Mortality due to Air Pollution at Low levels of Exposure (MAPLE)

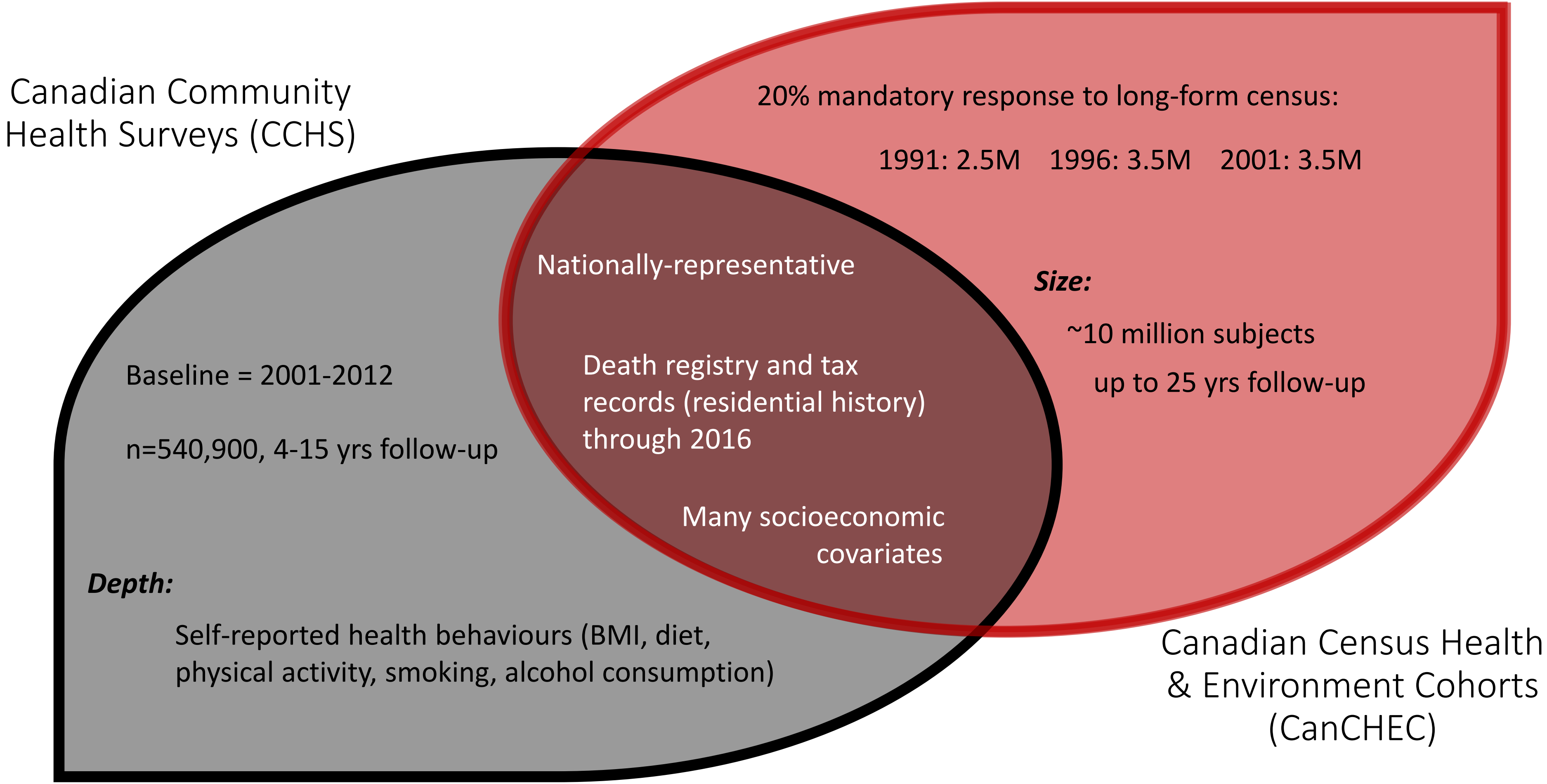
Michael Brauer

School of Population and Public Health

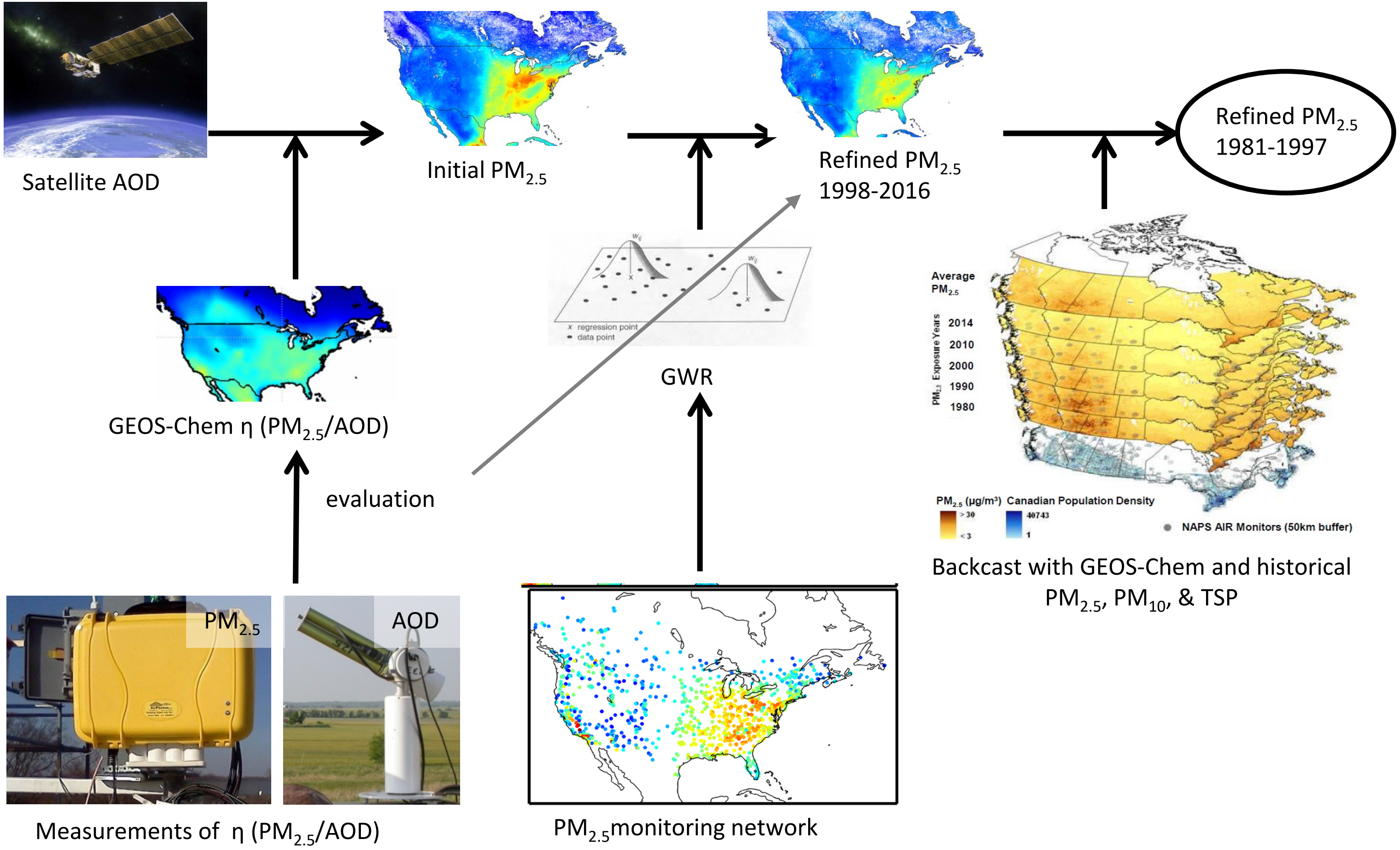
THE UNIVERSITY OF BRITISH COLUMBIA

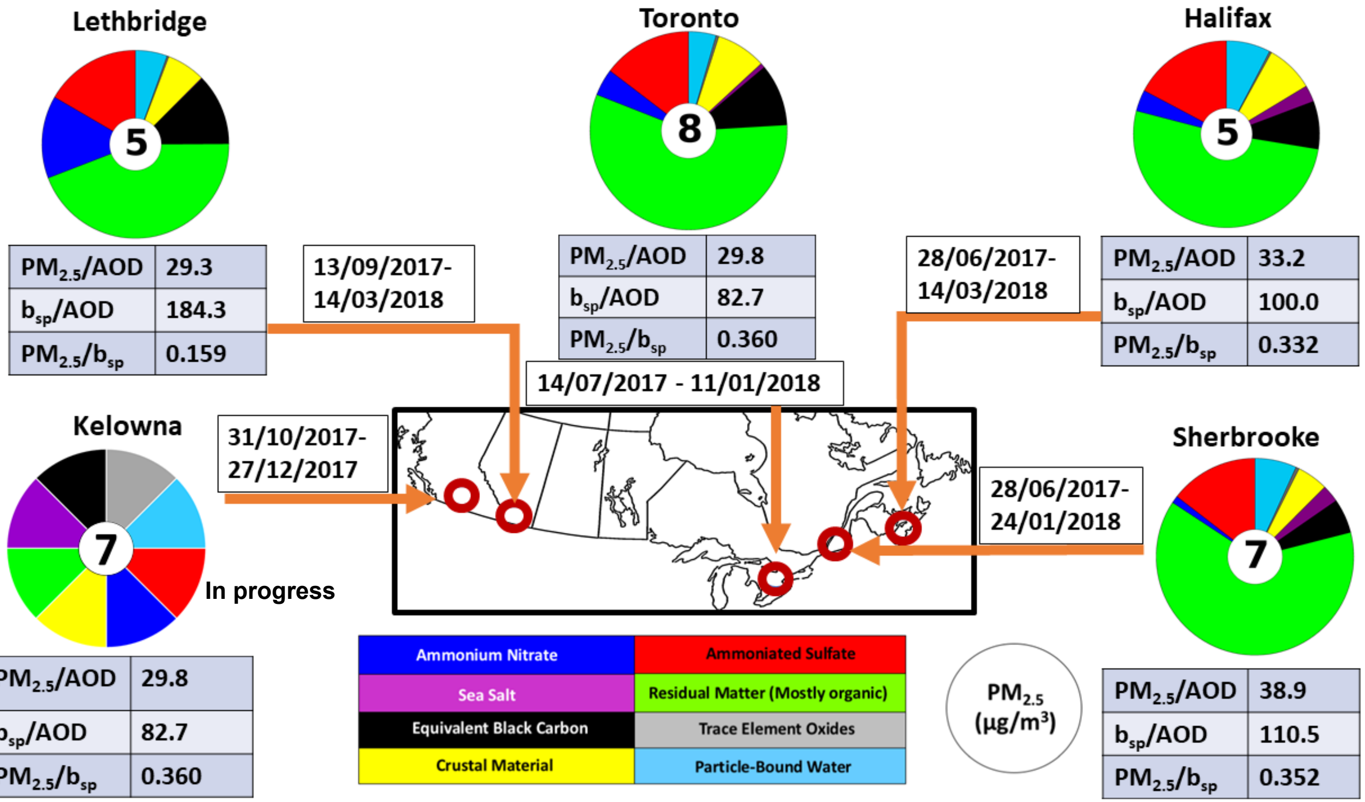
HEI/ERS/WHO, January 21, 2020. Brussels

Cohorts


Canadian Community Health Surveys (CCHS)
20% mandatory response to long-form census:
1991: 2.5M 1996: 3.5M 2001: 3.5M
Nationally-representative
Size:
~10 million subjects
up to 25 yrs follow-up
Baseline = 2001-2012
Death registry and tax records (residential history) through 2016
n=540,900, 4-15 yrs follow-up
Many socioeconomic covariates
Depth:
Self-reported health behaviours (BMI, diet, physical activity, smoking, alcohol consumption)
