Environment Canada Environnement Canada

Canada

Air Pollution: Monitoring, Managing and Minimizing Effects on Health

OEH SEMINAR
TORONTO
NOV. 21, 2013

J. R. Brook
Senior Scientist
Air Quality Research Division

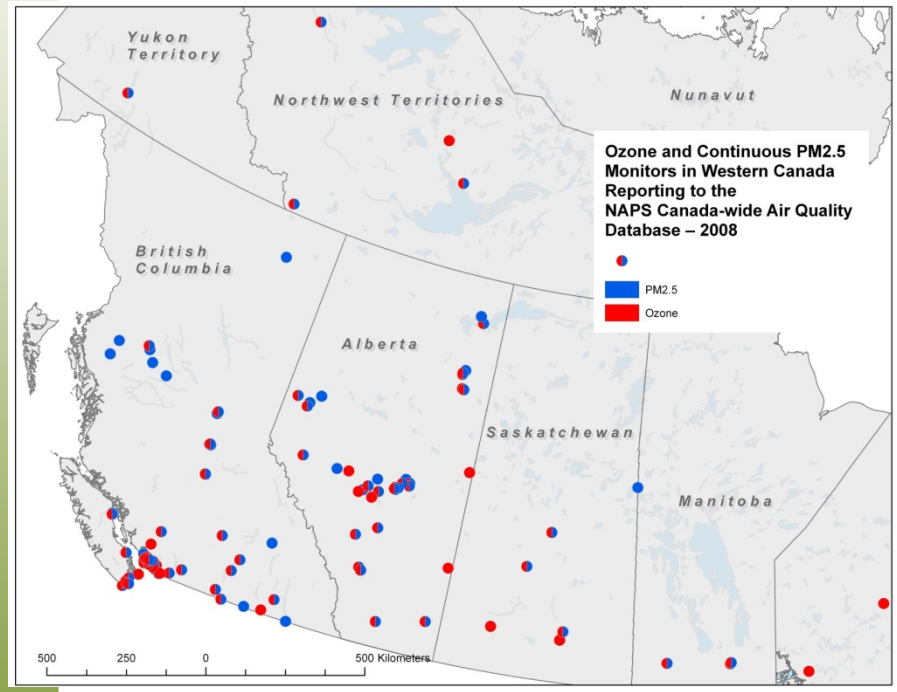
Learning Objectives

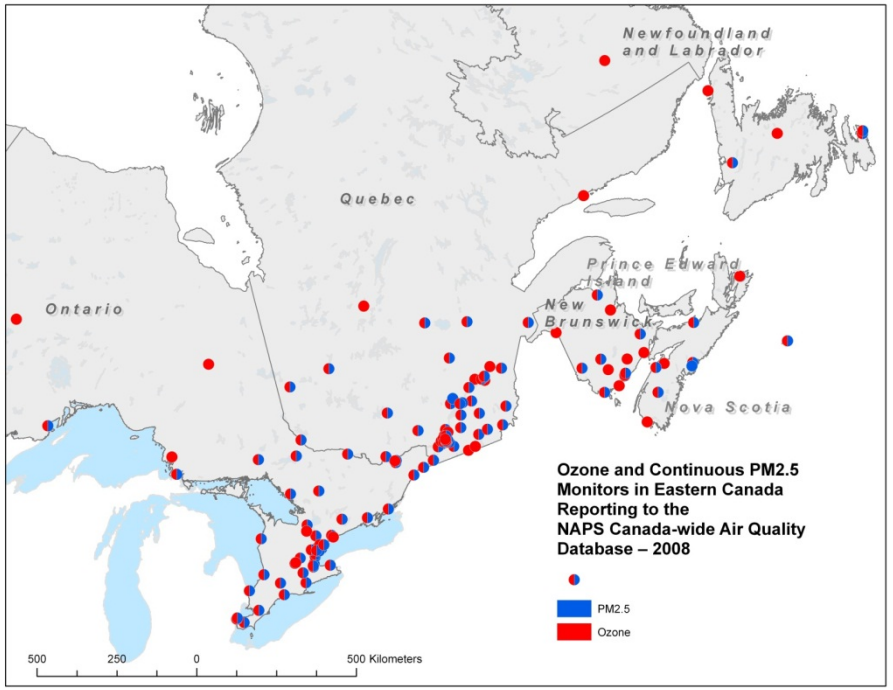
- To become familiar with the new Federal-Provincial Air Quality Management System.
- To understand more about approaches available and being developed to improve characterization of individual and population exposures to air pollutants.
- To learn about some recent research results and ongoing challenges regarding air pollutant exposures and effects

Outline

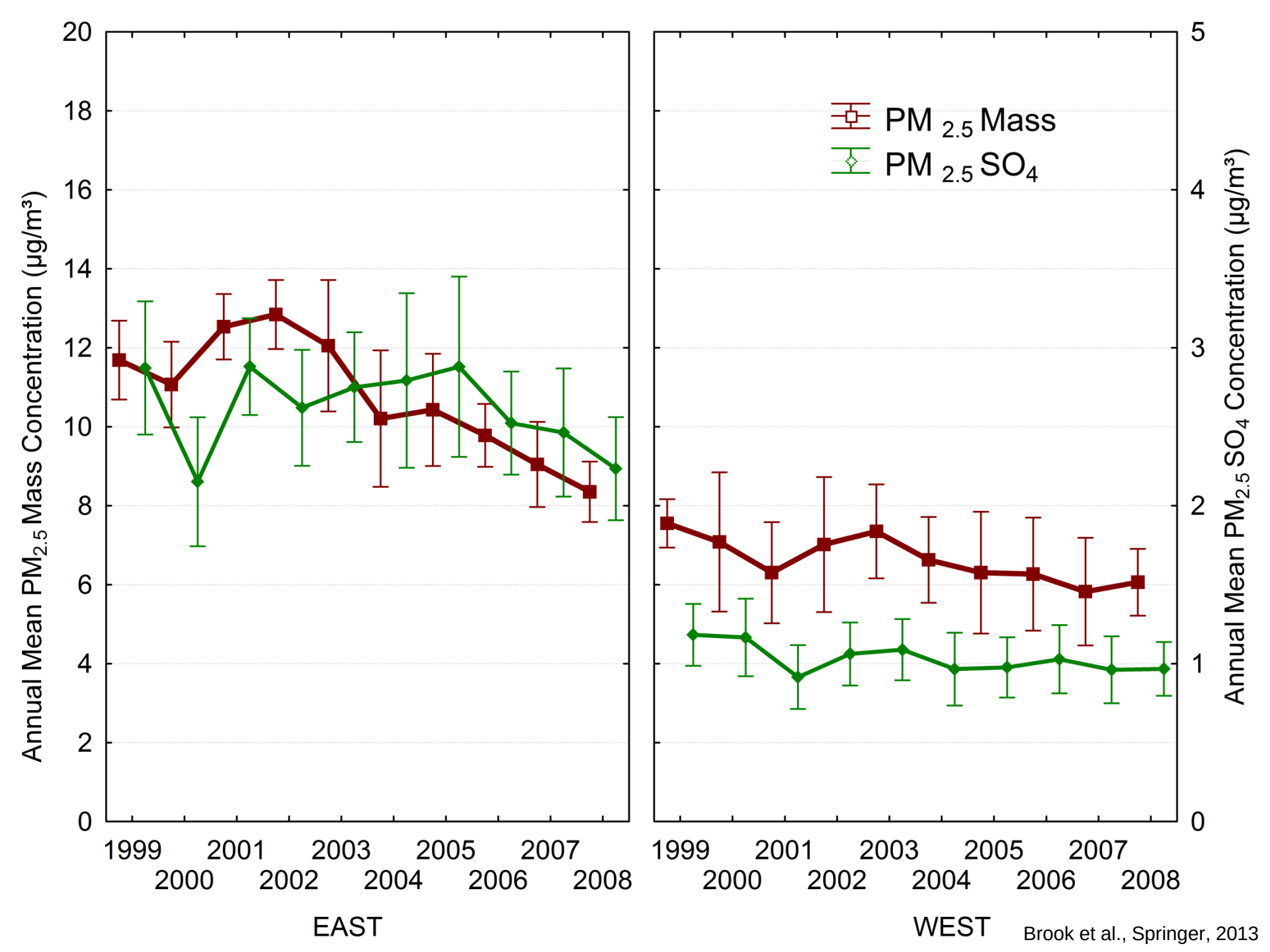
- Monitoring
  - Traditional networks of surface stations
  - New developments
- Managing
  - The new Federal-Provincial Air Quality Management System (AQMS)
  - Prediction of future levels
- Minimizing
  - Learning more about health effects
- Concluding Remarks

Canadian National Air Pollution Surveillance (NAPS) Monitoring Sites

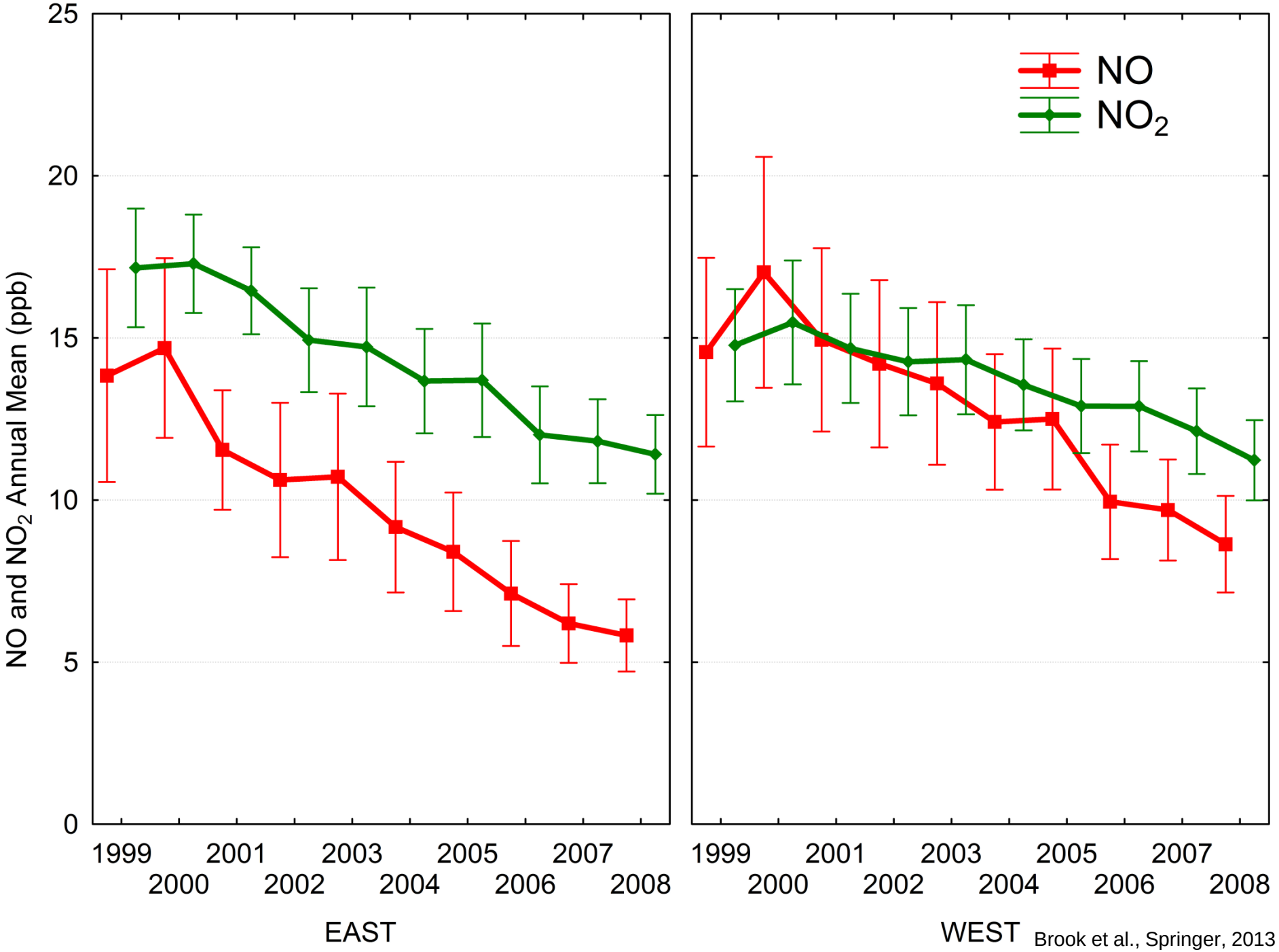




What has this monitoring told us?

