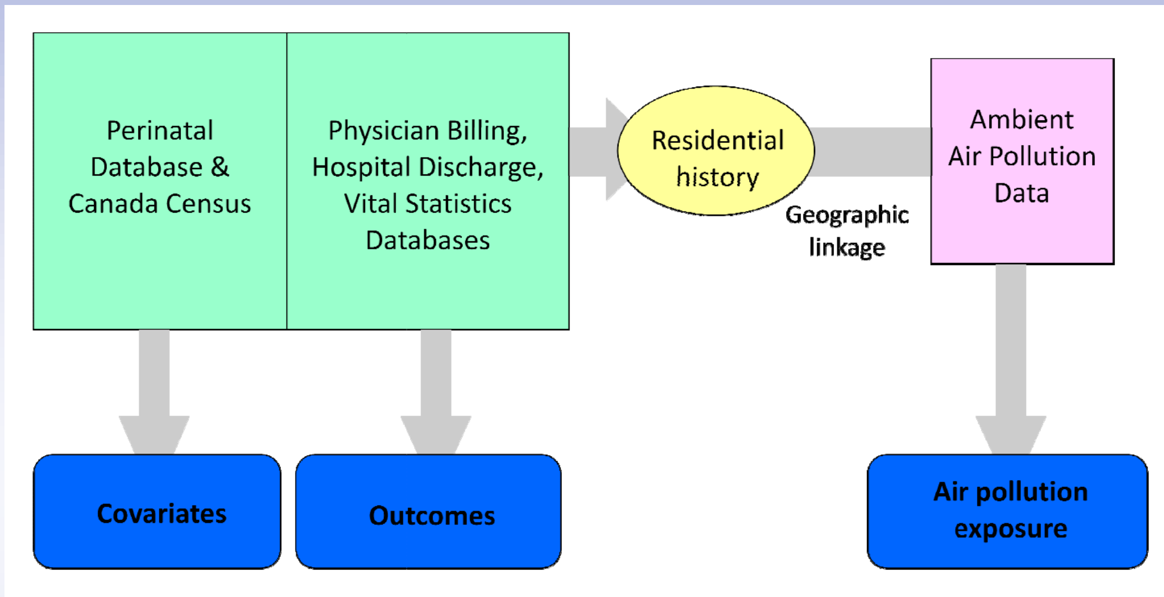
UNIVERSITY OF WASHINGTON

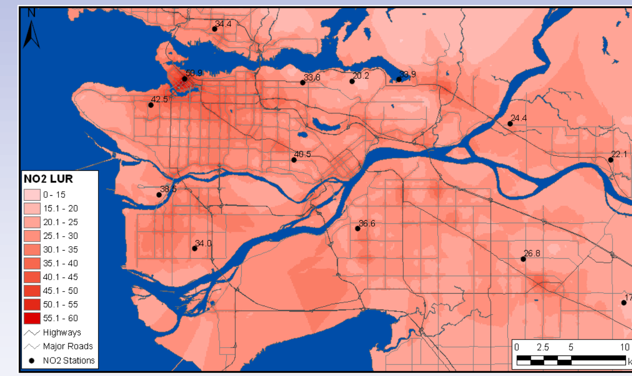
BAQS

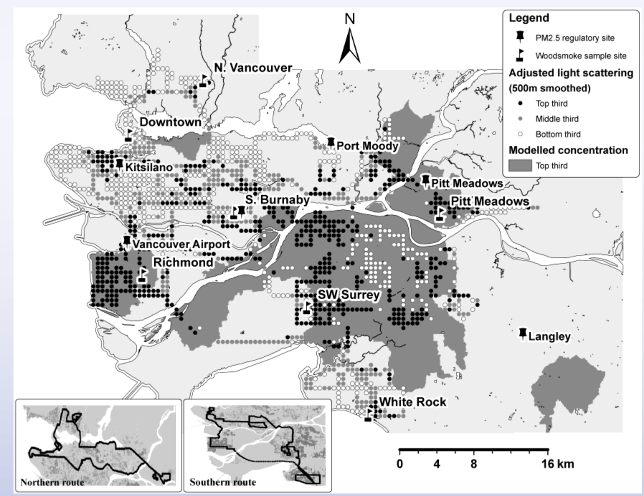
If you build it…they will come



If you build it…they will come







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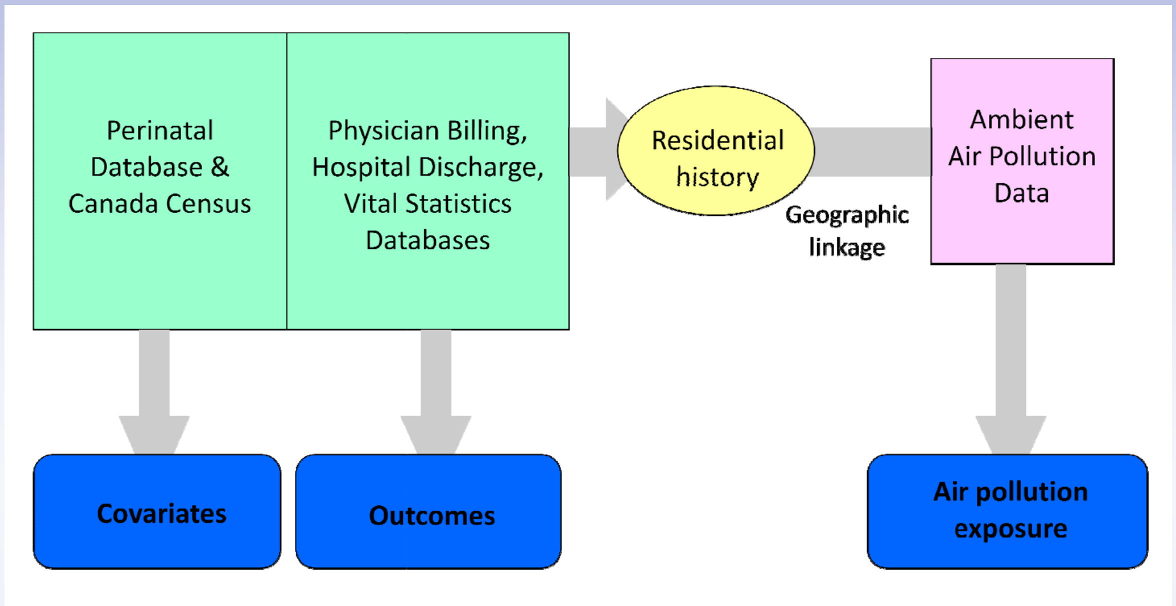

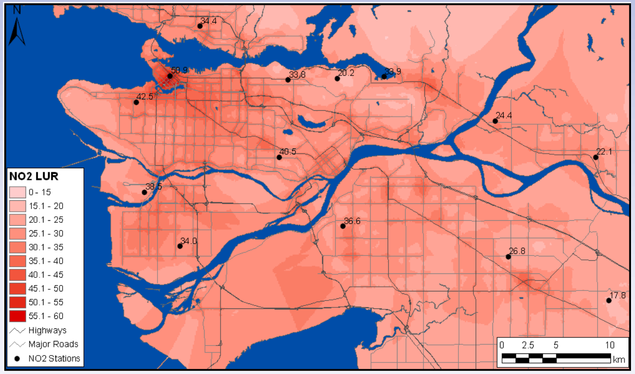

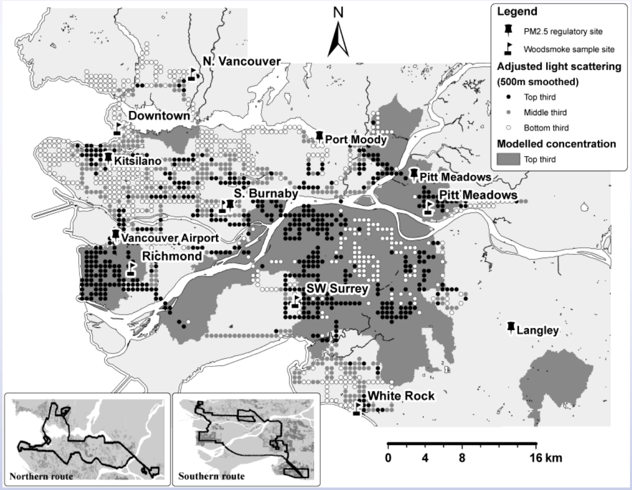

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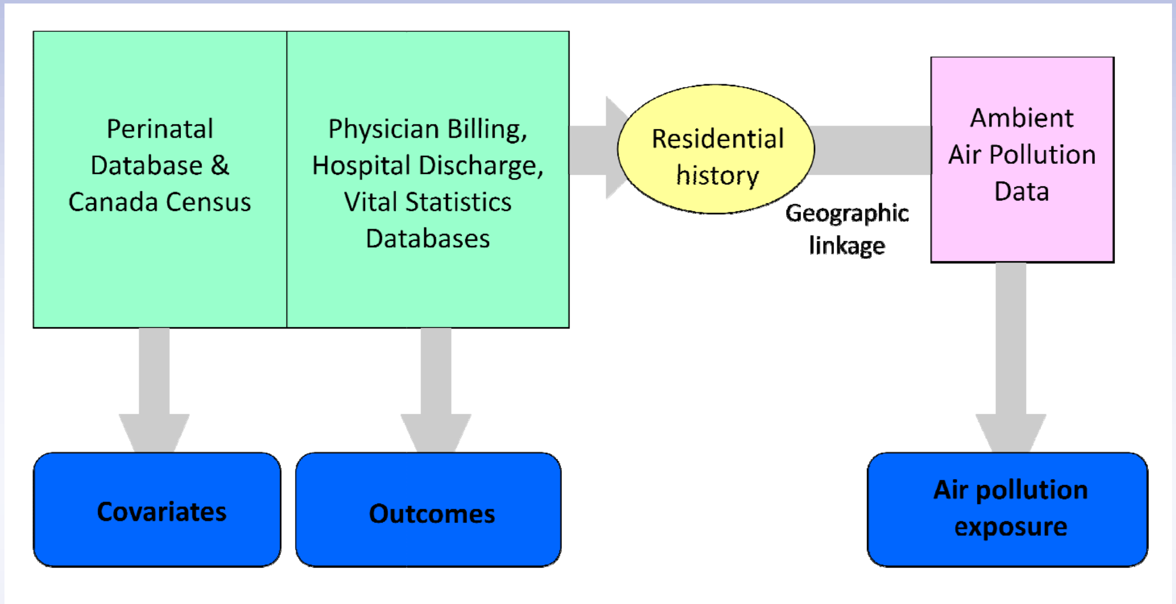
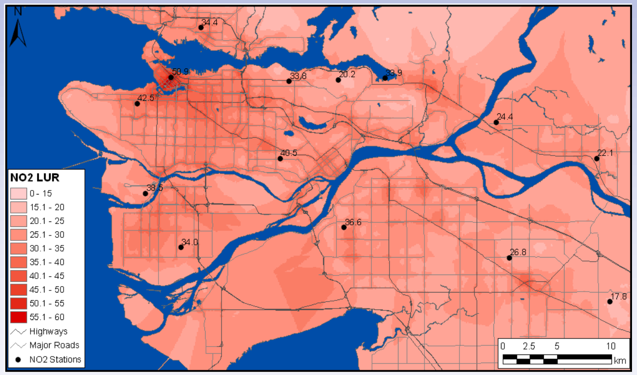
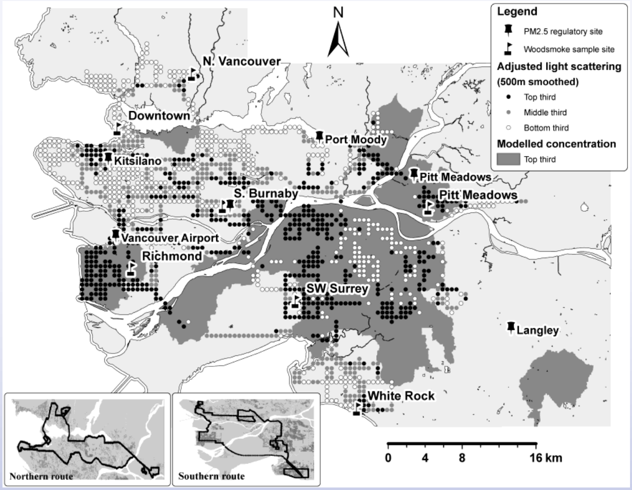
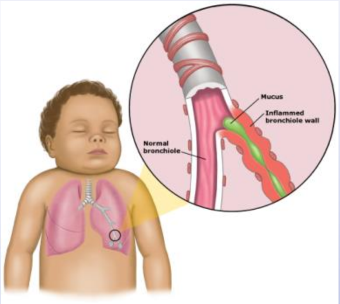
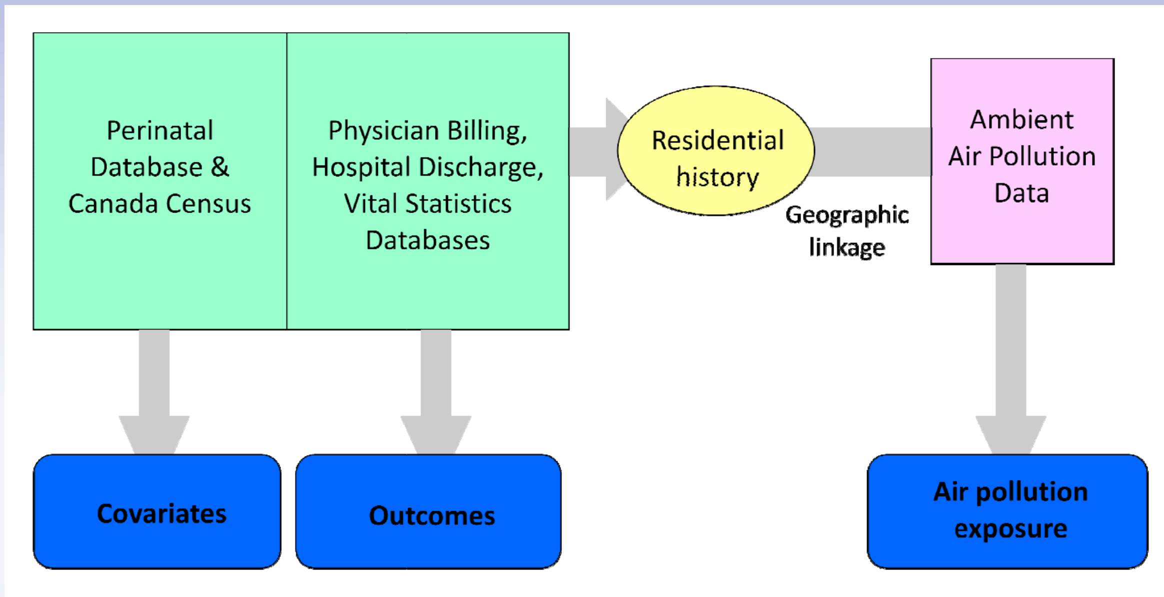