Canadian Census Health & Environment Cohorts (CanCHEC)

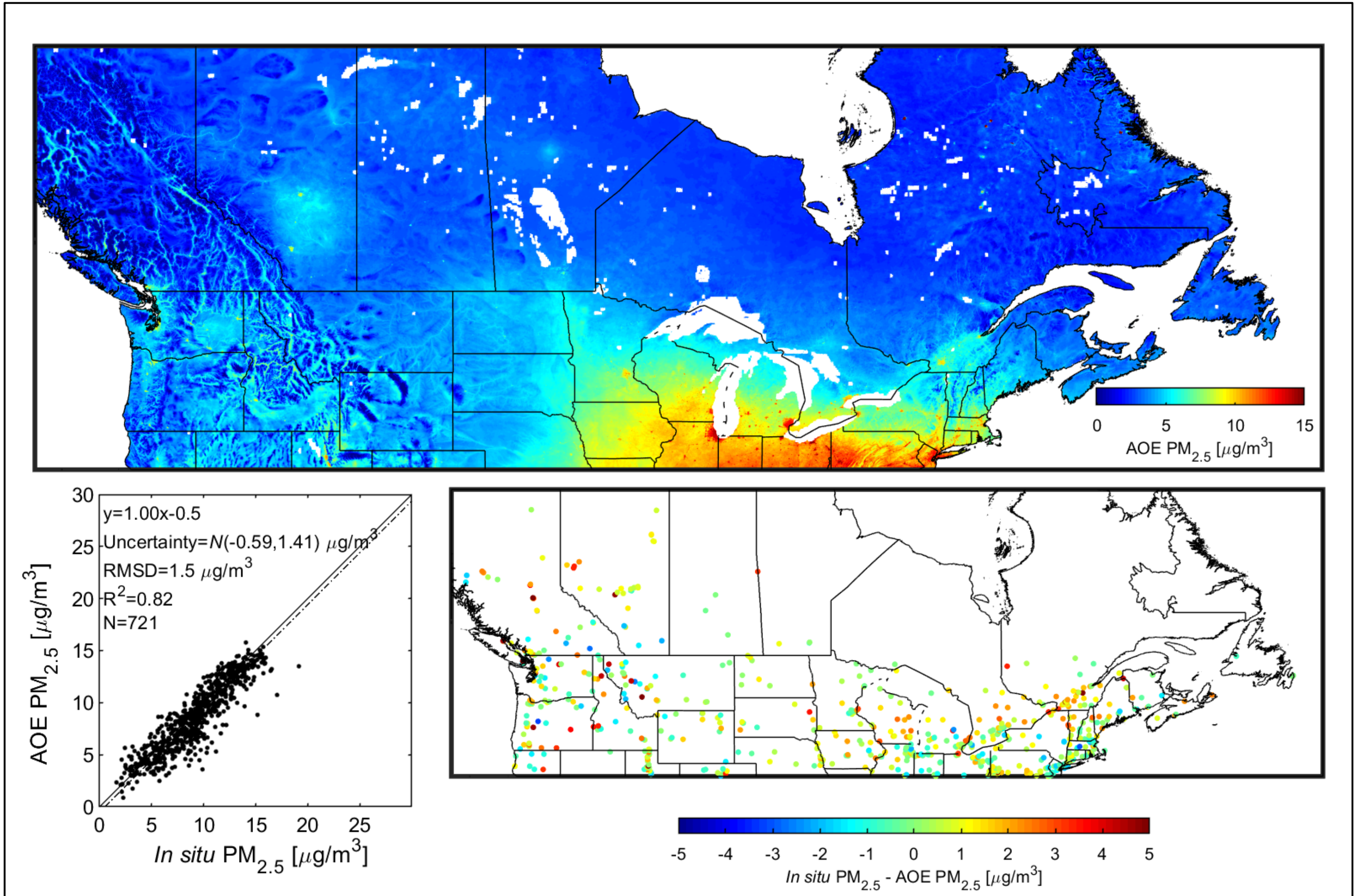
Exposure estimation



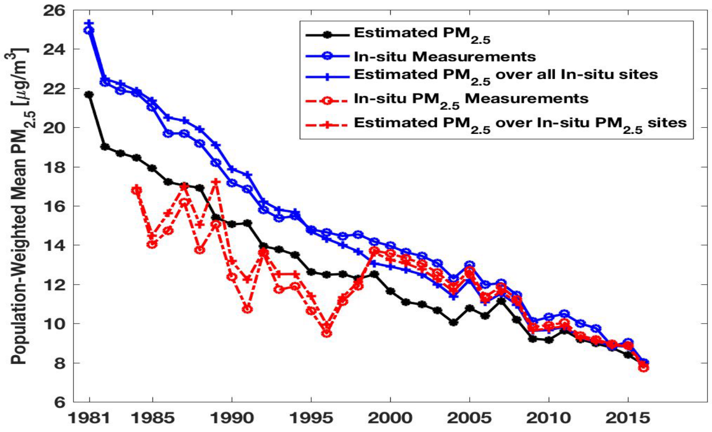


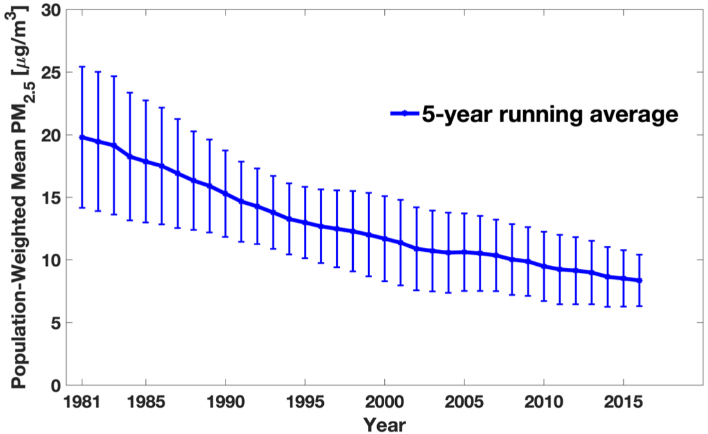
Not final results

Exposure estimation



Exposure backcasting (1981 – 1997)





Backcasting with historical ground-based measurements of $PM_{2.5}$, PM_{10}, and TSP, remote sensing, chemical transport model, and elevation data

Captures temporal & spatial changes in concentrations over time

Estimates from nearest grid cell assigned to residential postal codes

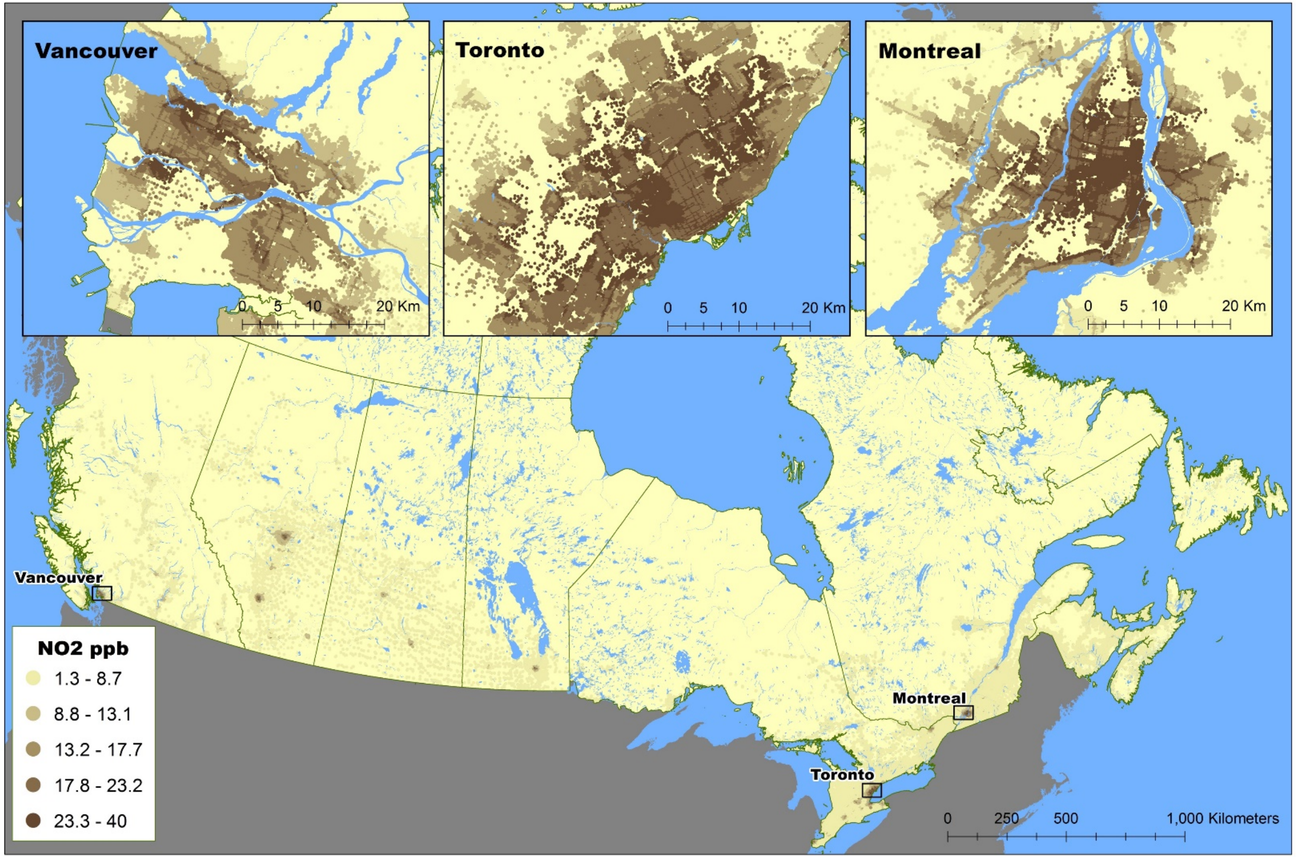
Meng et al., ES&T 2019

NO_2 Estimation

- LUR model (satellite estimates, road length (10 km), area of industrial land use (2 km), mean summer rainfall