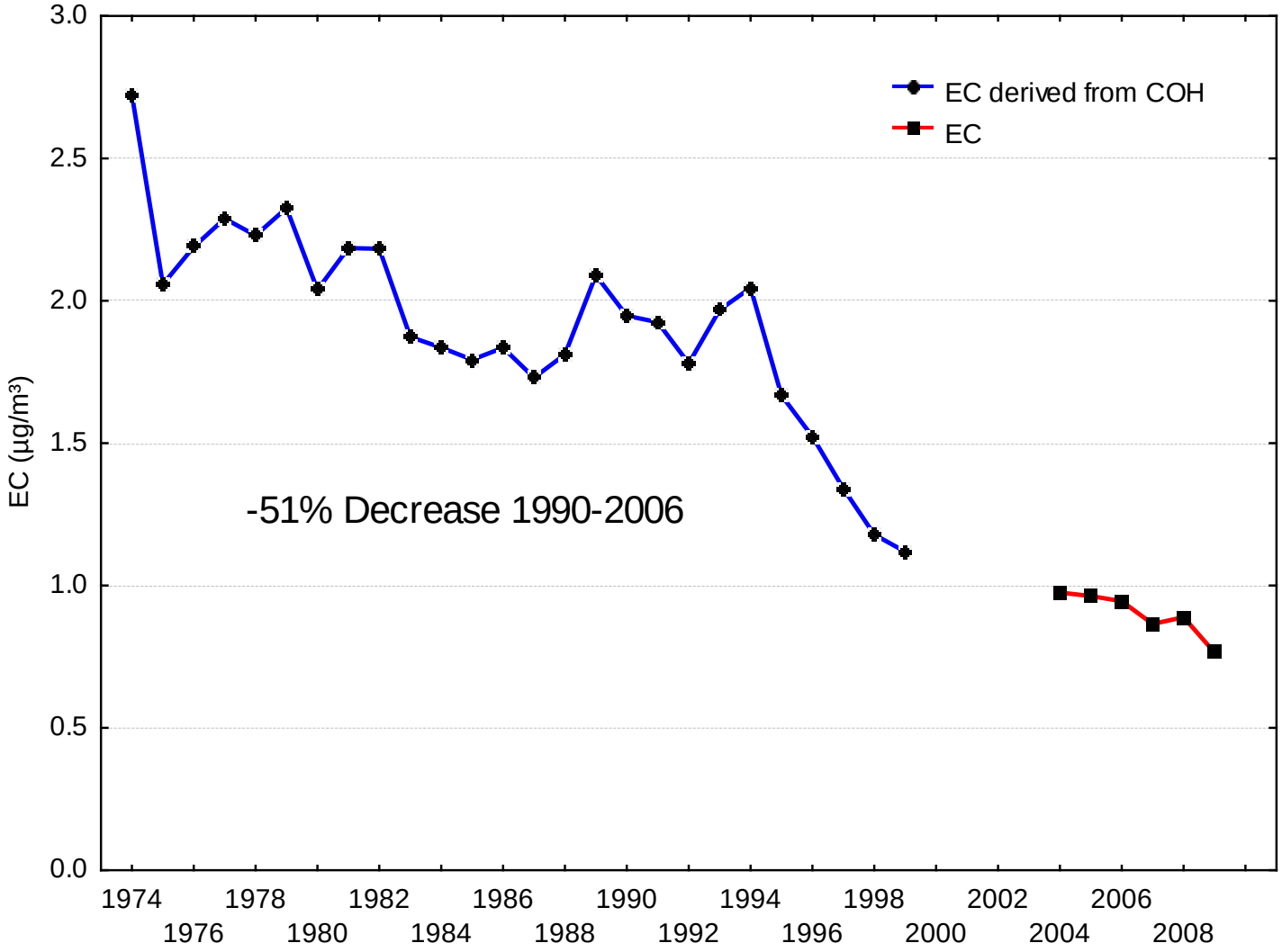


Brook et al., Springer, 2013



Brook et al., Springer, 2013

Long-Term Trend in “Soot”



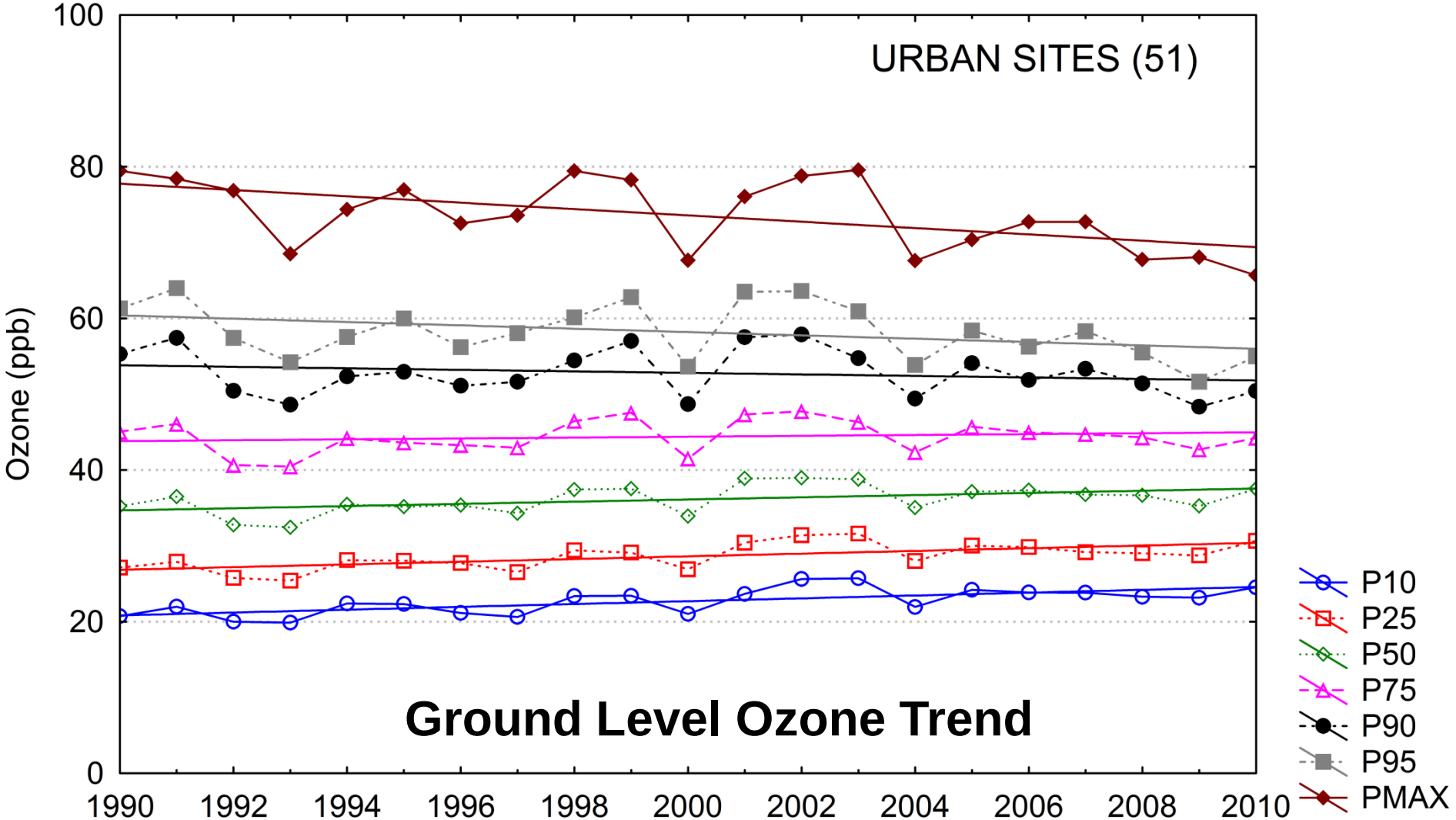
Courtesy of Tom Dann

An Environmental Management

City of Toronto Archives, Series 376, s0376_fl0004_it0039

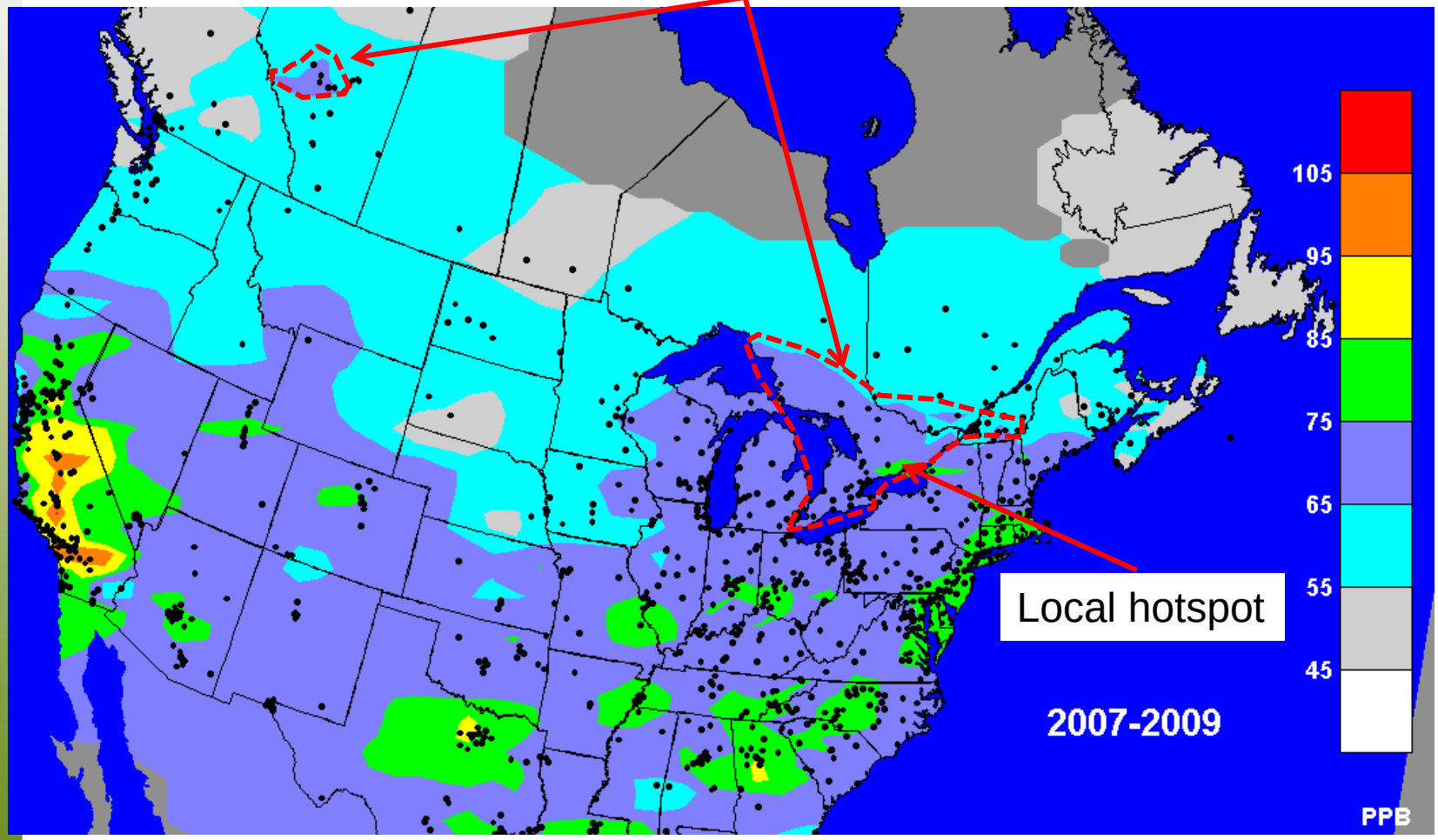
Brook et al., Springer, 2013

P10 = 20.8 +0.19 * YEAR **
P25 = 26.8 + 0.18 * YEAR **
P50 = 34.7 + 0.14 * YEAR
P75 = 43.8 + 0.06 * YEAR
P90 = 53.8 - 0.10 * YEAR
P95 = 60.4 - 0.22 * YEAR
PMAX = 77.8 - 0.42 * YEAR **



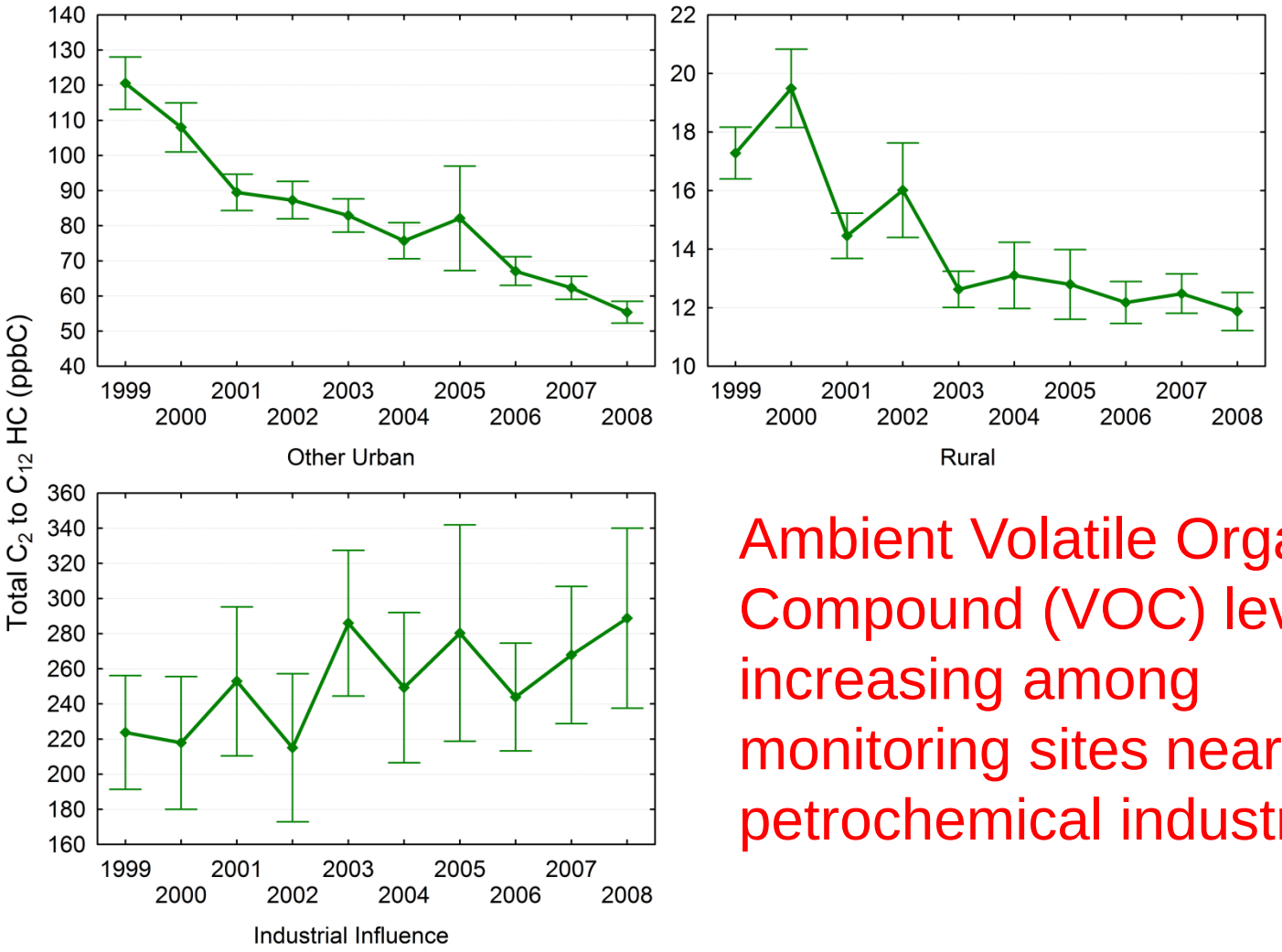
Ozone has declined since the early 2000s, however…

Large regions encompassing a large fraction of the population still exceed the CAAQS