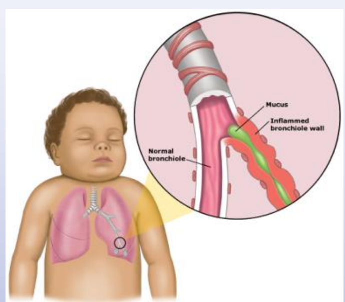


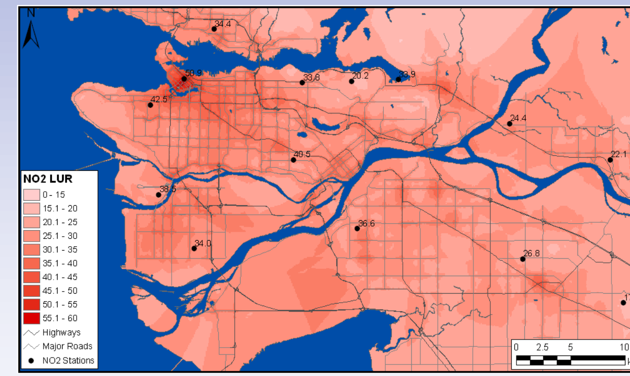


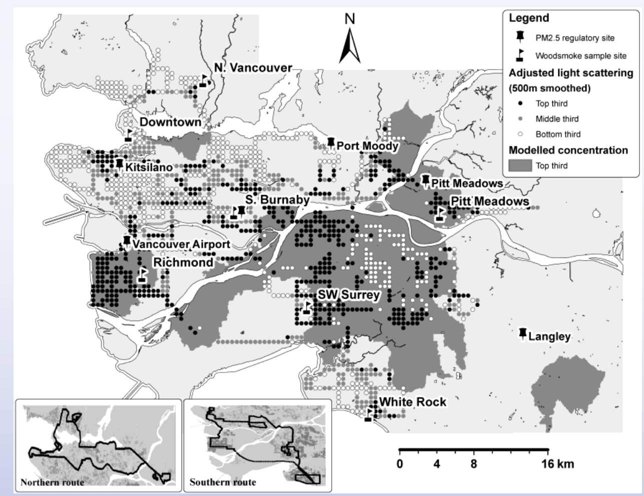


If you build it…they will come



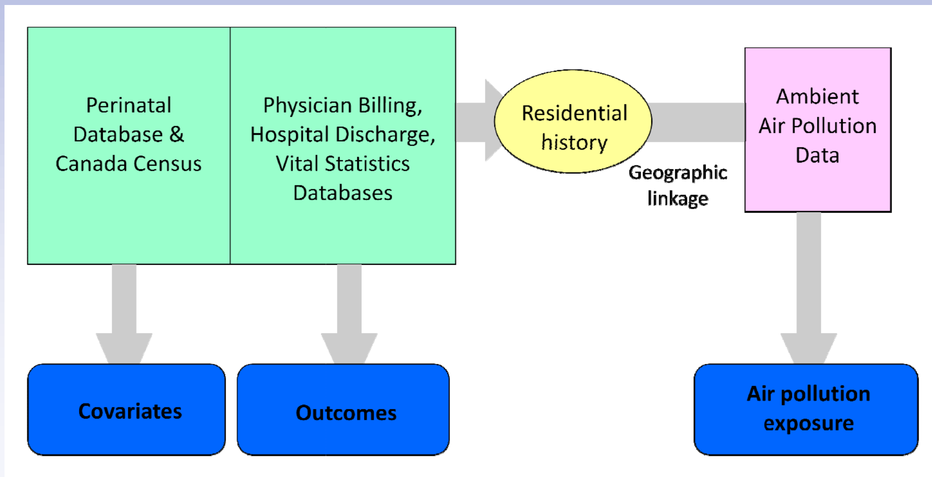


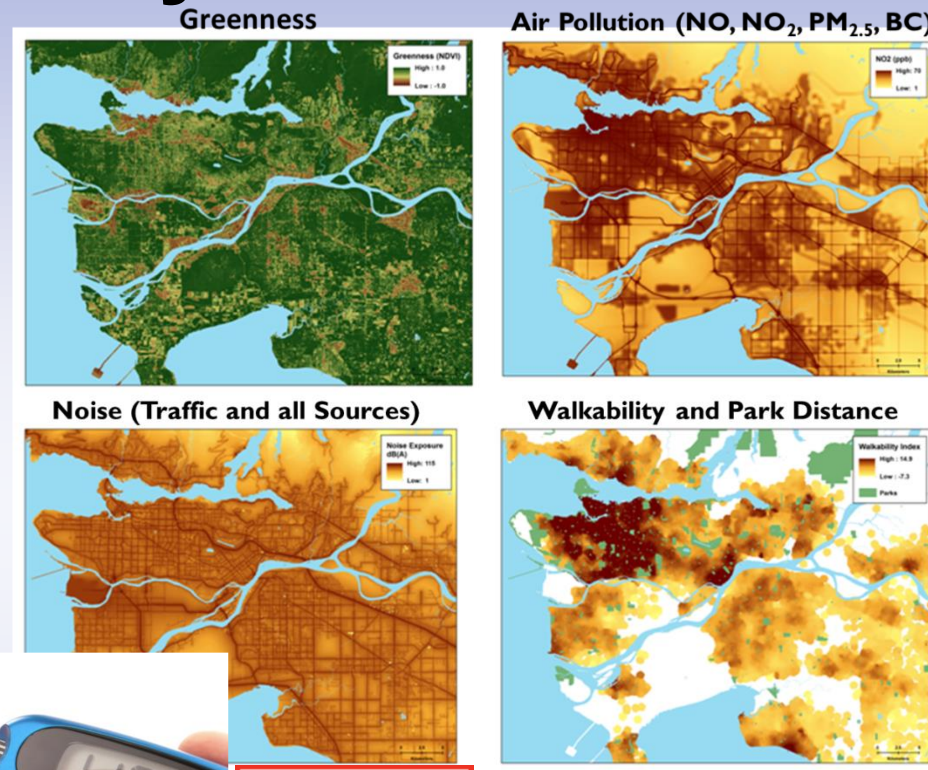


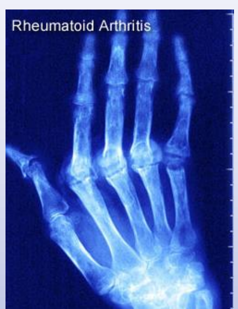


BAQS

If you build it…they will come





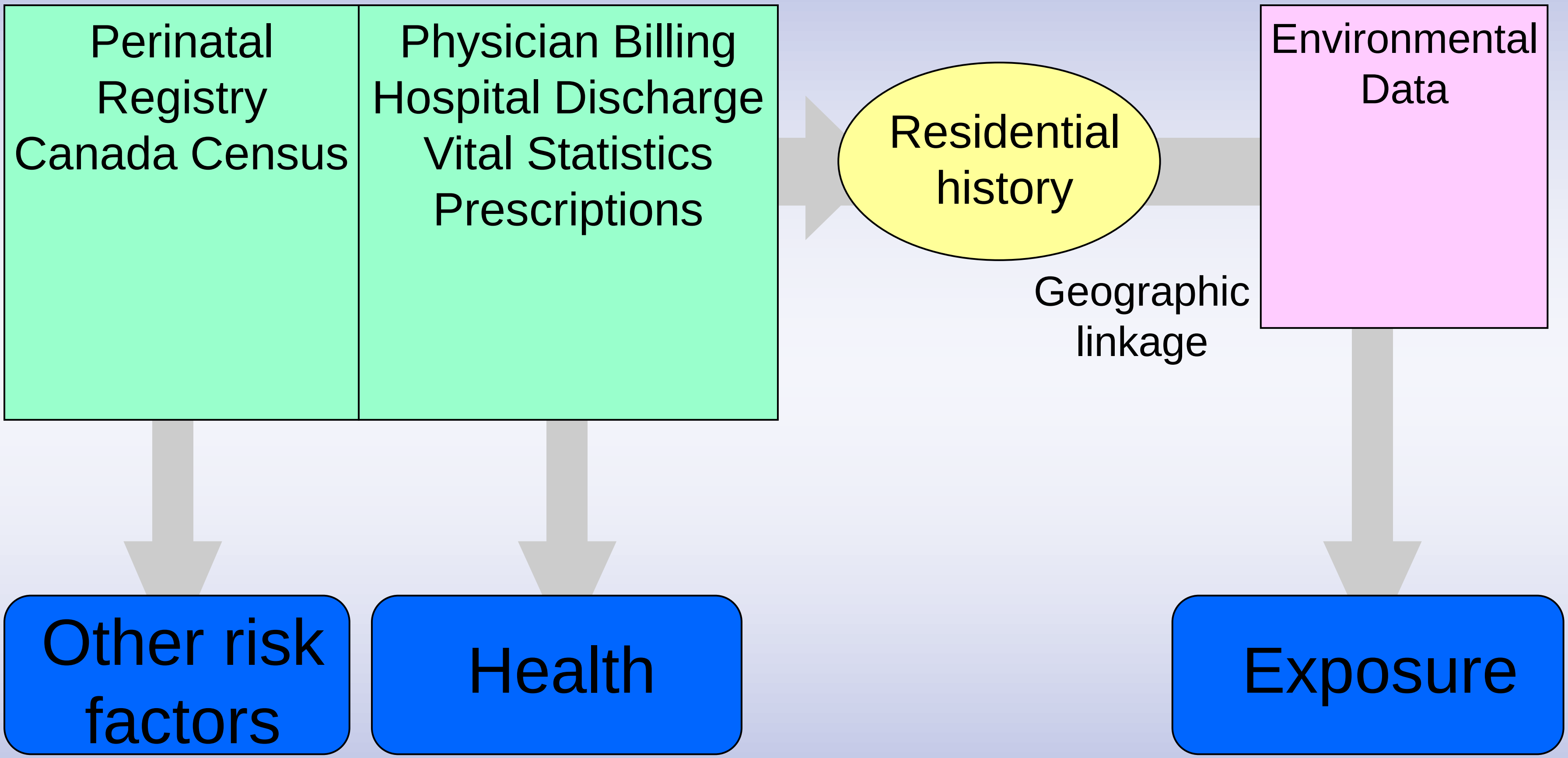


MS

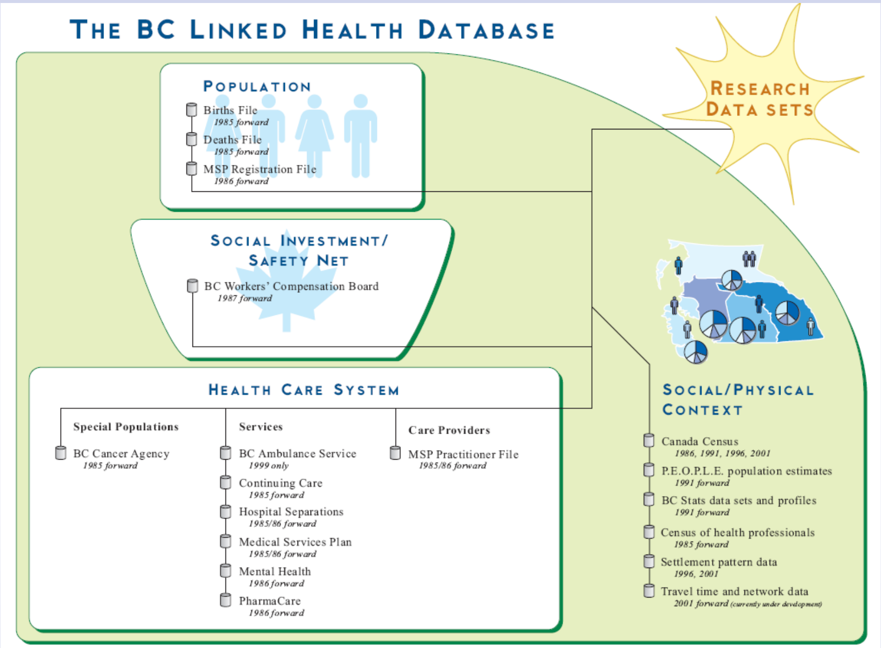
and more…

BAQS

Database linkage



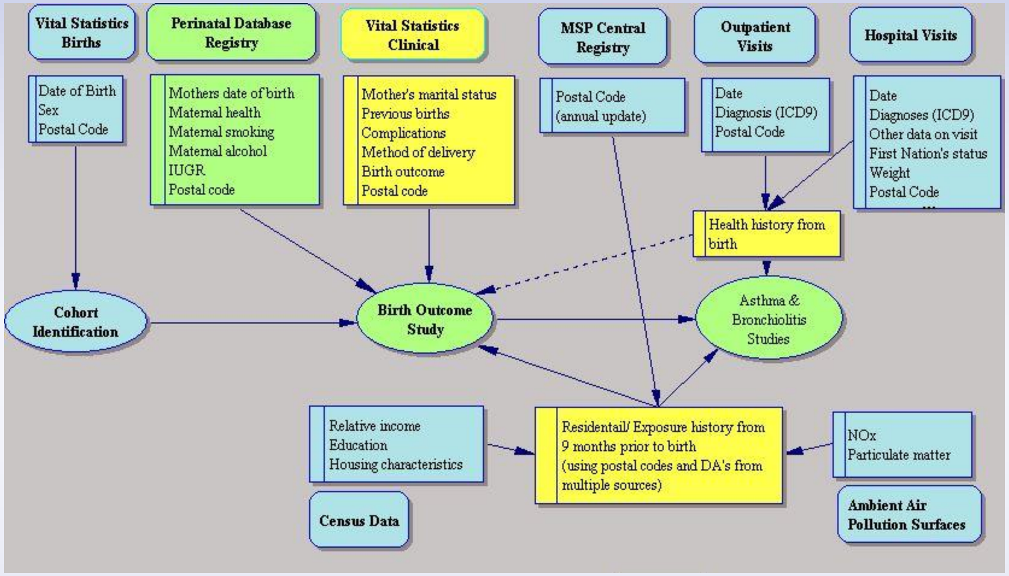
Birth Cohort



Birth Cohort

populationdata BC

- **Birth cohort** identified 92,158 children born in the study area during a 4-year period (1999–2002).
- **Early childhood cohort** followed these newborns in 1999/2000 for 8 years

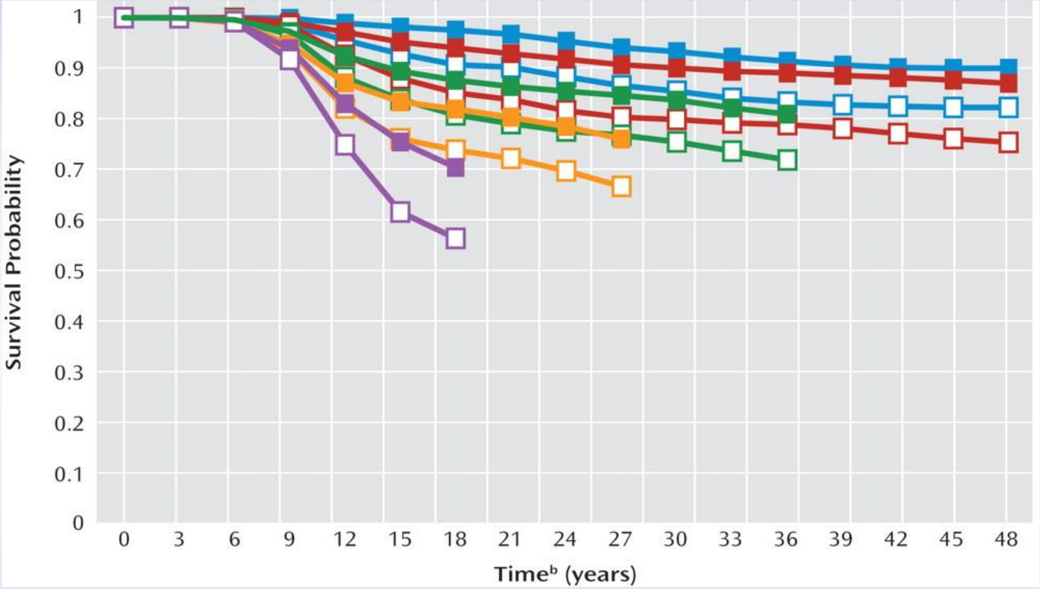


BAQS

Adult Cohort

populationdata BC

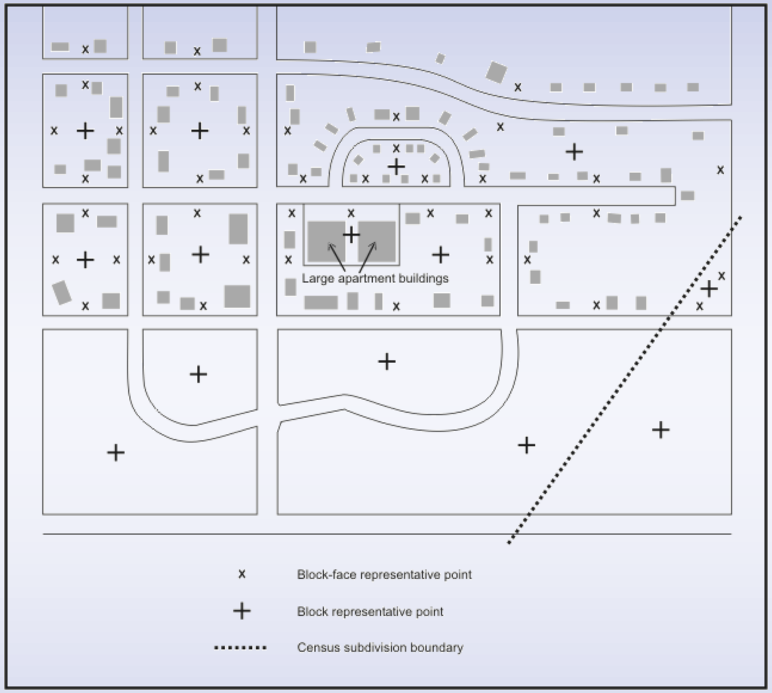
- 678,361 adults 45–84 yrs (1999) area residents who lived in study area
- 5-year cohort definition period (1994–1998) to assess pre-existing diseases
- Follow-up to 2002



BAQS

Residential Histories

- Provincial health plan registry files, hospital discharges, and physician billing records used to establish residential histories (postal code resolution).
  - Not straightforward: multiple databases of residential addresses (of varying qualities), updated at different times.
  - 34.9 % of cohort had 2 addresses during pregnancy.
  - Opportunity to examine what happens when you change exposure (due to residential mobility).

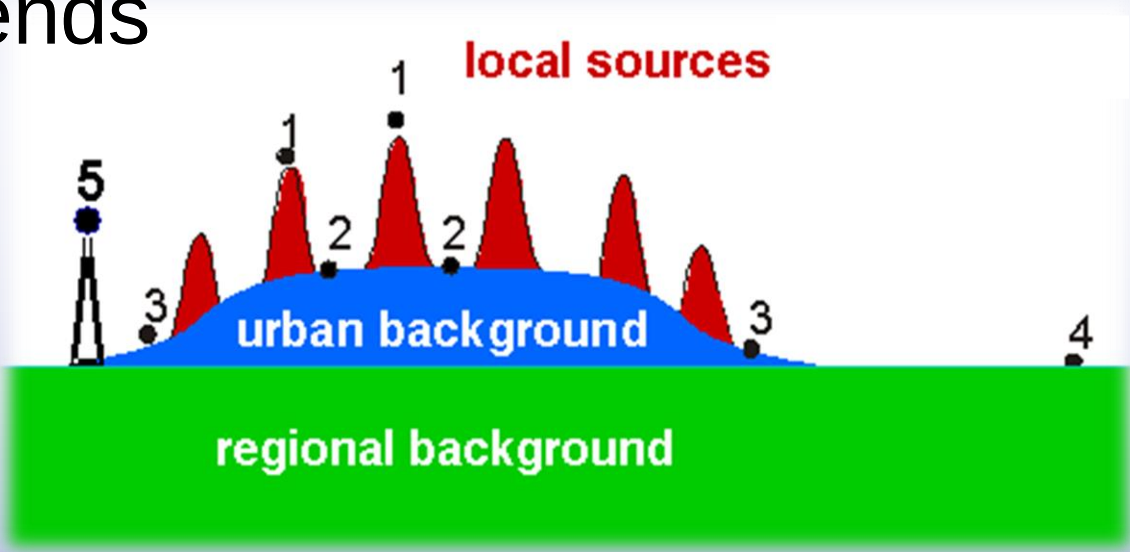


89.2 % of postal codes referenced to block face

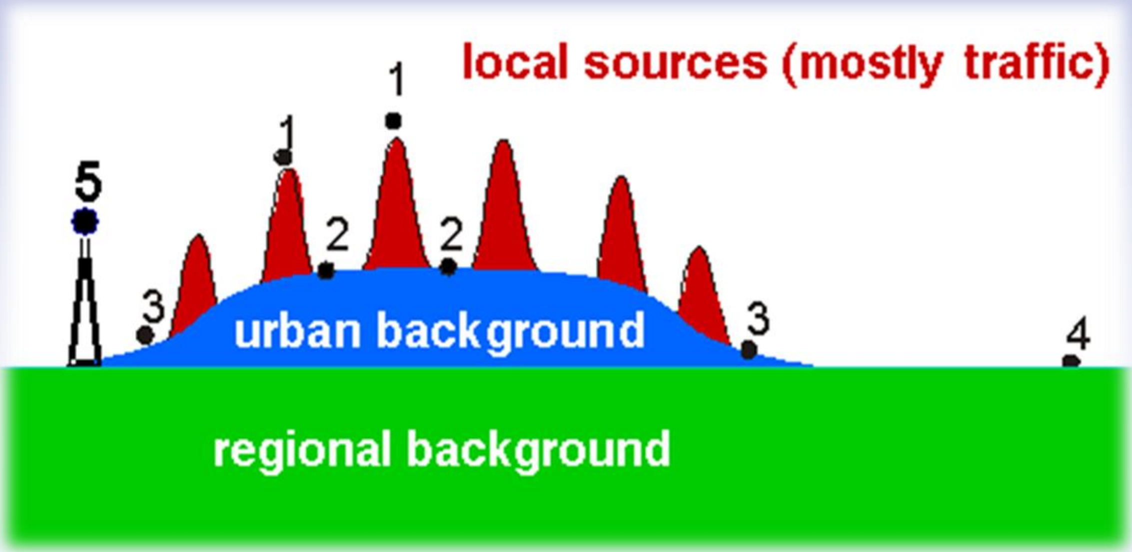
Air pollution exposure

Typically,

- Measure a few key ingredients of complex mixture
- Measure background
- Capture time trends



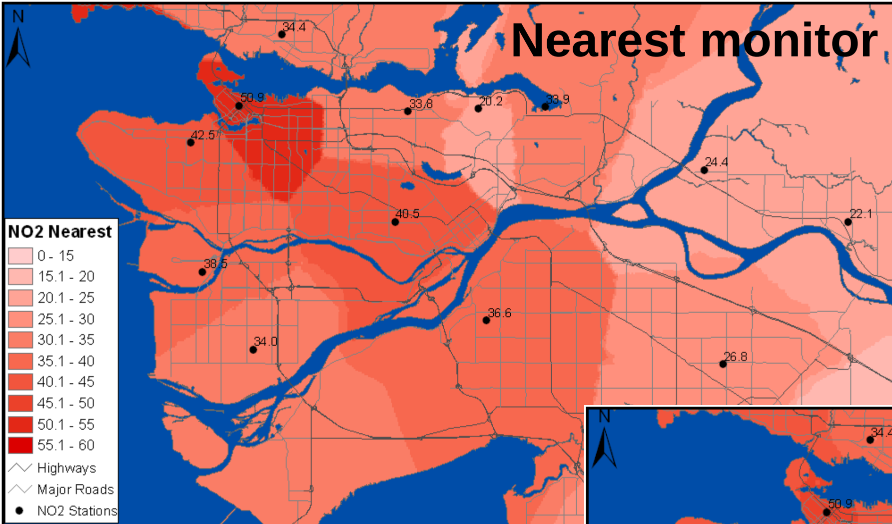
Exposure Assessment Design

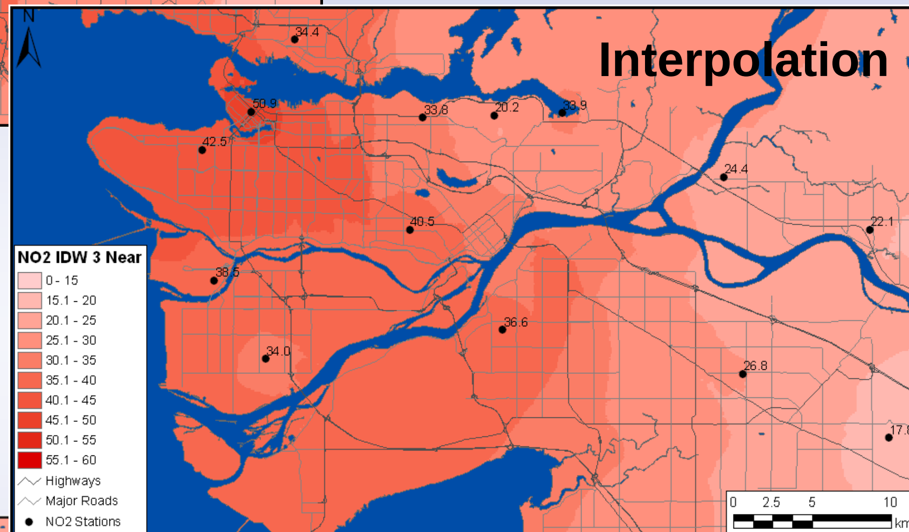


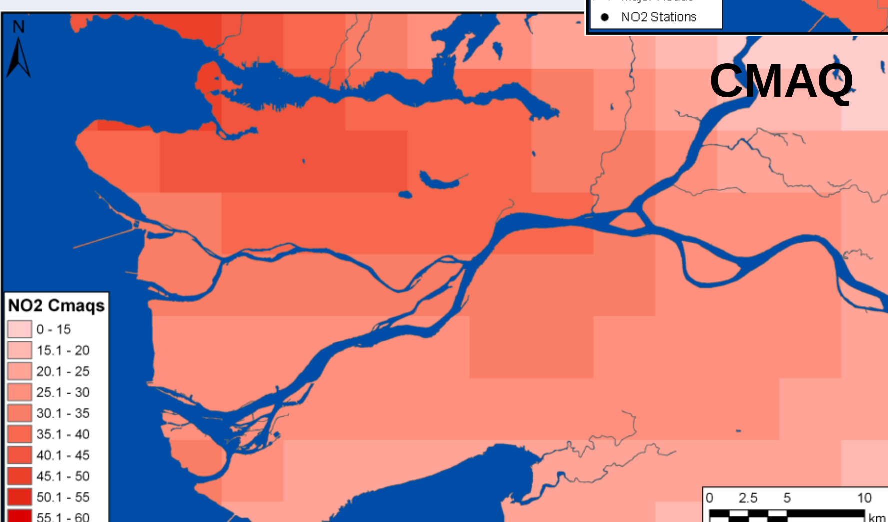
$$Exposure = C_{region} + C_{urban} + \mathbf{C_{traffic}} + \mathbf{C_{woodburning}} + \mathbf{C_{point\ source}}$$

