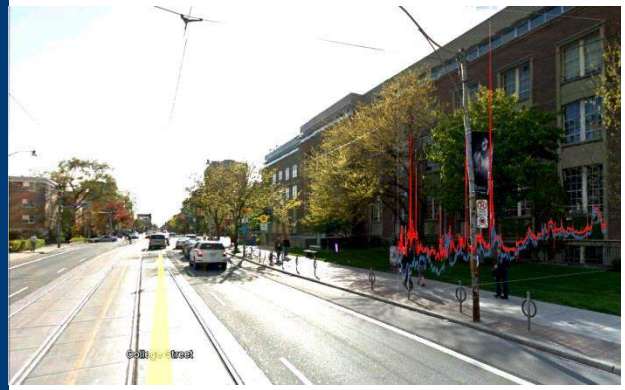
PHO
Jan 2015

SOCAAR

Every Breath You Take: Probing the Properties of Particulate Pollution

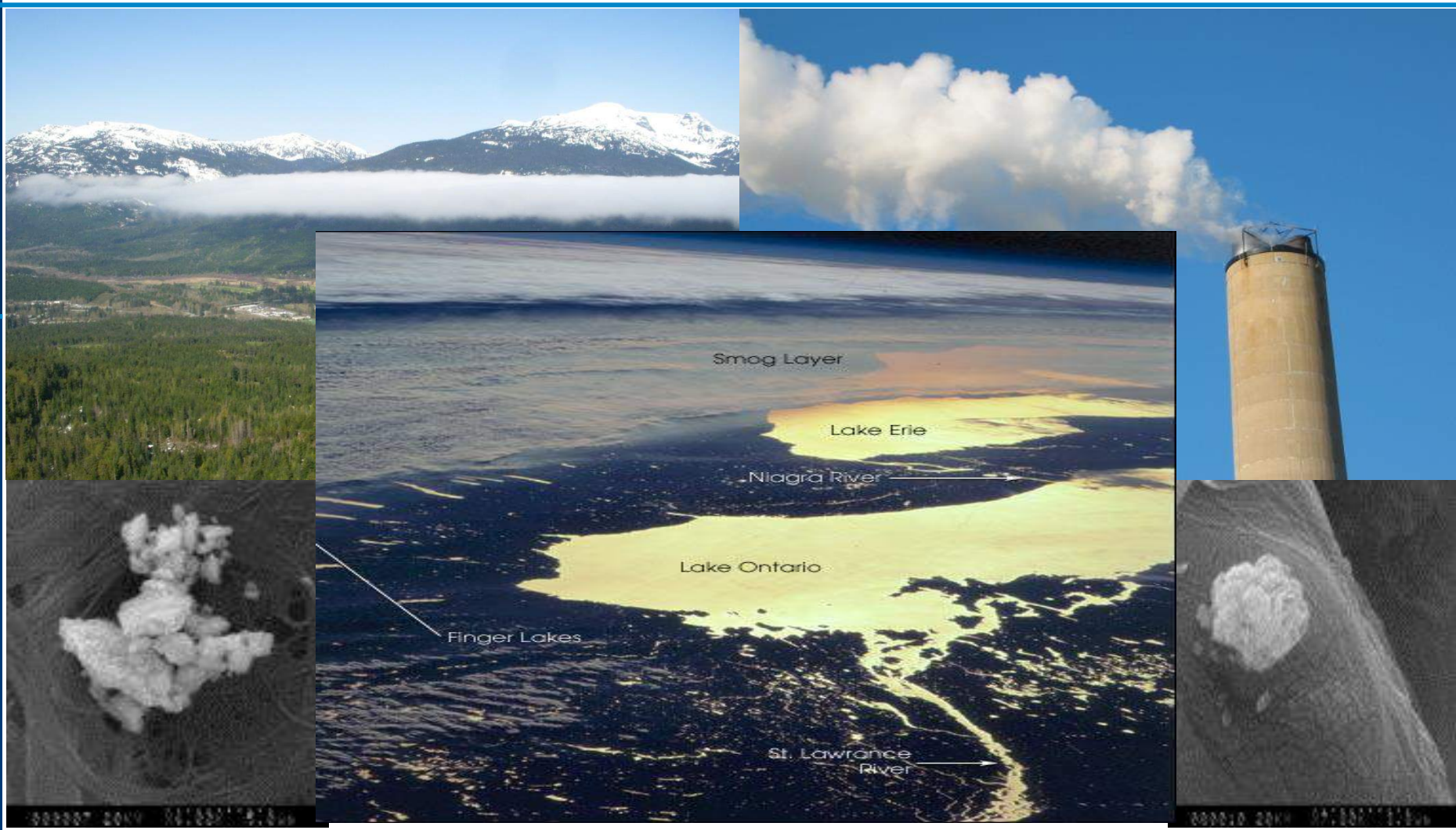


Prof.
Greg Evans

UNIVERSITY *of* TORONTO

Southern Ontario Centre for Atmospheric Aerosol Research

Aerosol Particles Are Everywhere….



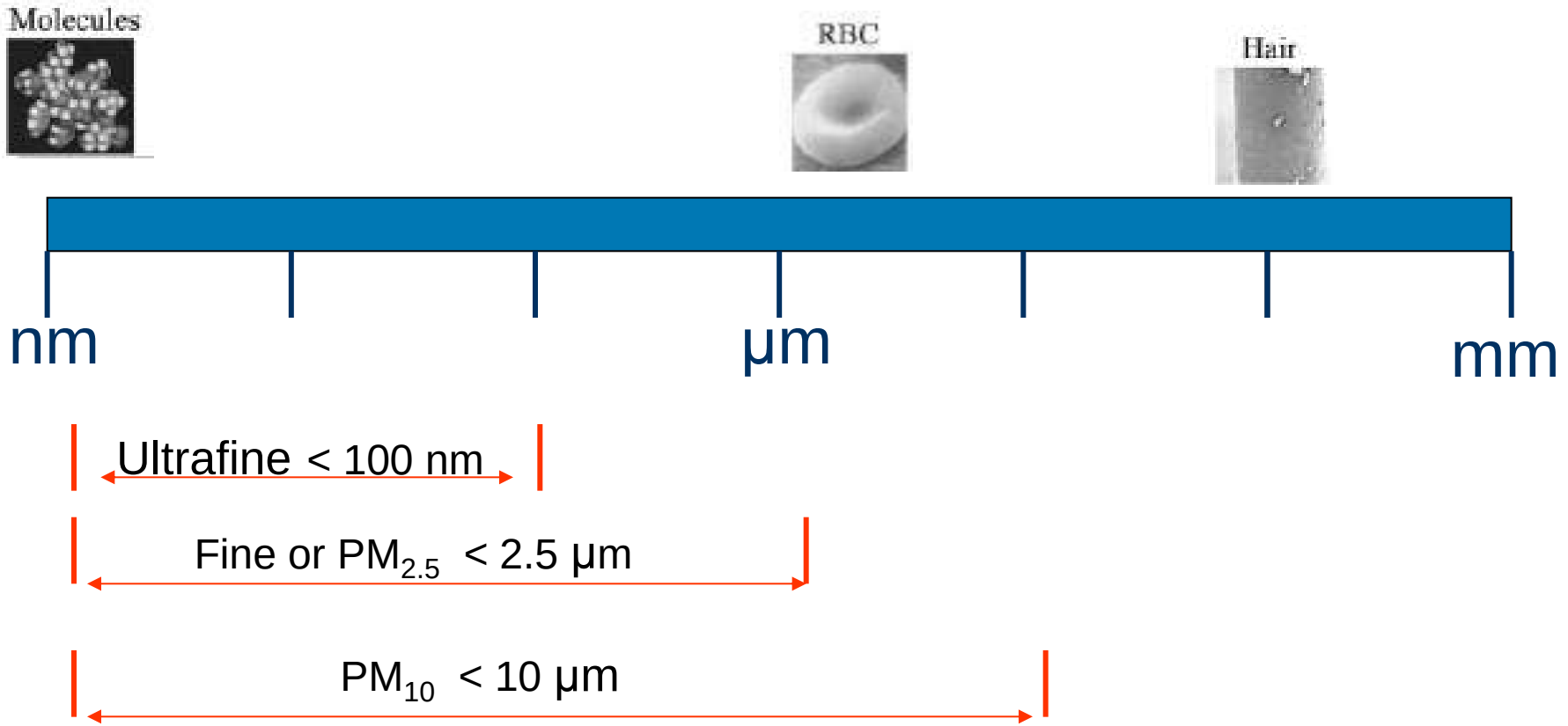
SOCAAR

UNIVERSITY *of* TORONTO

Look! Up in the Sky….