- 2006 annual mean concentrations (~10 m)

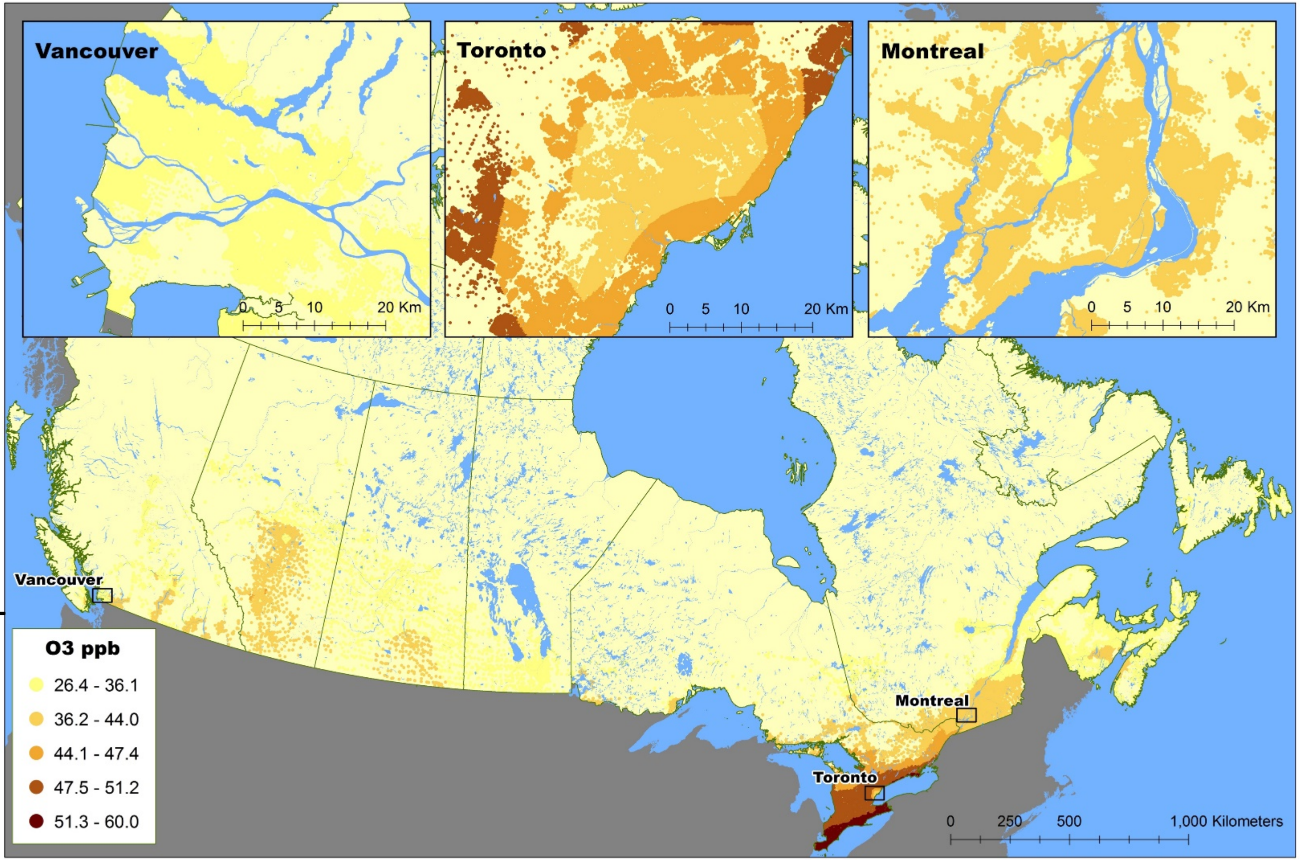
- Year-adjusted using ground-based time-series measurements from 24 Census Divisions (1981 – 2016)



Hystad P et al. 2011. Creating national air pollution models for population exposure assessment in Canada. Environ Health Perspect 119(8):1123-9.

O_3 Estimation

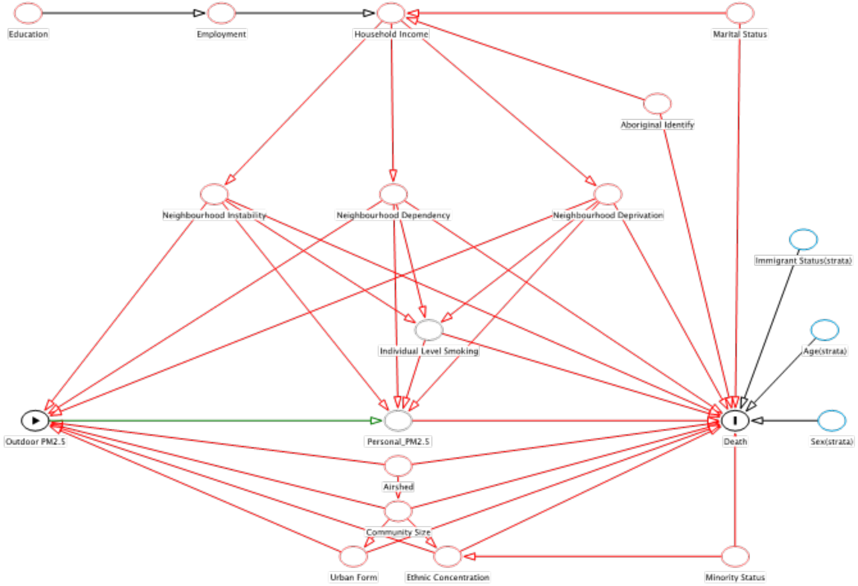
- Linear combination of hourly modelled (CTM forecast) ozone surface and ground-based observations
- Mean daily 8-hour max. warm season (1 May–31 October) concentration, 2002-16 (11 - 21 km)
- Year-adjusted using ground-based time-series measurements from 24 Census Divisions (1981 - 2016)



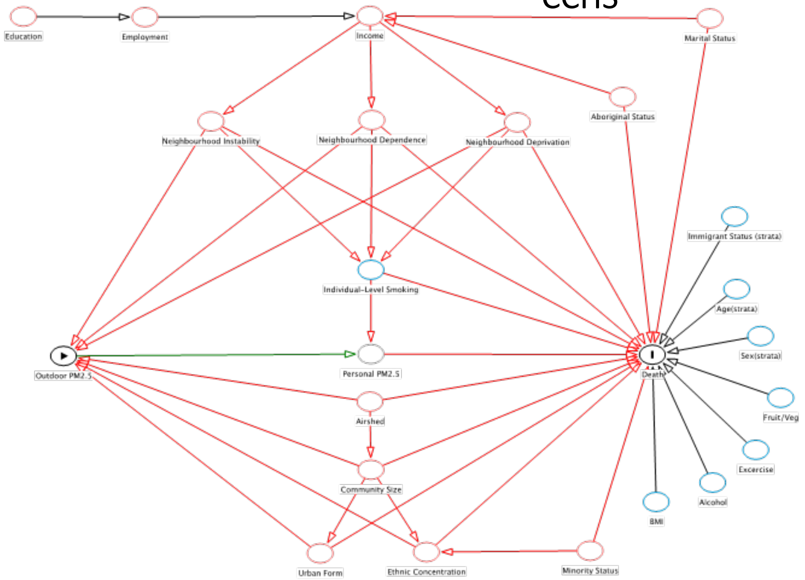
Robichaud A, Ménard R. 2014. Multi-year objective analyses of warm season ground-level ozone and PM2.5 over North America using real-time observations and the Canadian operational air quality models. Atmospheric Chemistry and Physics 14(4):1769-1800.