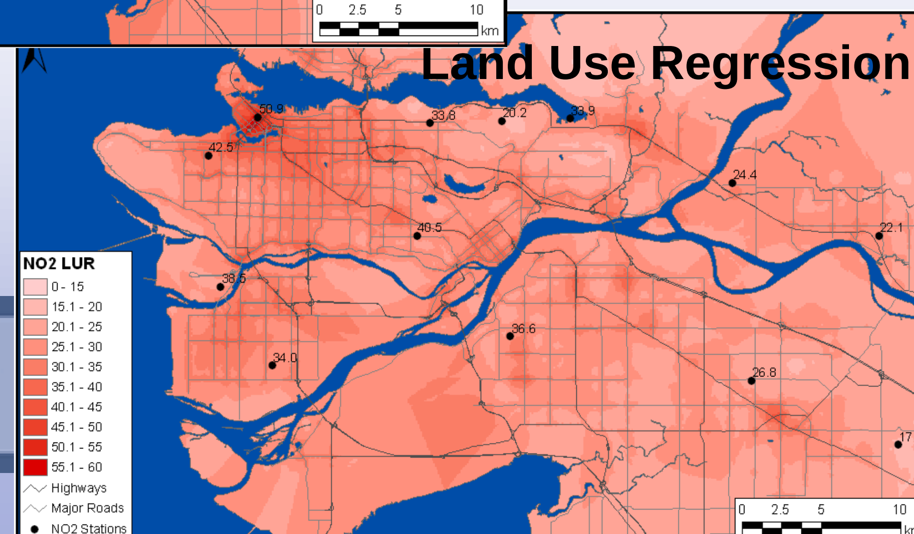
BAQS

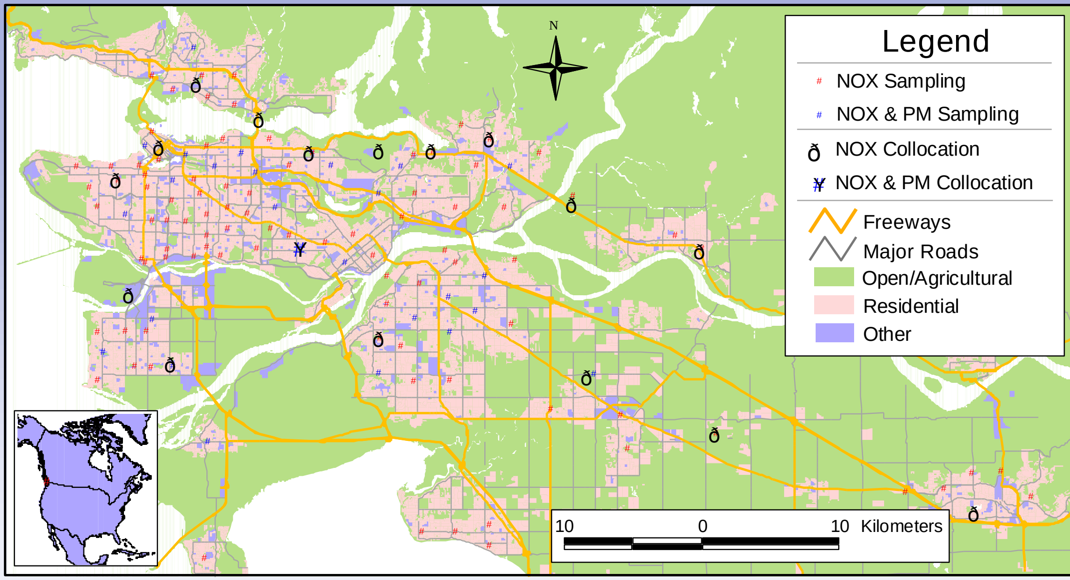
NO_2 Exposure Surfaces

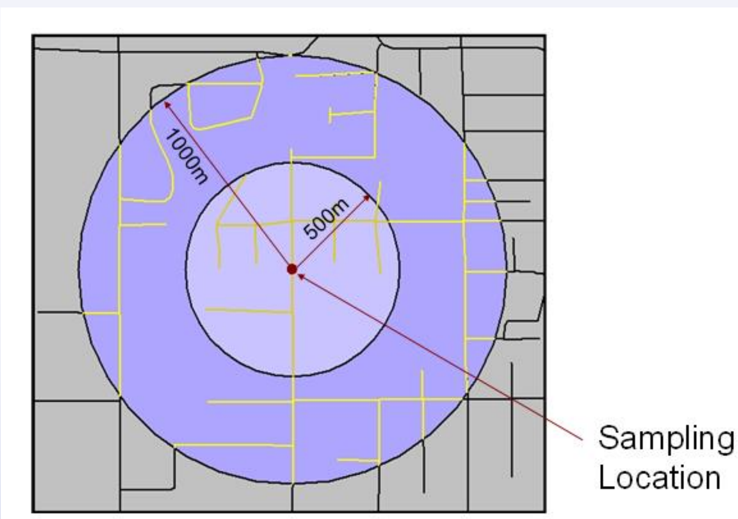


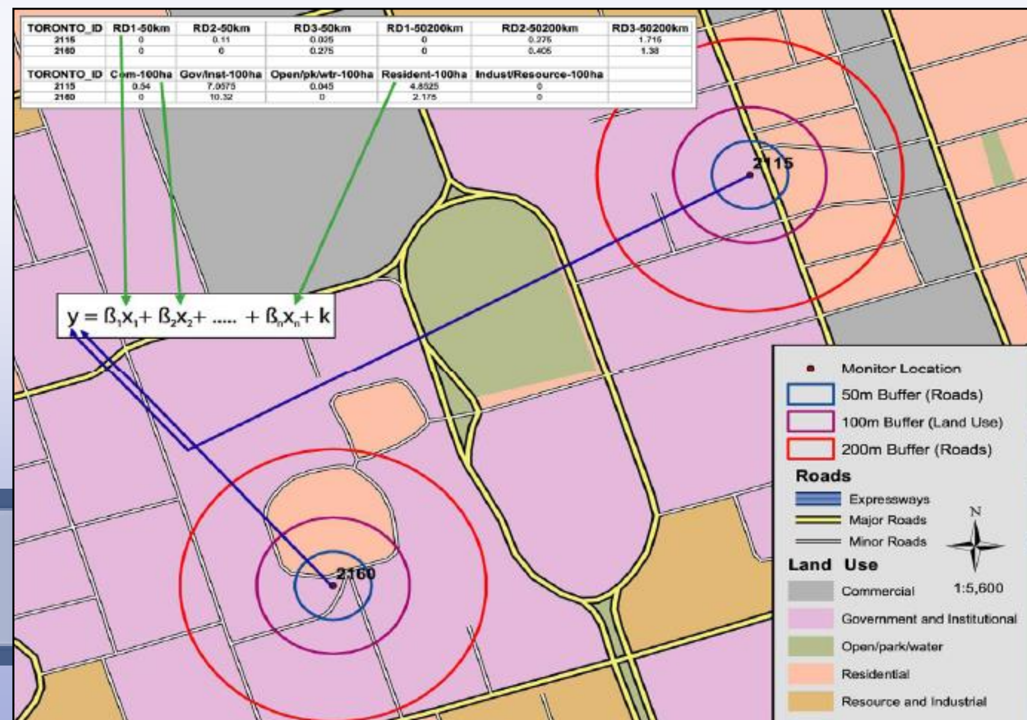




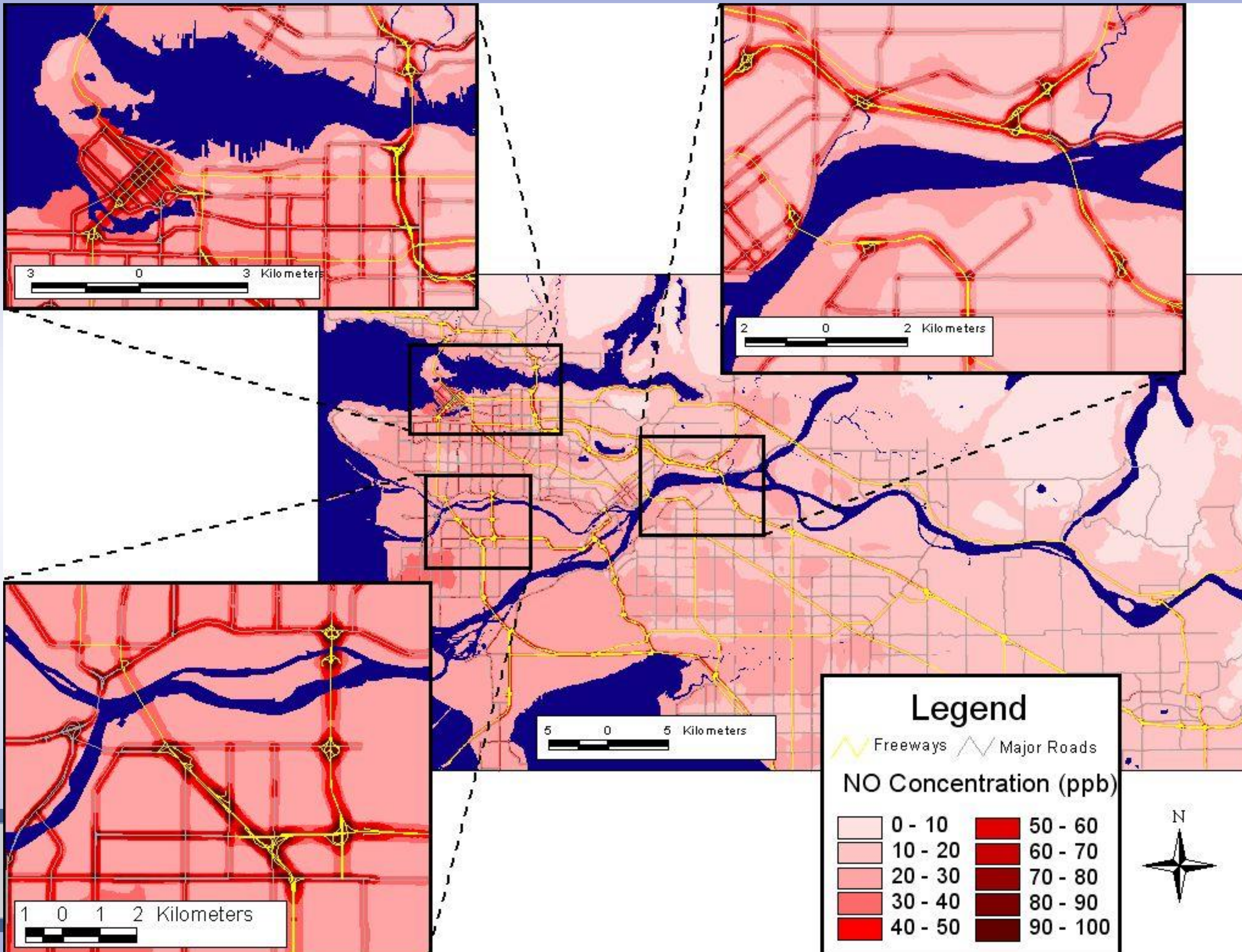








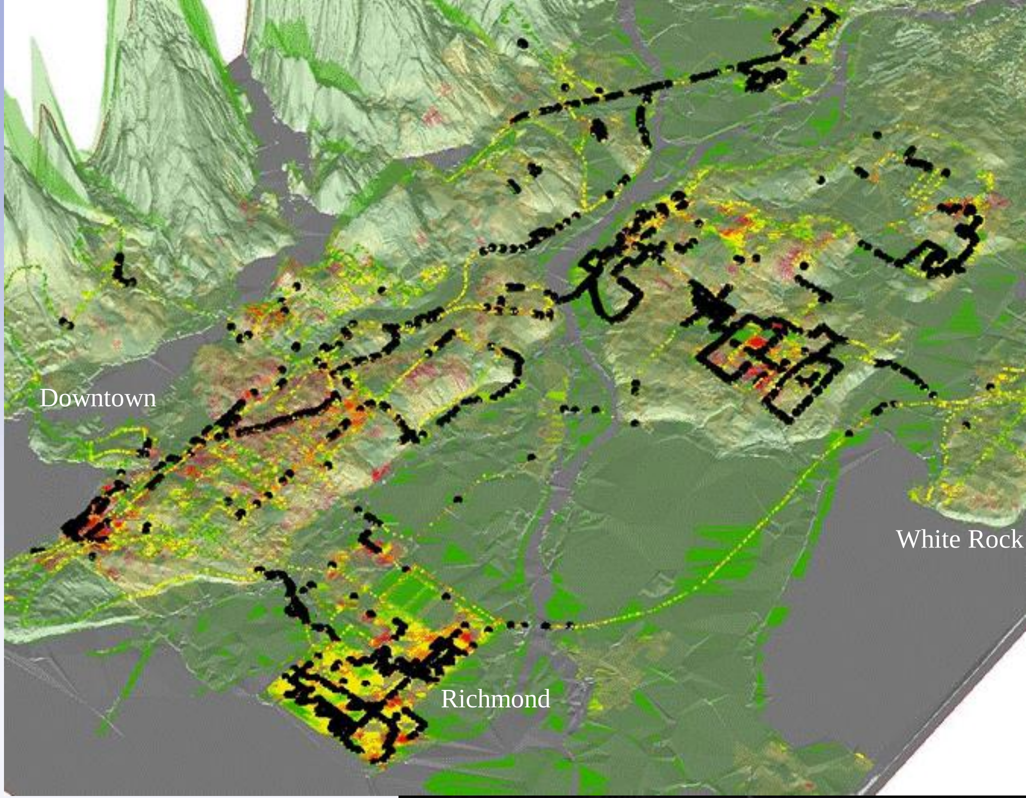
Land Use Regression



3 0 3 Kilometers
2 0 2 Kilometers
5 0 5 Kilometers
1 0 1 2 Kilometers
Legend
Freeways
Major Roads
NO Concentration (ppb)
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
60 - 70
70 - 80
80 - 90
90 - 100
N

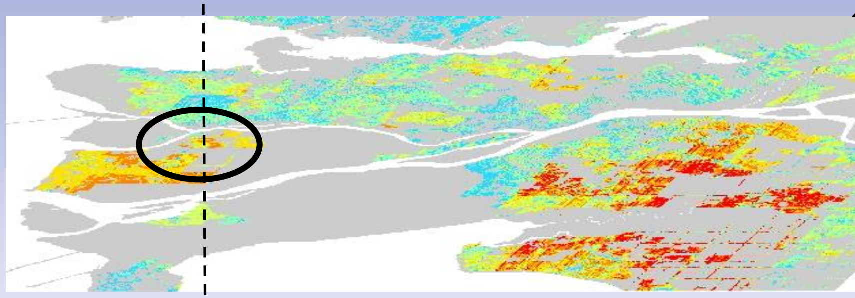
Woodsmoke

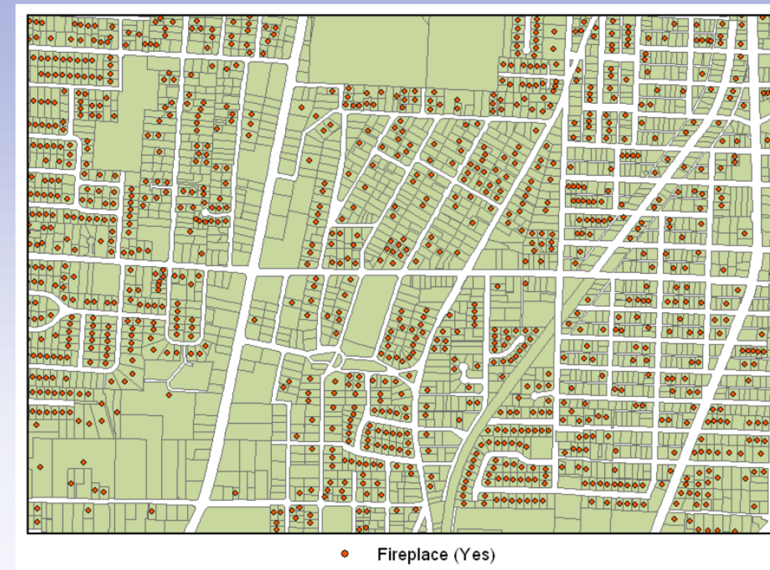
Mobile Monitoring on Cold, Clear Winter Evenings

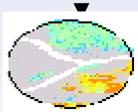


(~ 12,000 points)

Spatially resolved independent variables (e.g., dwellings)



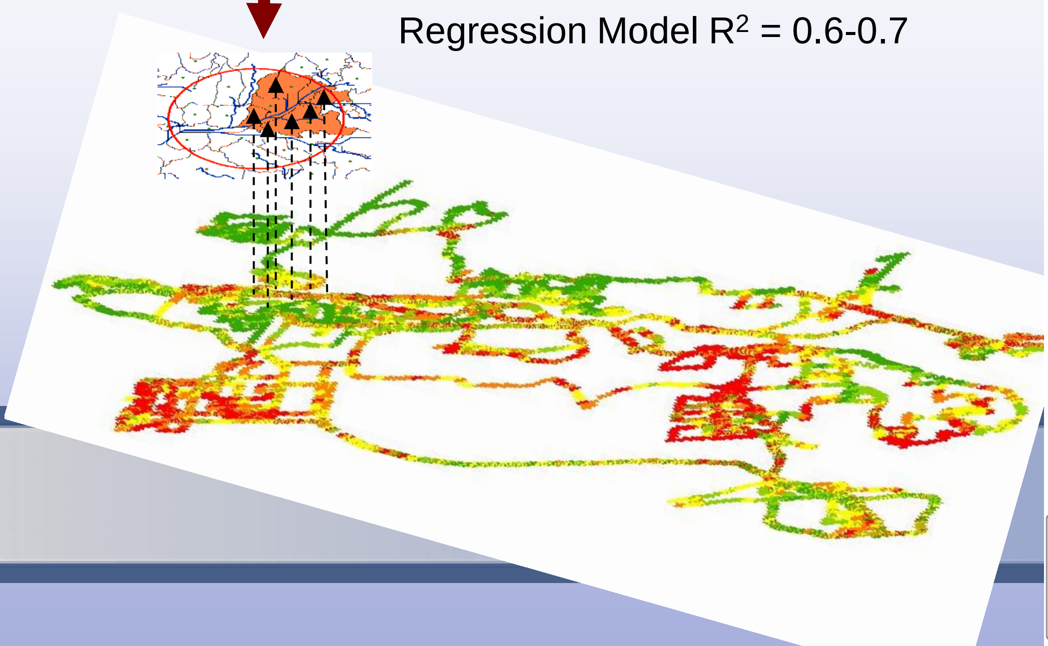


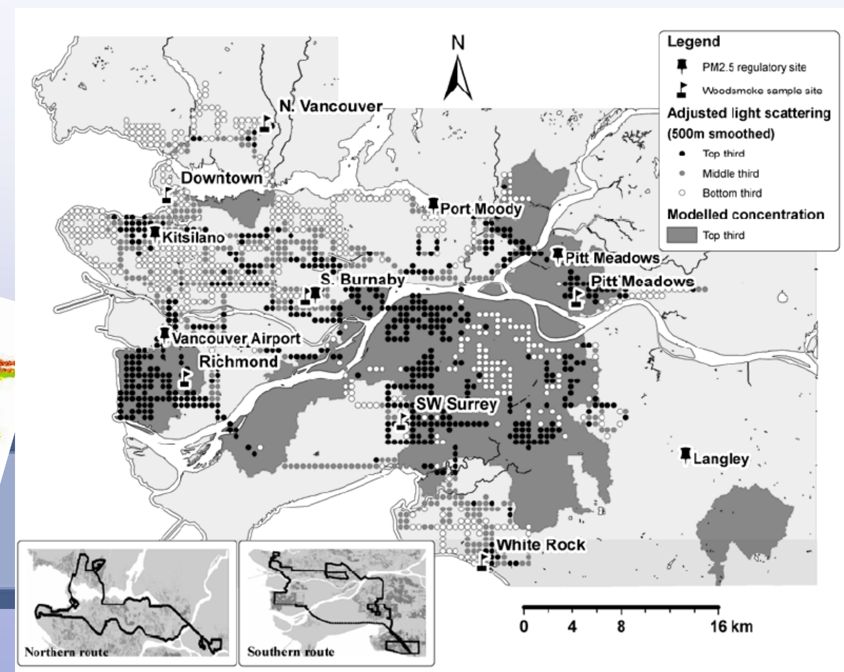


Catchment area buffer extracted independent variable (e.g. emissions, bldg. Age, SES, population)