Brook et al., Springer, 2013

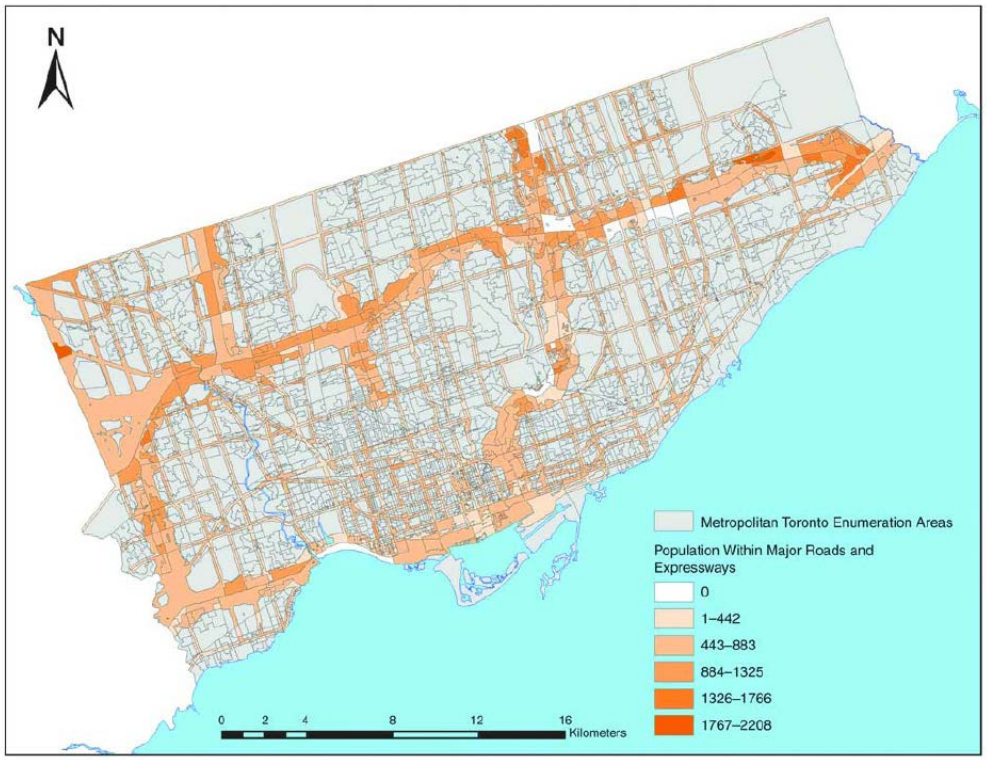
Other Exposure Hotspots - Industry



Ambient Volatile Organic Compound (VOC) levels increasing among monitoring sites near petrochemical industries

Exposure to traffic emissions – An issue in all Canadian cities

- health effects have been demonstrated in Canada and elsewhere



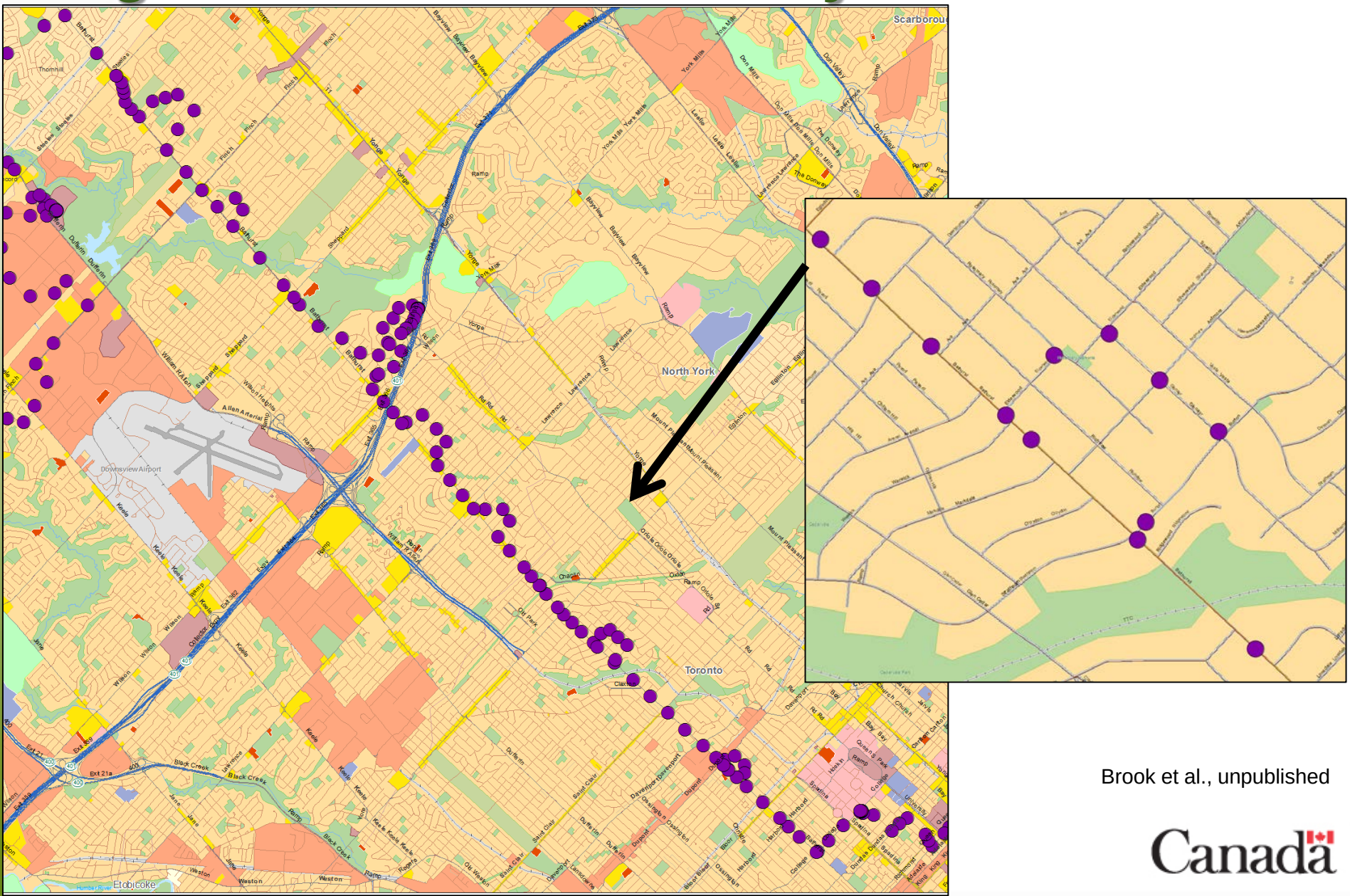
45% of Metro Toronto population lives within 500m of a highway or 100m of a major road

- HEI, 2010

East Montréal Mobile Lab Observations (CRUISER)

- *A focus on multi-pollutant exposure in an industrial area*
  - *Levy et al, EHP, 2013*

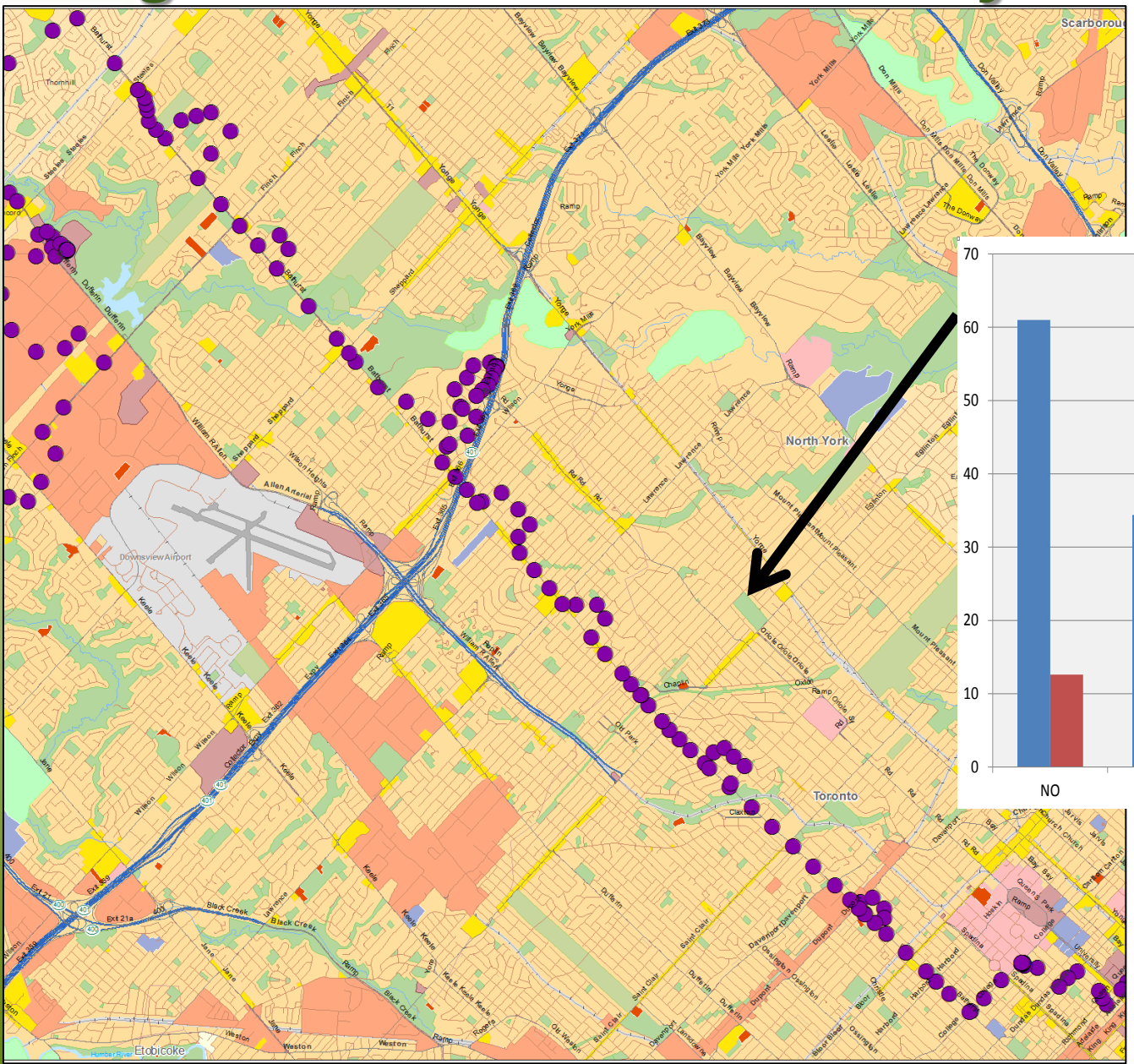
Toronto Surveys – Neighbourhood vs. Main City Streets

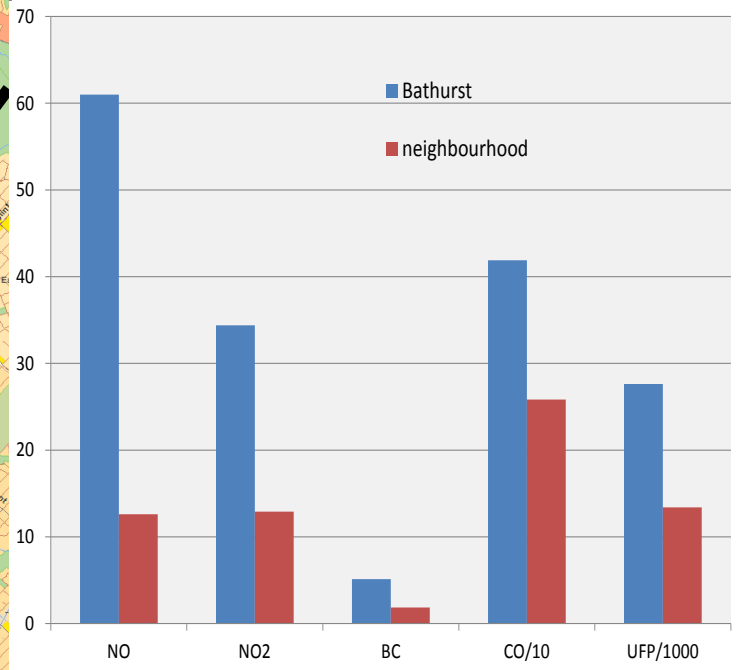


Brook et al., unpublished

Canada

Toronto Surveys – Neighbourhood vs. Main City Streets

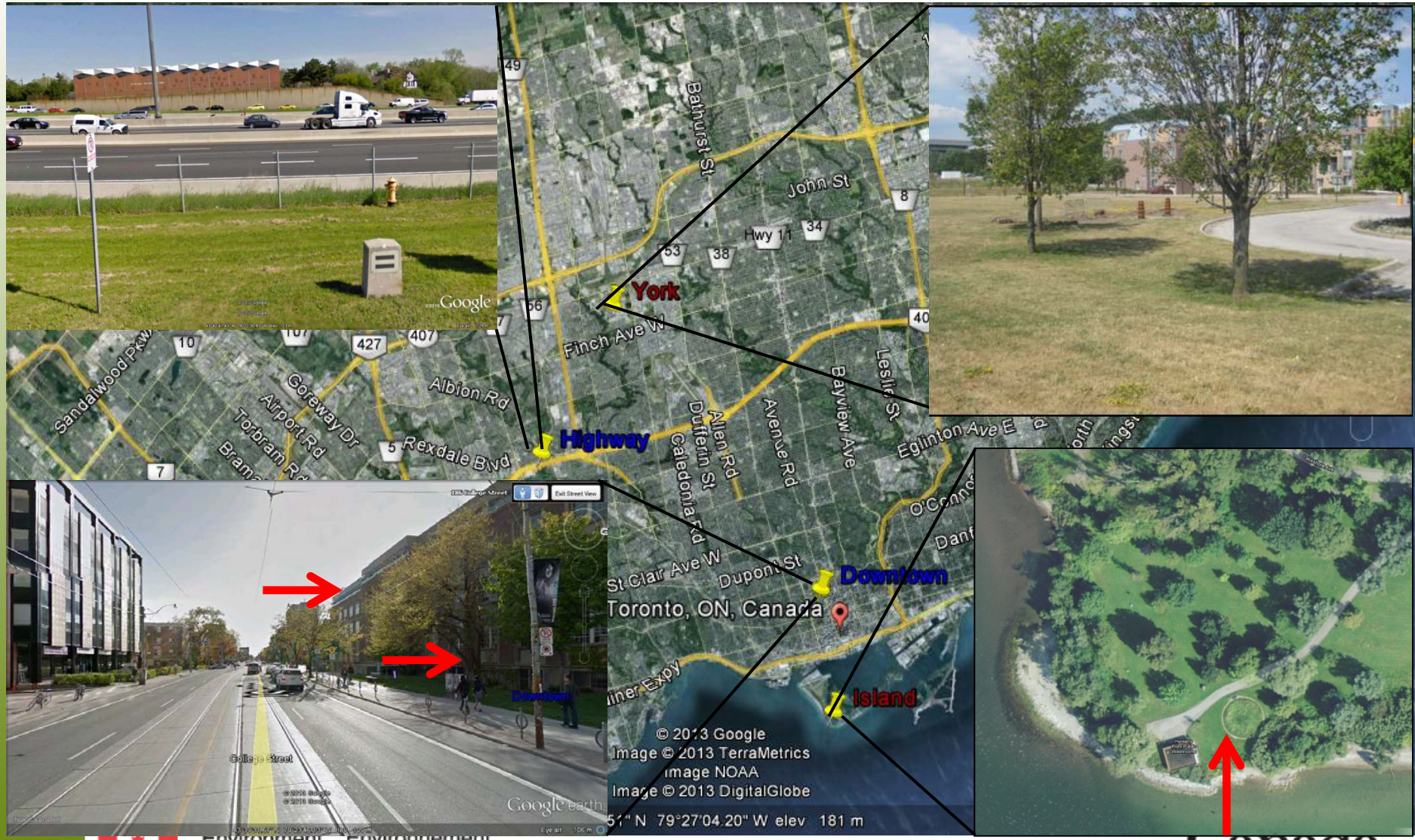




Brook et al., unpublished

Canada

Location of New Toronto Near-Roadway Sites
A Partnership with Provinces & Municipalities