At a sunset…

Aerosol Particle Size Categories

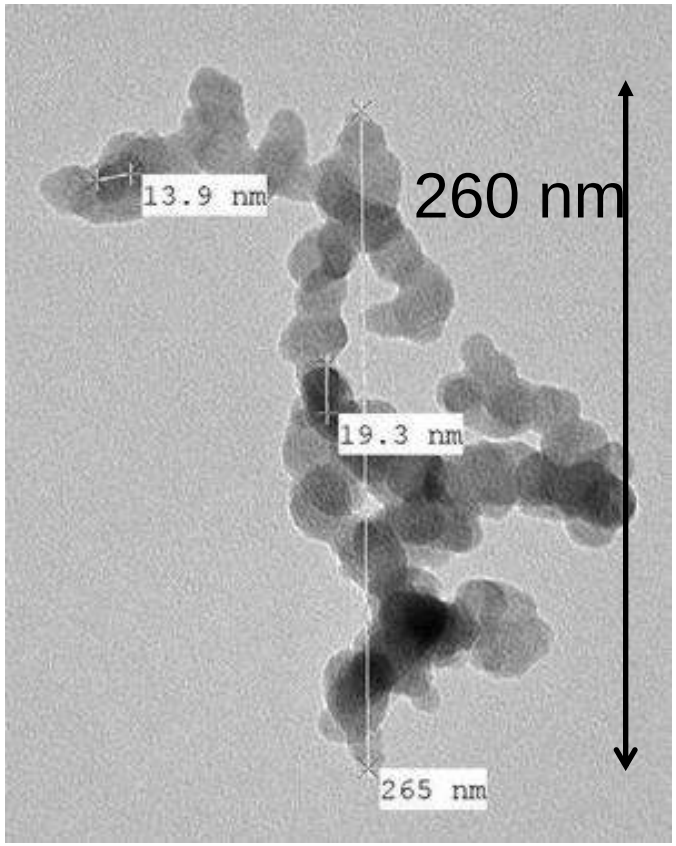


Adapted from Brook R et.al Circulation 2005

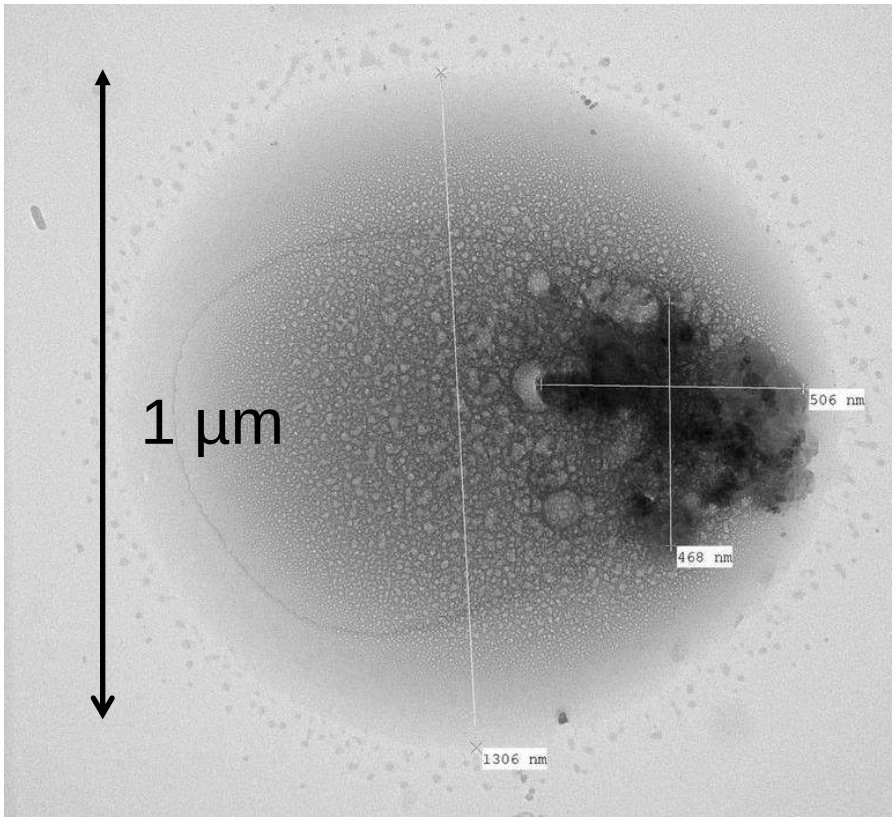
Particles: they are all different!

SOCAAR

Fresh Black Carbon

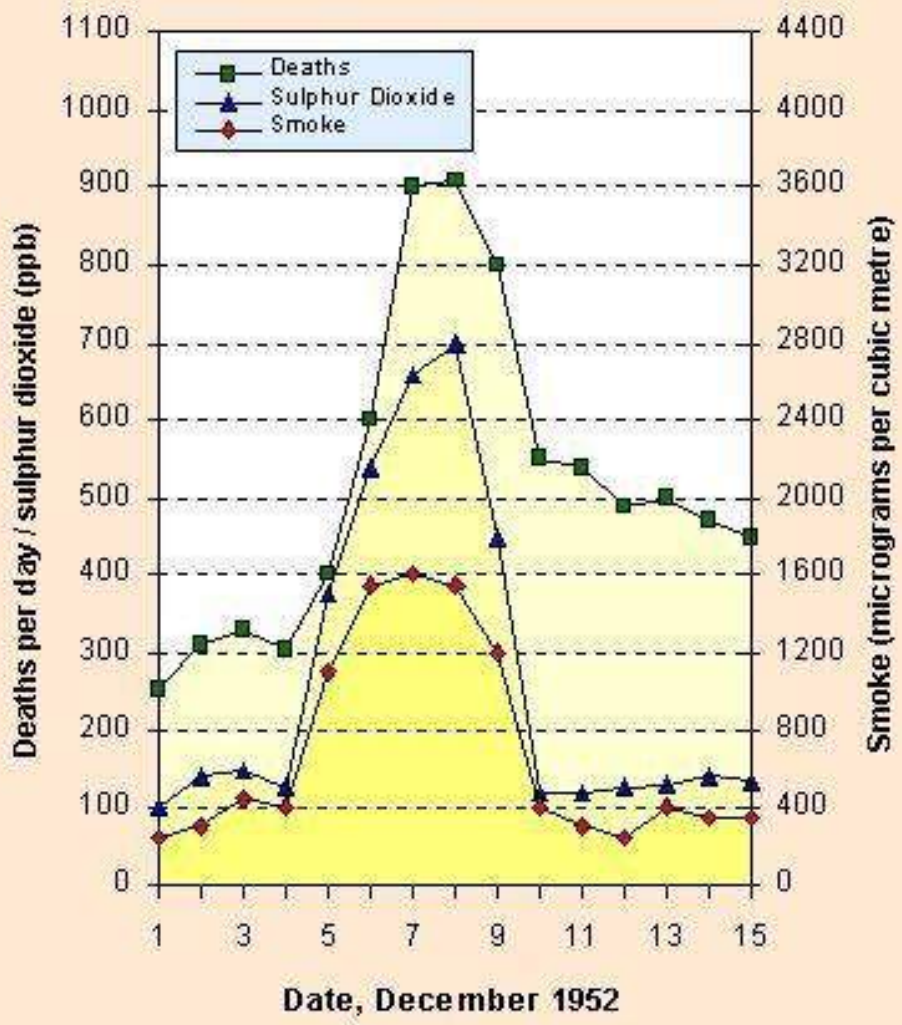


Coated Black Carbon



College Street June 2013

Air Quality and Health



London Smog Episode Dec 1952

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

Divisions of Environmental Health and Biostatistics, Department of Preventive Medicine, and Atherosclerosis Research Unit, Division of Cardiovascular Medicine, Keck School of Medicine, University of Southern California, Los Angeles, California, USA