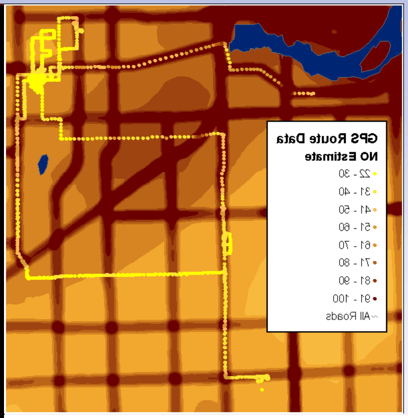
Average of all measurements within buffer area (dependent variable)

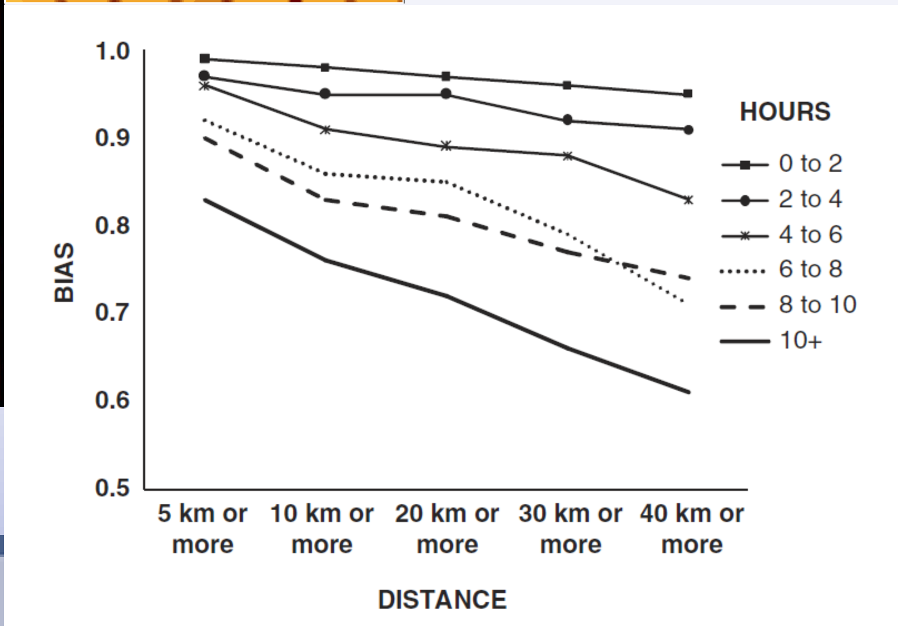
Regression Model R^2 = 0.6-0.7



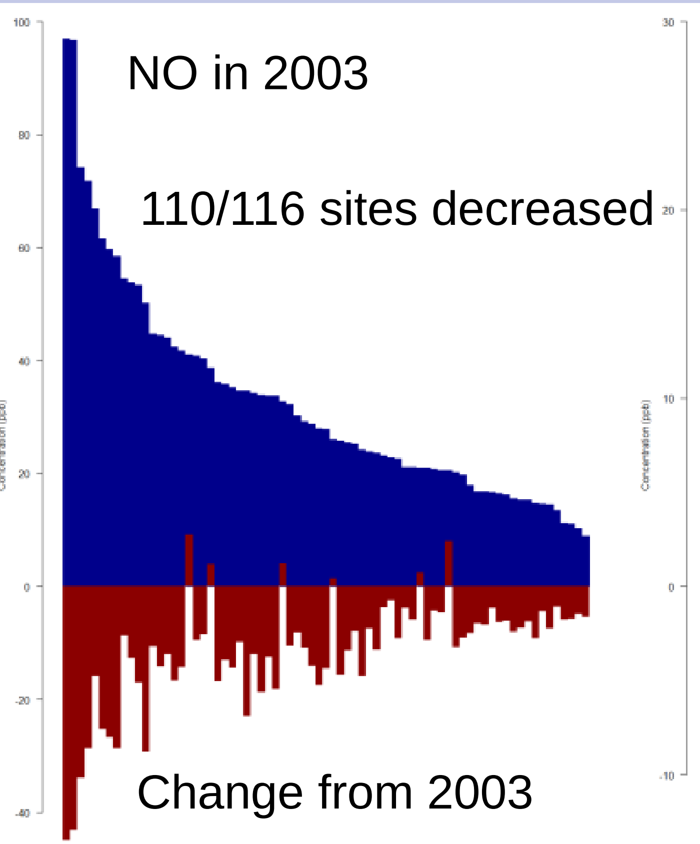


Evaluation studies: mobility



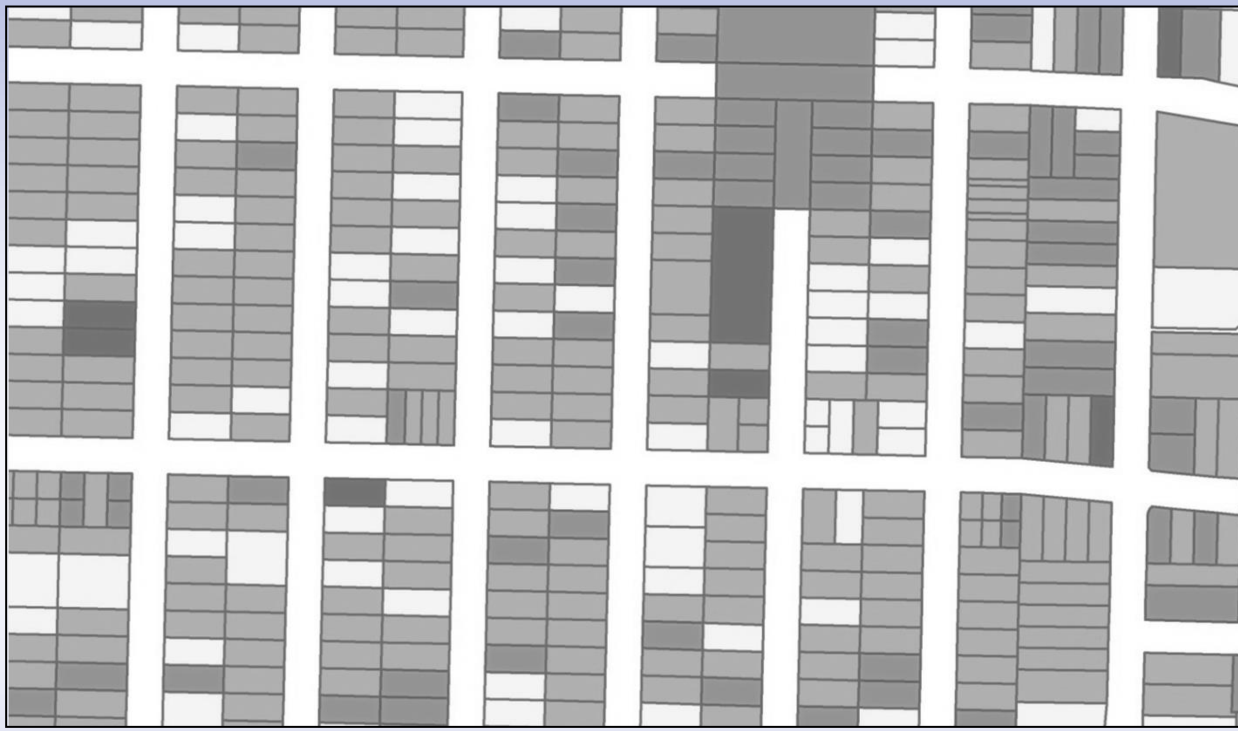


Evaluation studies: model stability



NO2, length model	Method 1 (temporal trend)	Method 2 (predictor values)	Method 3 (1&2 joint)	Method 4 (calibrating coefficient s)
Forecast, using 2003 model (**R^2 = 0.52**) to predict concentrations in 2010				
R^2	**0.54**	**0.52**	**0.52**	**0.61**
Error mean	1.57	4.62	1.15	0.00
SD	2.35	2.34	2.34	2.08
Back-cast, using 2010 model (**R^2 = 0.63**) to predict concentrations in 2010				
R^2	**0.44**	**0.46**	**0.46**	**0.49**
Error mean	- 1.58	- 5.16	-1.69	0.00
SD	3.08	3.05	3.05	2.96

Evaluation studies: infiltration



F_{inf} Model Results

0.36 [5.4 *ug*/m^3][1]

0.45 [6.75 *ug*/m^3][1]

0.51 [7.65 *ug*/m^3][1]

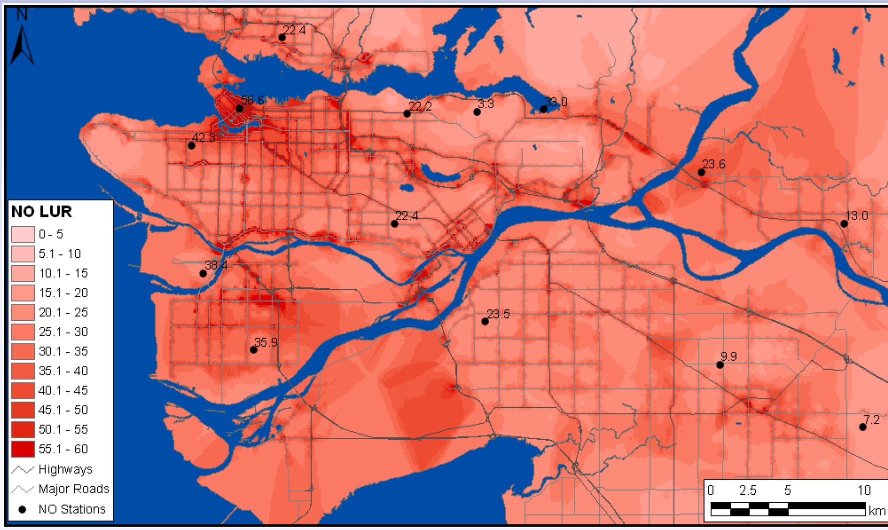
0.60 [9.0 *ug*/m^3][1]

Non residential

Average outdoor $PM_{2.5}$ level **15 μg/m^3** → indoor levels **5 –9** μg/m^3

Traffic-related air pollution (children)

- Increased low birthweight and pre-term birth
  - living <50m from provincial highway: 21% ↑ low birthweight
- Bronchiolitis
  - living <50m from provincial highway: 6% ↑
- Middle ear infections
  - 7% of cases attributable to traffic
- Asthma (early life exposure)
  - 13% of childhood asthma attributable to traffic

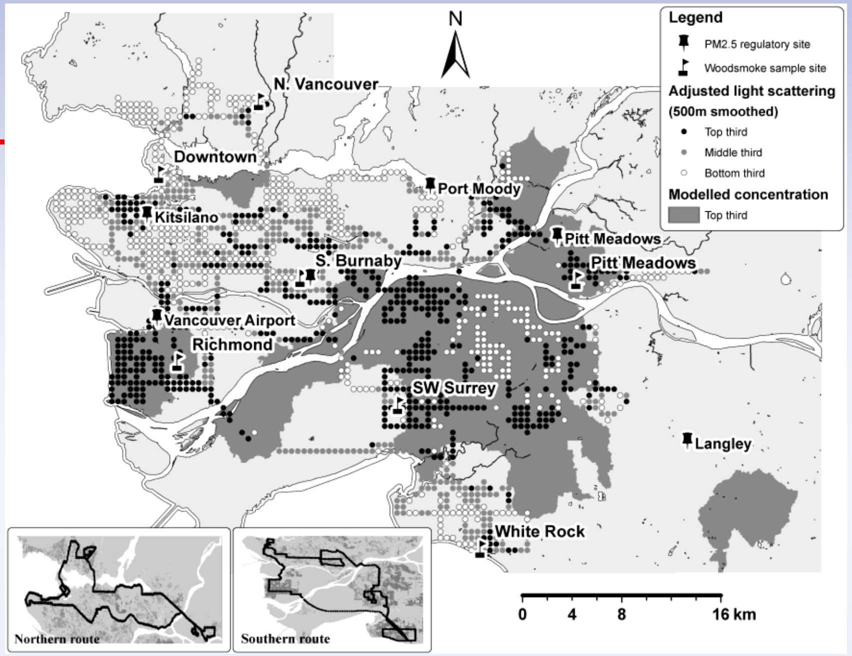


Traffic-related air pollution

Brauer M, et al. Environ Health Perspect. 2008; Clark NA, et al. Environ Health Perspect 2010. Karr CJ et al. Am J Resp Crit Care Med 2009; MacIntyre et al. Epidemiology. 2010

Woodsmoke

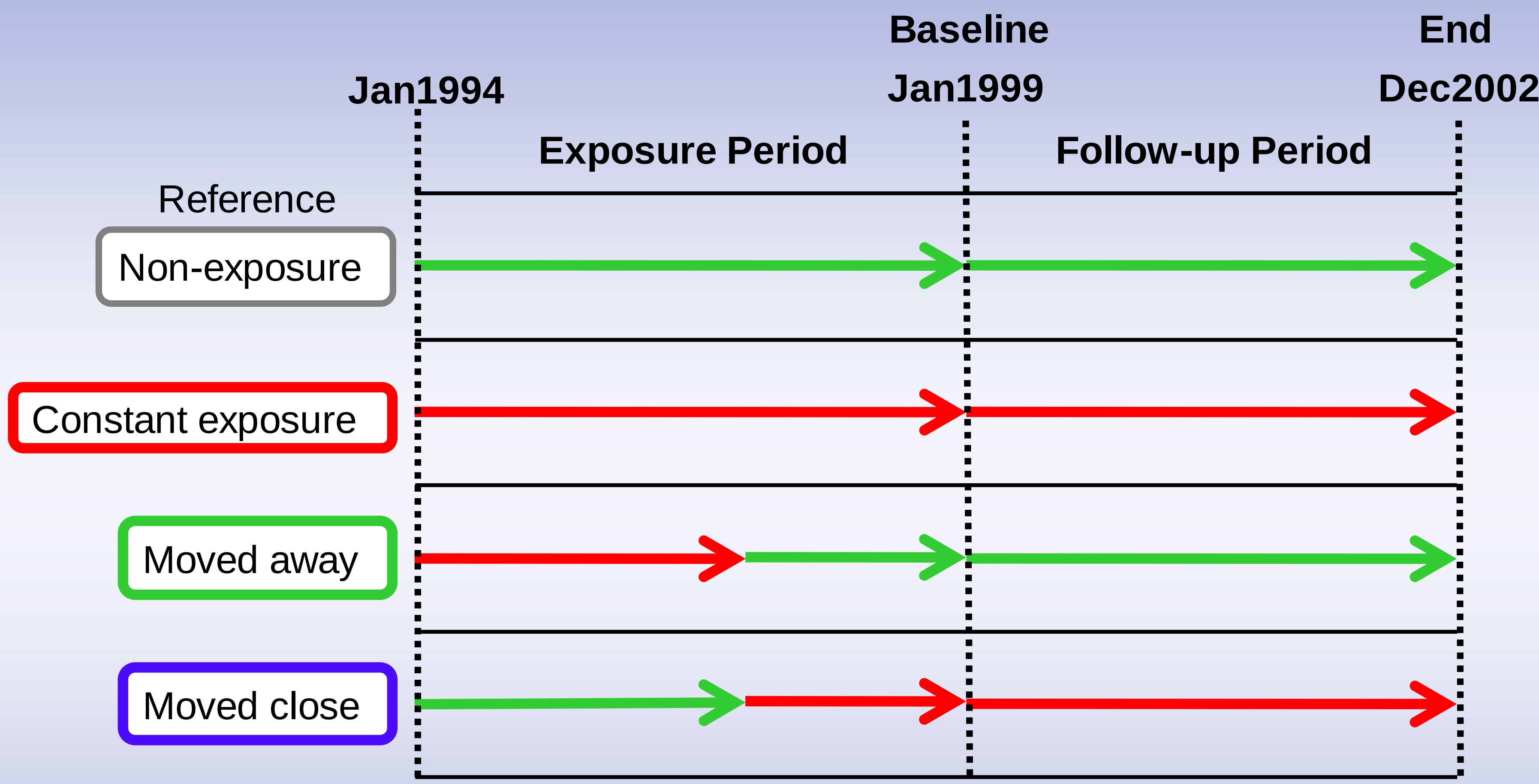
- 15% increase in SGA birth[+]
- 32% increase in otitis media[+]
- 8% increase in bronchiolitis[*]
- 15% increase in COPD hospitalization[+]
- No associations with:
  - pre-term birth[-]
  - asthma *incidence*[-]
  - cardiovascular, COPD mortality[-]



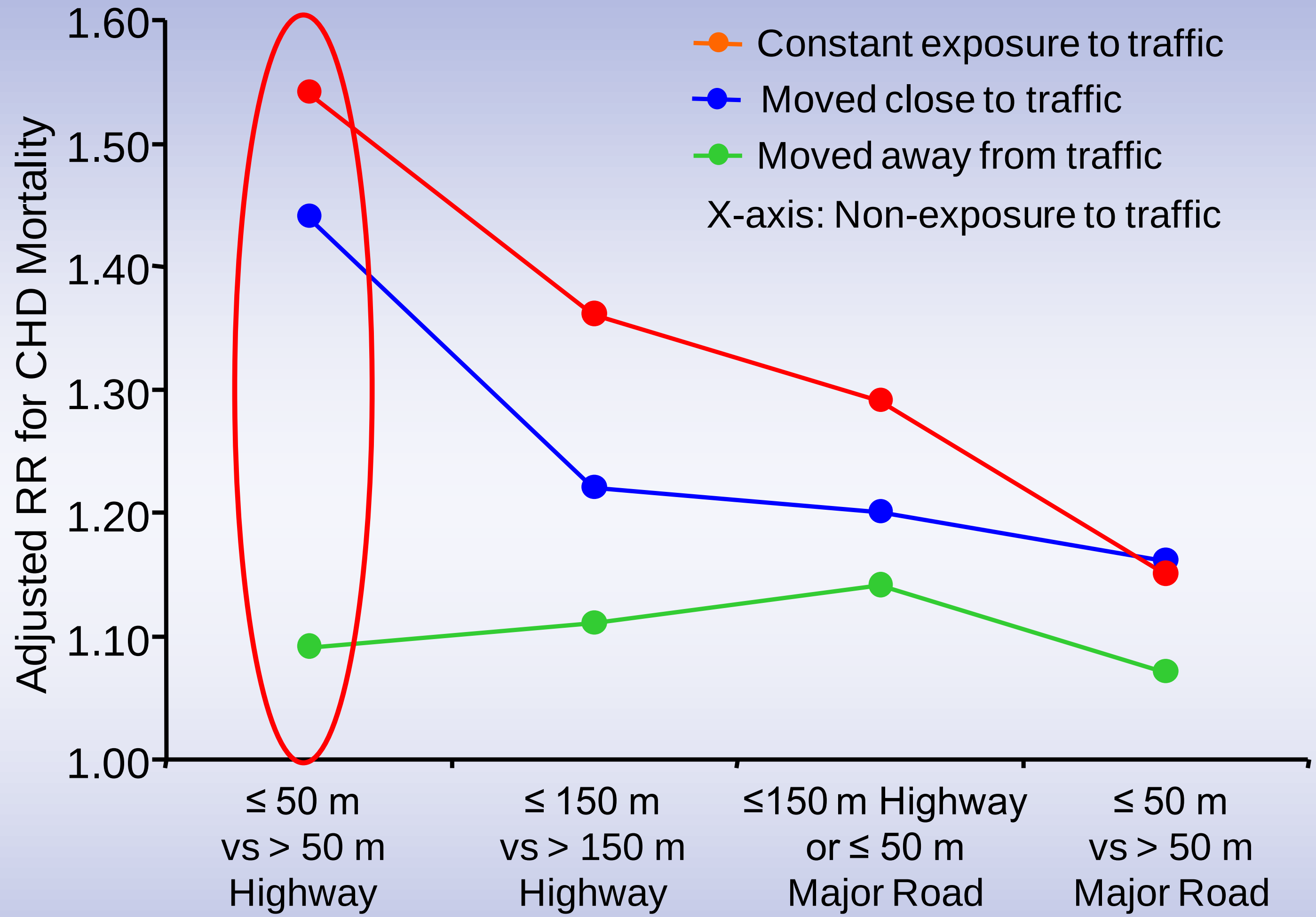
[++] > traffic pollution, [+] ~traffic, [-] <traffic