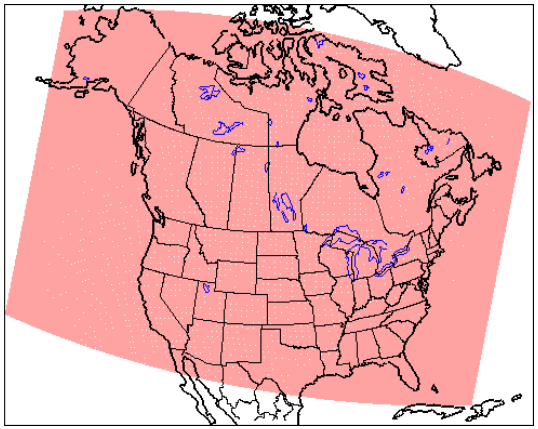


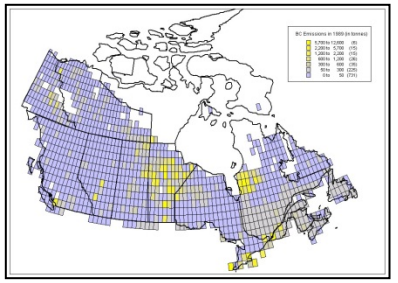
Remote sensing of air pollutants: A new tool with increasing applications

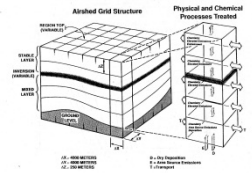
Most useful at present for PM2.5 and NO2

Air Quality Models

- Evaluating the effects of changes in emissions due to future growth or policies
  - Effects on air quality, deposition to the surface (acid rain) and climate
- Assessing our level of scientific understanding
- Forecasting future conditions
  - services such as the AQHI forecast

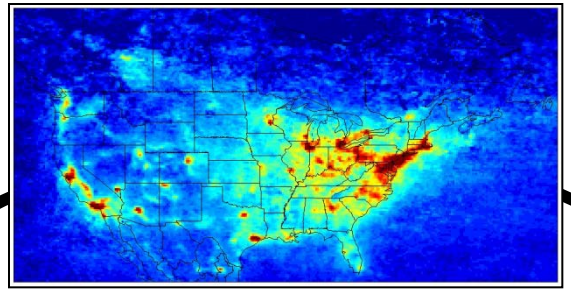




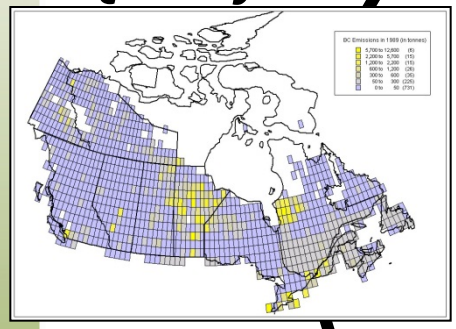


Canadian Air Quality Model Forecasts:
http://weather.gc.ca/aqfm/index_e.html

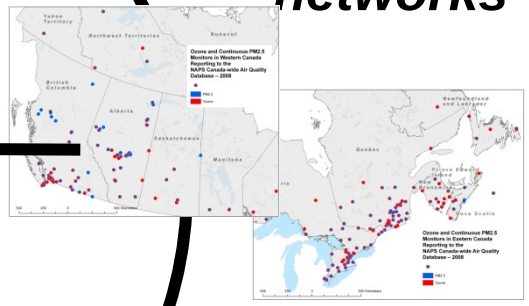
Satellite observations



Air Quality Model

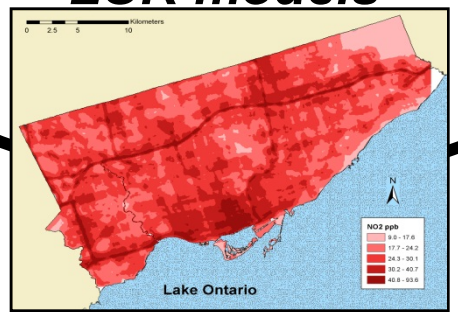


Measurement networks

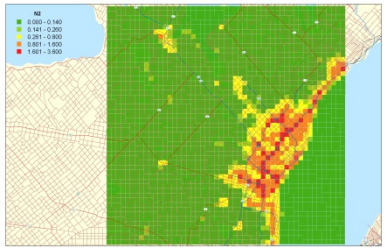


‘Optimal’ longer-term concentration/exposure

LUR models



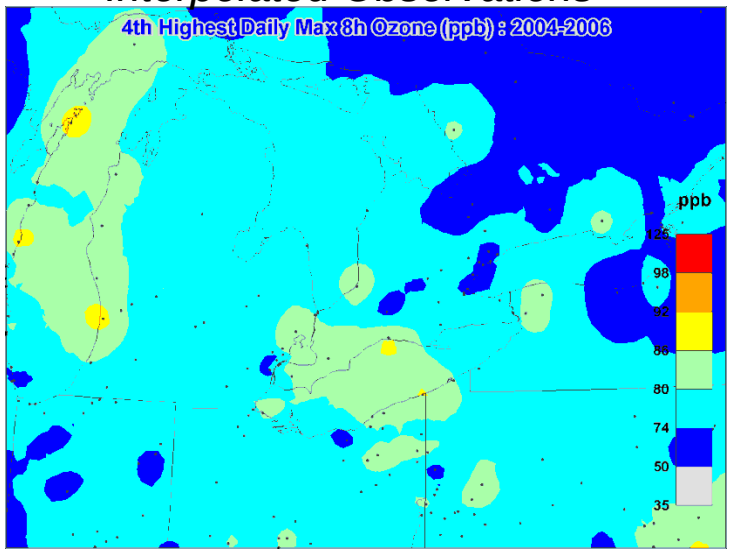
Hi-res Emissions



Combining Model Output and Observations ('Data Fusion')

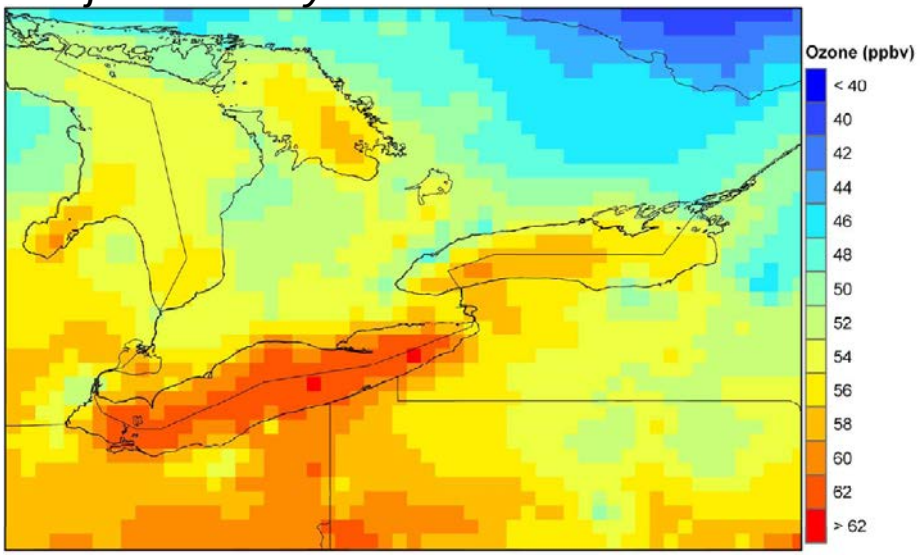
- Allows a better characterization of the hotspots and their causes
- Led to a process and modelling research focus in the 2007 BAQS-Met Study, which led to significant model improvements
- Supporting AQHI program and health effects studies