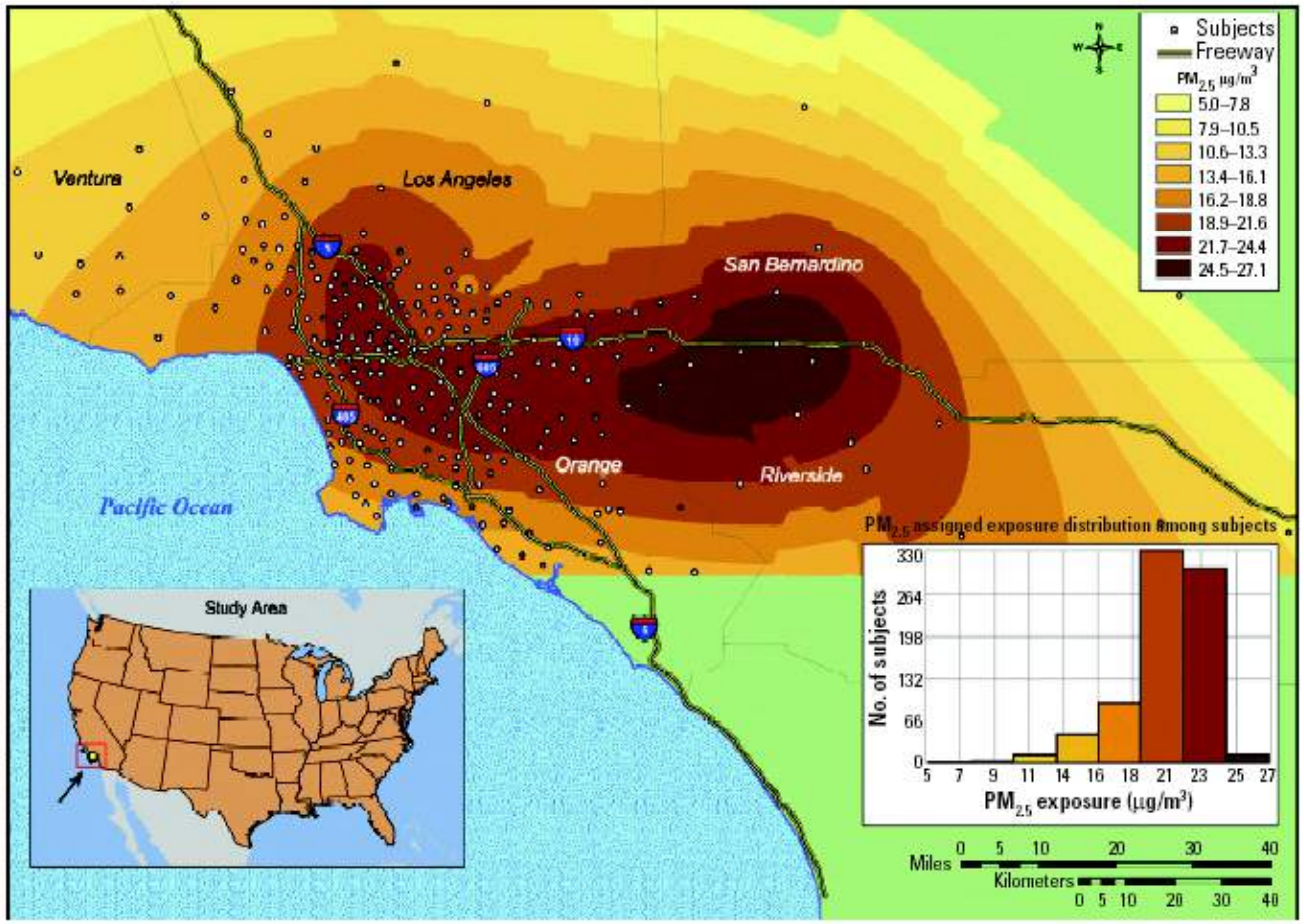


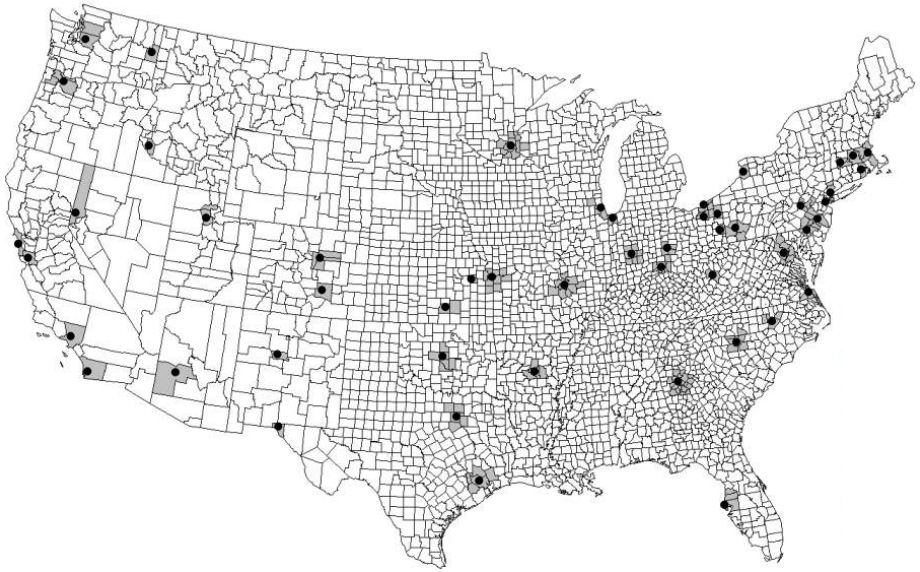
Figure 1. ZIP code locations of the study population geocoded on the $PM_{2.5}$ surface, modeled with 2000 $PM_{2.5}$ data, and distribution of individually assigned concentrations.

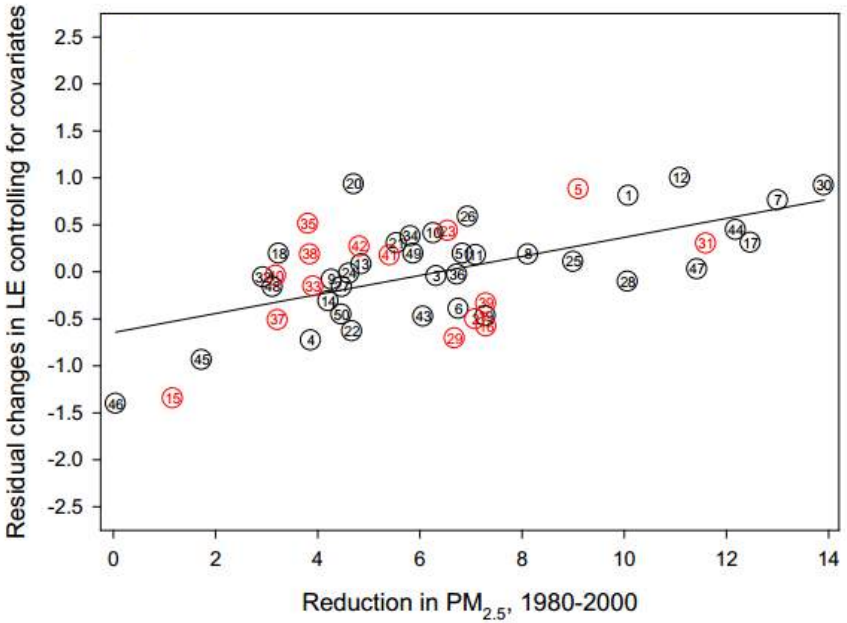
- Used data from two clinical trials on atherosclerosis prevention
- Mapped study subjects to PM2.5 exposure
- Exposure was associated with atherosclerosis

The NEW ENGLAND JOURNAL of MEDICINE

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.





- Matching **particulate concentrations** and **life expectancy** data for two periods (1979-1983 and 1999-2000) in 51 metro areas
- Evaluated changes in life expectancy with changes in air pollution for the 2-decade period.

- A **10 µg m^{-3} particulate decrease** in was associated with a **7.3 month increase in life expectancy**.

The life expectancy change persistence even after controlled for socio-economic, demographic or smoking variables.

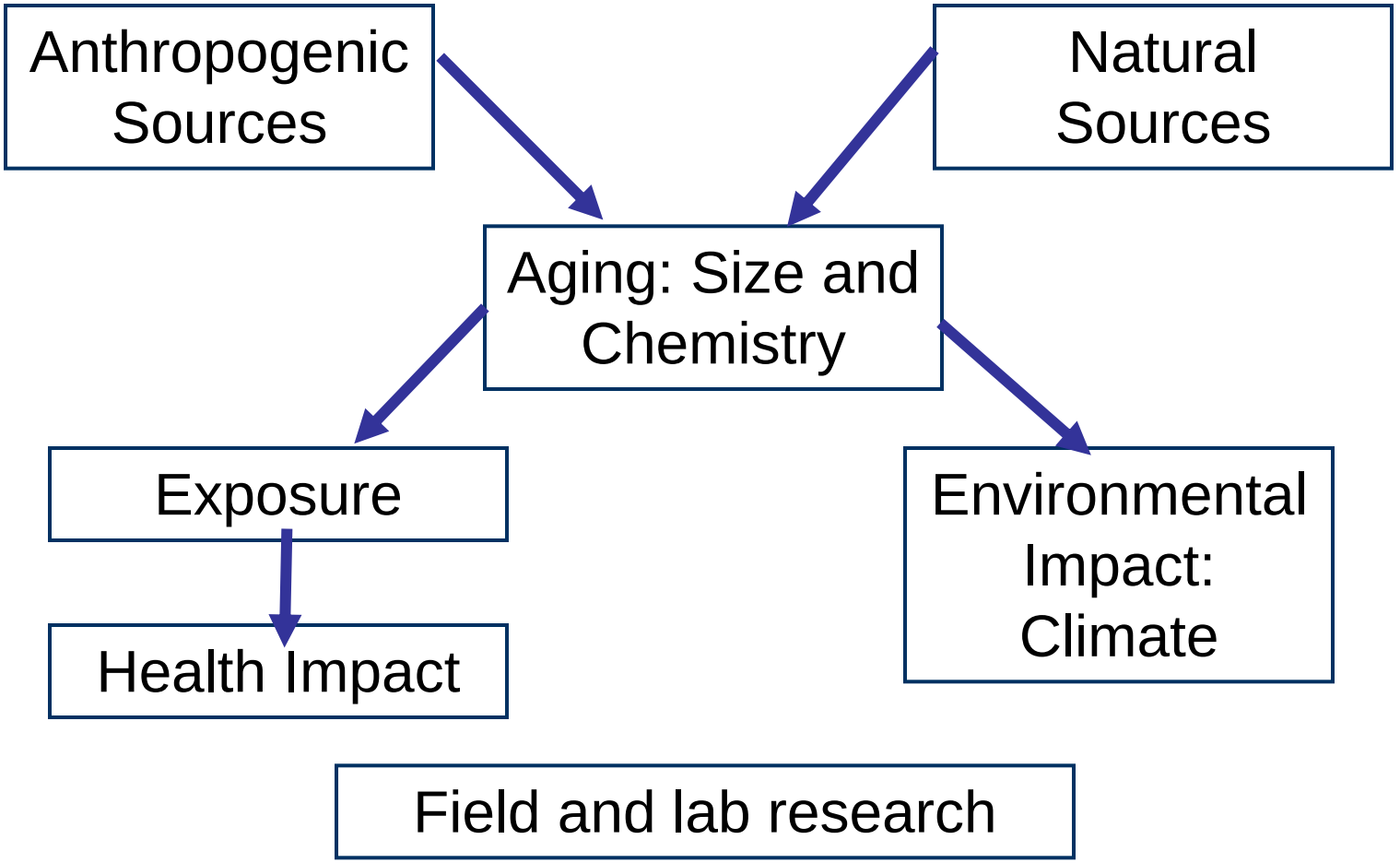
Outline

- **Global scale**: PM around the world
- **Regional scale**: Sources and Impacts
- **City Scale**: Vehicle Emissions
- **Individual scale**: Exposome, sensors and toxicity

- I do not have any conflicts of interest to disclose related to this presentation

SOCAAR: Research Overview

Southern Ontario Centre for Atmospheric Aerosol Research



Acknowledgments

Research Group

- Krystal Godri
- Ezzat Jaroudi
- Cheol Jeong
- Rob Healy
- Nathan Hilker
- Maygan McGuire
- Natalia Mykhaylova
- Andrew Knox
- Kelly Sabaliauskas
- Jon Wang
- Naomi Zimmerman

Funding and Partners

- CFI/OIT/MRI
- NSERC
- CIHR
- Environment Canada
- Health Canada

All results should be considered as preliminary

Conclusions do not necessarily reflect views or position of funding agencies

I DO NOT have any conflicts of Interest to disclose related to this presentation

Global Scale: Why Isn't the Sky Blue?