BAQS

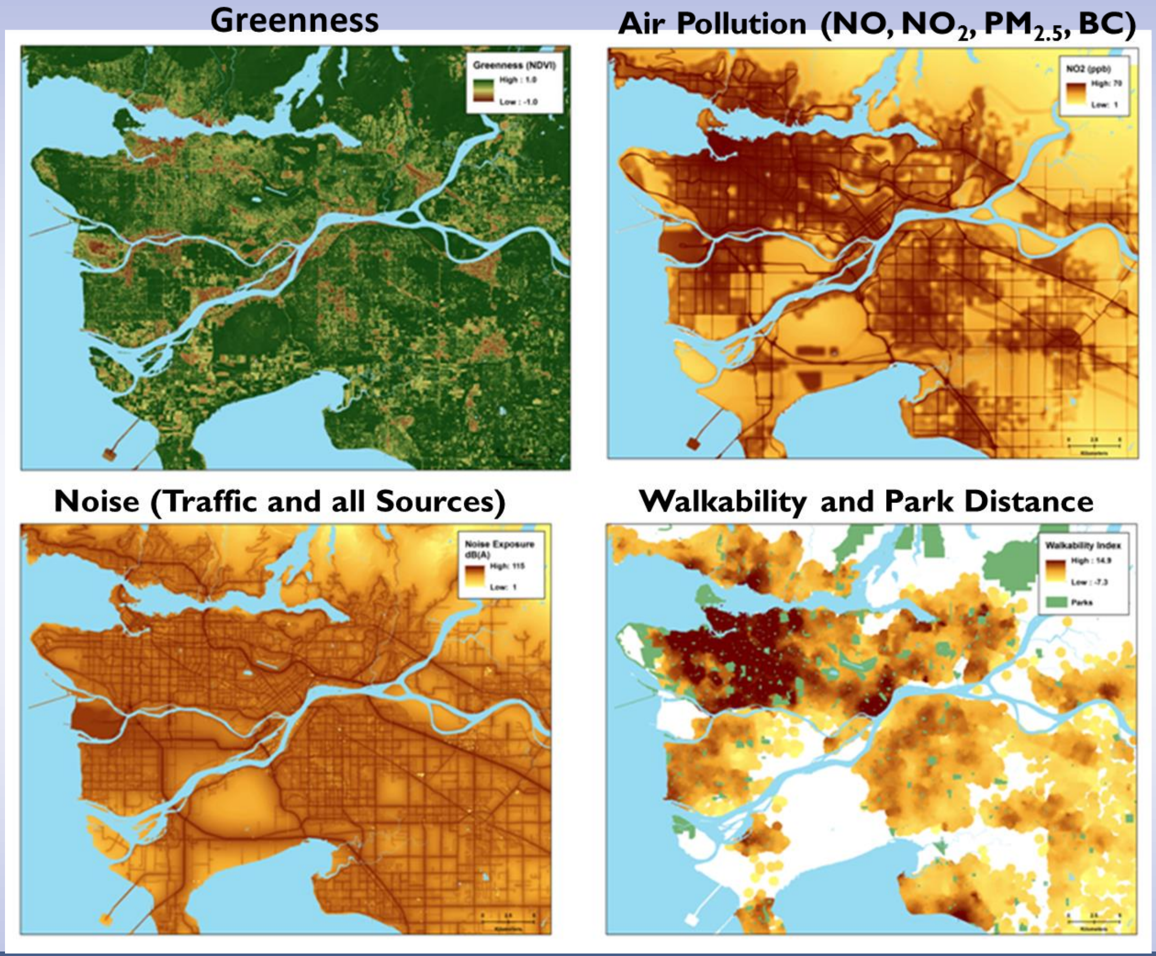
Design “natural experiments”



Road proximity & cardiovascular death



Additional linkages to assess multiple built environment characteristics



Noise and air pollution joint effects

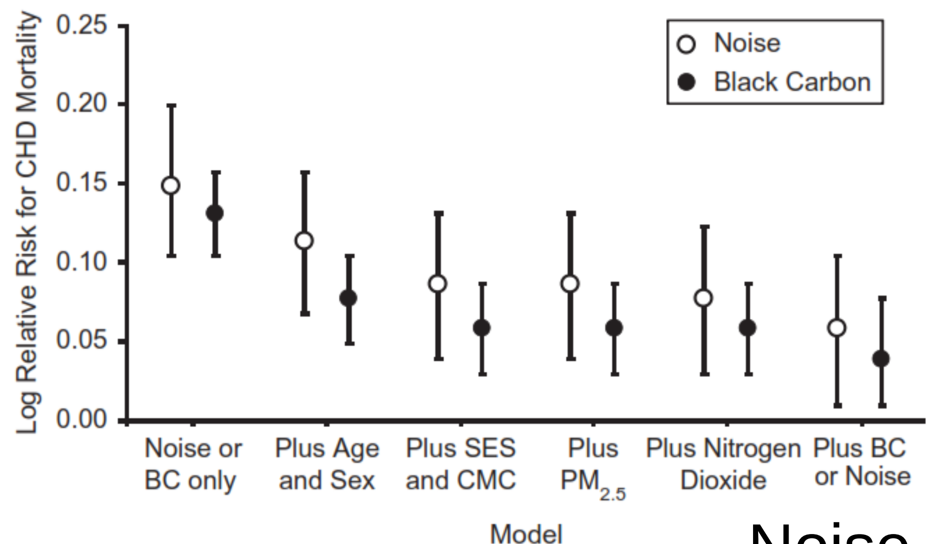
American Journal of Epidemiology

DOI: 10.1093/aje/kwr424

Original Contribution

Association of Long-term Exposure to Community Noise and Traffic-related Air Pollution With Coronary Heart Disease Mortality

Wen Qi Gan, Hugh W. Davies, Mieke Koehoorn, and Michael Brauer*

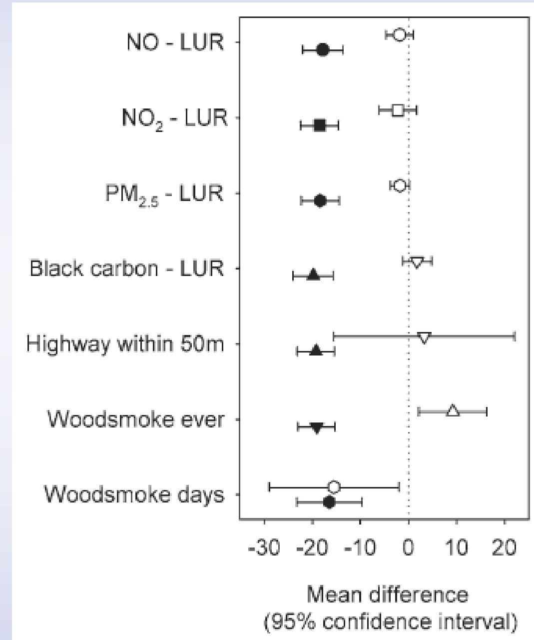


Noise

Impact of Noise and Air Pollution on Pregnancy Outcomes

Ulrike Gehring,[a] Lillian Tamburic,[b] Hind Sbihi,[b] Hugh W. Davies,[b] and Michael Brauer[b]

Term birthweight

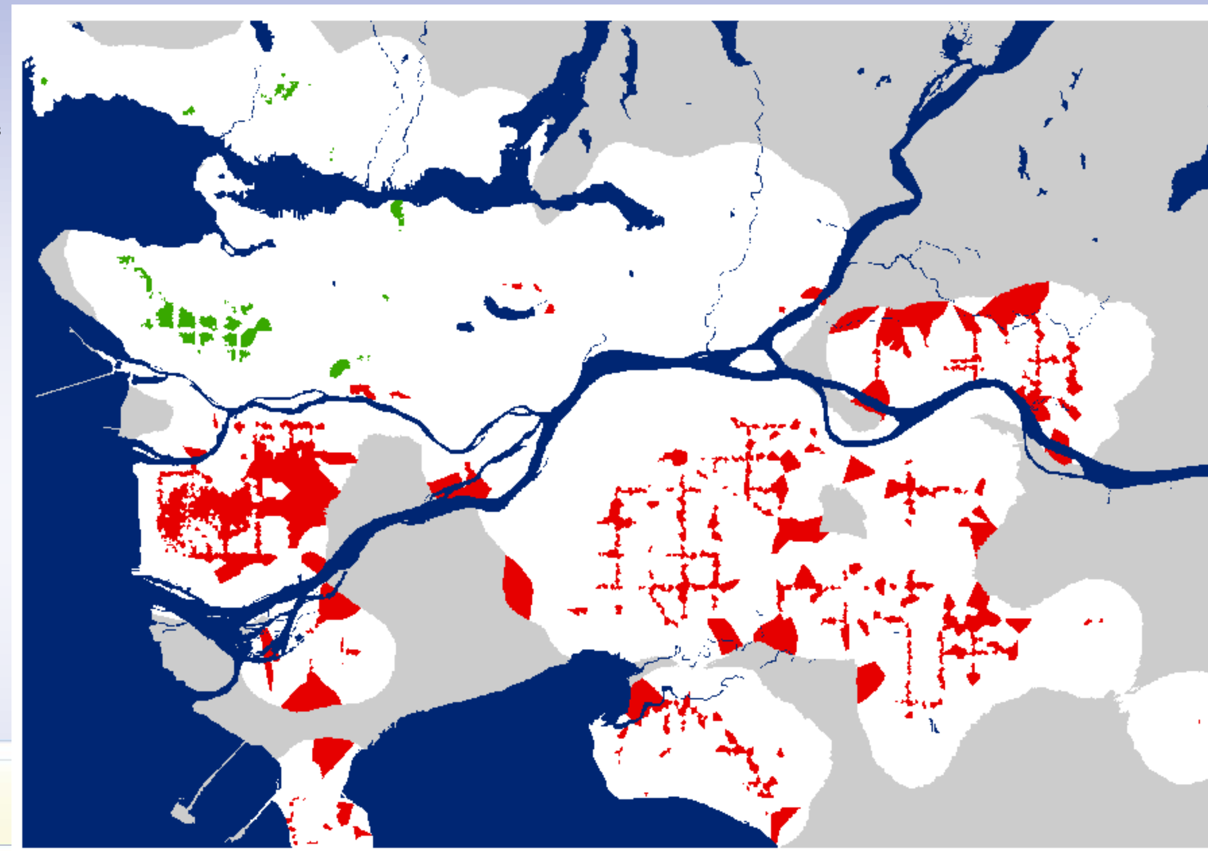


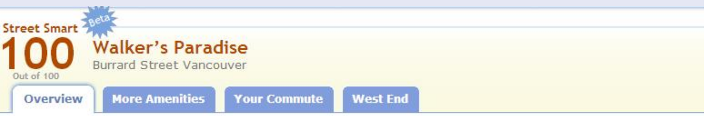
Joint associations of transportation noise● and air pollution○