Interpolated Observations



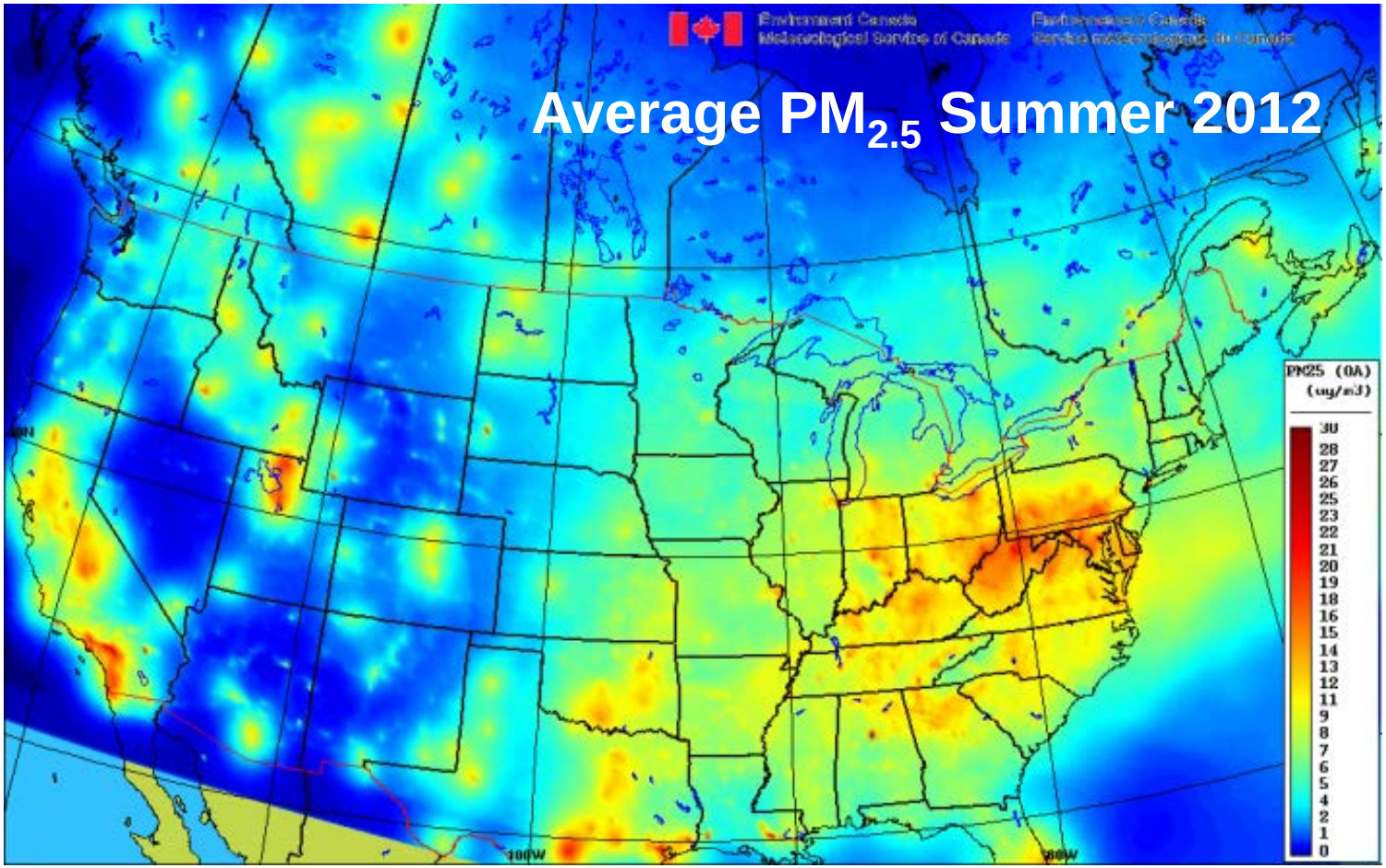
Brook et al., CRC Press, 2010

Objective Analysis of Obs. and Model



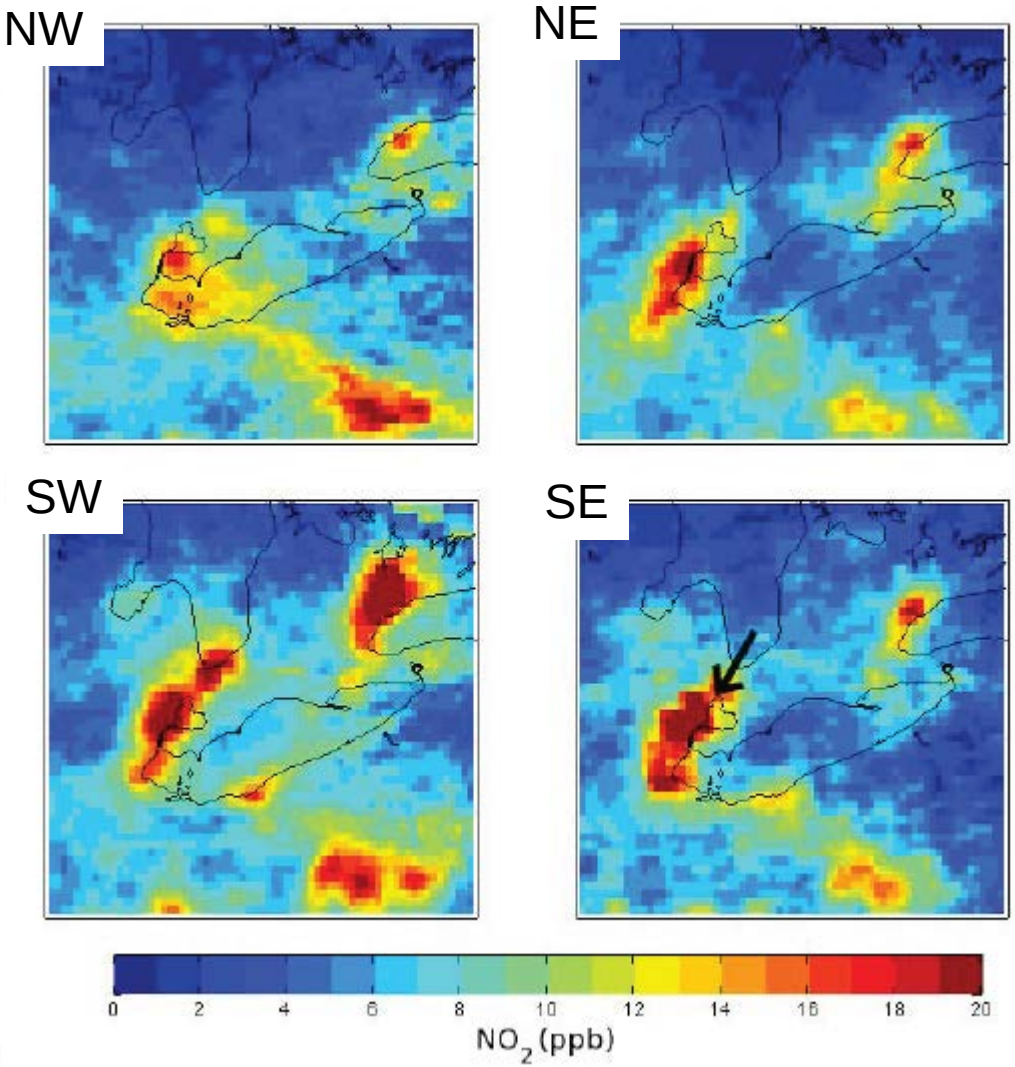
Brook et al., ACP, 2013

Combination of Model and Monitor $PM_{2.5}$



Robichaud and Menard, ACP, 2013

Average NO_2 over SW Ontario by wind direction from satellite

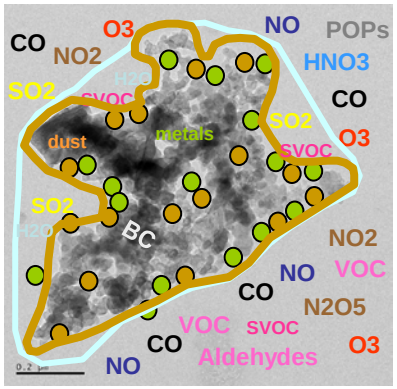


Can infer movement of urban emissions and gain insight into the size of the area that is impacted

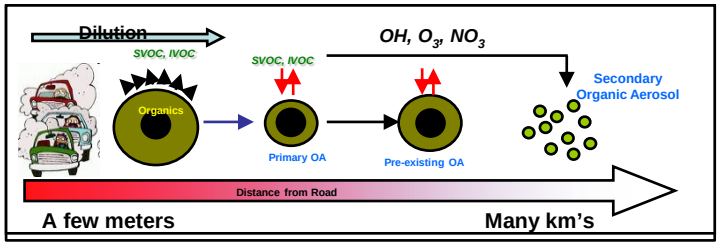
Lee et al., ACP, 2011

Scientific Challenges in AQ Research

- Air pollution is a complex mixture
  - What are the multi-pollutant effects?
  - How do we manage AQ holistically?
  - How reliable is the model?

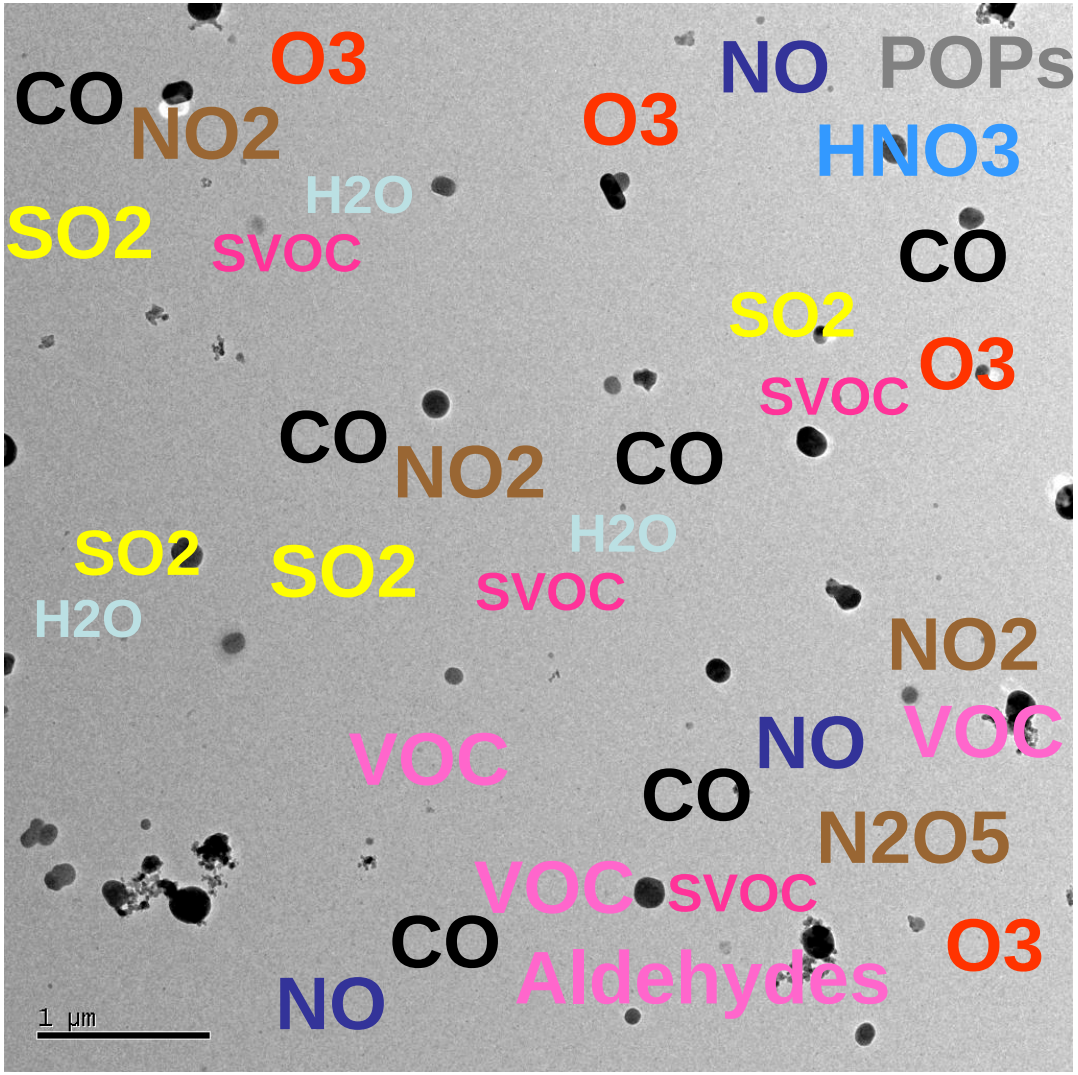


- Exposure from traffic emissions
  - Near roadway processes
  - Details of the mixture
  - How do changes in engine, fuel and after treatment technologies affect health?



- Improvement of high resolution models

Emissions from most sources are a complex mixture of pollutants and contribute to multiple secondary pollutants



Co-Benefits of Reducing Black Carbon Emissions

Bounding the role of black carbon in the climate system: A scientific assessment

by

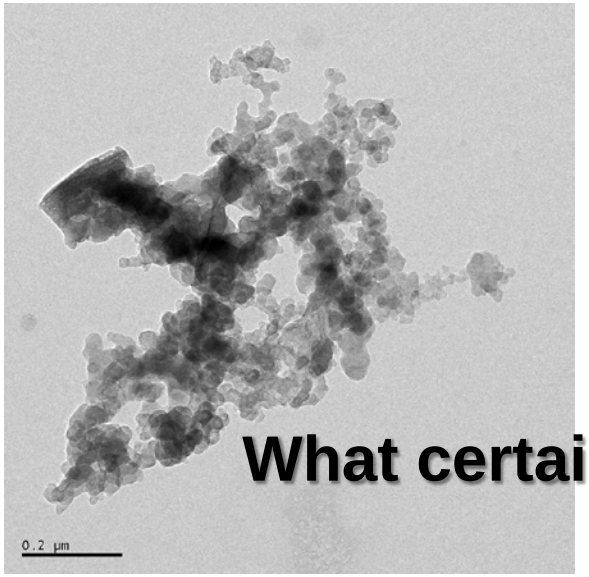
T. C. Bond[1], S. J. Doherty[2], D. W. Fahey[3], P. M. Forster[4], T. Berntsen[5], B. J. DeAngelo[6], M. G. Flanner[7], S. Ghan[8], B. Kärcher[9], D. Koch[10], S. Kinne[11], Y. Kondo[12], P. K. Quinn[13], M. C. Sarofim[6], M. G. Schultz[14], M. Schulz[15], C. Venkataraman[16], H. Zhang[17], S. Zhang[18], N. Bellouin[19], S. K. Guttikunda[20], P. K. Hopke[21], M. Z. Jacobson[22], J. W. Kaiser[23], Z. Klimont[24], U. Lohmann[25], J. P. Schwarz[3], D. Shindell[26], T. Storelvmo[27], S. G. Warren[28], C. S. Zender[29]

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1002/jgrd.50171

BC-Climate Science Community:

[63] While health effects are not evaluated in this report, there is always the potential to obtain some degree of health benefits by mitigating BC emissions. Emissions that preferentially occur in populated areas have large health impacts,

[64] Diesel sources of BC appear to offer the most promising mitigation opportunities in terms of near-term forcing and maturity of technology and delivery programs. Although some options, such as diesel retrofits, may be costly relative to other BC mitigation options, they may also deliver significant health benefits.

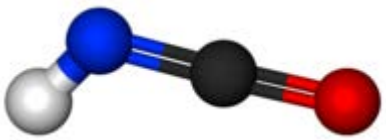


What degree?

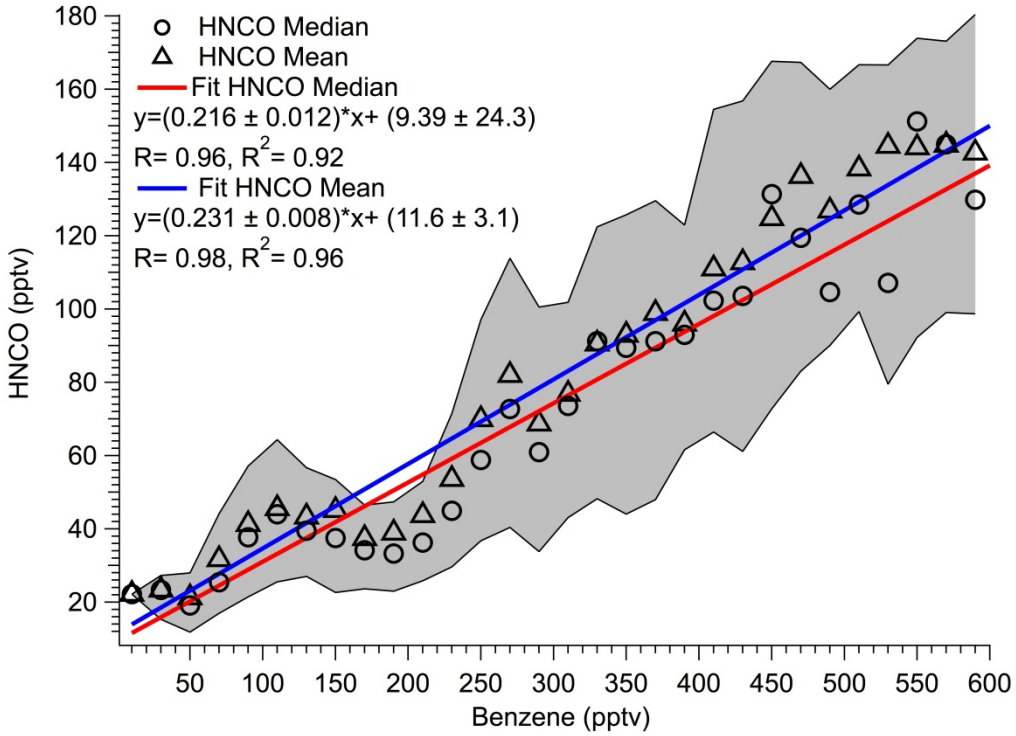
What certainty is there in the health benefits?