Covariates

CanCHEC



CCHS



DAG Model: Airshed, Community Size, **Urban Form**, (**Ethnic Concentration**, **Dependency, Deprivation, Instability) +** strata for age, sex, immigrant status (cohort)

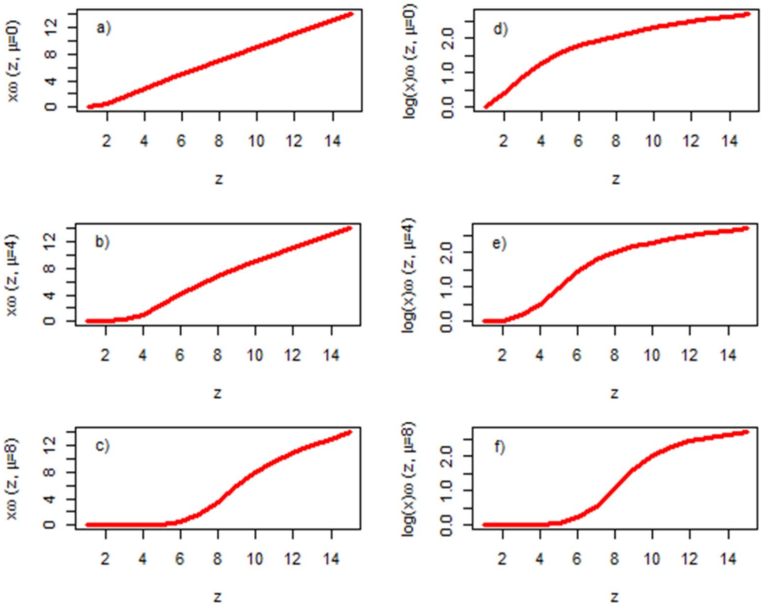
Full model (+ available individual-level covariates)

CanCHEC: income, education, marital status, indigenous identity, employment status, occupational class, visible minority status, and years since immigrating to Canada

CCHS: + fruit and vegetable consumption, leisure exercise frequency, alcohol consumption, smoking, BMI

Analysis

- Cox Proportional Hazards
- Non-accidental deaths
- Primary exposure time-window is a 3-year moving average with 1-year lag
  - (e.g. exposure for person-year in 2001 = mean of 1998, 1998, 2000)
- Evaluate shape with restricted cubic splines (RC) (15 knots) and Shape Constrained Health Impact Function (SCHIF)
- Evaluate sensitivity of associations to:
  - Exposure time-windows (1 – **8** yrs)
  - Spatial scales (**1-km^2** vs 10-km^2)
  - Sub-populations (e.g. immigrant status)
  - Co-pollutants



Nasari et al. Air Qual Atmos Health. A class of non-linear exposure-response models suitable for health impact assessment applicable to large cohort studies of ambient air pollution. 2016; 9(8): 961–972. doi: [10.1007/s11869-016-0398-z](10.1007/s11869-016-0398-z)

Crouse et al., Epidemiology 2019; Erickson et al., 2020

Results: CCHS

- One of largest analyses of $PM_{2.5}$ and mortality including individual-level behavioural risk factors (4.4 million person-years)
- Over 50k deaths from non-accidental causes; up to 15 years follow-up
- Annual average $PM_{2.5}$ concentration: 5.9 µg/m^3 (s.d. 2.0)

	HR per 10 µg/m^3 $PM_{2.5}$
Full (CanCHEC) model: [individual-level SES and contextual (e.g. city size, marginalization) covariates	**1.13 (1.06-1.21)**
+ behavioural covariates (fruit and vegetable consumption, leisure exercise frequency, alcohol consumption, and smoking behaviours)	**1.11 (1.04-1.18)**

Christidis et al., Environmental Health, 2019

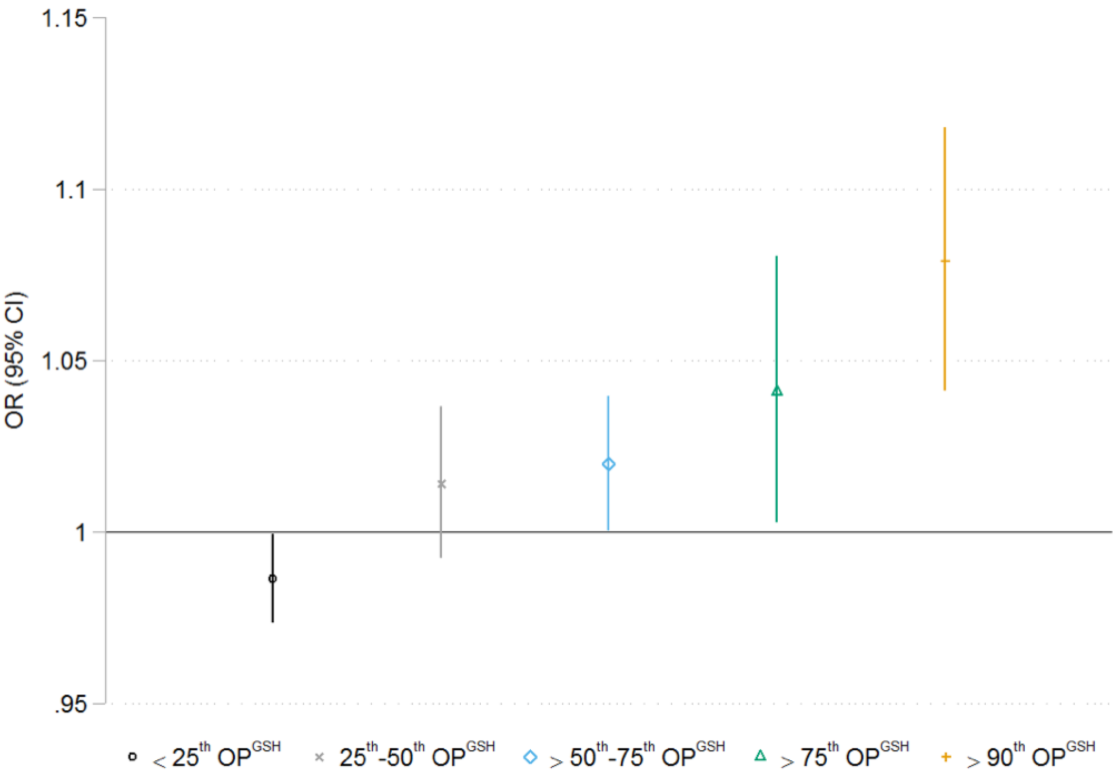
Results: CanCHEC

- ~8.5 million individuals (151 million person-years)
- ~1.5 million deaths; up to 25 years of follow-up
- Annual average $PM_{2.5}$ concentration: 7.4 μg/m^3 (s.d. 2.9)

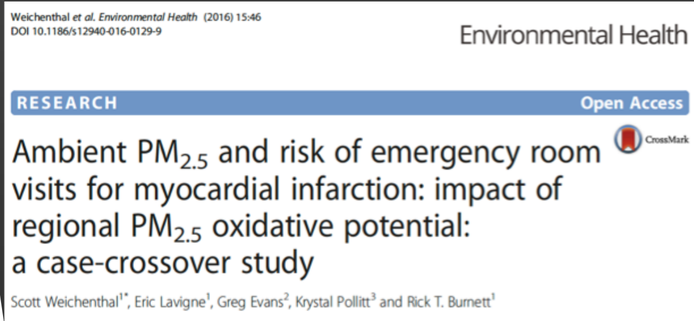
	HR per 10 μg/m^3 $PM_{2.5}$
DAG model: contextual (e.g. city size, marginalization) covariates	**1.044 (1.031 – 1.056)**
Full (CanCHEC) model: [individual-level SES and contextual (e.g. city size, marginalization) covariates	**1.053 (1.041 – 1. 065)**
+ NO_2	**1.043 (1.030 – 1.056)**
+ O_3	**0.982 (0.970 – 0.994)**
+ Ox	**0.955 (0.943 – 0.968)**

Pappin et al., 2019.

ER Visits: Myocardial Infarction (per 5 ug/m³)



Between-City Differences in $PM_{2.5}$ OP Modify Risk of Acute MI



Weichenthal *et al. Environmental Health* (2016) 15:46
DOI 10.1186/s12940-016-0129-9

Environmental Health

RESEARCH **Open Access**

Ambient $PM_{2.5}$ and risk of emergency room visits for myocardial infarction: impact of regional $PM_{2.5}$ oxidative potential: a case-crossover study

Scott Weichenthal[1*], Eric Lavigne[1], Greg Evans[2], Krystal Pollitt[3] and Rick T. Burnett[1]

ER Visits: Myocardial Infarction (per 5 ug/m³)

Percentile of 3-day mean O_x^{wt}	Percentile of Regional OP^{GSH}			
	≤50th	>50th	>75th	>90th
≤50th	−2.0 (−5.0, 1.0)	0.57 (−4.0, 5.0)	2.9 (−1.2, 7.2)	6.0 (0.0, 13)
>50th	1.5 (−0.6, 3.6)	5.5 (3.0, 8.0)	6.4 (2.0, 11)	10 (7.5, 13)
>75th	1.5 (−1.3, 4.4)	5.7 (2.5, 9.1)	6.7 (1.8, 12)	13 (6.8, 19)
>90th	1.4 (−4.6, 7.8)	9.0 (3.5, 15)	9.2 (0.46, 19)	29 (26, 33)

Risk estimates reflect a 5 μg/m³ change in $PM_{2.5}$. All models are adjusted for 3-day mean ambient temperature and relative humidity (cubic splines)

The largest risk is observed in regions with high $PM_{2.5}$ OP and high O_x

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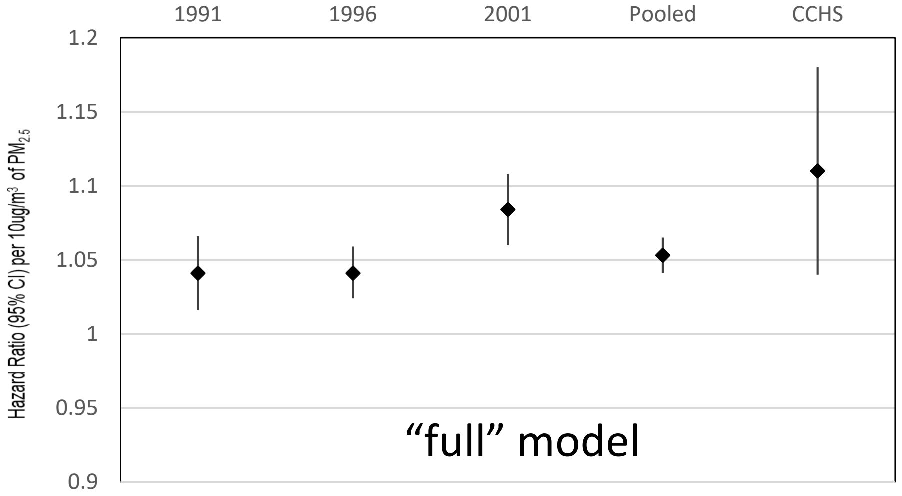
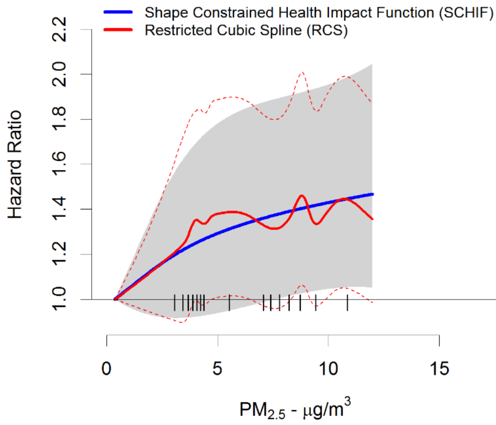
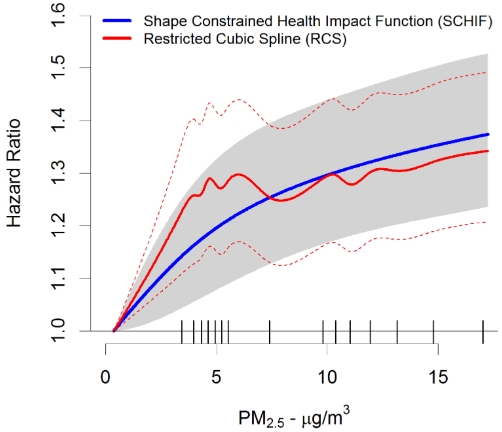