Healthy neighborhoods – walkability and air pollution

HIGH walkability / LOW NO / LOW O_3

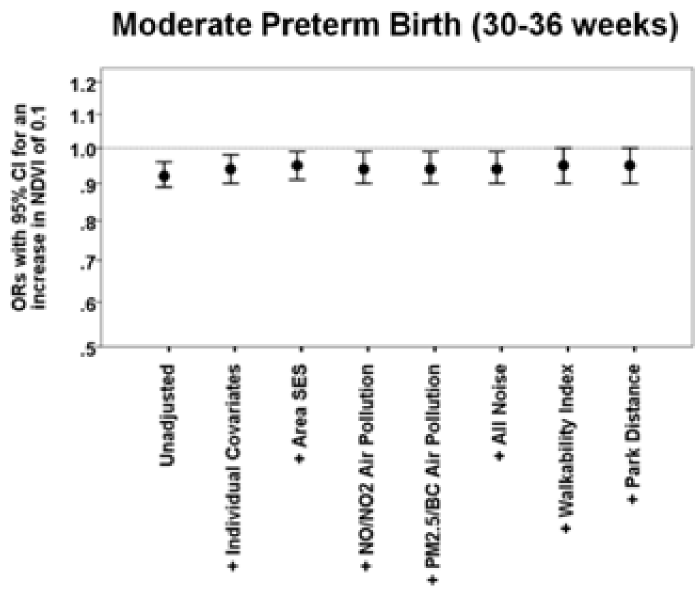
LOW walkability / HIGH NO / HIGH O_3

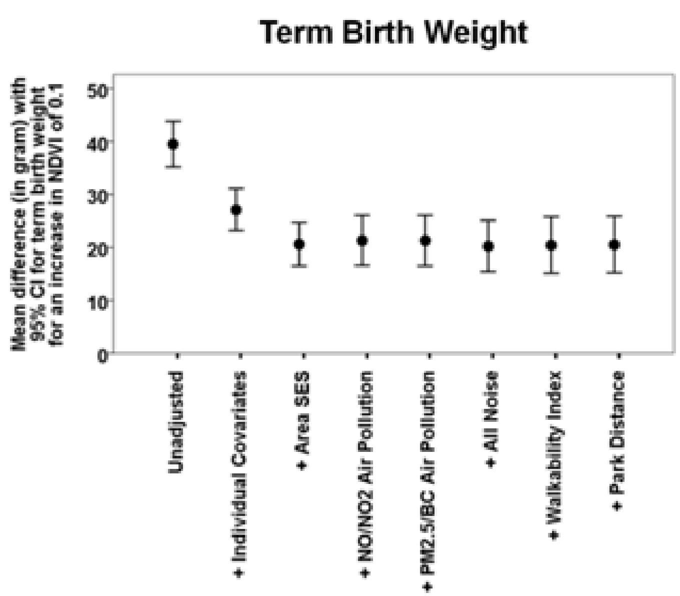


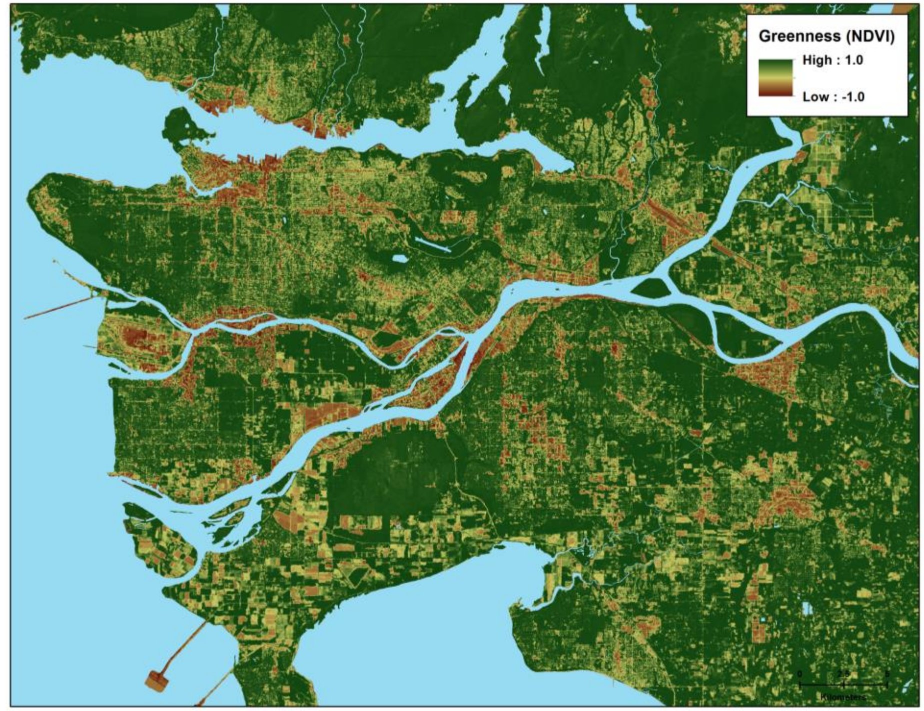


BAQS

Joint Exposure – Birth Outcomes







Greenness

Greenspace counteracts the negative impacts of air pollution and noise

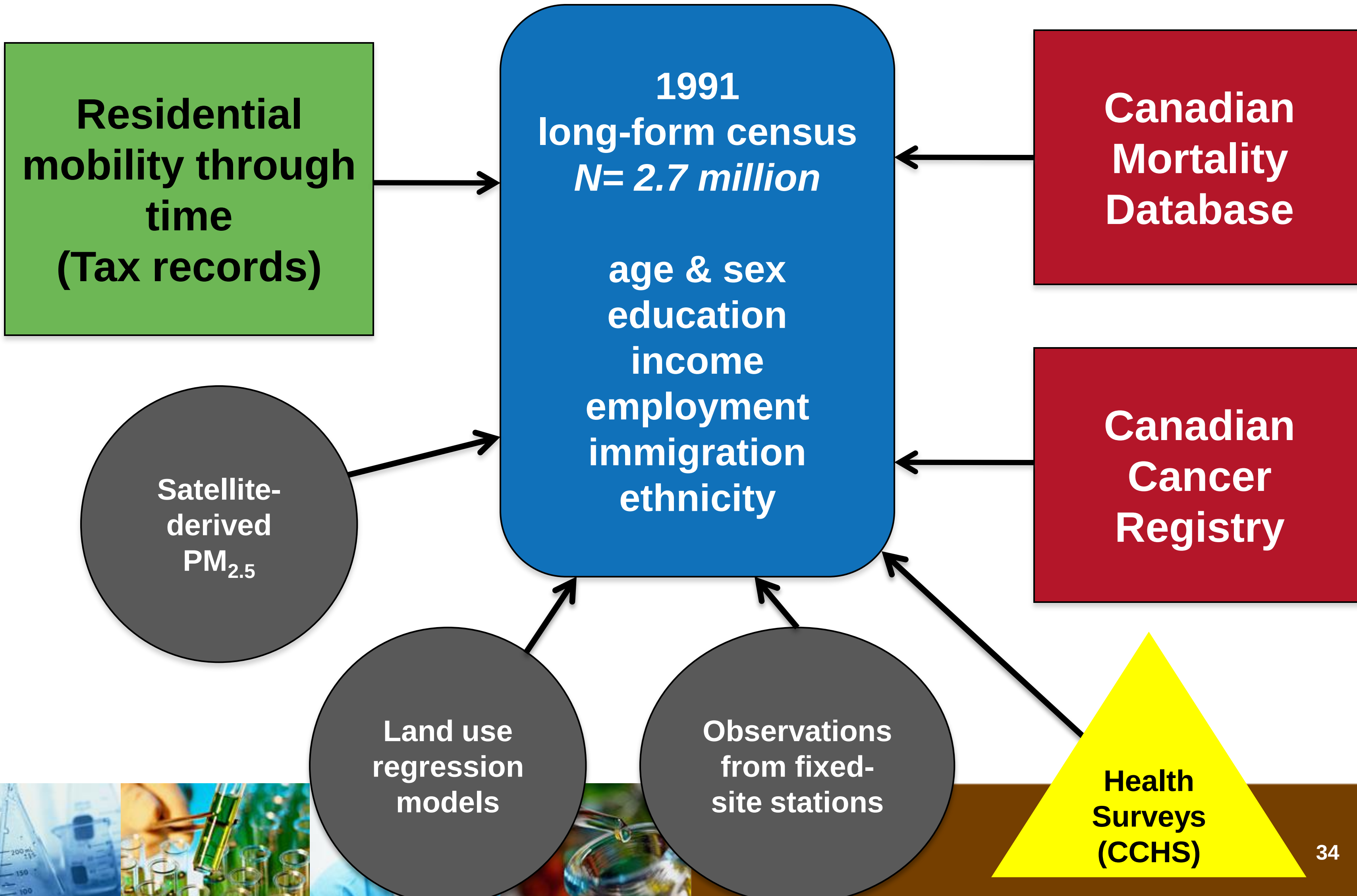
BAQS

The Canadian Census Health and Environment Cohort

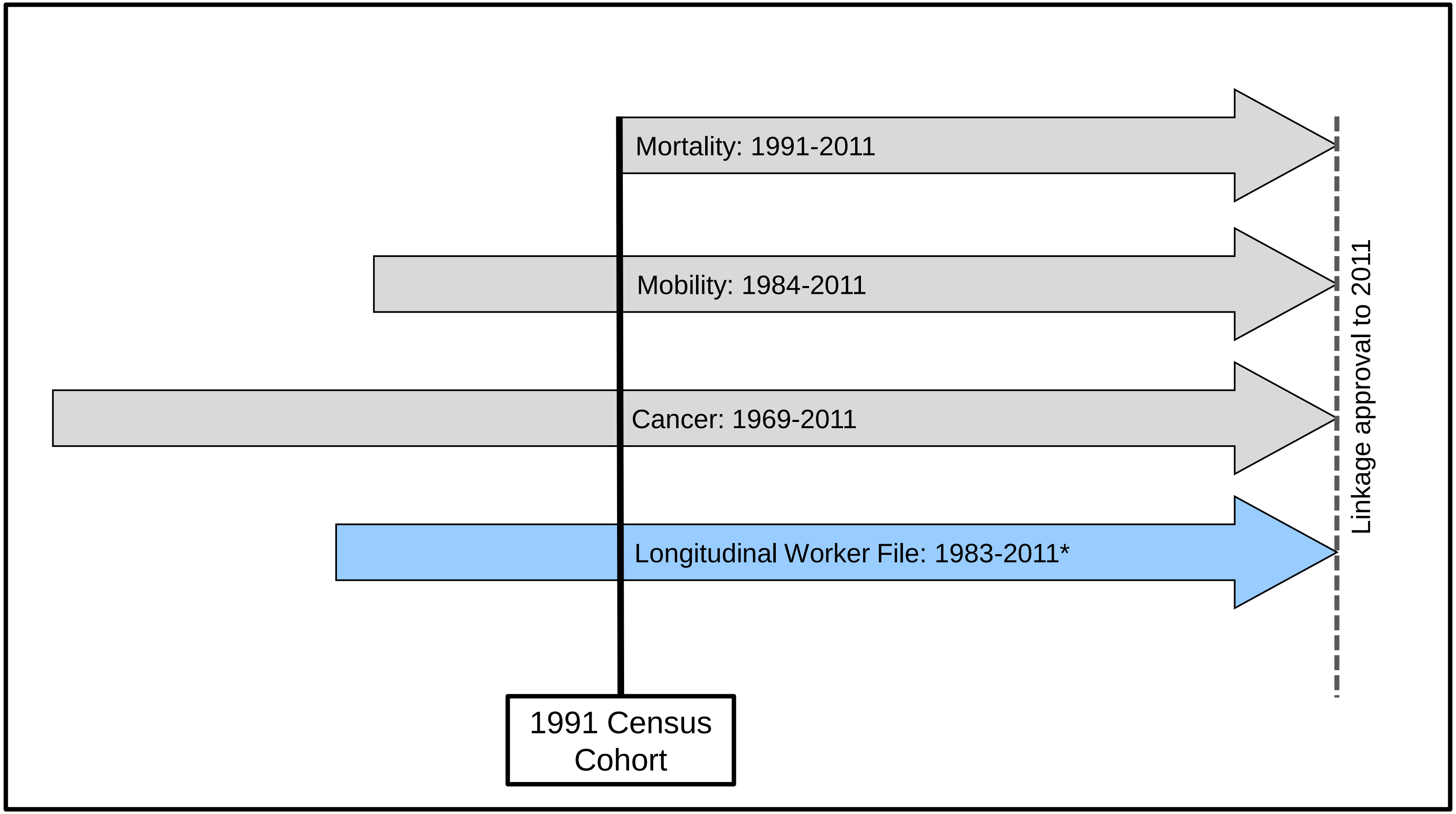
Rick Burnett, Health Canada
Dan Crouse, Health Canada -> University of New Brunswick
Michael Tjekema, Statistics Canada

33

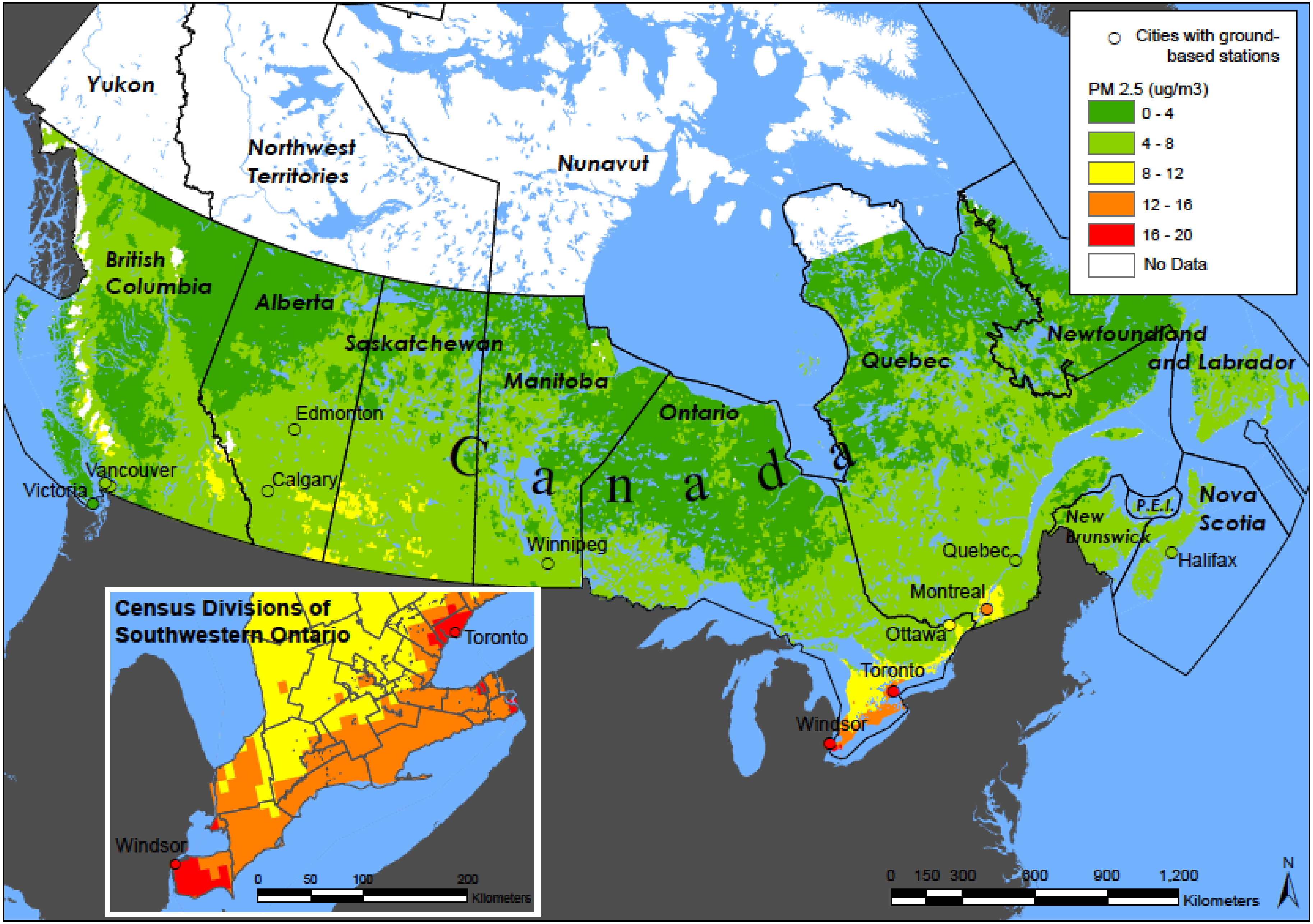
Canadian Census Health and Environment Cohort (CanCHEC)



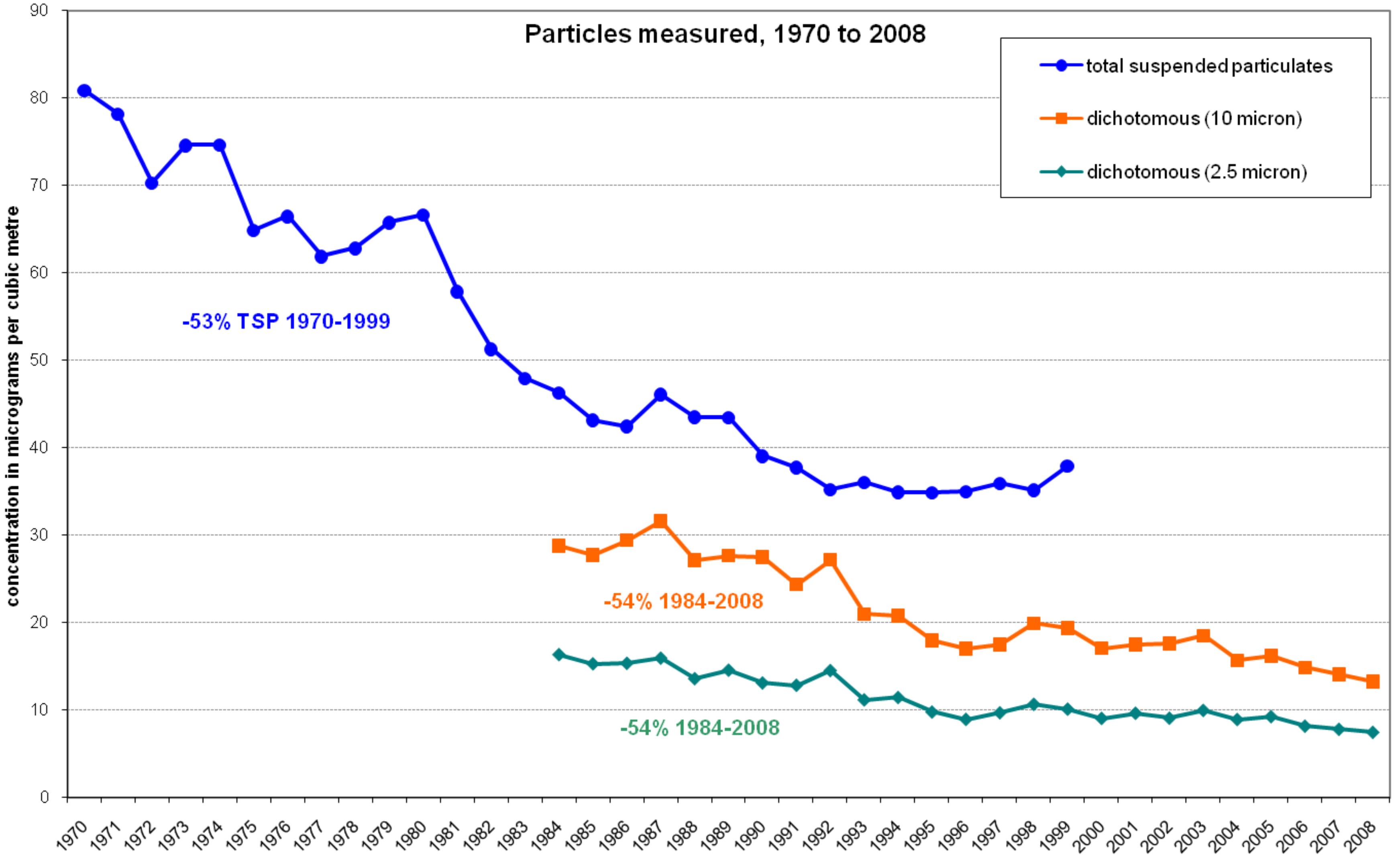
Structure of the 1991 Canadian Census Cohort



*Available for ~200,000 Cohort members



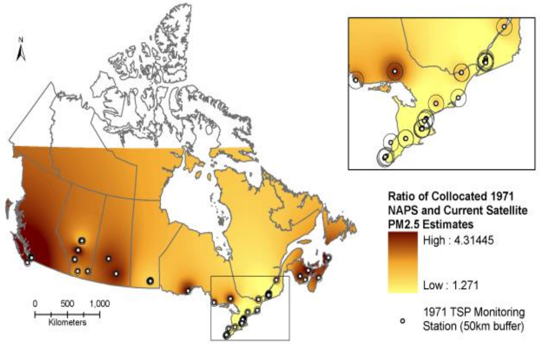
Crouse, et al. 2012



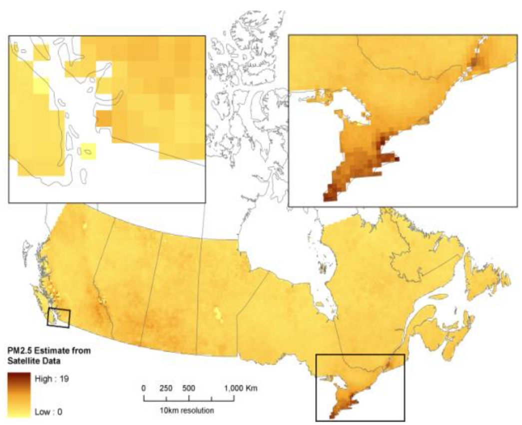
Particles measured, 1970 to 2008
total suspended particulates
dichotomous (10 micron)
dichotomous (2.5 micron)
-53% TSP 1970-1999
-54% 1984-2008
-54% 1984-2008
concentration in micrograms per cubic metre
0
10
20
30
40
50
60
70
80
90
1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008

Canadian national lung cancer case-control study

(National Enhanced Cancer Surveillance System)



x



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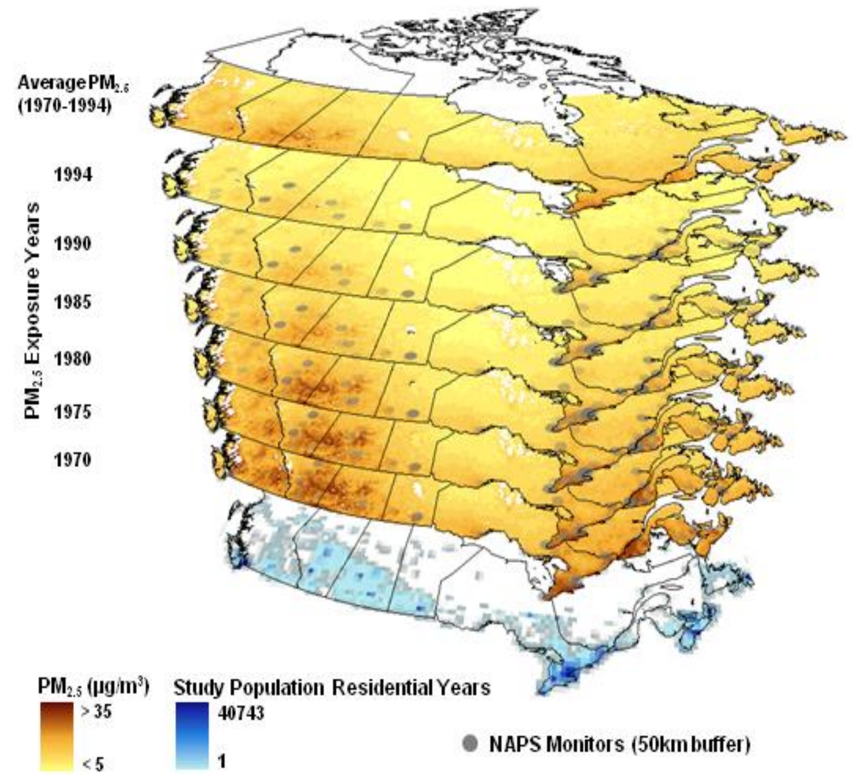

OR (95% CI) all lung cancer per 10 µg/m^3 increase in $PM_{2.5}$

Spatiotemporal model: 1.29 (0.95 – 1.76)

Urban subset (monitors): 1.33 (0.82 – 2.15)

Hystad P, Demers PA, Johnson KC, Carpiano RM, Brauer M. Long-term Residential Exposure to Air Pollution and Lung Cancer Risk. Epidemiology. 2013;24(5):762-72.

Hystad P, Demers PA, Johnson KC, Brook J, van Donkelaar A, Lamsal L, Martin R, Brauer M. Spatiotemporal air pollution exposure assessment for a Canadian population-based lung cancer case-control study. Environ Health. 2012;11:22..

Indirect adjustment of health risk behaviours (e.g. smoking)

Environmental Research 134 (2014) 482–487

Contents lists available at ScienceDirect

Environmental Research

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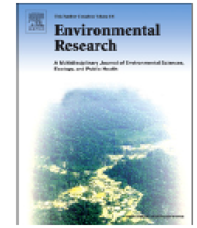


Indirect adjustment for multiple missing variables applicable to environmental epidemiology

CrossMark

Hwashin H. Shin [a,b], Sabit Cakmak [a], Orly Brion [a], Paul Villeneuve [a,c], Michelle C. Turner [d], Mark S. Goldberg [e], Michael Jerrett [f], Hong Chen [g], Dan Crouse [a], Paul Peters [h], C Arden Pope III[i], Richard T. Burnett [a,*]

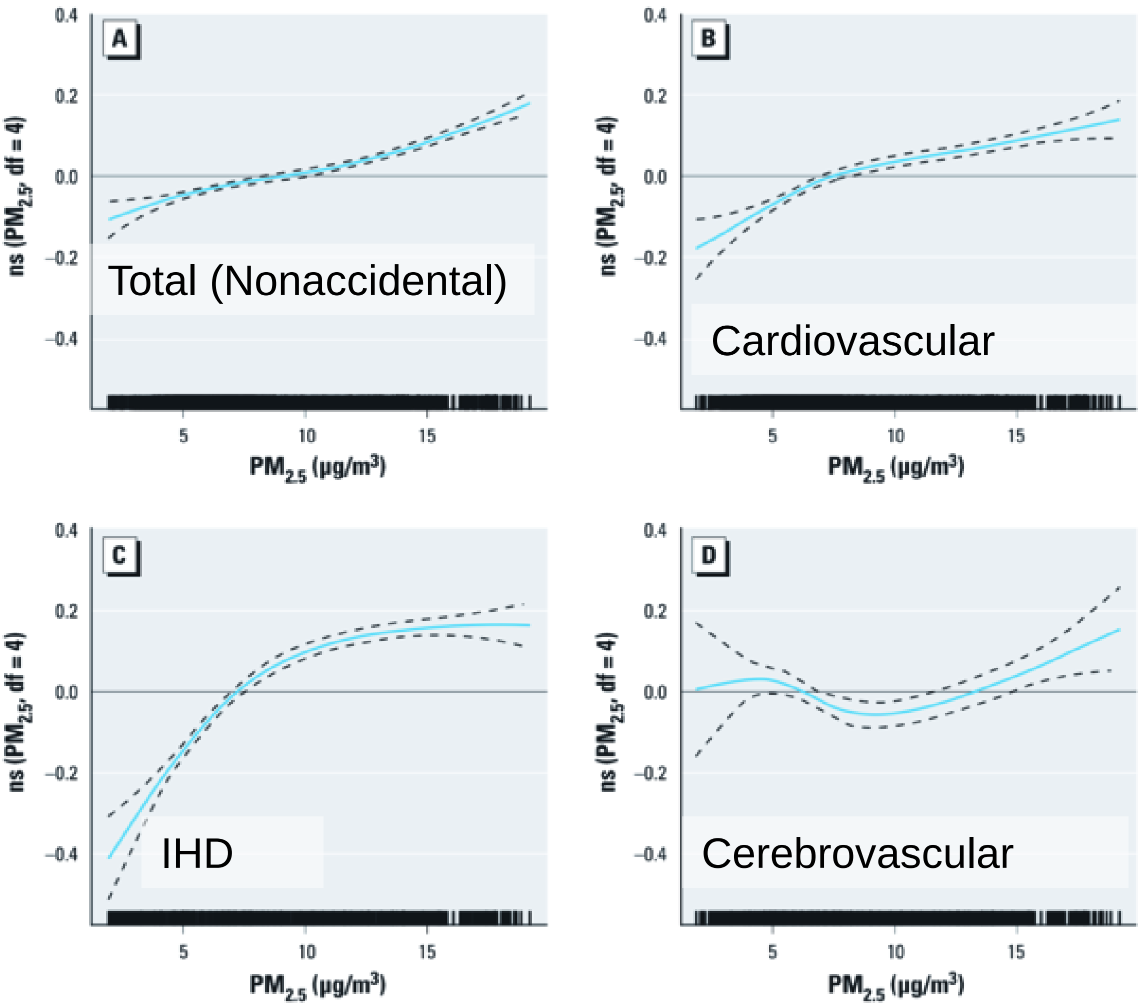
$$HR_{adj} = \frac{HR_{unadj}}{HR_{smoking}^{p_{se} - p_e p_s}}.$$

p_e proportion of subjects exposed
p_S proportion of subjects who smoke
p_{se} proportion of subjects exposed, who smoke