Photo by J Brook

Toronto

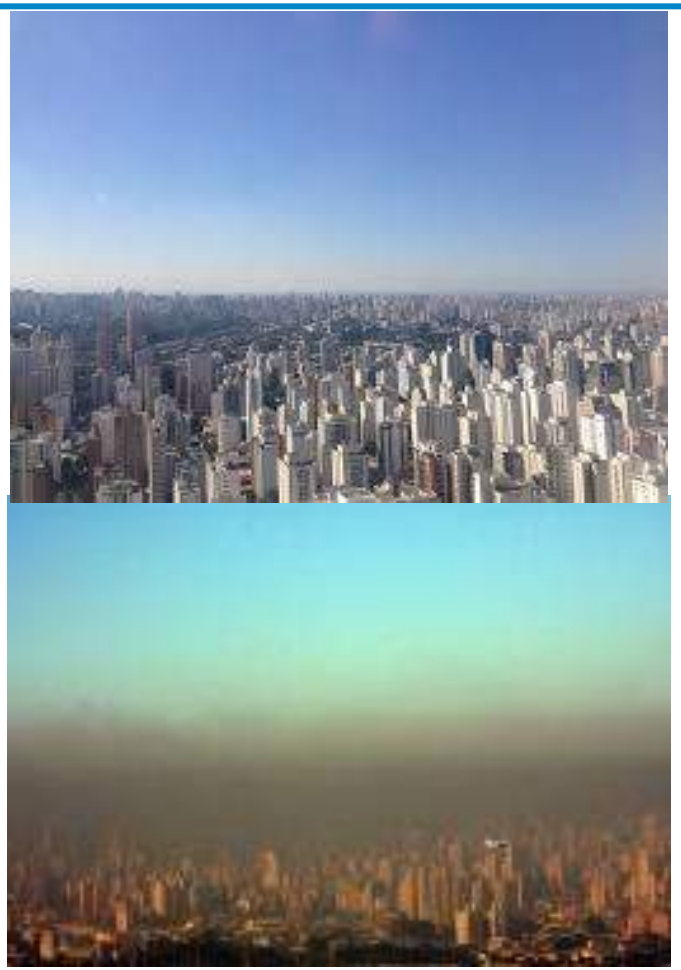


Photo carbonsolutions.com

Sao Paulo

SOCAAR

Chengdu January 2013

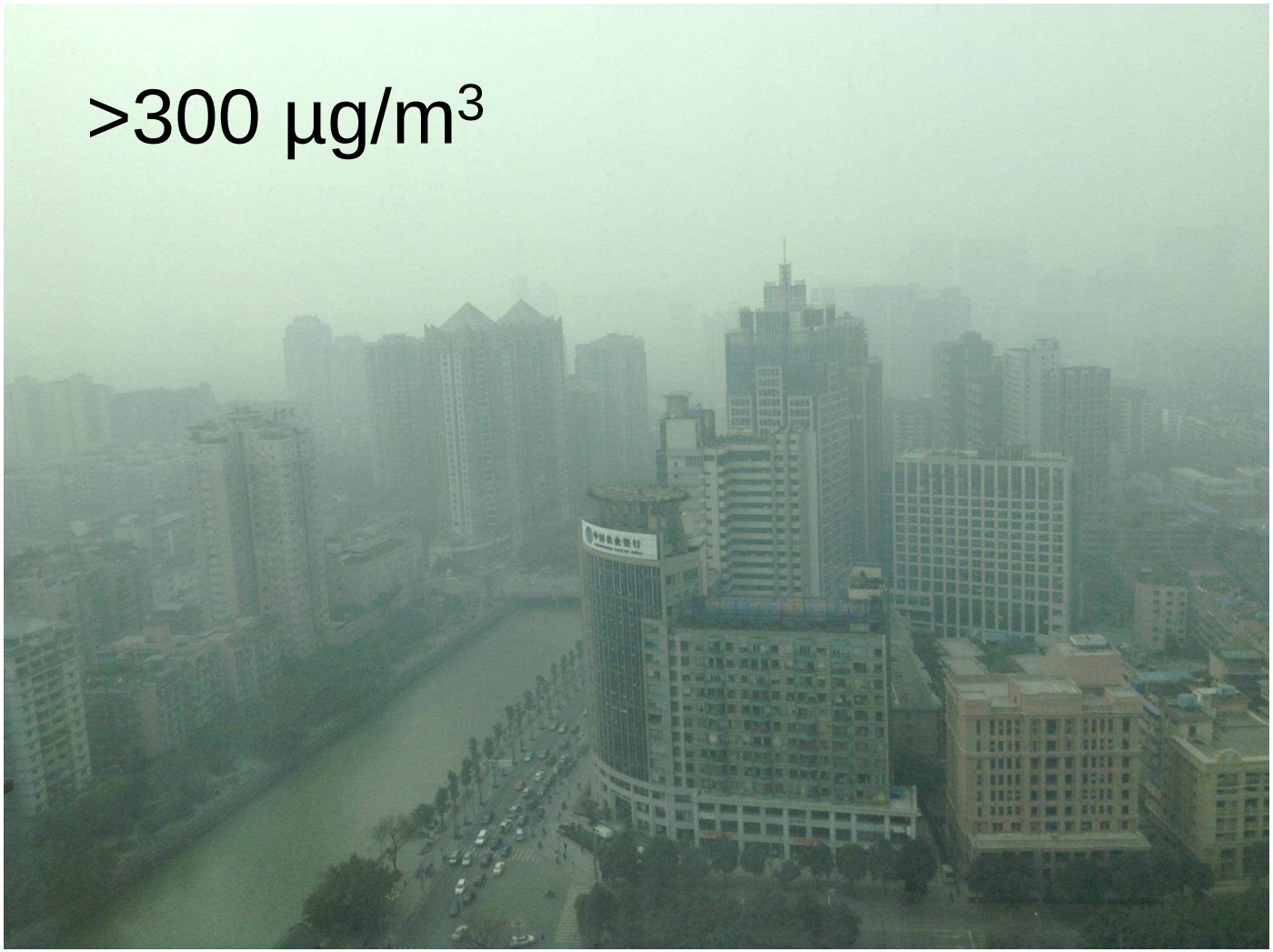


Photo by YL Cheng

Athens January 2013

Photo from Antonis Batsos

Singapore June 2013

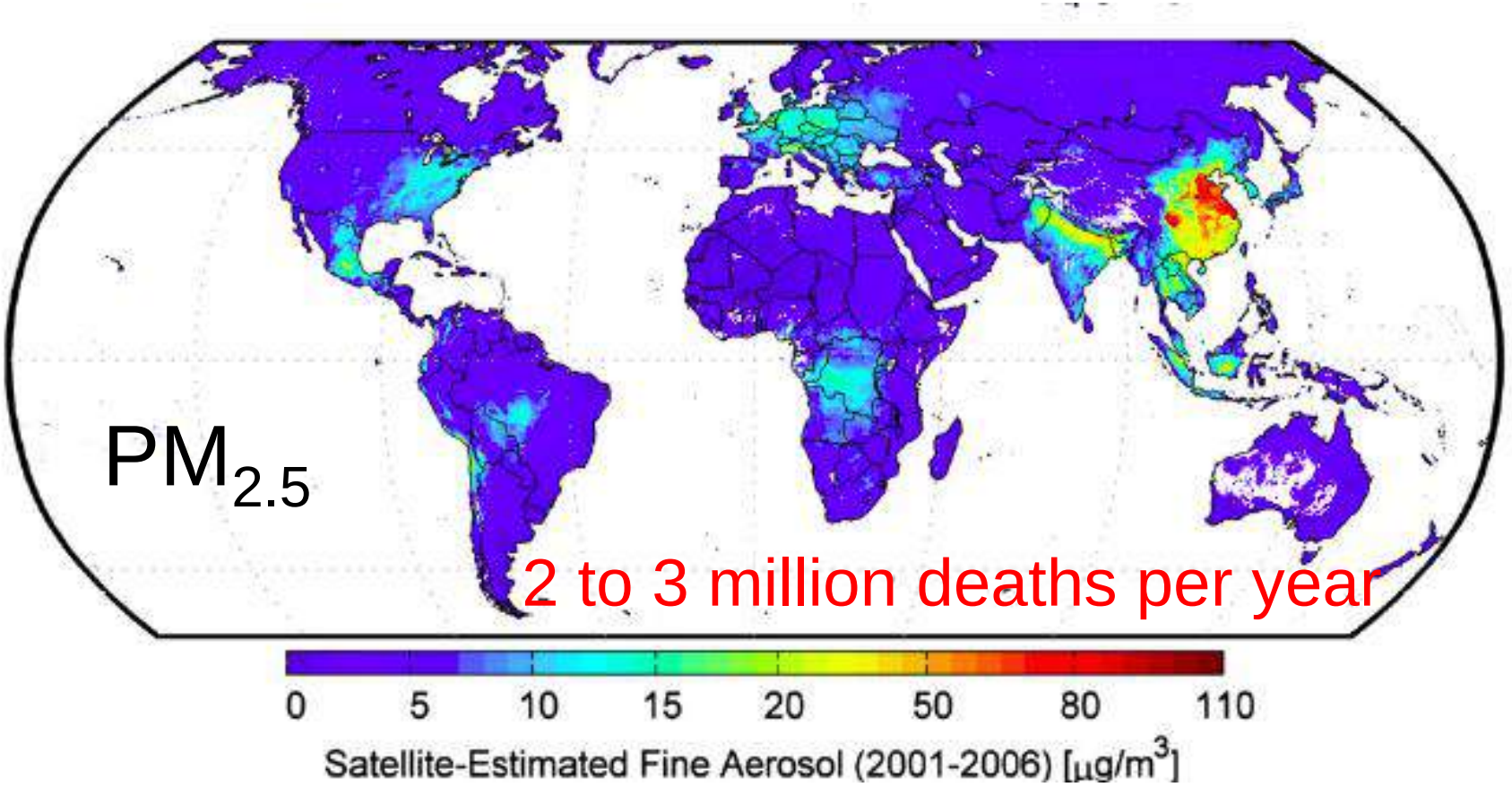
Air quality in Beijing

Photo from Flickr, bfishadow

Photo from Bill Bishop/Sinocism China Newsletter

Harbin China October 2013

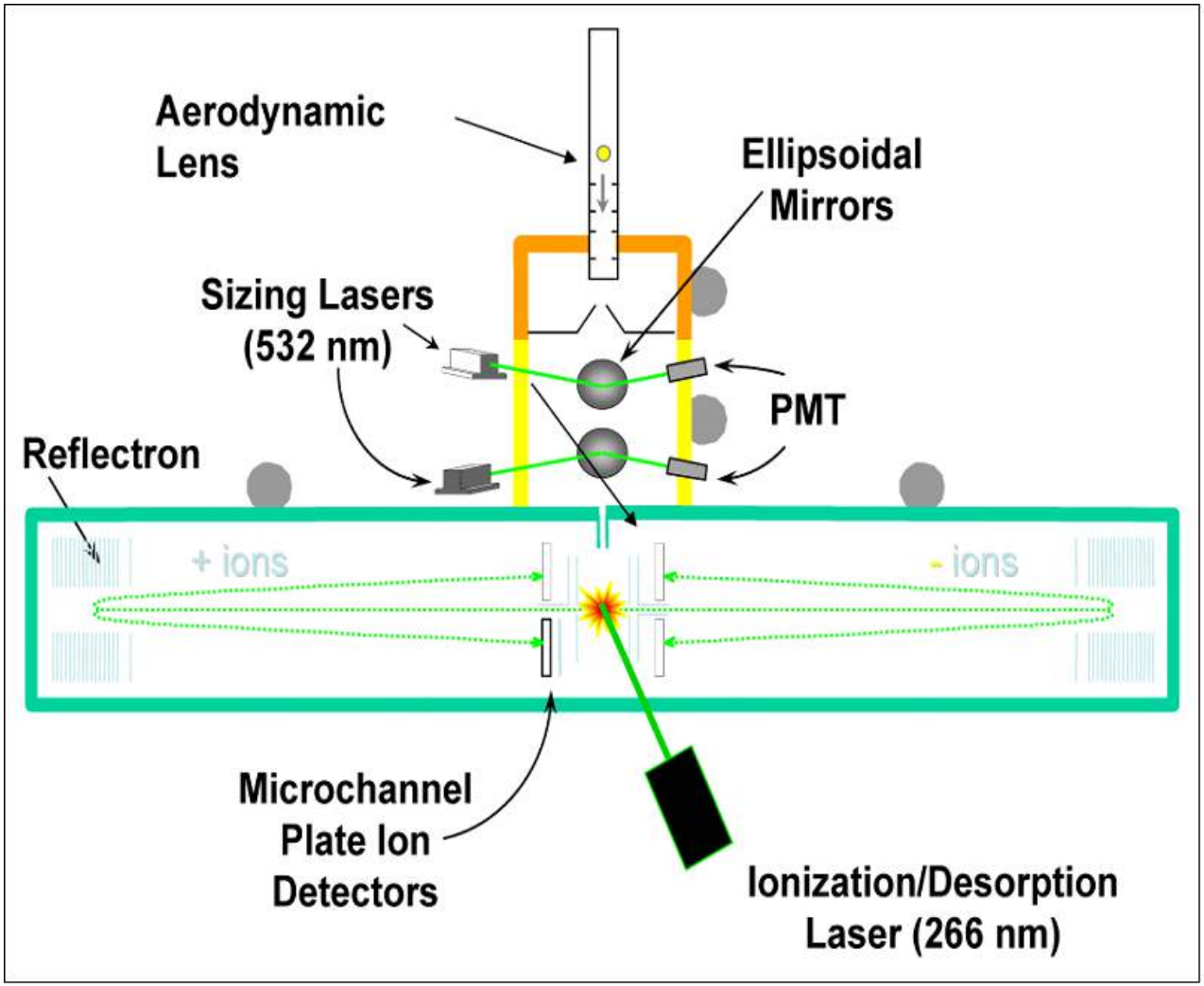
Global Scale: $PM_{2.5}$ Exposure