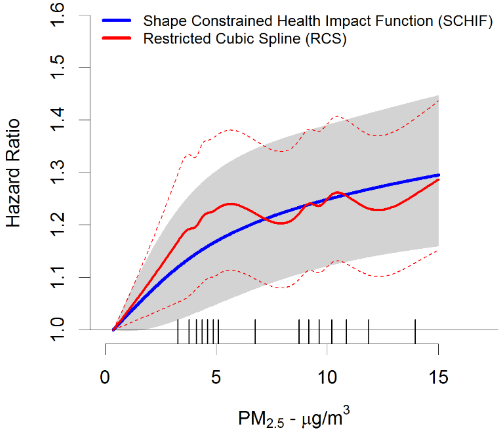
Canadian Community Health Survey



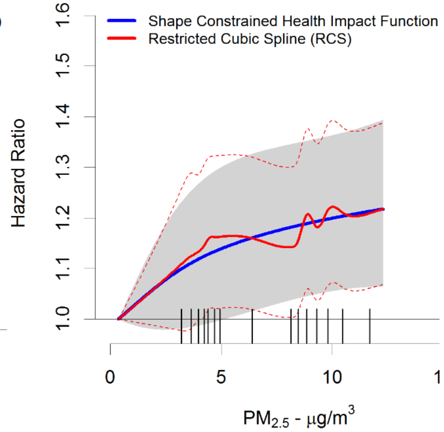
1991 CanCHEC



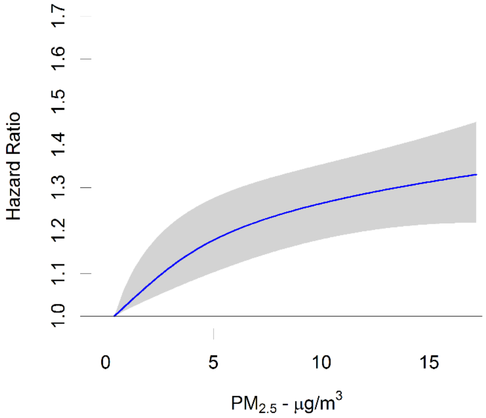
1996 CanCHEC



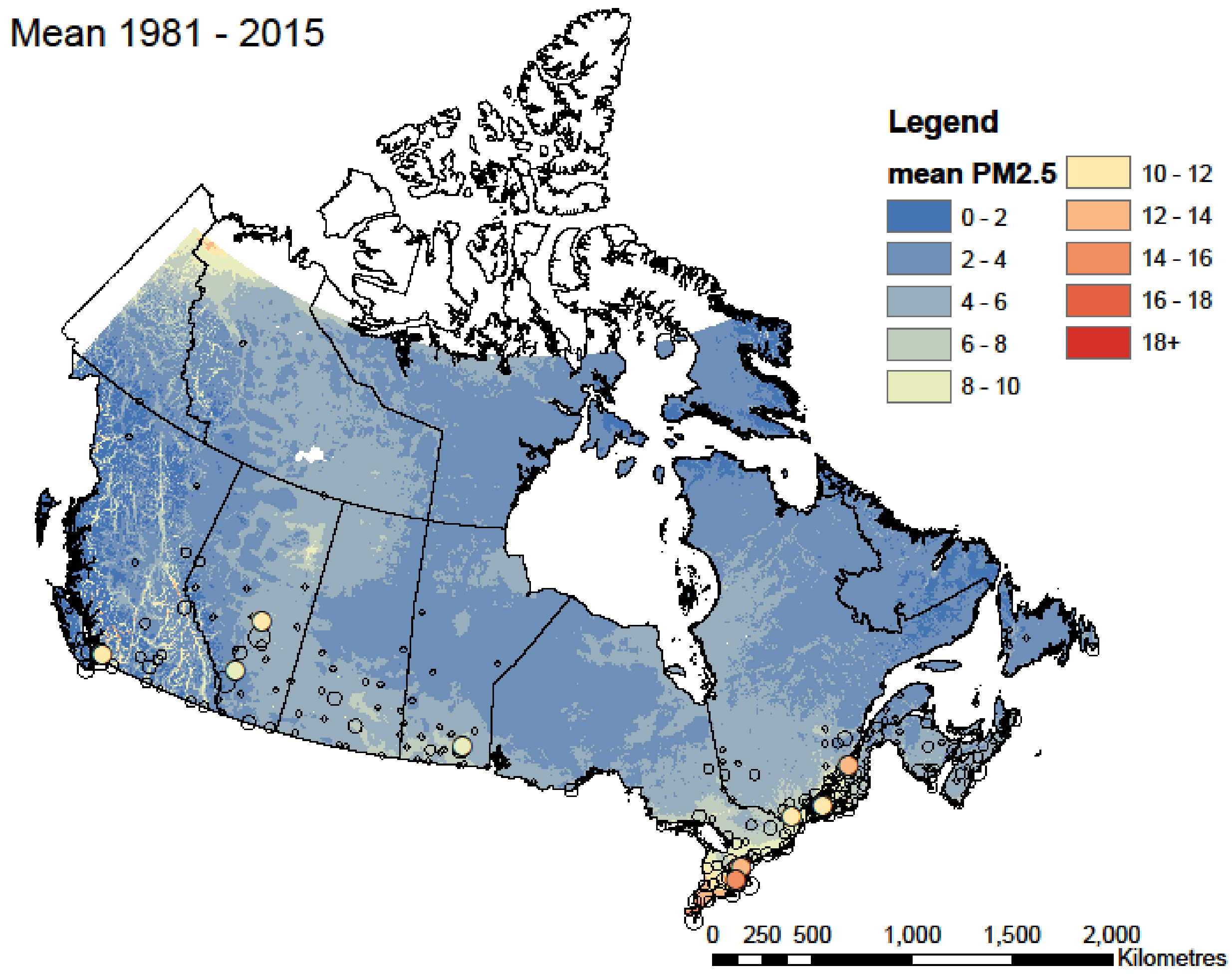
2001 CanCHEC



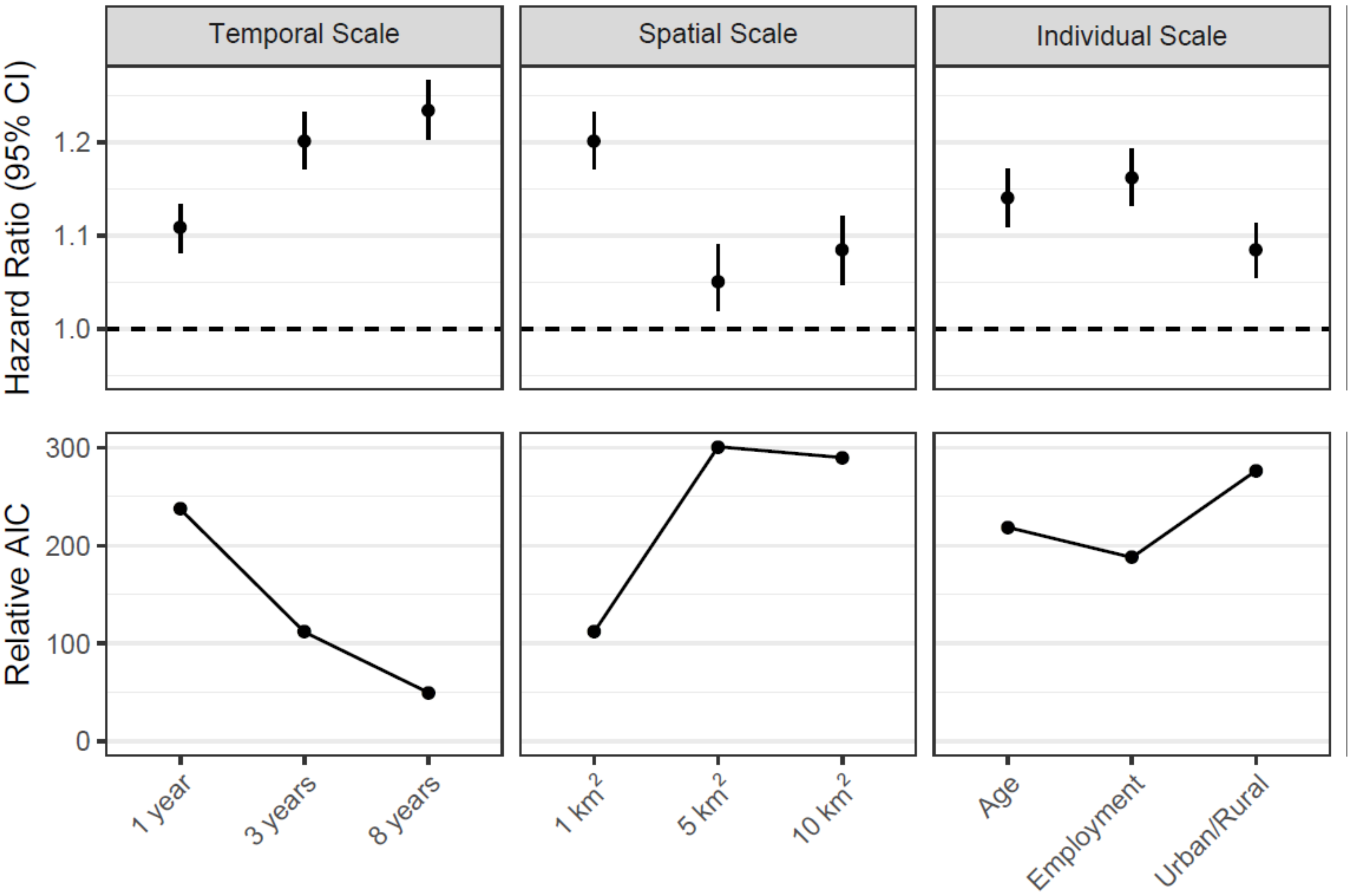
Pooled SCHIF



Pappin et al., 2019; Christidis et al., 2019



Mean 1981 - 2015
Legend
mean PM2.5
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16 - 18
18+
0 250 500 1,000 1,500 2,000
Kilometres