Unmeasured chemicals in the traffic emissions mixture

Correlation between Benzene and isocyanic acid during the Toronto morning rush hour



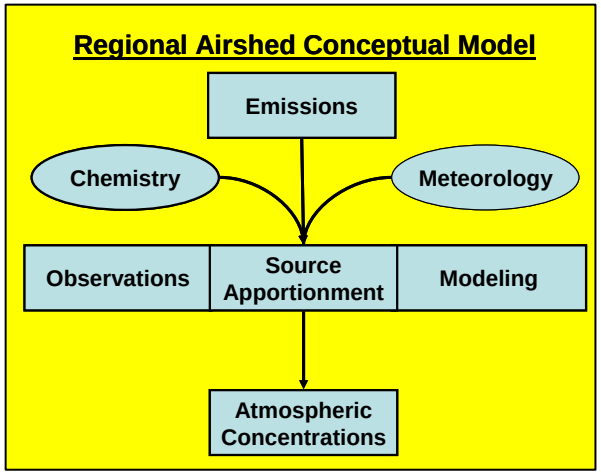
HNCO



Wentzell et al., ES&T 2013

Assessing Air Quality Holistically and from the Regional Perspective to Best Aid Management

- Local emission sectors of importance, present and future
- Meteorological influences on AQ
- The role of long-range and transboundary transport



- Considering the lattest scientific insights resulting from data analyses/interpretation
- Insights from special field studies contributing further local and national knowledge and testing models
- Focus on region-specific knowledge gaps

Main Concepts in Current Canadian Air Quality Management Approach

- Establish new standards for $PM_{2.5}$ and O_3 that are lower than the current values
- Maintain current levels where they are below the standard
- Engage industry to obtain agreements on emission reductions by sector
- Apply cost-benefit analyses for policies considered

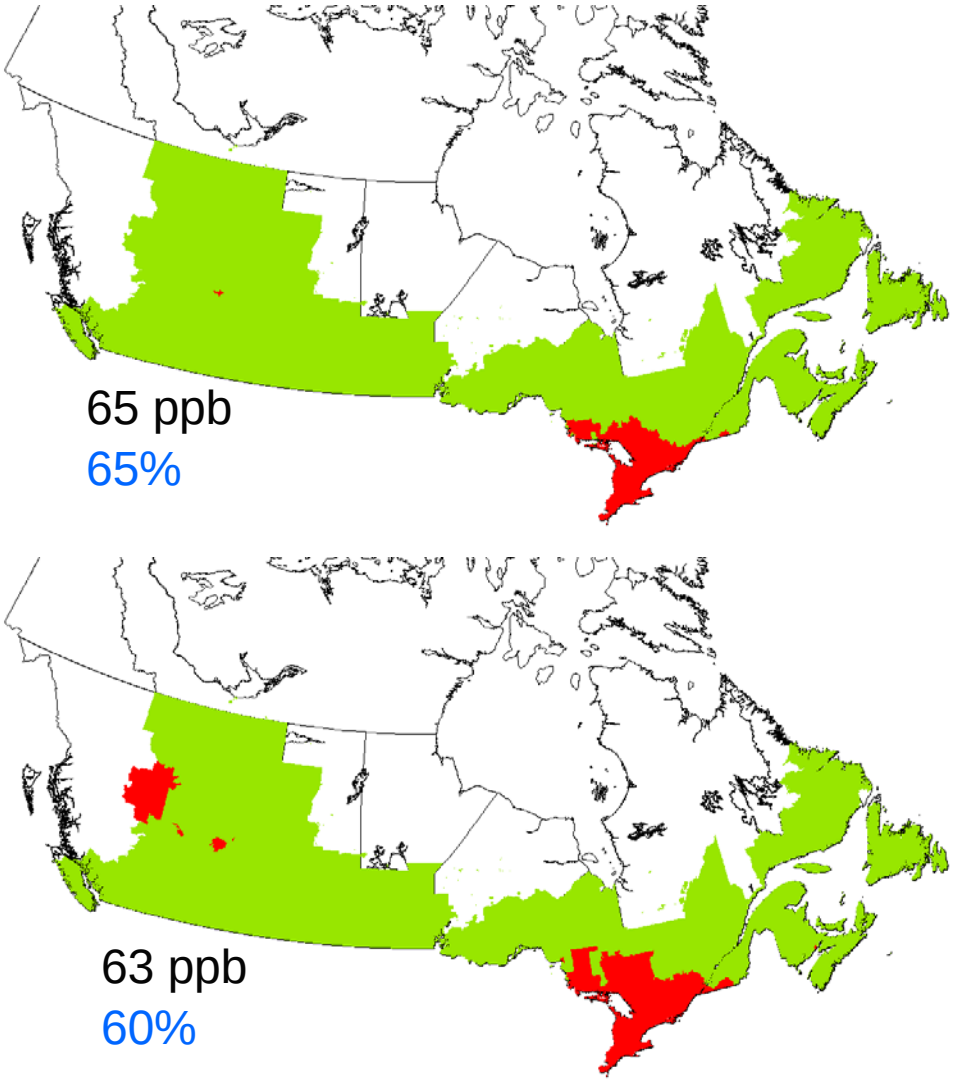
Canadian Ambient Air Quality Standards (CAAQS)

- **Derived following the exposure reduction concept:**
  - Applying the principle of continuous improvement, an AQO is expressed as a required percentage decrease in concentrations.
- **Concentration values determined by using a new Population Improvement Approach (PIA)**
  - links ambient concentrations to the size of the population exposed.
  - The potential standards can then be set by specifying the desired reduction in exposed population.

Ranges for 2015 - PIA of 5-10%

- Ozone = 60-62 ppb
- $PM_{2.5}$ (24h) = 28 -29 $\mu g/m^3$
- $PM_{2.5}$ (annual) = 9.9-10.5 $\mu g/m^3$

The ongoing challenge of dealing with O_3



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Canada Gazette

Part I

OTTAWA, SATURDAY, MAY 25, 2013

Vol. 147, nº 21

Gazette du Canada

Partie I

OTTAWA, LE SAMEDI 25 MAI 2013

New Canadian Ambient Air Quality Standards (CAAQS)

- Achieve CAAQS
- Prevent CAAQS Exceedances
- Prevent Air Quality Deterioration
- Keep clean areas clean

Goal of air quality management actions	Range of air pollution concentration					
	$PM_{2.5}$ 24-hour ($\mu g/m^3$)		$PM_{2.5}$ Annual ($\mu g/m^3$)		Ozone 8-hour (ppb)	
	2015	2020	2015	2020	2015	2020
Achieve CAAQS	>28	>27	>10.0	>8.8	>63	>62
Prevent CAAQS exceedance	>19 and ≤28	>19 and ≤27	>6.4 and ≤10.0	>6.4 and ≤8.8	>56 and ≤63	>56 and ≤62
Prevent air quality deterioration	>10 and ≤19		>4.0 and ≤6.4		>50 and ≤56	
Keep clean areas clean	≤10		≤4.0		≤50	

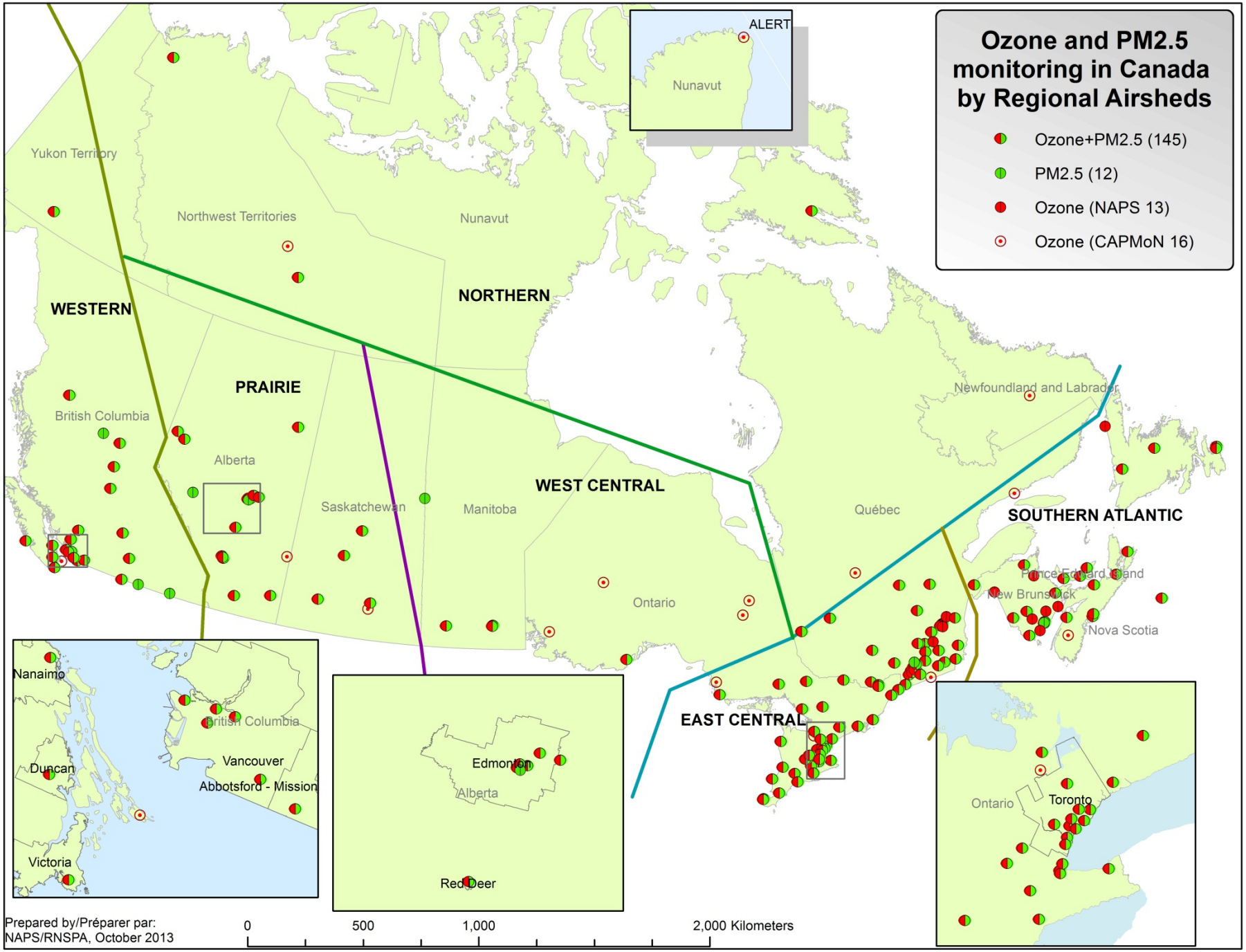
In addition, the AQMS delineates Canada in six regional airsheds that cut across jurisdictional boundaries and that have similar air quality characteristics or air movement patterns. They will serve as the basis for interjurisdictional collaboration to address air quality issues.

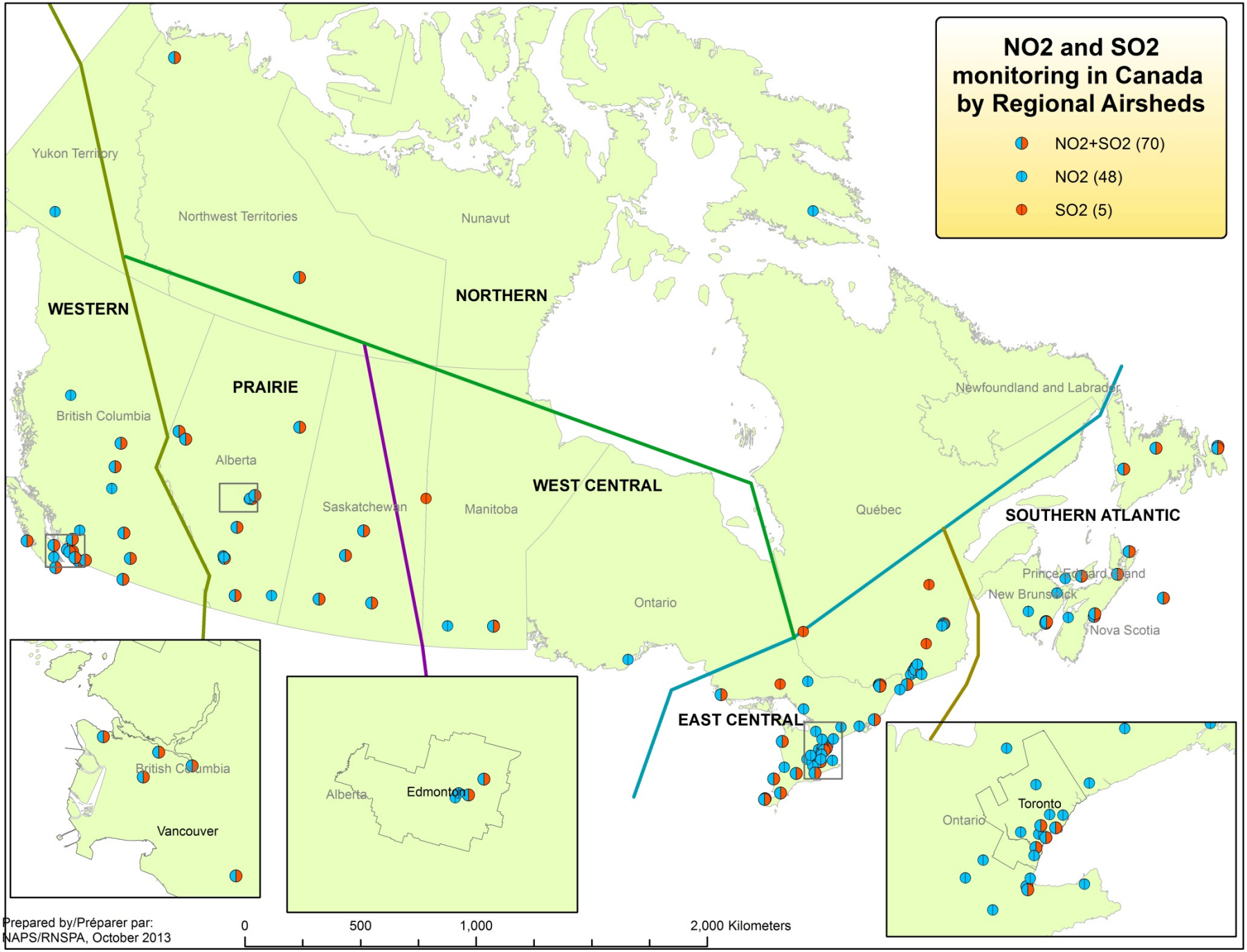
Air Quality Management System

- The Government of Canada is working with the provinces, territories and stakeholders to implement the new Air Quality Management System to address air pollution issues
- The system includes:
  - New Canadian Ambient Air Quality Standards (CAAQS)
    - $PM_{2.5}$ and Ozone published in Canada Gazette, May 2013
    - Future CAAQS being developed for NO_2 and SO_2
  - Establishment of base-level industrial emissions requirements for major industrial sectors and equipment types
  - Air zones delineated by provinces and territories will target key sources of air pollutants contributing to poor air quality at the local level
    - Annual air zone reporting by provinces and territories starting in 2014
  - 6 Regional Airsheds with unique air quality characteristics
    - State of Air reports (starting 2015 and then every 5 years) will be based on analysis of air quality and management actions within airsheds.
  - Collaborative process to reduce the emissions from mobile sources