Satellite remote sensing (2001-06)



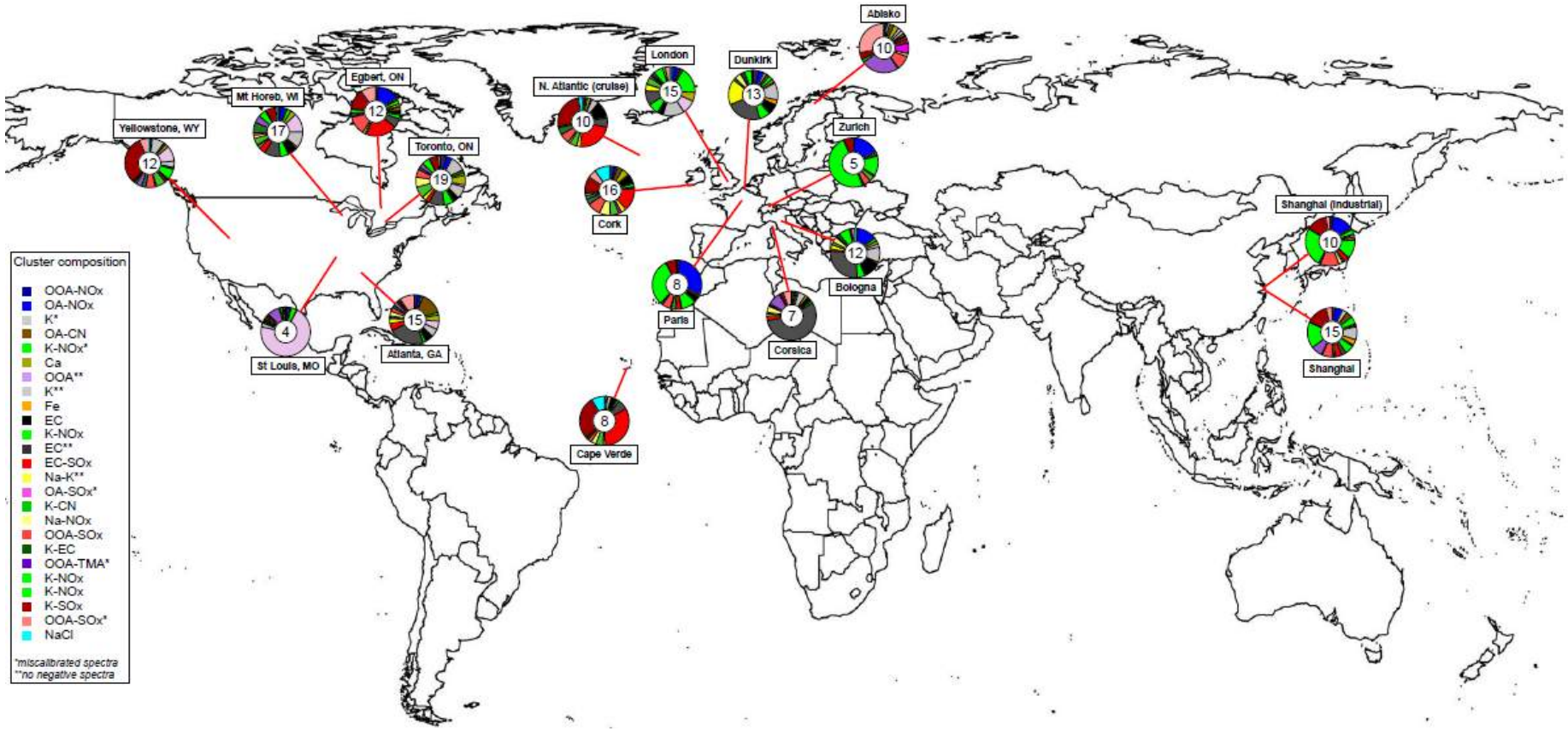
Cardiopulmonary disease 8% (5.5-10.5)
Lung Cancer 12.8% (5.9-18.5)
Heart Disease 9.4% (6.6-11.8)

Env Res (120), 2013

Single Particle Analysis



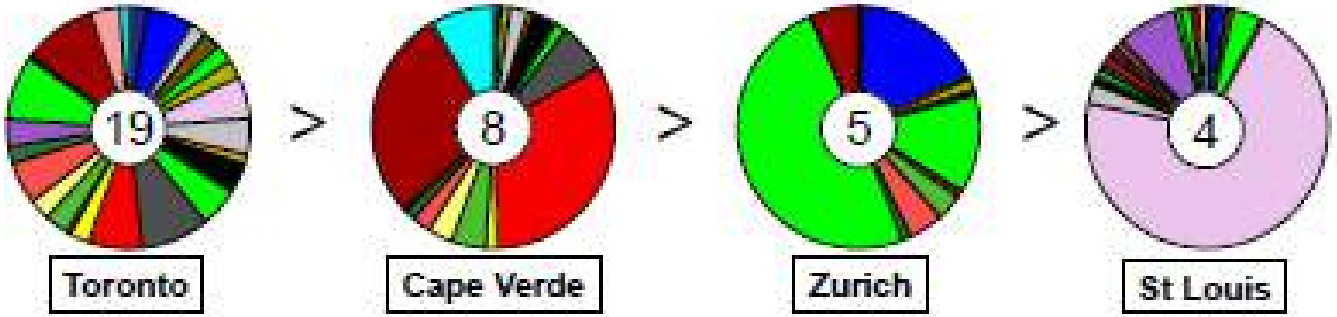
Global Particle Type Diversity



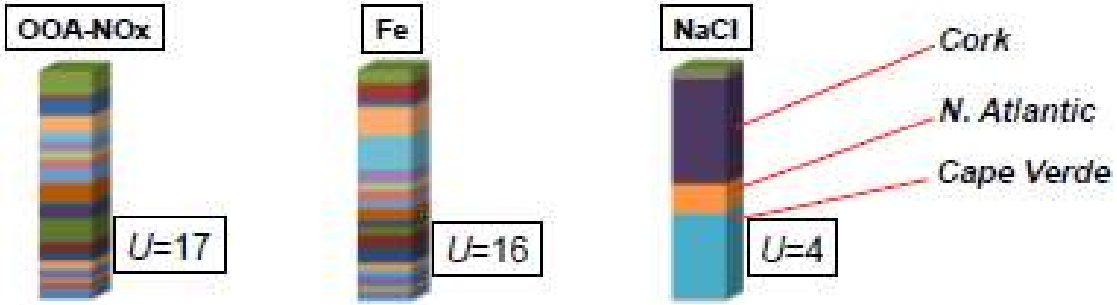
Global library of 25 particles types from 18 locations

Diversity and Ubiquity

Diversity: How externally mixed are the particles at a given site?