Temporal Scale
Spatial Scale
Individual Scale
Hazard Ratio (95% CI)
1.0
1.1
1.2
Relative AIC
0
100
200
300
1 year
3 years
8 years
1 km^2
5 km^2
10 km^2
Age
Employment
Urban/Rural

In progress

- (further) Refined exposure estimates
- Specific causes of death
- Restricted exposure analyses (12, 10, 8, or 6 $\mu g/m^3$)

Summary points

- In both cohorts, supra-linear association between $PM_{2.5}$ and non-accidental mortality (to concentrations as low as 5 μg/m^3 or lower)
- No evidence of threshold or sub-linear association
- Associations not affected substantially by adjustment for smoking or other health behaviours

Publications

MAPLE

- **Latimer and Martin.** Interpretation of measured aerosol mass scattering efficiency over North America using a chemical transport model. Atmos. Chem. Phys. 2019
- **Meng et al.** Estimated long-term (1981-2016) concentrations of ambient fine particulate matter across North America from chemical transport modeling, satellite remote sensing and ground-based measurements. Environ Sci Technol. 2019
- **Erickson et al.** Evaluation of a method to indirectly adjust for unmeasured covariates in the association between fine particulate matter and mortality. Environ Res. 2019
- **Crouse et al.** Evaluating the sensitivity of $PM_{2.5}$-mortality associations to the spatial and temporal scale of exposure assessment at low particle mass concentrations. Epidemiology. 2019
- **Christidis et al.** Low concentrations of fine particle air pollution and mortality in the Canadian Community Health Survey cohort. Environmental Health. 2019
- **Pappin et al.** Nonlinear associations between low levels of fine particulate matter and mortality across three cycles of the Canadian Census Health and Environment Cohort. EHP. 2019
- **Erickson et al.** Disease assimilation: the mortality impacts of fine particulate matter on immigrants to Canada. Health Reports. 2020

- **Pinault et al.** Diabetes status and susceptibility to the effects of $PM_{2.5}$ exposure on cardiovascular mortality in a national Canadian cohort. Epidemiology. 2018
- **Pinault et al.** Associations between fine particulate matter and mortality in the 2001 Canadian Census Health and Environment Cohort. Environ Res. 2017

MAPLE Team

Michael Brauer, The University of British Columbia

Jeffrey Brook, University of Toronto

Rick Burnett, Health Canada

Tanya Christidis, Statistics Canada

Yen Chu, University of British Columbia

Dan Crouse, University of New Brunswick

Anders Erickson, The University of British Columbia

Perry Hystad, Oregon State University

Chi Li, Dalhousie University

Jun Meng, Dalhousie University

Amanda Pappin, Statistics Canada

Lauren Pinault, Statistics Canada

Randall Martin, Dalhousie University

Alain Robichaud, Environment & Climate Change Canada

Michael Tjepkema, Statistics Canada

Richard Ménard, Environment & Climate Change Canada

Aaron van Donkelaar, Dalhousie University

Scott Weichenthal, McGill University

MAPLE

CANUE

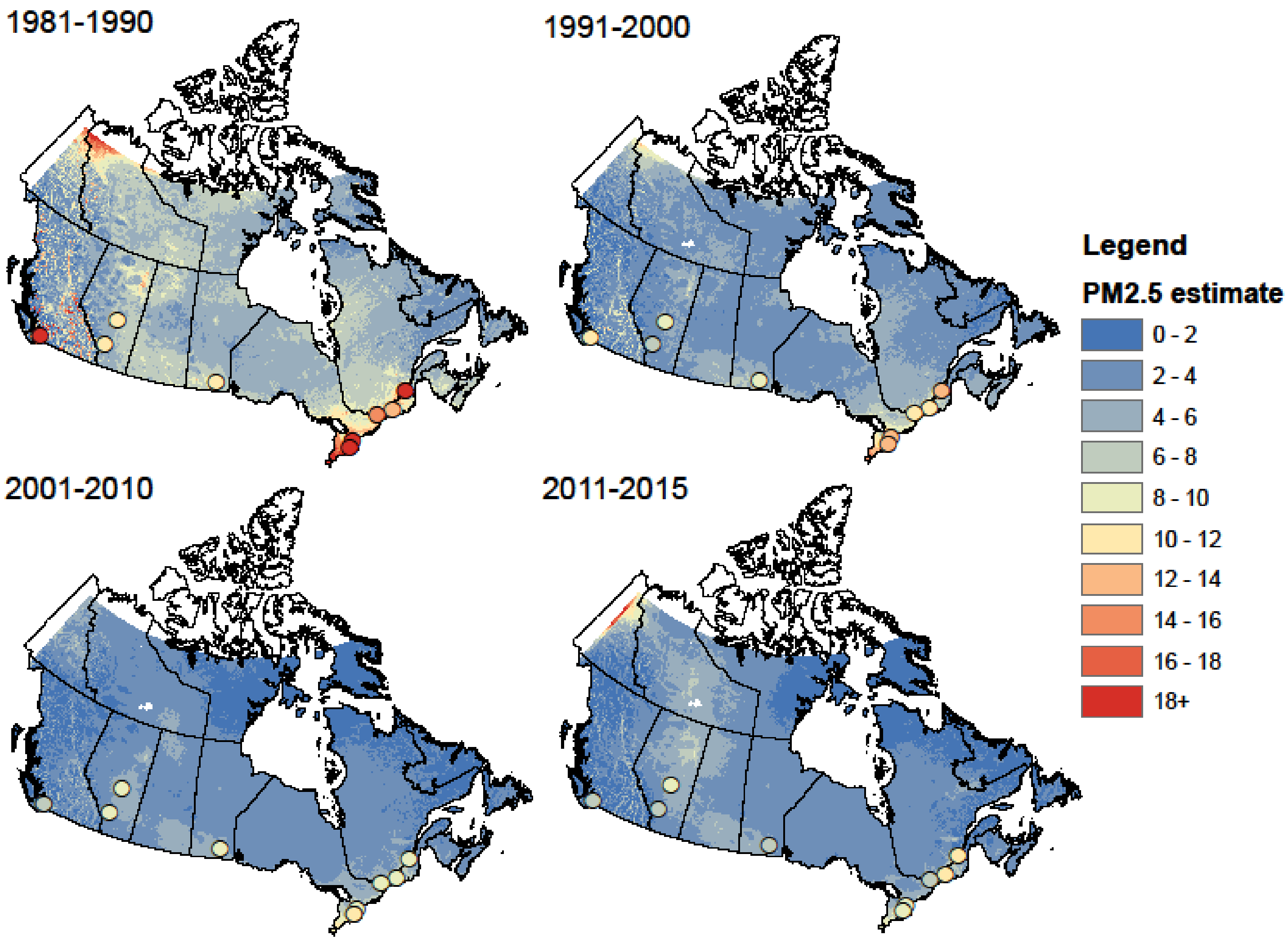
CRDCN Canadian Research Data Centre Network