Obtained from ancillary dataset (e.g. CCHS)

Canadian Census Cohort (1991 – 2001)

Mortality

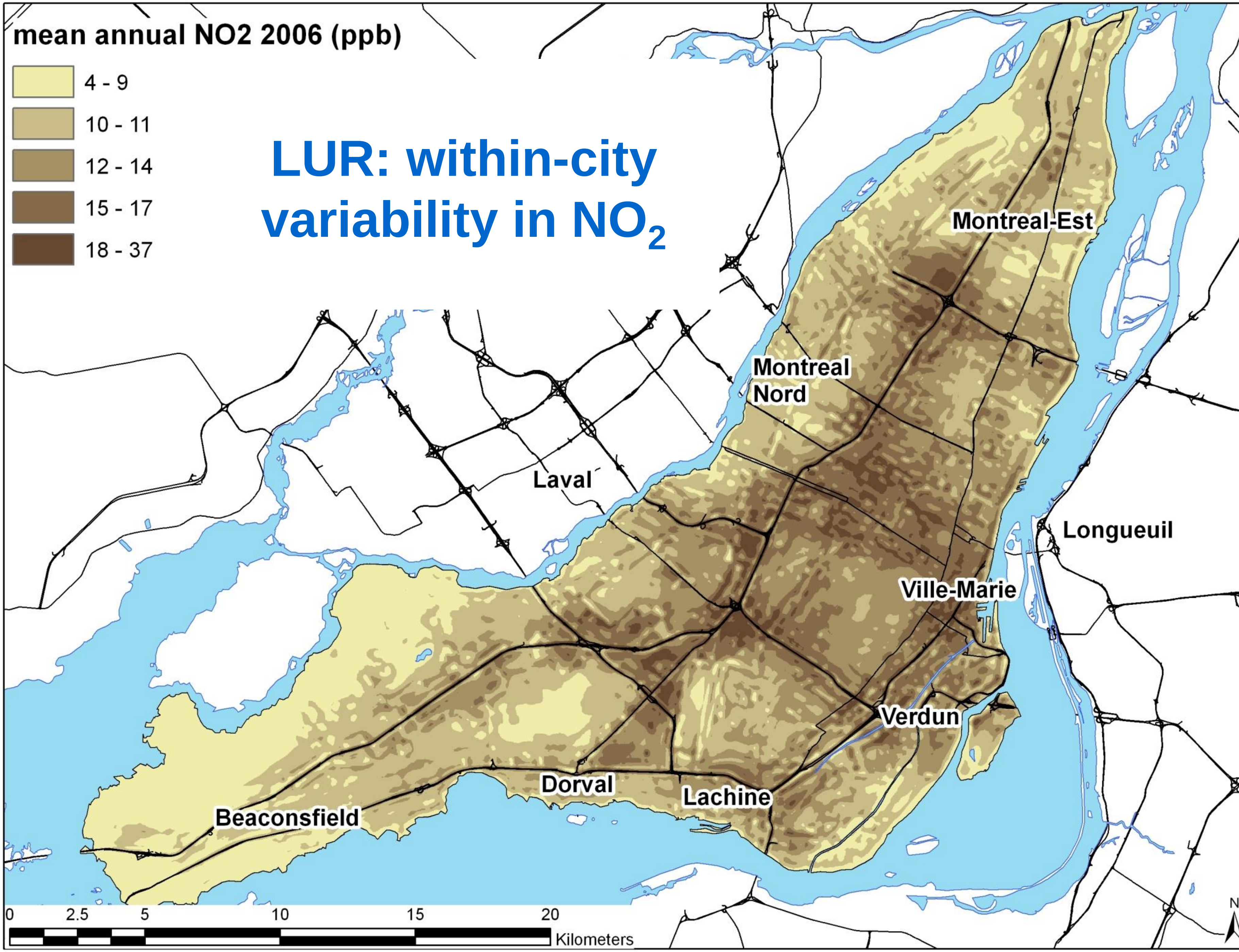


2.1 million subjects, exposures estimated 1987 – 2001

Adjustment for multiple individual-level, contextual covariates

Crouse DL, Peters PA, van Donkelaar A, Goldberg MS, Villeneuve PJ, Brion O, Khan S, Atari DO, Jerrett M, Pope CA, Brauer M, Brook JR, Martin RV, Stieb D, Burnett RT. Risk of nonaccidental and cardiovascular mortality in relation to long-term exposure to low concentrations of fine particulate matter: a Canadian national-level cohort study. Environ Health Perspect. 2012;120(5):708-14.

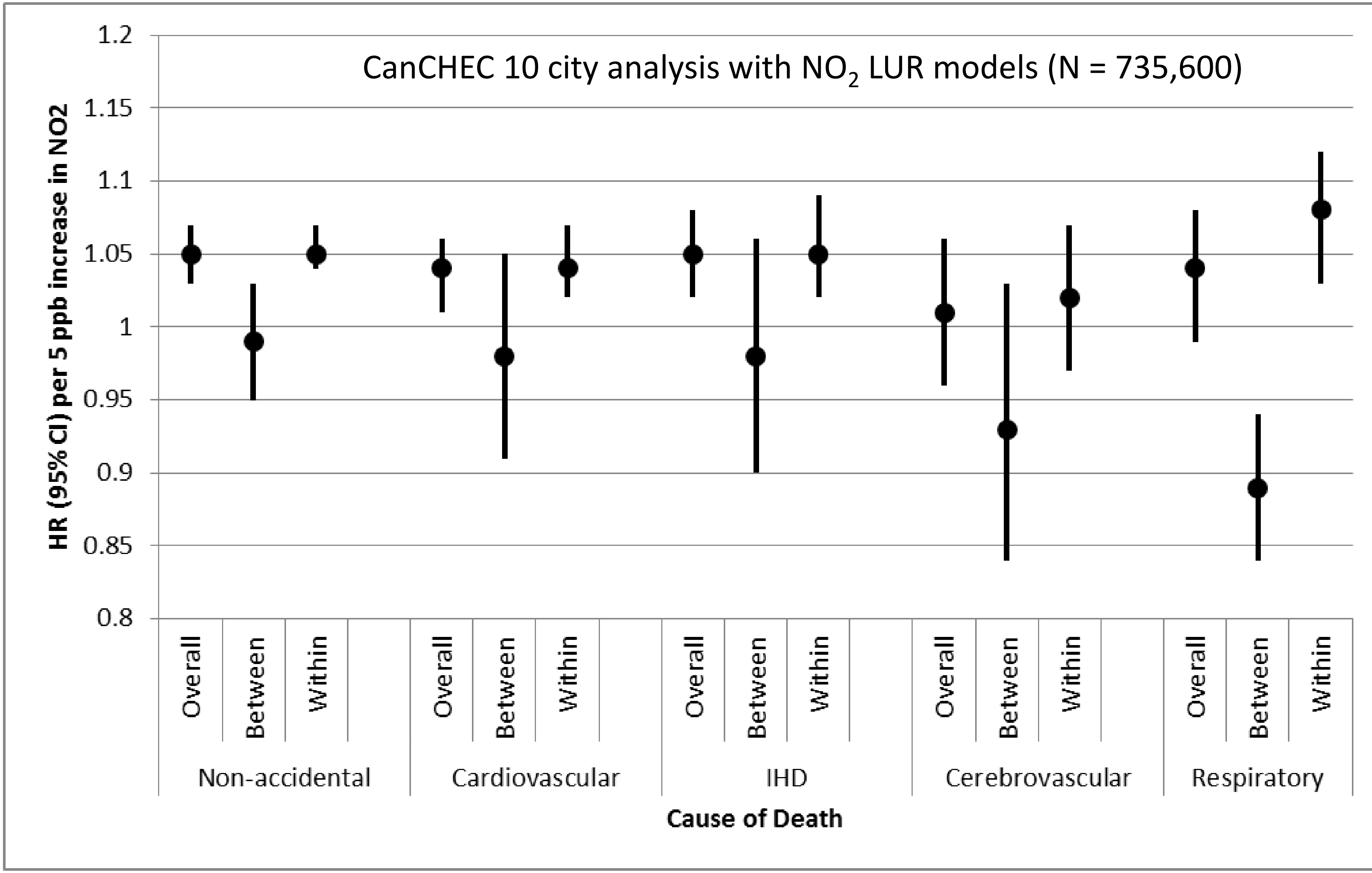
CANADA
Yukon
Northwest Territories
Nunavut
British Columbia
Alberta
Saskatchewan
Manitoba
Ontario
Quebec
Newfoundland and Labrador
New Brunswick
P.E.I.
Nova Scotia
Edmonton
Vancouver
Victoria
Winnipeg
Montreal
Toronto
Hamilton
Sarnia
London
Windsor
0 250 500 1,000
Kilometers
N


mean annual NO2 2006 (ppb)
4 - 9
10 - 11
12 - 14
15 - 17
18 - 37
LUR: within-city variability in NO_2
Montreal-Est
Montreal Nord
Laval
Longueuil
Ville-Marie
Verdun
Dorval
Lachine
Beaconsfield
0 2.5 5 10 15 20
Kilometers
N

Partitioning exposure into within- and between-city contrasts (ppb)

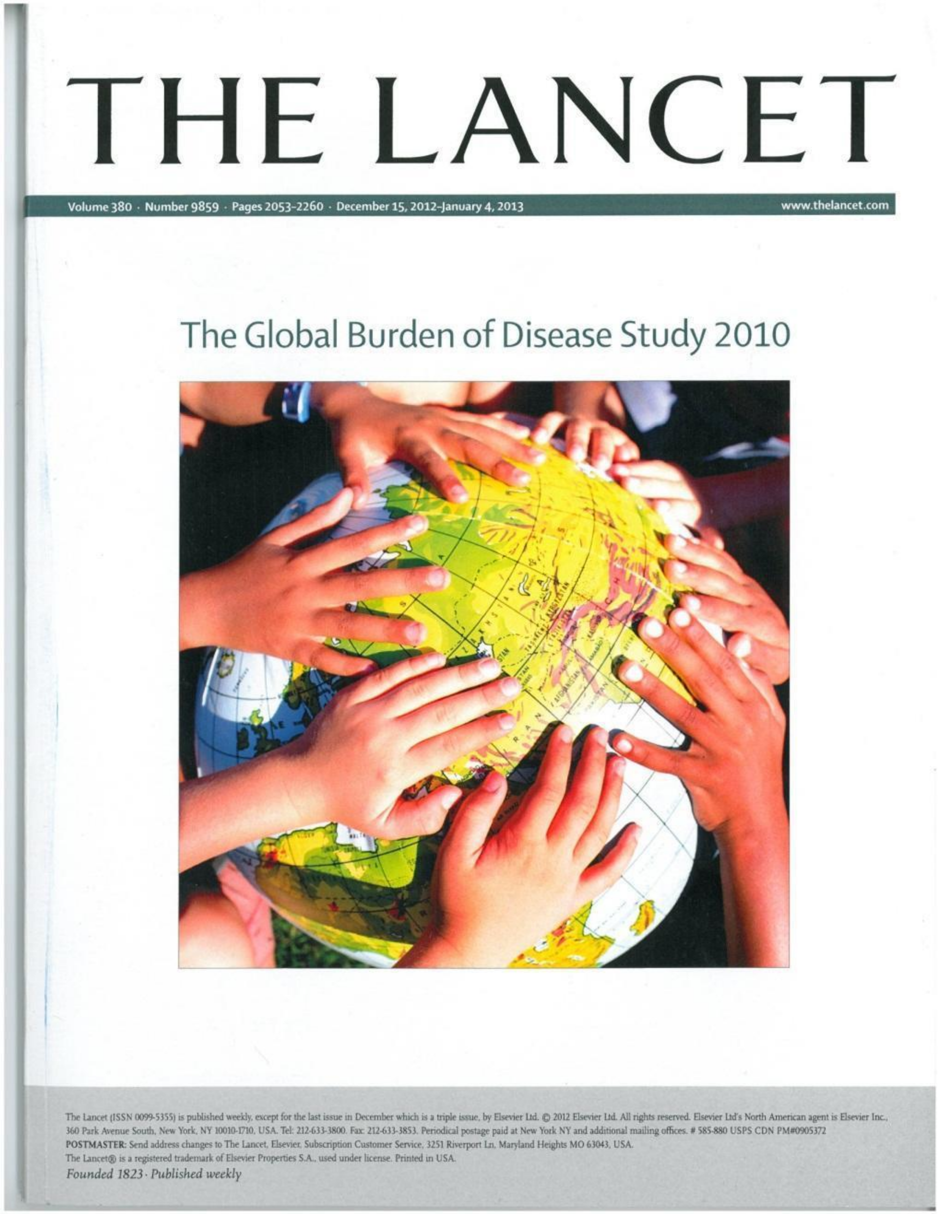
Year	City	Within-city	Between-city	Overall exposures
		Subject-level LUR estimate – LUR mean	Citywide mean from the long-term trend	Sum of within & between
2006	Montreal	15 - 11 = 4	19	23
2005	Montreal	15 - 11 = 4	18	22
2004	Windsor	18 - 10 = 8	20	28
…				
1984	Windsor	18 - 10 = 8	27	35



Adjusted Mortality HRs (Personal: immigrant, visible minority, marital status, education, income, occupational class, employment status; Contextual: income, education, % recent immigrants, temperature) with city random effect and indirect adjustment for smoking and BMI.

Crouse et al., 2015.



Articles

A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010

Stephen S Lim‡, Theo Vos, Abraham D Flaxman, Goodarz Danaei, Kenji Shibuya, Heather Adair-Rohani*, Markus Amann*, H Ross Anderson*, Kathryn G Andrews*, Martin Aryee*, Charles Atkinson*, Loraine J Bacchus*, Adil N Bahalim*, Kalpana Balakrishnan*, John Balmes*, Suzanne Barker-Collo*, Amanda Baxter*, Michelle L Bell*, Jed D Blore*, Fiona Blyth*, Carissa Bonner*, Guilherme Borges*, Rupert Bourne*, Michel Boussinesq*, Michael Brauer*, Peter Brooks*, Nigel G Bruce*, Bert Brunekreef*, Claire Bryan-Hancock*, Chiara Bucello*, Rachelle Buchbinder*, Fiona Bull*, Richard T Burnett*, Tim E Byers*, Bianca Calabria*, Jonathan Carapetis*, Emily Carnahan*, Zoe Chafe*, Fiona Charlson*, Honglei Chen*, Jian Shen Chen*, Andrew Tai-Ann Cheng*, Jennifer Christine Child*, Aaron Cohen*, K Ellicott Colson*, Benjamin C Cowie*, Sarah Darby*, Susan Darling*, Adrian Davis*, Louisa Degenhardt*, Frank Dentener*, Don C Des Jarlais*, Karen Devries*, Mukesh Dherani*, Eric L Ding*, E Ray Dorsey*, Tim Driscoll*, Karen Edmond*, Suad Eltahir Ali*, Rebecca E Engell*, Patricia J Erwin*, Saman Fahimi*, Gail Falder*, Farshad Farzadfar*, Alize Ferrari*, Mariel M Finucane*, Seth Flaxman*, Francis Gerry R Fowkes*, Greg Freedman*, Michael K Freeman*, Emmanuela Gakidou*, Santu Ghosh*, Edward Giovannucci*, Gerhard Gmel*, Kathryn Graham*, Rebecca Grainger*, Bridget Grant*, David Gunnell*, Hialy R Gutierrez*, Wayne Hall*, Hans W Hoek*, Anthony Hogan*, H Dean Hosgood III*, Damian Hoy*, Howard Hu*, Bryan J Hubbell*, Sally J Hutchings*, Sydney E Ibeanusi*, Gemma L Jacklyn*, Rashmi Jasrasaria*, Jost B Jonas*, Haidong Kan*, John A Kanis*, Nicholas Kassebaum*, Norito Kawakami*, Young-Ho Khang*, Shahab Khatibzadeh*, Jon-Paul Khoo*, Cindy Kok*, Francine Laden*, Ratilal Lalloo*, Qing Lan*, Tim Lathlean*, Janet L Leasher*, James Leigh*, Yang Li*, John Kent Lin*, Steven E Lipshultz*, Stephanie London*, Rafael Lozano*, Yuan Lu*, Joelle Mak*, Reza Malekzadeh*, Leslie Mallinger*, Wagner Marcenes*, Lyn March*, Robin Marks*, Randall Martin*, Paul McGale*, John McGrath*, Sumi Mehta*, George A Mensah*, Tony R Merriman*, Renata Micha*, Catherine Michaud*, Vinod Mishra*, Khayriyyah Mohd Hanafiah*, Ali A Mokdad*, Lidia Morawska*, Dariush Mozaffarian*, Tasha Murphy*, Mohsen Naghavi*, Bruce Neal*, Paul K Nelson*, Joan Miquel Nolla*, Rosana Norman*, Casey Olives*, Saad B Omer*, Jessica Orchard*, Richard Osborne*, Bart Ostro*, Andrew Page*, Kiran D Pandey*, Charles D H Parry*, Erin Passmore*, Jayadeep Patra*, Neil Pearce*, Pamela M Pelizzari*, Max Petzold*, Michael R Phillips*, Dan Pope*, C Arden Pope III*, John Powles*, Mayuree Rao*, Homie Razavi*, Eva A Rehfuess*, Jürgen T Rehm*, Beate Ritz*, Frederick P Rivara*, Thomas Roberts*, Carolyn Robinson*, Jose A Rodriguez-Portales*, Isabelle Romieu*, Robin Room*, Lisa C Rosenfeld*, Ananya Roy*, Lesley Rushton*, Joshua A Salomon*, Uchechukwu Sampson*, Lidia Sanchez-Riera*, Ella Sanman*, Amir Sapkota*, Soraya Seedat*, Peilin Shi*, Kevin Shield*, Rupak Shivakoti*, Gitanjali M Singh*, David A Sleet*, Emma Smith*, Kirk R Smith*, Nicolas J C Stapelberg*, Kyle Steenland*, Heidi Stöckl*, Lars Jacob Stovner*, Kurt Straif*, Lahn Straney*, George D Thurston*, Jimmy H Tran*, Rita Van Dingenen*, Aaron van Donkelaar*, J Lennert Veerman*, Lakshmi Vijayakumar*, Robert Weintraub*, Myrna M Weissman*, Richard A White*, Harvey Whiteford*, Steven T Wiersma*, James D Wilkinson*, Hywel C Williams*, Warwick Williams*, Nicholas Wilson*, Anthony D Woolf*, Paul Yip*, Jan M Zielinski*, Alan D Lopez†, Christopher J L Murray†, Majid Ezzati†

Lancet 2012; 380: 2224–60

See Comment pages 2053, 2054, 2055, 2058, 2060, 2062, and 2063

See Special Report page 2067

See Articles pages 2071, 2095, 2129, 2144, 2163, and 2197

*Author listed alphabetically

†Joint senior authors

‡Corresponding author

See Online for appendix

For **interactive versions of figures 3, 4, and 6** see http://healthmetricsandevaluation.org/gbd/visualizations/regional

Institute for Health Metrics and Evaluation (S S Lim PhD, A D Flaxman PhD, K G Andrews MPH, C Atkinson BS, E Carnahan BA, K E Colson BA, R E Engell BA, G Freedman BA, M K Freeman BA, E Gakidou PhD, R Jasrasaria BA,

Summary

Background Quantification of the disease burden caused by different risks informs prevention by providing an account of health loss different to that provided by a disease-by-disease analysis. No complete revision of global disease burden caused by risk factors has been done since a comparative risk assessment in 2000, and no previous analysis has assessed changes in burden attributable to risk factors over time.