Ubiquity: How well represented is a given particle type across the sites?



Regional Scale:

The sources and Impacts of $PM_{2.5}$

SOCAAR

Monetizing Air Quality Impacts

- Where does the PM go?
- How many are exposed?

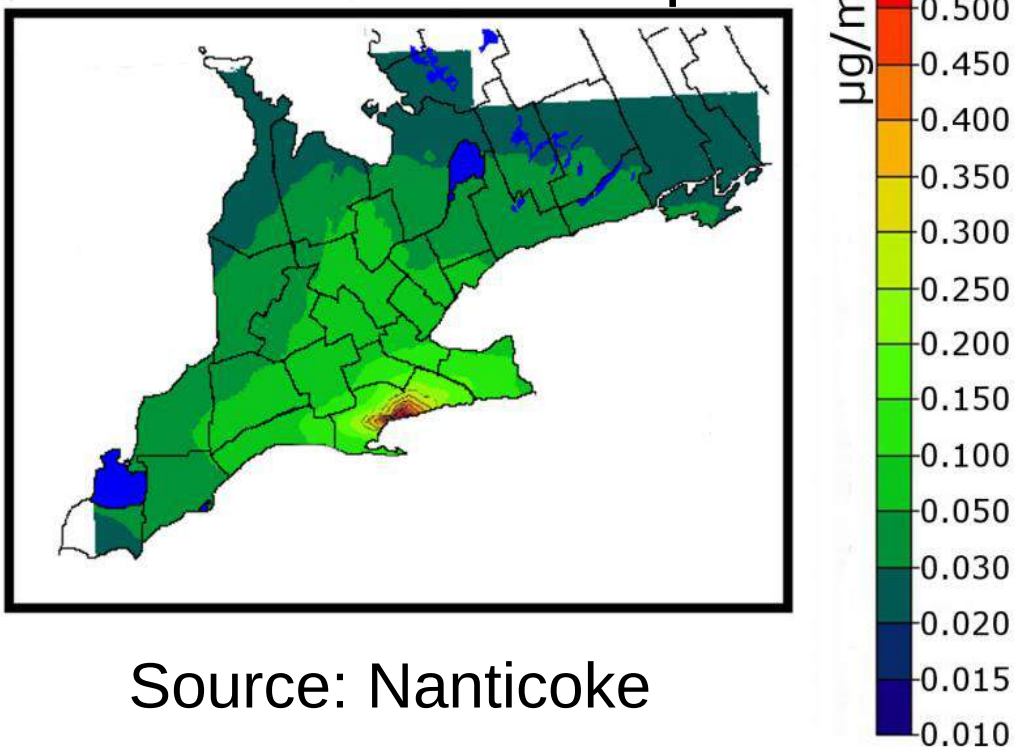
Health impact

Financial cost

Economic Burden from Ontario's coal based electricity generation

SOCAAR

Particulate Matter Concentration Map

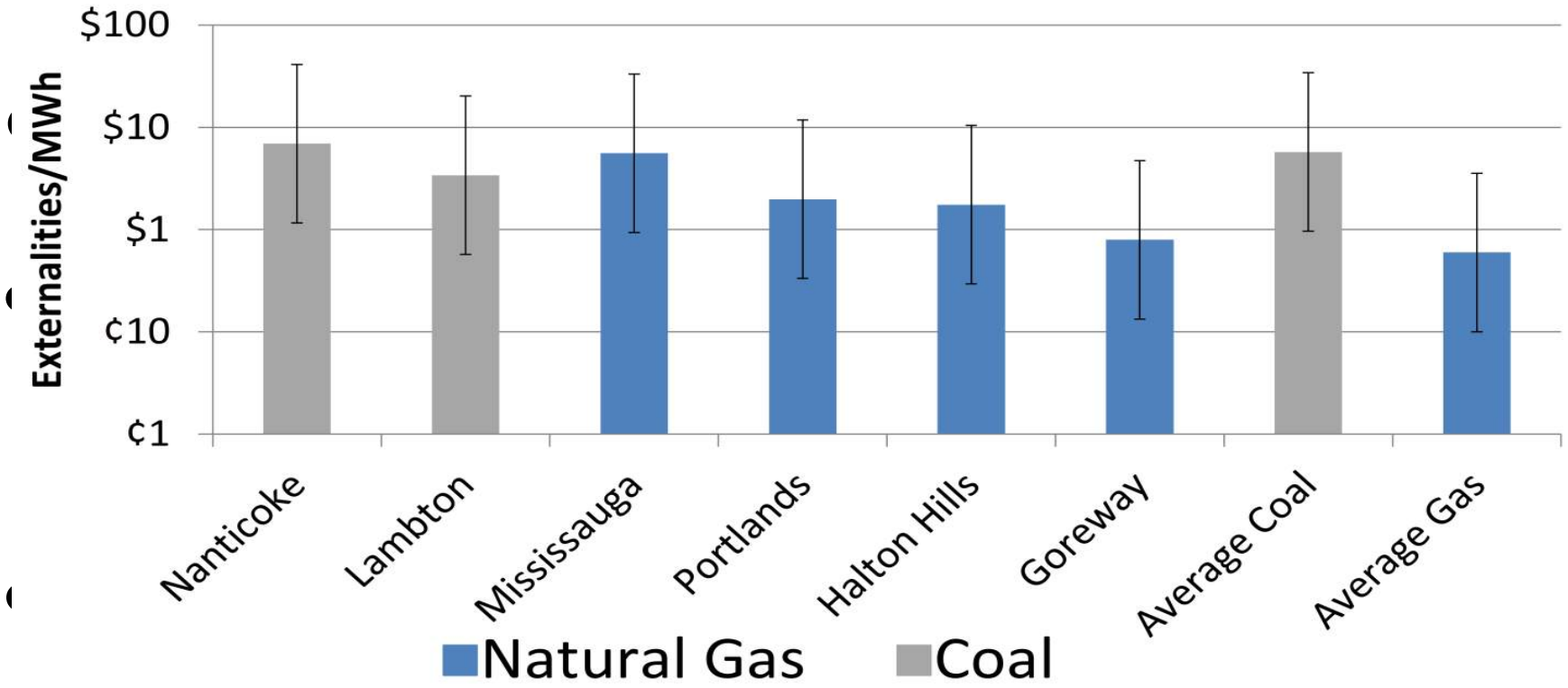


Source: Nanticoke

Damage = $\sum C \times P \times S_{CR} \times E$

- **C**= $PM_{2.5}$
- **P** = Population exposed
- **S_{CR}**= Concentration – responce function
- **E** = Cost per unit damage

Air Quality- Health Externalities from Electricity in Ontario



Benefit of coal phase out: ~$300 million/year

What if we reintroduce coal in 30 years?

$450 to $900 million/year!

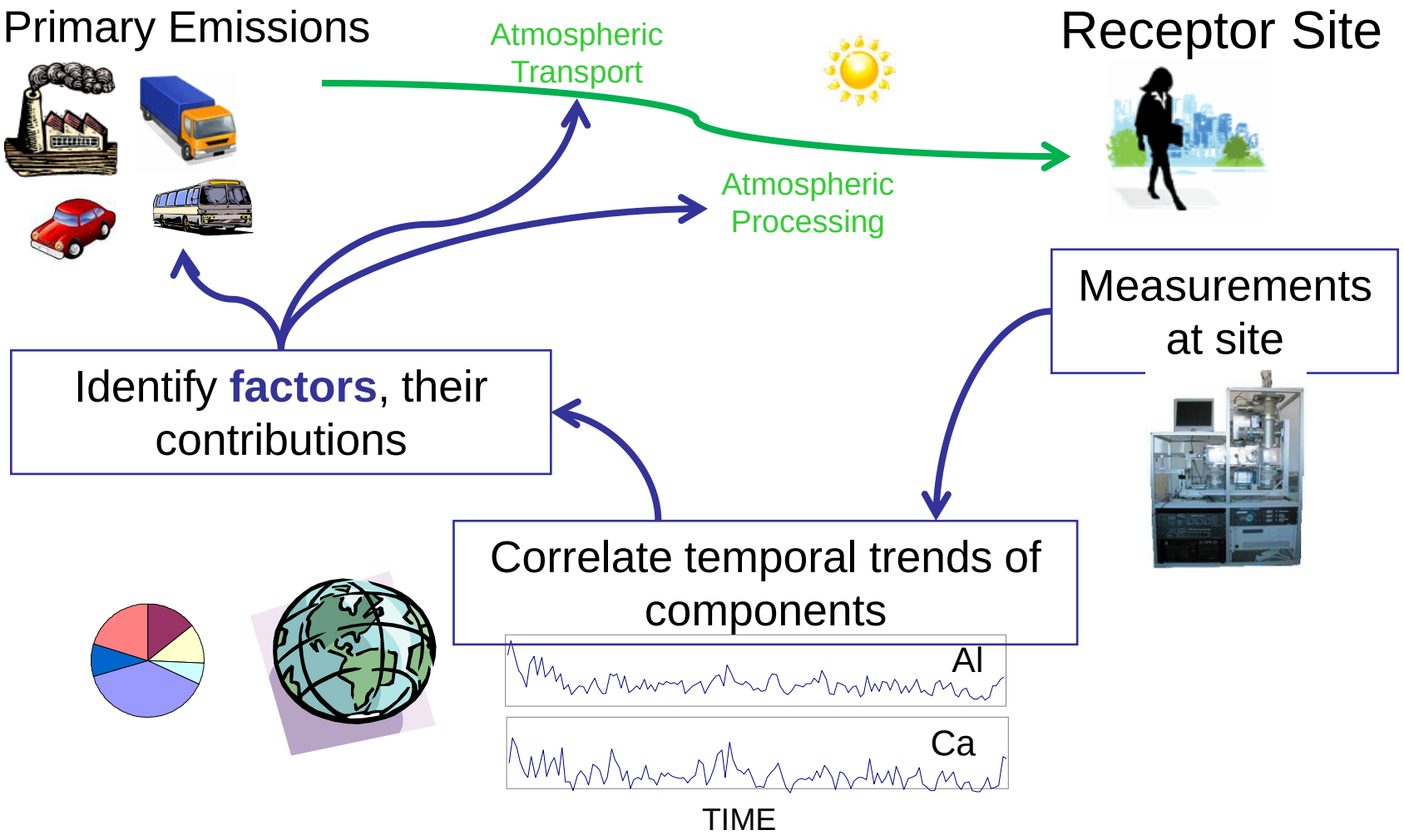
Health co-benefit savings of energy conservation in homes