HEI

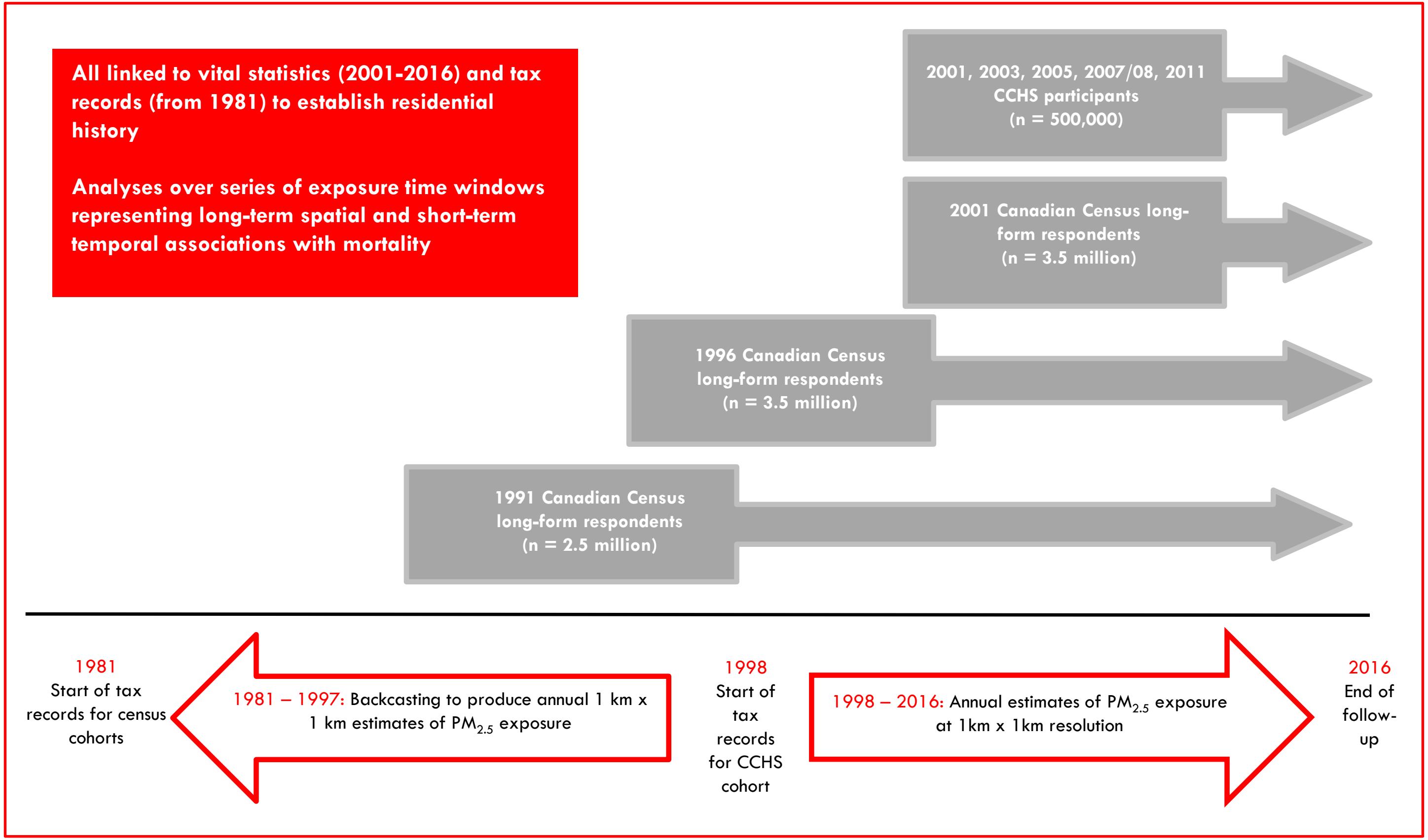
THANK YOU

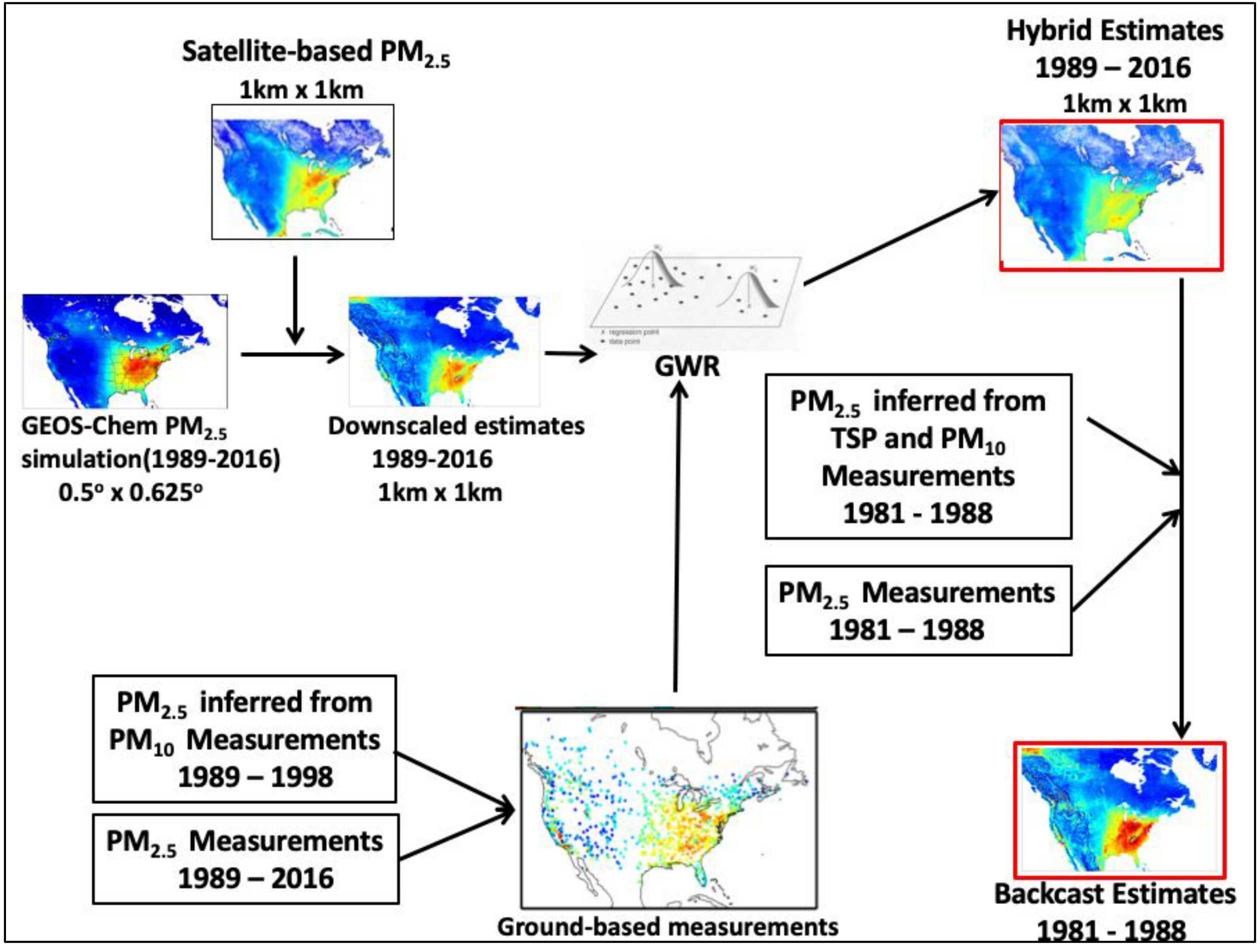
michael.brauer@ubc.ca

EXTRA SLIDES

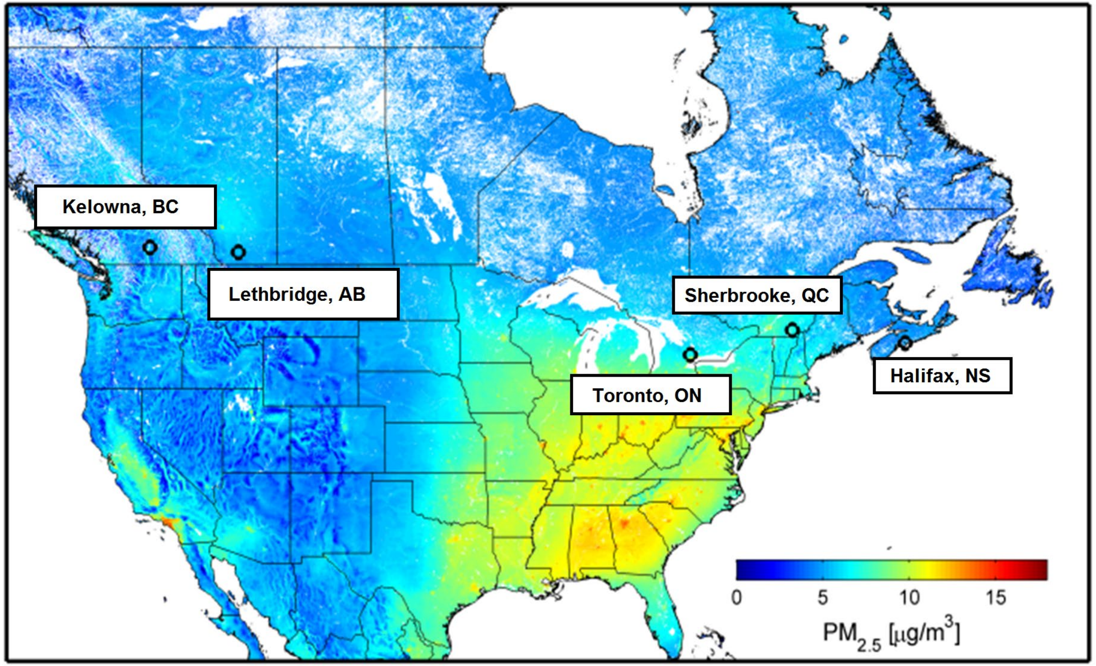

1981-1990
1991-2000
2001-2010
2011-2015
Legend
PM2.5 estimate
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16 - 18
18+

Cohorts and follow-up

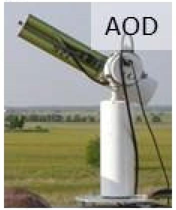



Satellite-based $PM_{2.5}$
1km x 1km
Hybrid Estimates
1989 – 2016
1km x 1km
GEOS-Chem $PM_{2.5}$
simulation(1989-2016)
0.5^o x 0.625^o
Downscaled estimates
1989-2016
1km x 1km
GWR
$PM_{2.5}$ inferred from
TSP and PM_{10}
Measurements
1981 - 1988
$PM_{2.5}$ Measurements
1981 – 1988
$PM_{2.5}$ inferred from
PM_{10} Measurements
1989 – 1998
$PM_{2.5}$ Measurements
1989 – 2016
Ground-based measurements
Backcast Estimates
1981 - 1988

SPARTAN network expansion



Sherbrooke



Measurements of η ($PM_{2.5}$/AOD)

Surface/Column **Diurnal** **Mass Scattering Efficiency**

$$\eta = \frac{PM_{2.5}}{AOD} = \left(\frac{b_{sp,overpass}}{AOD_{overpass}}\right)\left(\frac{b_{sp,24h}}{b_{sp,overpass}}\right)\left(\frac{PM_{2.5,24h}}{b_{sp,24h}}\right)$$

b_{sp} = nephelometer measurements of aerosol scatter

overpass = satellite overpass time

Geographic Identifiers & Contextual Covariates

Regional airsheds

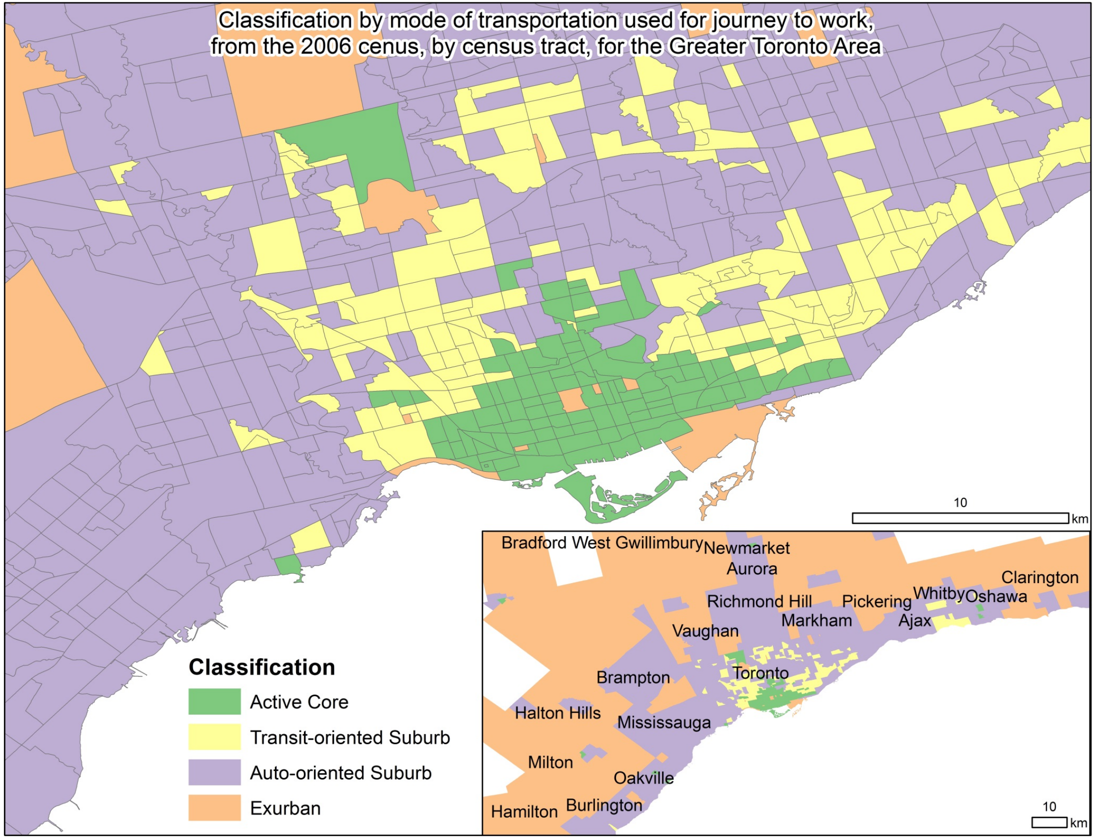
Neighbourhood-level marginalization:

- material deprivation
- residential instability
- dependency
- ethnic concentration

Geographic Identifiers & Contextual Covariates

Community size
(6 levels. small town → large city)

Urbanization
(4 levels. transit reliant suburb → urban core,)



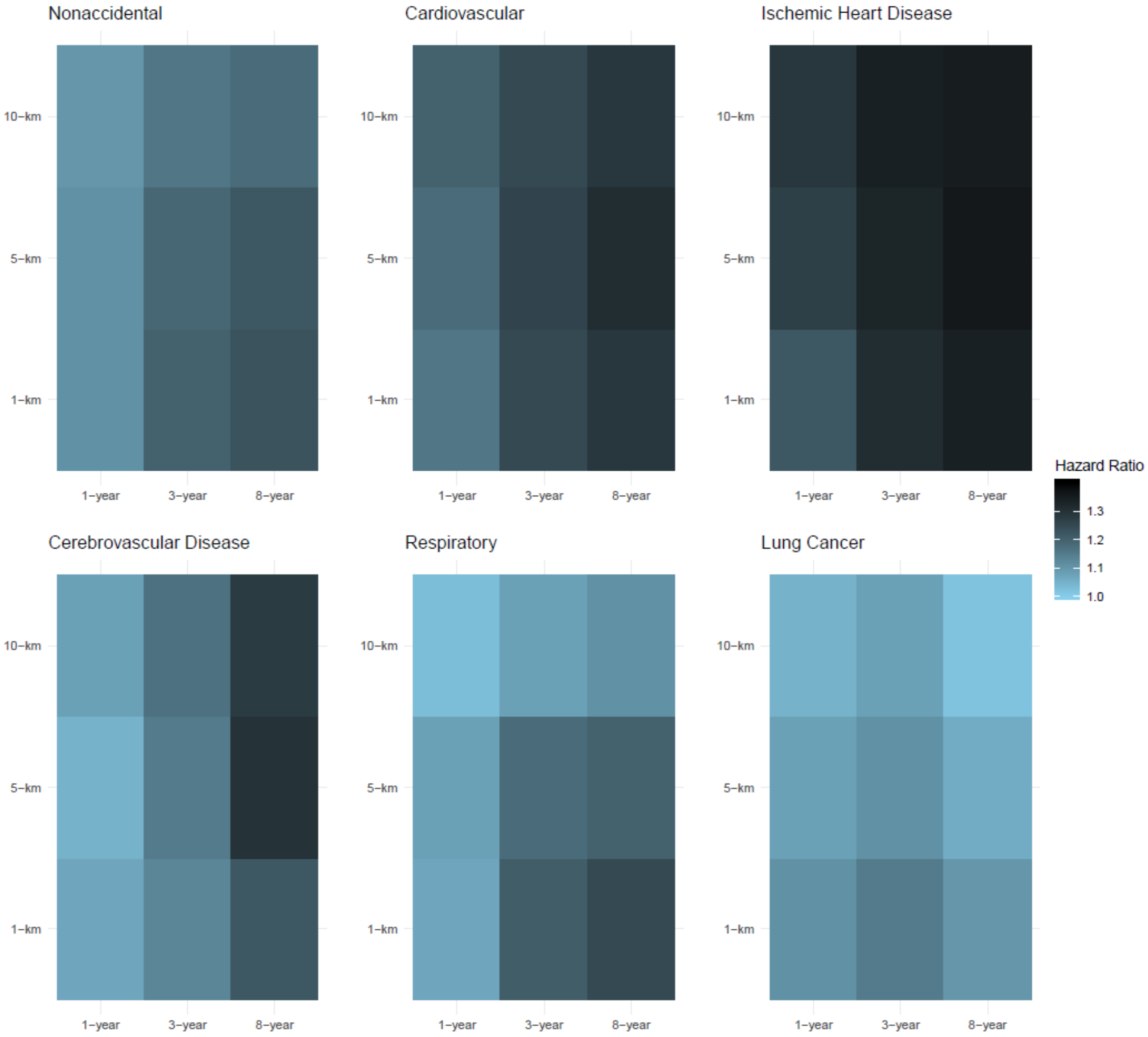
Individual and contextual covariates

Individual Variables at Baseline	CanCHEC	CCHS
Income	X	X
Education	X	X
Occupation	X	some
Immigration (time, source region)	X	X
Ethnicity	X	X
Household composition (marital status, living arrangements)	X	X
Housing (type, tenure, repair)	X	X
Education	X	X
Aboriginal identity	X	X
Alcohol consumption		X
Smoking (current, former)		X
Fruit and vegetable consumption		X
Physical activity		X
Body mass index		X

Contextual Variables	Source
% unemployed, % low income, % low education, % recent immigrants	Census
Social deprivation (CanMARG)	Census-derived Index
Population centre size, Airshed, Climate zone	Regional

Individual and contextual covariates

Individual Variables at Baseline	Harvard	CanCHE C	CCHS
Income	X (Medicaid eligible)	X	X
Education	(contextual)	X	X
Occupation		X	some
Immigration (time, source region)		X	X
Ethnicity	X	X	X
Household composition (marital status, living arrangements)		X	X
Housing (type, tenure, repair)	(contextual)	X	X
Education	(contextual)	X	X
Aboriginal identity	(contextual)	X	X
Alcohol consumption	(contextual, BRFSS)		X
Smoking (current, former)	(contextual, BRFSS)		X
Fruit and vegetable consumption	(contextual, BRFSS)		X
Physical activity	(contextual, LDL-C, A1C + other BRFSS)		X
Body mass index	(contextual, BRFSS)		X
Contextual Variables		**Source**	
% unemployed, % low income, % low education, % recent immigrants	Household Income, Home Value, Education Rate, Owner Occupied Housing, Hispanic/Black Population	Census	



Nonaccidental
Cardiovascular
Ischemic Heart Disease
Cerebrovascular Disease
Respiratory
Lung Cancer
10−km
5−km
1−km
1−year
3−year
8−year
Hazard Ratio
1.3
1.2
1.1
1.0

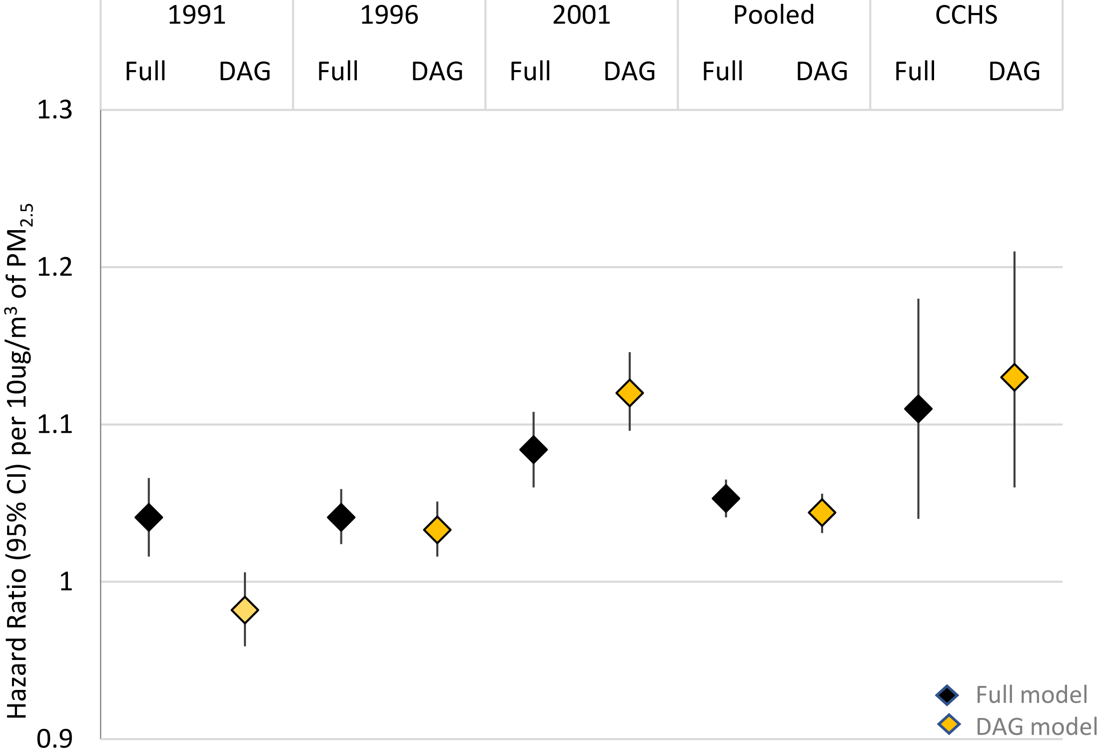


Figure 2*. Hazard Ratio estimates and 95% confidence intervals for the association between $PM_{2.5}$ and non-accidental mortality for Full and DAG-informed models*