Canadian Regional Airsheds

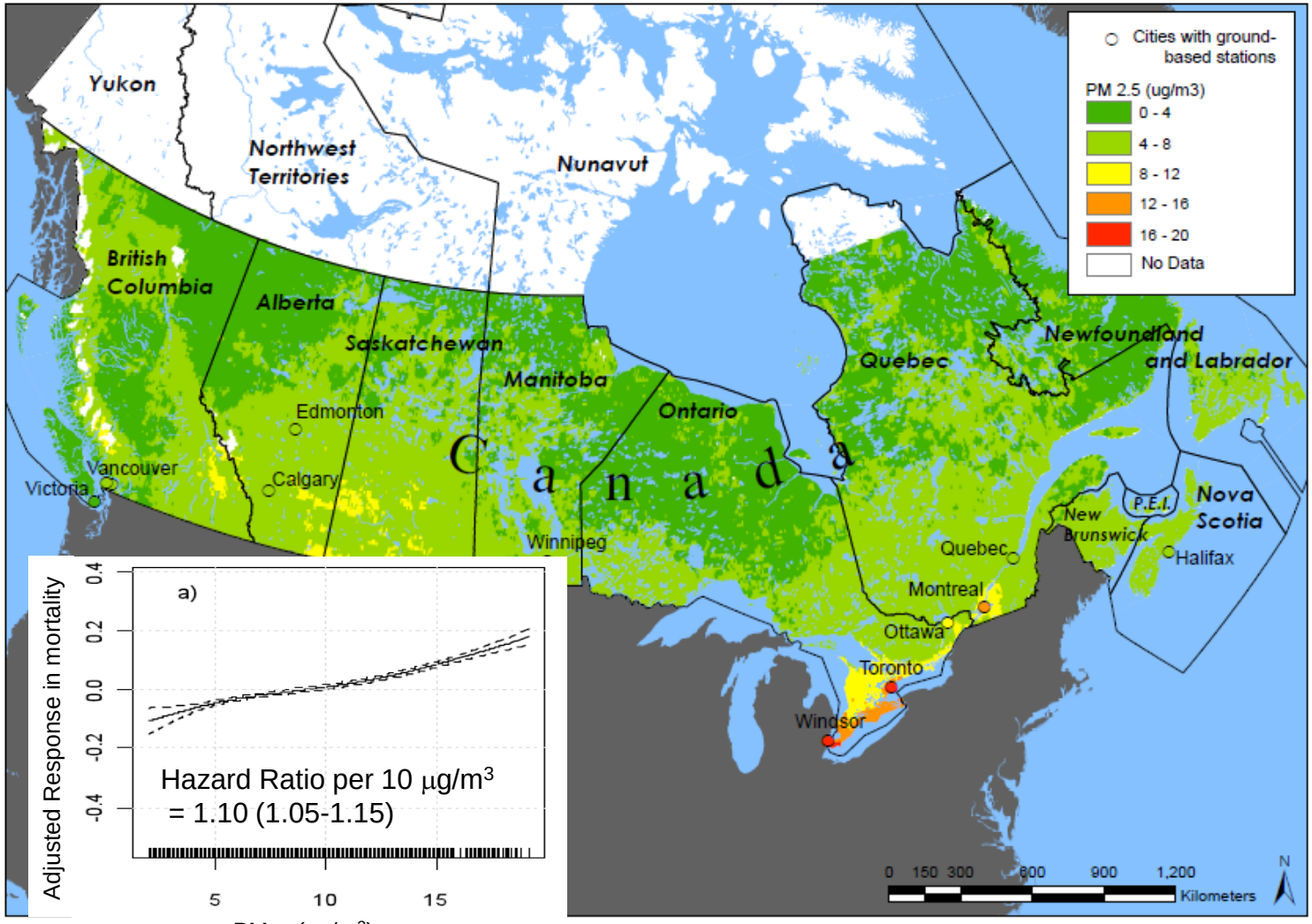
- Geographic regions defined to have similar air quality profiles based on factors such as air flow trajectories, weather patterns and topography
- Encompass several jurisdictions crossing provincial/territorial and national boundaries


Ozone and PM2.5 monitoring in Canada by Regional Airsheds
Ozone+PM2.5 (145)
PM2.5 (12)
Ozone (NAPS 13)
Ozone (CAPMoN 16)
ALERT
Nunavut
Yukon Territory
Northwest Territories
Nunavut
WESTERN
NORTHERN
PRAIRIE
WEST CENTRAL
SOUTHERN ATLANTIC
EAST CENTRAL
British Columbia
Alberta
Saskatchewan
Manitoba
Ontario
Québec
Newfoundland and Labrador
Prince Edward Island
New Brunswick
Nova Scotia
Nanaimo
British Columbia
Vancouver
Abbotsford - Mission
Duncan
Victoria
Edmonton
Alberta
Red Deer
Ontario
Toronto
Prepared by/Préparer par:
NAPS/RNSPA, October 2013
0
500
1,000
2,000 Kilometers


NO2 and SO2 monitoring in Canada by Regional Airsheds
NO2+SO2 (70)
NO2 (48)
SO2 (5)
Yukon Territory
Northwest Territories
Nunavut
WESTERN
NORTHERN
PRAIRIE
WEST CENTRAL
EAST CENTRAL
SOUTHERN ATLANTIC
British Columbia
Alberta
Saskatchewan
Manitoba
Ontario
Québec
Newfoundland and Labrador
Prince Edward Island
New Brunswick
Nova Scotia
Vancouver
Edmonton
Toronto
Prepared by/Préparer par:
NAPS/RNSPA, October 2013
0
500
1,000
2,000 Kilometers

Satellite $PM_{2.5}$ used for Canadian Census Health and Environment Cohort (CanCHEC)

Increased Risk of mortality shown to well below 10 µg/m³

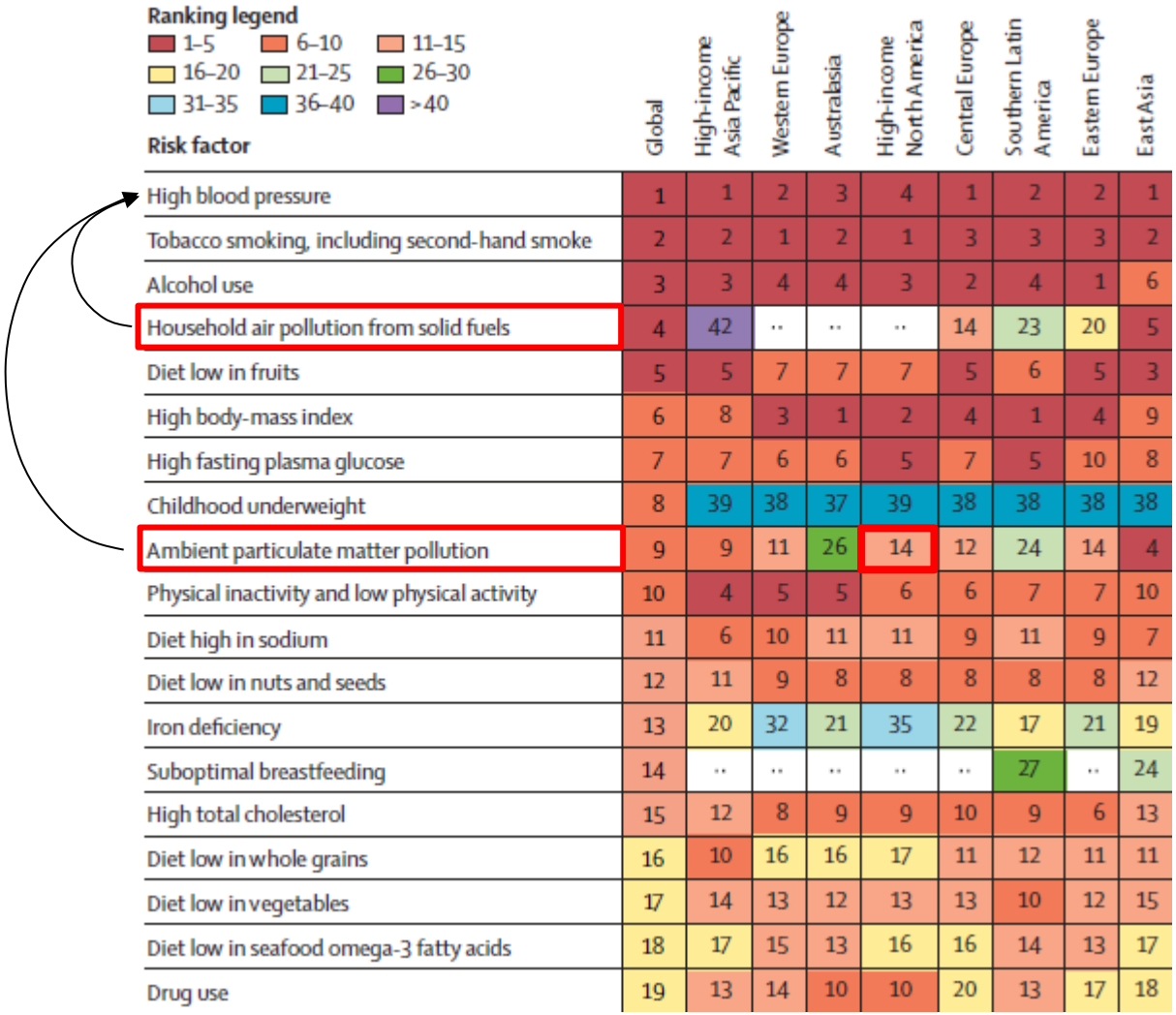


Crouse et al, EHP, 2012

Air Pollution Health Effects: Key insights over the past 25 years

- There are effects at the current (low) levels
- The existence and importance of cardiovascular effects
  - and a growing number of other outcomes (e.g., birth, neurological, cancer)
- The mounting evidence of the risks associated with traffic-related air pollution, a pervasive exposure in modern society
- The commonality of the physiological pathways that air pollution acts upon vs. many other adverse conditions
  - Oxidative stress, inflammation

Globally, two risks from inhalation exposures are top ten disease burdens



Ranking legend

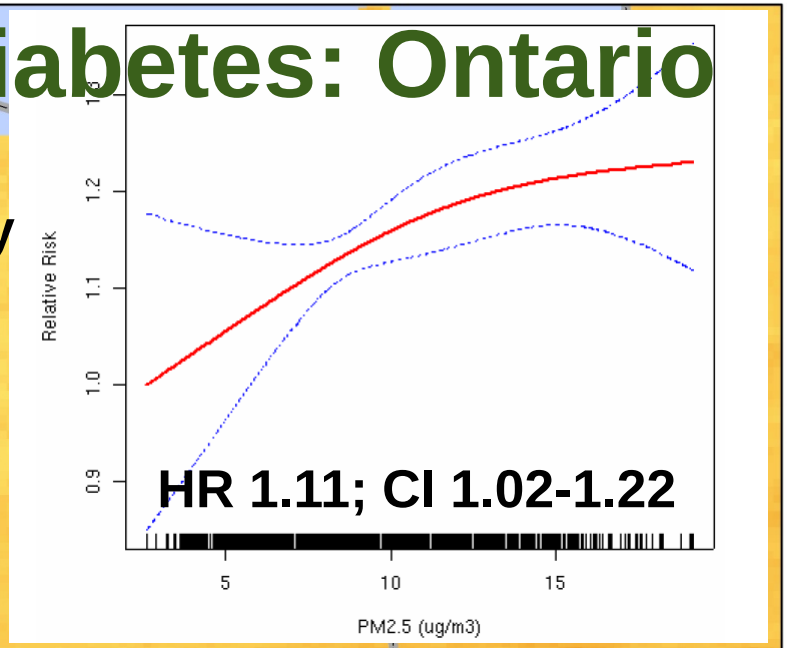
1–5 | 6–10 | 11–15 | 16–20 | 21–25 | 26–30 | 31–35 | 36–40 | >40

Risk factor	Global	High-income Asia Pacific	Western Europe	Australasia	High-income North America	Central Europe	Southern Latin America	Eastern Europe	East Asia
High blood pressure	1	1	2	3	4	1	2	2	1
Tobacco smoking, including second-hand smoke	2	2	1	2	1	3	3	3	2
Alcohol use	3	3	4	4	3	2	4	1	6
Household air pollution from solid fuels	4	42	..	..	..	14	23	20	5
Diet low in fruits	5	5	7	7	7	5	6	5	3
High body-mass index	6	8	3	1	2	4	1	4	9
High fasting plasma glucose	7	7	6	6	5	7	5	10	8
Childhood underweight	8	39	38	37	39	38	38	38	38
Ambient particulate matter pollution	9	9	11	26	14	12	24	14	4
Physical inactivity and low physical activity	10	4	5	5	6	6	7	7	10
Diet high in sodium	11	6	10	11	11	9	11	9	7
Diet low in nuts and seeds	12	11	9	8	8	8	8	8	12
Iron deficiency	13	20	32	21	35	22	17	21	19
Suboptimal breastfeeding	14	..	..	..	..	..	27	..	24
High total cholesterol	15	12	8	9	9	10	9	6	13
Diet low in whole grains	16	10	16	16	17	11	12	11	11
Diet low in vegetables	17	14	13	12	13	13	10	12	15
Diet low in seafood omega-3 fatty acids	18	17	15	13	16	16	14	13	17
Drug use	19	13	14	10	10	20	13	17	18

Lim et al. 2012
Lancet

Development of diabetes: Ontario

Retrospective Cohort from National Population Health Survey
N=62K ; 6.3K new cases
8 yr follow-up (1996-2010)

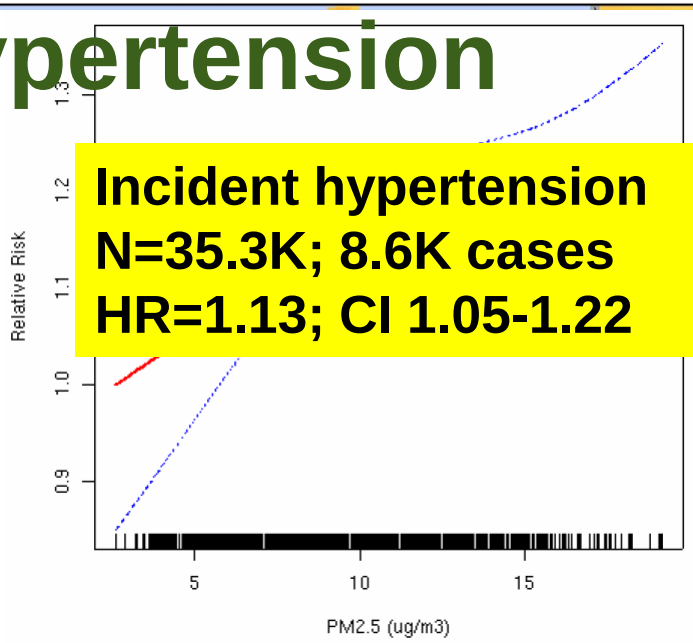


Chen et al., EHP, Apr. 2013.

Development of hypertension

Retrospective Cohort from National Population Health Survey
8 yr follow-up (1996-2010)

Incident hypertension
N=35.3K; 8.6K cases
HR=1.13; CI 1.05-1.22



Chen et al., Circulation Nov. 2013.

What do we need to know to minimize effects?