SOCAAR

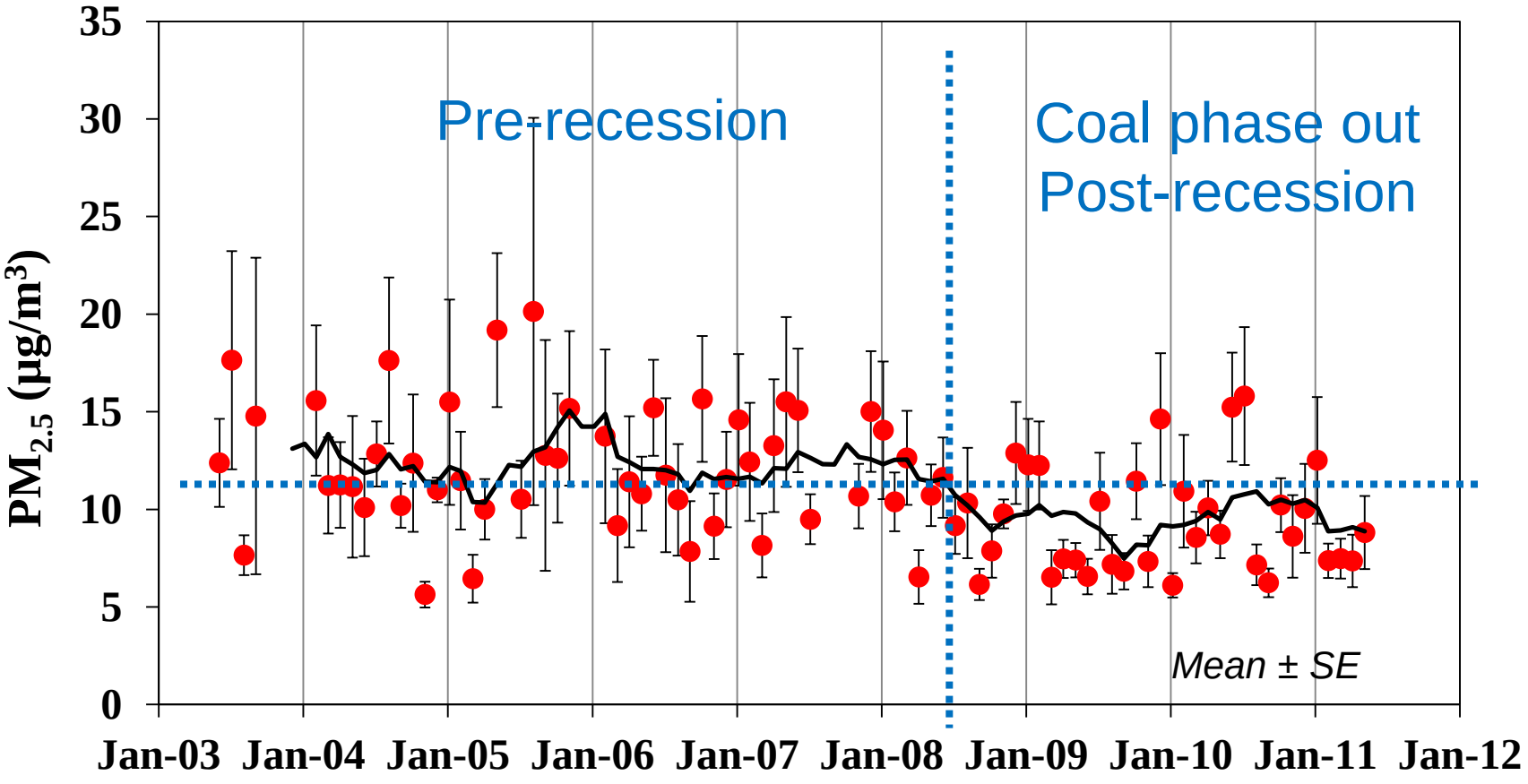
What if we built homes to a better building code to reduce electricity use?

The health co-benefit of building a low energy home is ~7% of additional cost.
Would be higher in higher population density region.

Identifying Sources: Receptor Modelling



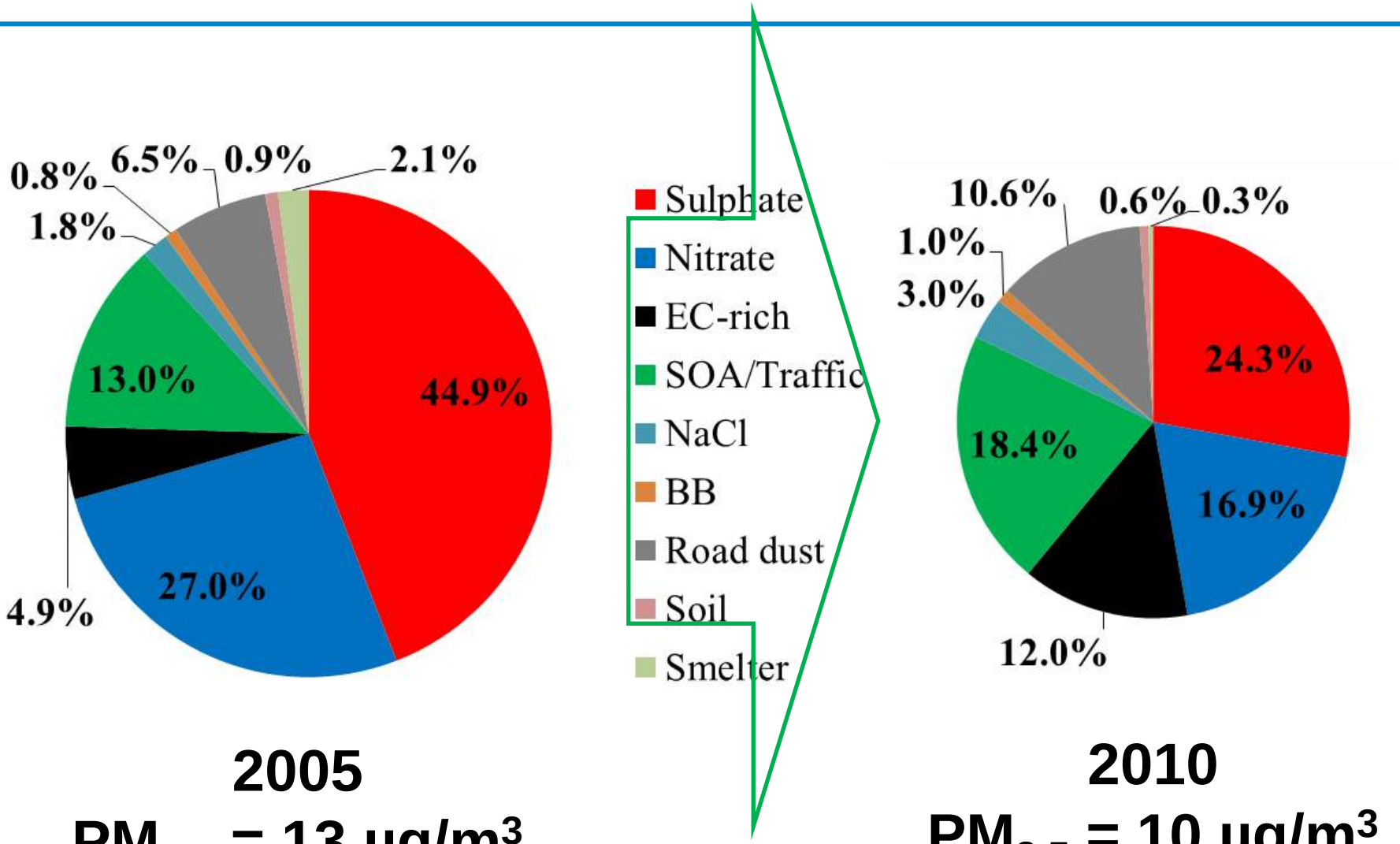
Application: Reduction of $PM_{2.5}$ in Toronto