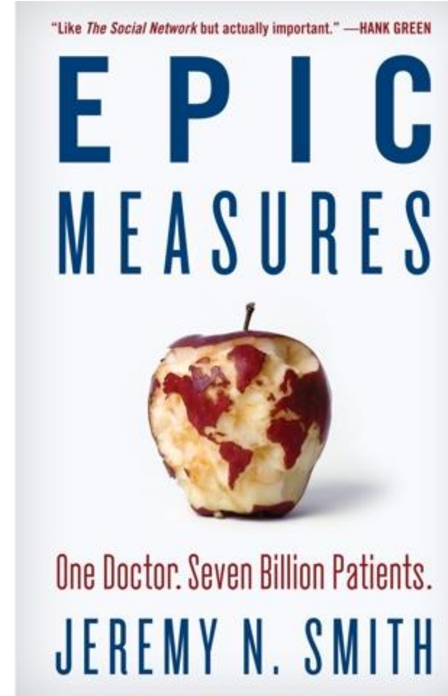
Methods We estimated deaths and disability-adjusted life years (DALYs; sum of years lived with disability [YLD] and years of life lost [YLL]) attributable to the independent effects of 67 risk factors and clusters of risk factors for 21 regions in 1990 and 2010. We estimated exposure distributions for each year, region, sex, and age group, and relative risks per unit of exposure by systematically reviewing and synthesising published and unpublished data. We used these estimates, together with estimates of cause-specific deaths and DALYs from the Global Burden of Disease Study 2010, to calculate the burden attributable to each risk factor exposure compared with the theoretical-minimum-risk exposure. We incorporated uncertainty in disease burden, relative risks, and exposures into our estimates of attributable burden.

Findings In 2010, the three leading risk factors for global disease burden were high blood pressure (7·0% [95% uncertainty interval 6·2–7·7] of global DALYs), tobacco smoking including second-hand smoke (6·3% [5·5–7·0]), and alcohol use (5·5% [5·0–5·9]). In 1990, the leading risks were childhood underweight (7·9% [6·8–9·4]), household air pollution from solid fuels (HAP; 7·0% [5·6–8·3]), and tobacco smoking including second-hand smoke (6·1% [5·4–6·8]). Dietary risk factors and physical inactivity collectively accounted for 10·0% (95% UI 9·2–10·8) of global DALYs in 2010, with the most prominent dietary risks being diets low in fruits and those high in sodium. Several risks that primarily affect childhood communicable diseases, including unimproved water and sanitation and childhood micronutrient deficiencies, fell in rank between 1990 and 2010, with unimproved water

http://www.thelancet.com/themed/global-burden-of disease

What is the Global Burden of Disease?

- Systematic quantification of magnitude of health loss due to diseases, injuries and risk factors
- Global disease, injury, & risk burden estimates for 1990 – 2013 (5 yr intervals) using comparable methods for 188 countries (+ sub-country analyses)
  - incidence and prevalence of 301 diseases and injuries and 2,337 relevant disabling sequelae, stratified by sex and 20 age groups
  - **Role of 76 modifiable risk factors in** burden of disease
- Collaborative effort coordinated by (Gates-funded) Institute for Health Metrics and Evaluation (UW), [WHO] **+ ~1000 volunteers….**
- Annual updates beginning in 2015



http://www.healthdata.org/gbd

Mortality and Burden of Disease

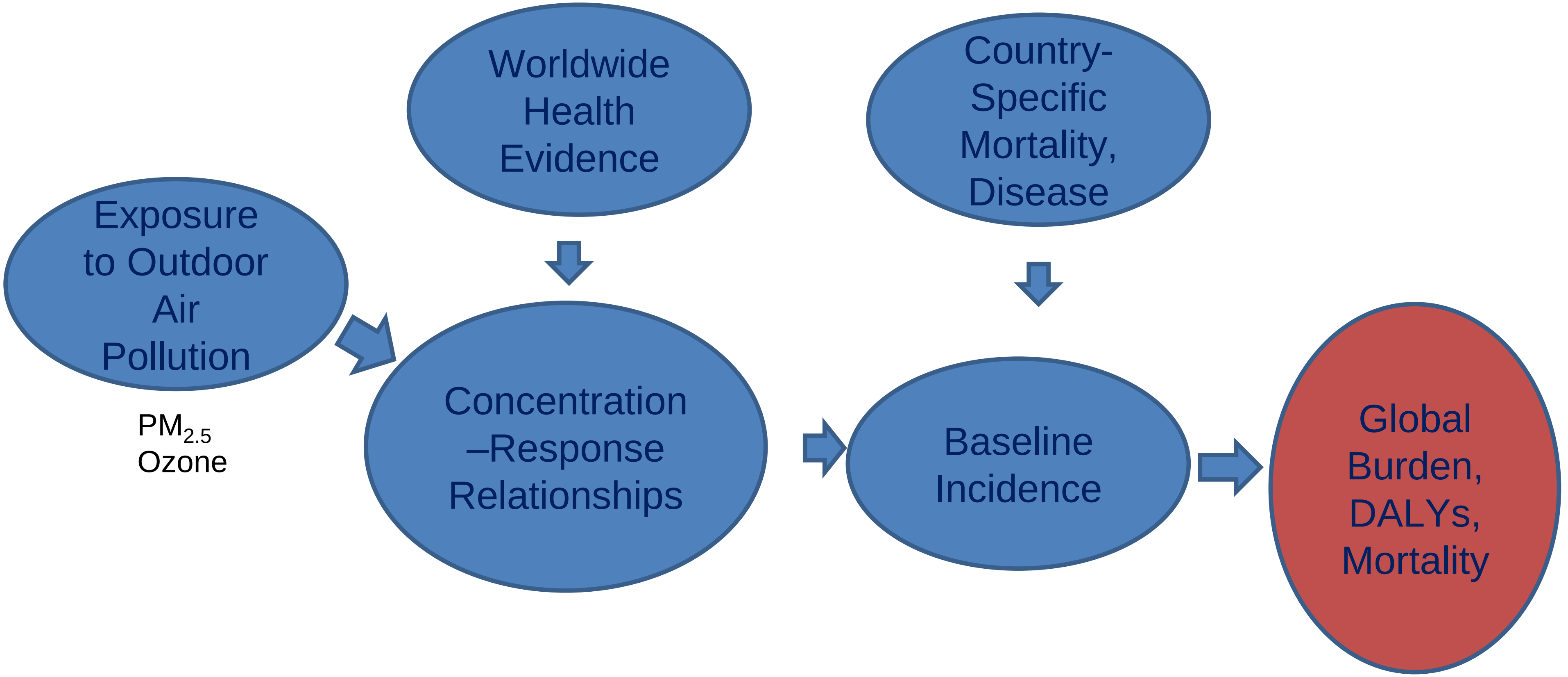
- Mortality = Numbers of Deaths
- Burden = Disability Adjusted Life Year (DALY)

DALY = YLL + YLD

- *years of life lost due to premature death (YLLs)*
- *years of life lived with disability (YLDs)*

one DALY = one lost year of healthy life

General approach



Population Attributable fraction X Deaths (cause-specific)

Population Attributable fraction X DALYs (cause specific)

Population attributable fraction

RR, relative risk at each exposure level

P, proportion of population at each exposure level

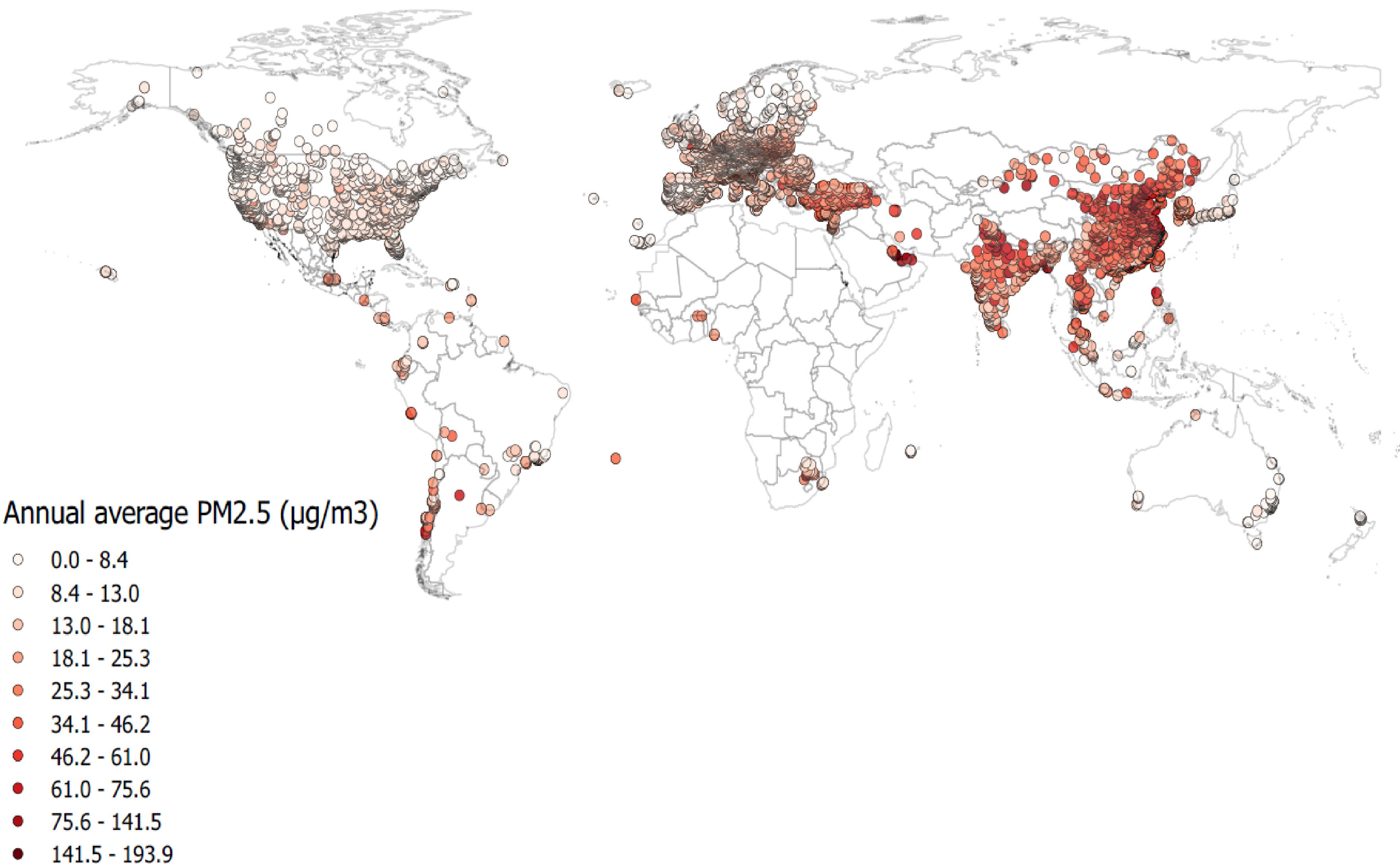
P’, counterfactual proportion of population at each exposure level

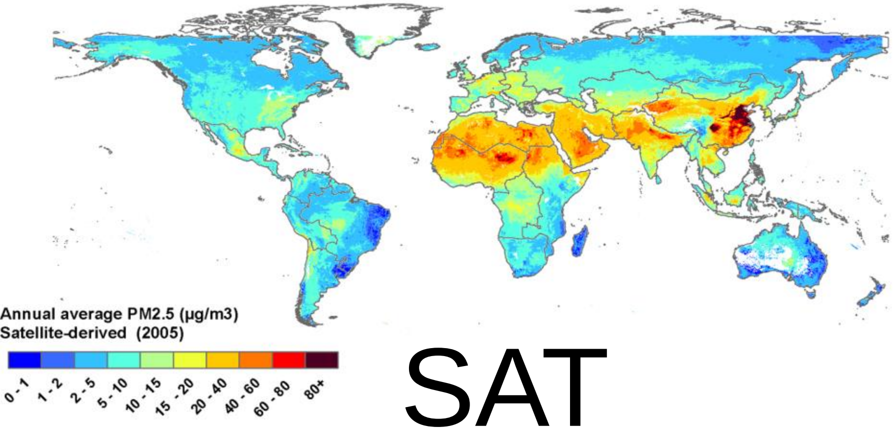
m, maximum exposure level

$$PAF = \frac{\int_{x=0}^{m} RR(x)P(x)dx - \int_{x=0}^{m} RR(x)P'(x)dx}{\int_{x=0}^{m} RR(x)P(x)dx}$$

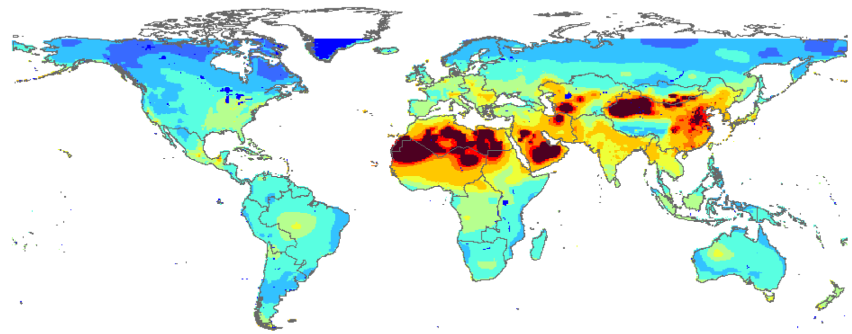
Population Attributable Fraction: sex, age, country, time

Measurements



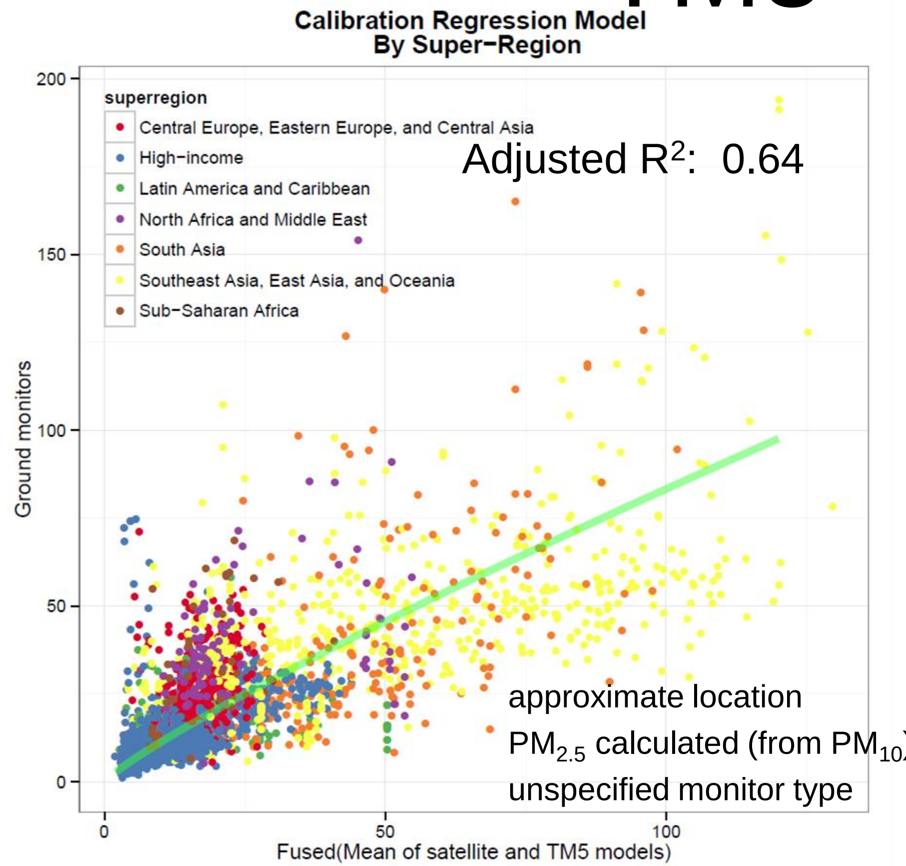


SAT



TM5

- Final estimates based on average of (1.4 million) grid cell values (SAT, TM5) and calibrated (regression model) with measurements
  - 0.1° x 0.1° resolution
- Incorporate variance between two estimates and measurements in uncertainty assessment
- Unique contributions from each approach



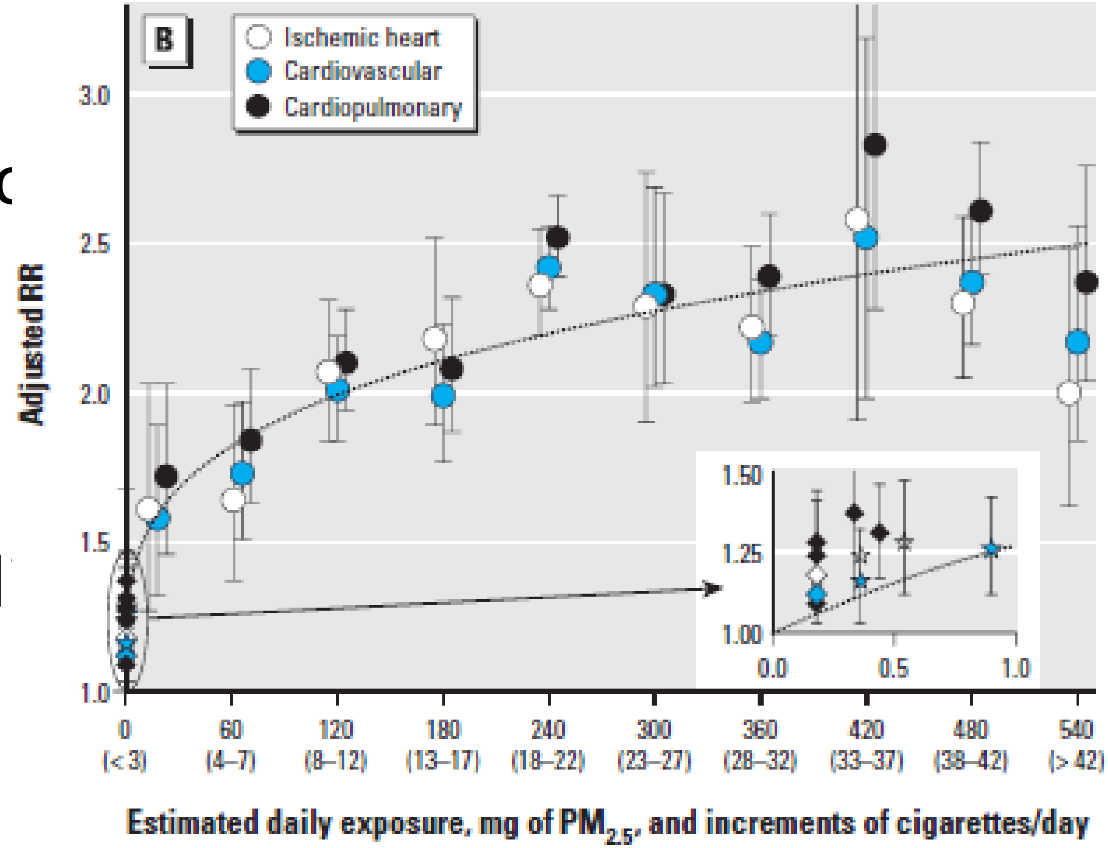
Integrating risk from multiple sources to estimate risk due to ambient $PM_{2.5}$
Integrated Exposure-Response functions (IER)

<u>Key assumption</u>

Risk is function of $PM_{2.5}$ inhaled dose regardless c source

<u>Extrapolation model</u>

- reflect change in risk observed in cohort stud at low concentrations
- near-linear at low concentrations
- predict risk for highest $PM_{2.5}$ consistent with risks from smoking (Pope et al.2011)



Burnett et al. 2014