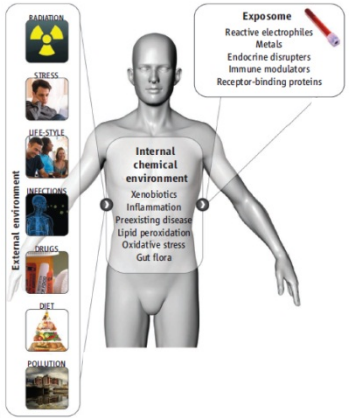
- Better quantification of the relationship between air pollution and health effects to guide policy
  - More accurate and more precise concentration-response functions by population sub-group
    - large cohorts with more precise exposure
  - More complete attribution of risk by including more endpoints and air pollution mixtures

- Develop protective measures for uncontrollable exposures or treatments or cures (therapeutics)

- Determine how to measure if an individual is exceeding their safe dose **before** disease development
  - Set guidelines
  - Personalized environmental medicine

While there are considerable strengths we have some significant weaknesses in Canada

- No concerted funding program for environmental health
  - Opportunities for groups working together and capitalizing on ideas, existing capacity and data are not realized
- Most prospective cohorts don't have a highly detailed environmental exposure aspect to their design
- No separate funding source to start and sustain environmental health cohorts
- Limited integration of biomarker research for diagnostics and exposures



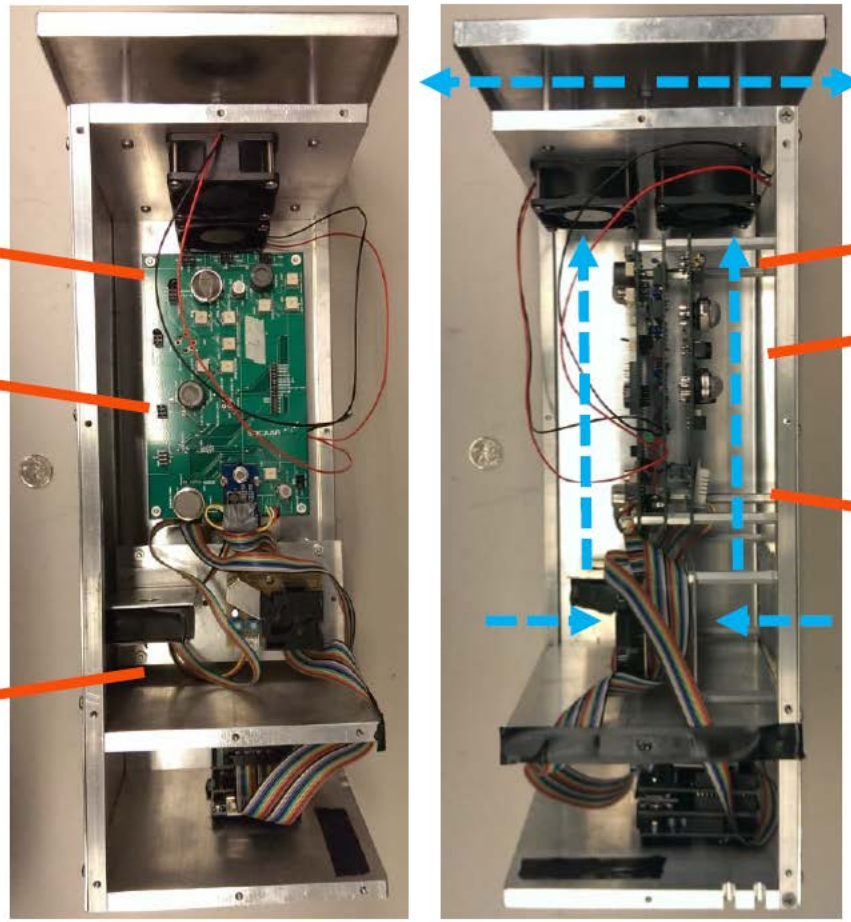
Strengths

- Public health care system
  - Complete coverage of population
  - Good records which can be linked with many databases
  - Relatively good management of population/individual health
- Some retrospective and prospective cohorts
- Exposure information; AQ monitoring and modelling
- Controlled exposure facilities for diesel, PM and gases
- Low levels in Canada, useful for assessing population thresholds and the shape of the dose-response
- Excellent scientific capacity, strong collaborative culture

Future Directions & Opportunities

- Very large cohorts – retrospective
- More pooling of existing prospective cohorts
- Improved characterization of exposure patterns
  - Toronto area studies related to the Pan AM Games
- Refining exposure measurement via the EXPOSOME concept
- CIHR Signature Initiative on Environment and Health

Inexpensive, multi-pollutant sensor arrays for enhanced monitoring



VOC sensors
18 types of MOS sensors

CO sensors
4 types of MOS sensors

PM sensors
3 types of optical sensors

NO2 sensors
3 types of MOS sensors, 2 types of electrochemical sensors

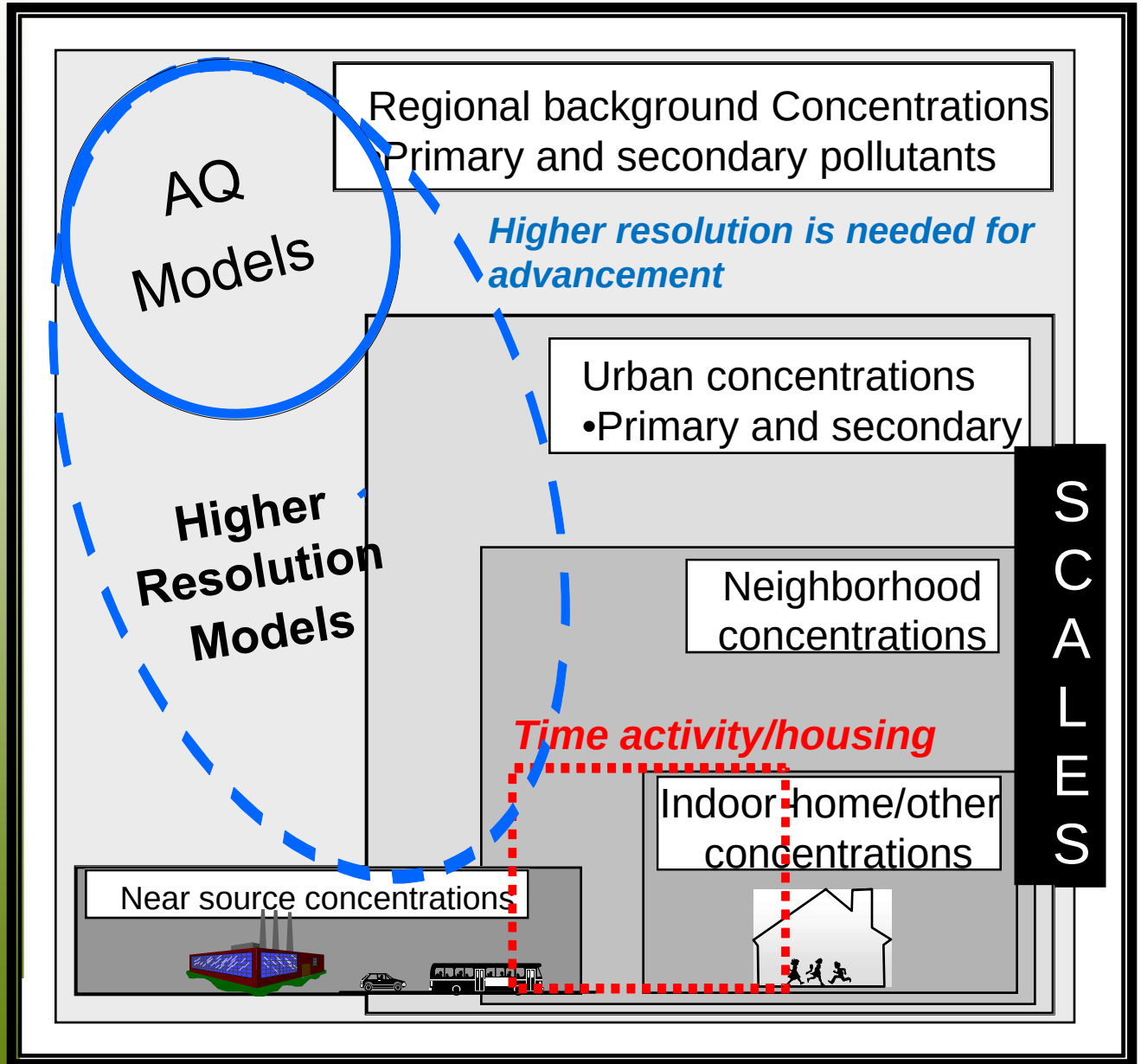
O3 sensors
3 types of MOS sensors

T/RH capacitive sensor

AllerGen TORONTO

Mykhaylova et al., AAAR, 2013

High Resolution AQ Models Coupled to Infiltration and Time-Activity Models



- **Ambient monitoring data collected by Environment Canada informs the regional and urban concentrations for specific pollutants**
- **Short term studies provide insight at the local scale (neighbourhood) and near source scales**
- **MODELS are required to combine the information to estimate past/current exposure and changes arising from policy scenarios**

Birth Cohort Examining the Origins of Asthma

A national platform for multi-disciplinary research on environment and health

CHILD

www.canadianchildstudy.ca

N = 3600

Exposures

Pollution

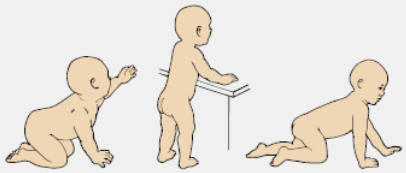
Home environment

Youth

Work & School environment

Stress

Genetics
Immune phenotypes
Clinical phenotypes



Diet

Viruses

SES

Pets

AllerGen

Environment Canada Environnement Canada

CMHC SCHL Canada

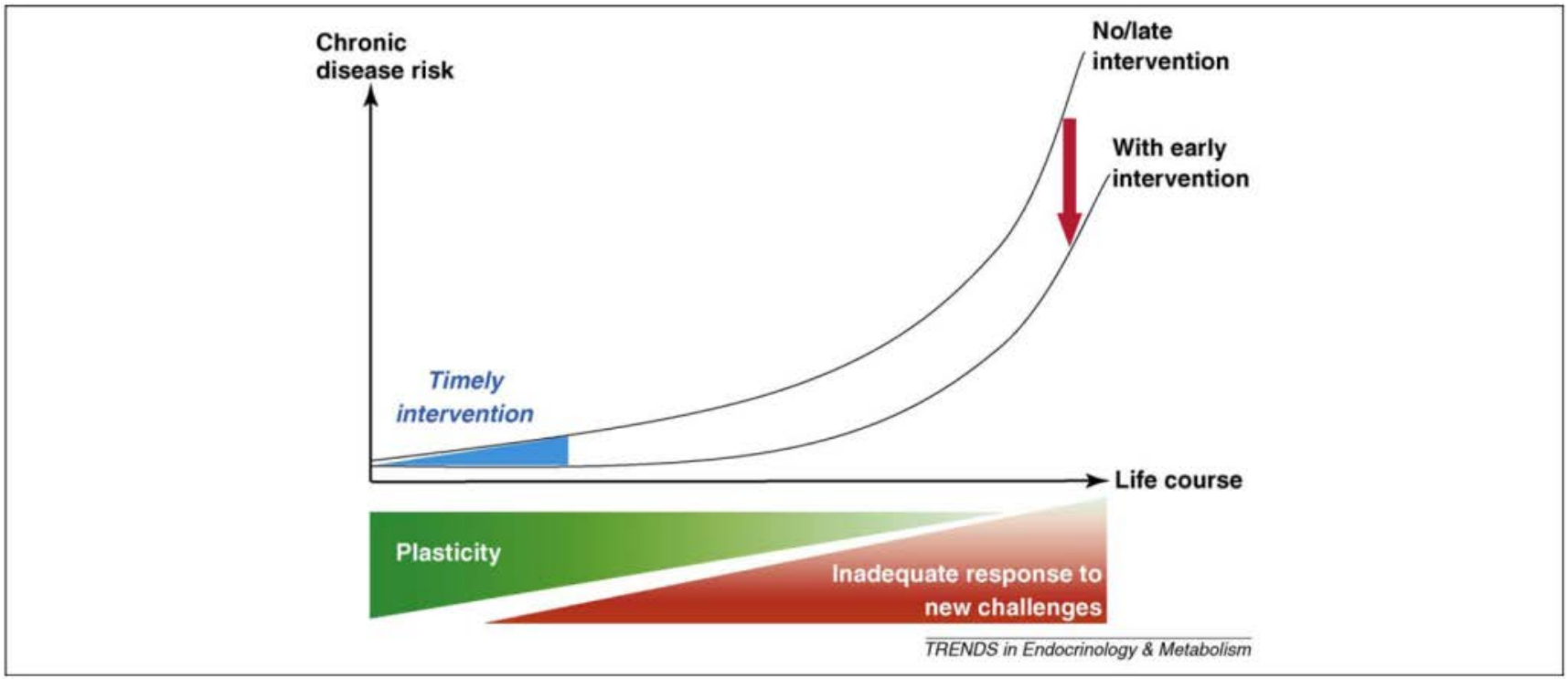
Health Canada Santé Canada

CIHR IRSC

Developmental Origins of Health and Disease (DOHaD)

- Hypothesizes that environmental exposures influence developmental pathways during critical periods of pre- and post-natal life, and subsequently induce permanent changes leading to disease susceptibility
  - Immune and lung development occur largely *in utero* and during early childhood
- Predictive adaptive responses of the fetus to *in utero* environmental cues promote a phenotype that is optimally suited for the postnatal environment
- The imprinting of environmental experiences on infant gene expression – epigenetic mechanisms – is increasingly thought to underlie the DOHaD hypothesis

Window of environmental intervention may be early in life



It is time for public health decision makers to give greater weight to human development. The global burden of NCD will have substantial economic effects, in both developed and developing societies, if left unchecked. This is a burden which we can ill afford.

Godfrey et al., Trends in Endocrinology and Metabolism 2010

Minimizing Effects: Can't be done independent of other risks/issues

Over-Arching Policy Questions:

- Are the impacts on public health due to current transportation and industrial practices large enough that the costs of changing would be less than the cost of inaction?
- What would the unintended consequences be of changes in transportation and industrial practices or other emissions motivated by a need to minimize, mitigate and/or adapt to climate change?

Concluding Remarks: Did we meet our learning objectives?

- ✓ To become familiar with the new Federal-Provincial Air Quality Management System.
- ✓ To understand more about approaches available and being developed to improve characterization of individual and population exposures to air pollutants.
- ✓ To learn about some recent research results and ongoing challenges regarding air pollutant exposures and effects

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