SOCAAR

UNIVERSITY *of* TORONTO

Change in $PM_{2.5}$ Source Contribution



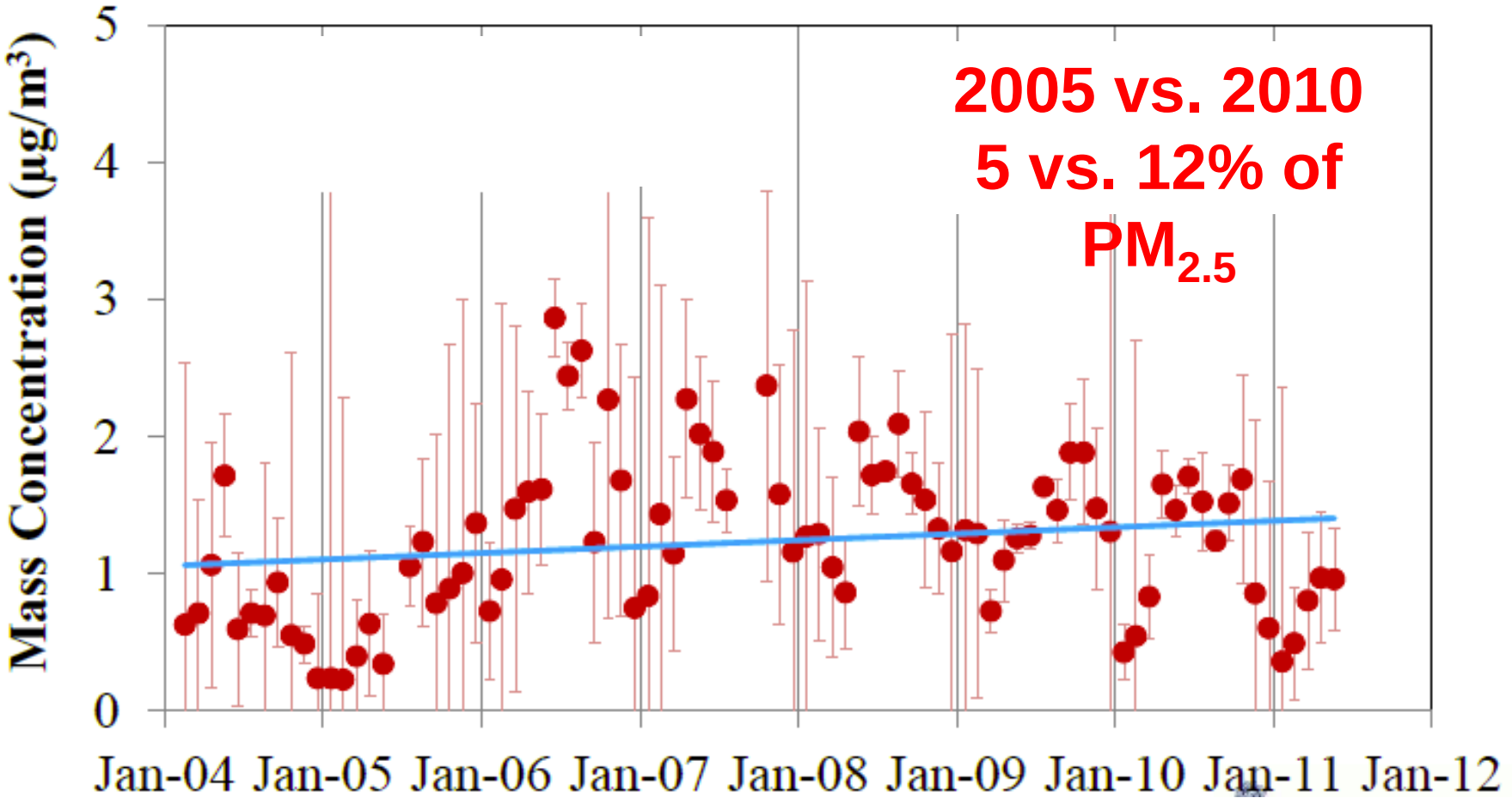
2005
$PM_{2.5}$ = 13 µg/m³

2010
$PM_{2.5}$ = 10 µg/m³

SOCAAR

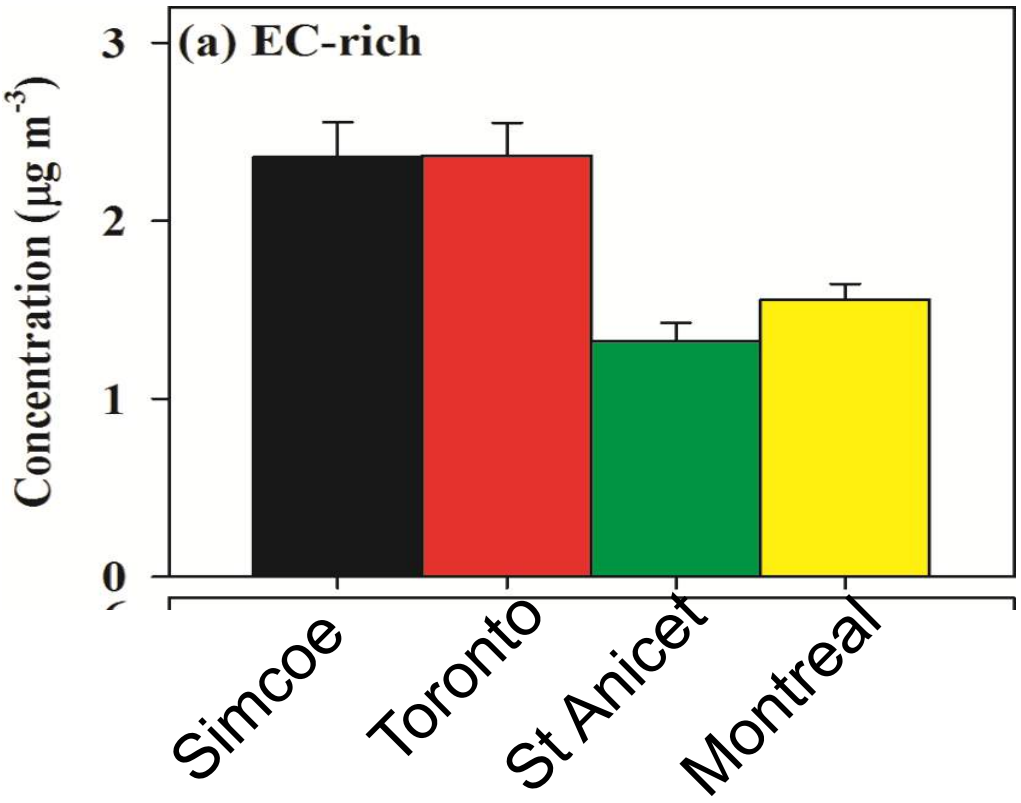
UNIVERSITY *of* TORONTO

Rise in Black Carbon Emissions



Windsor to Quebec Corridor

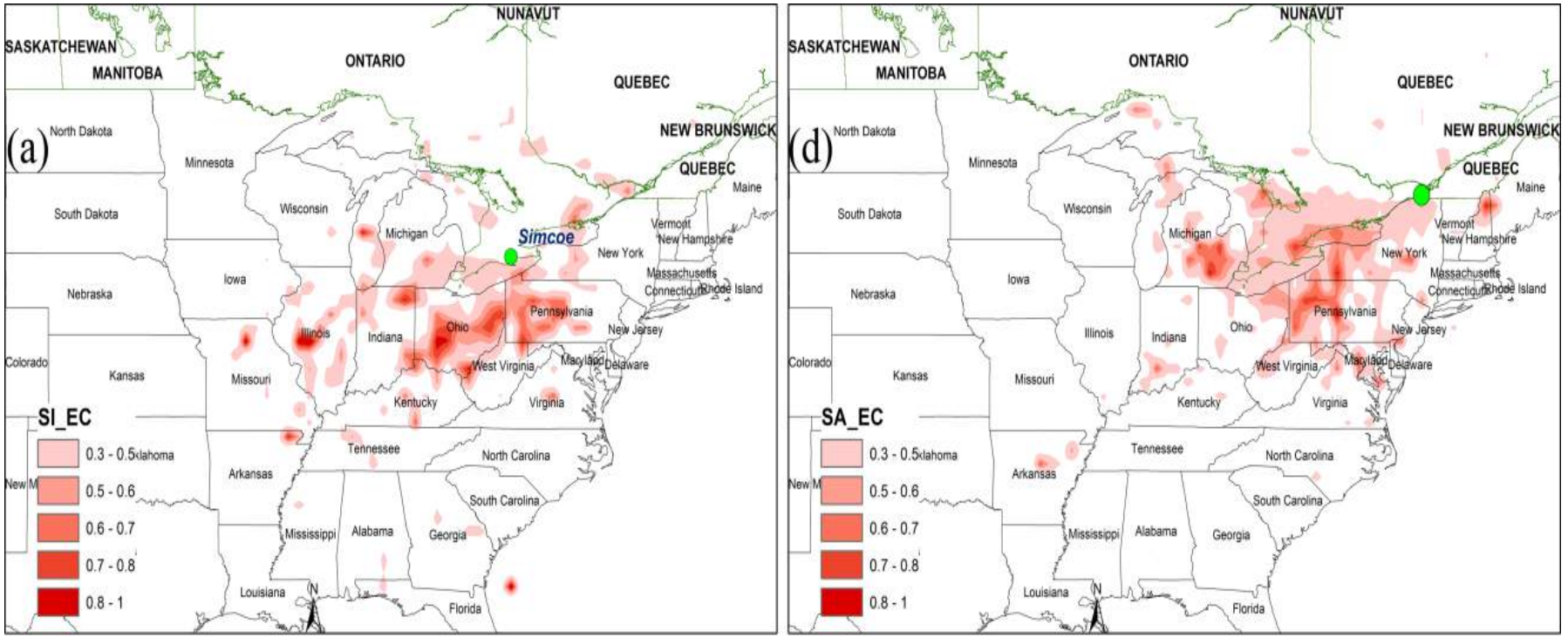
Do we know all the sources?
Black Carbon Rich Source



Substantial source of black carbon found at rural sites

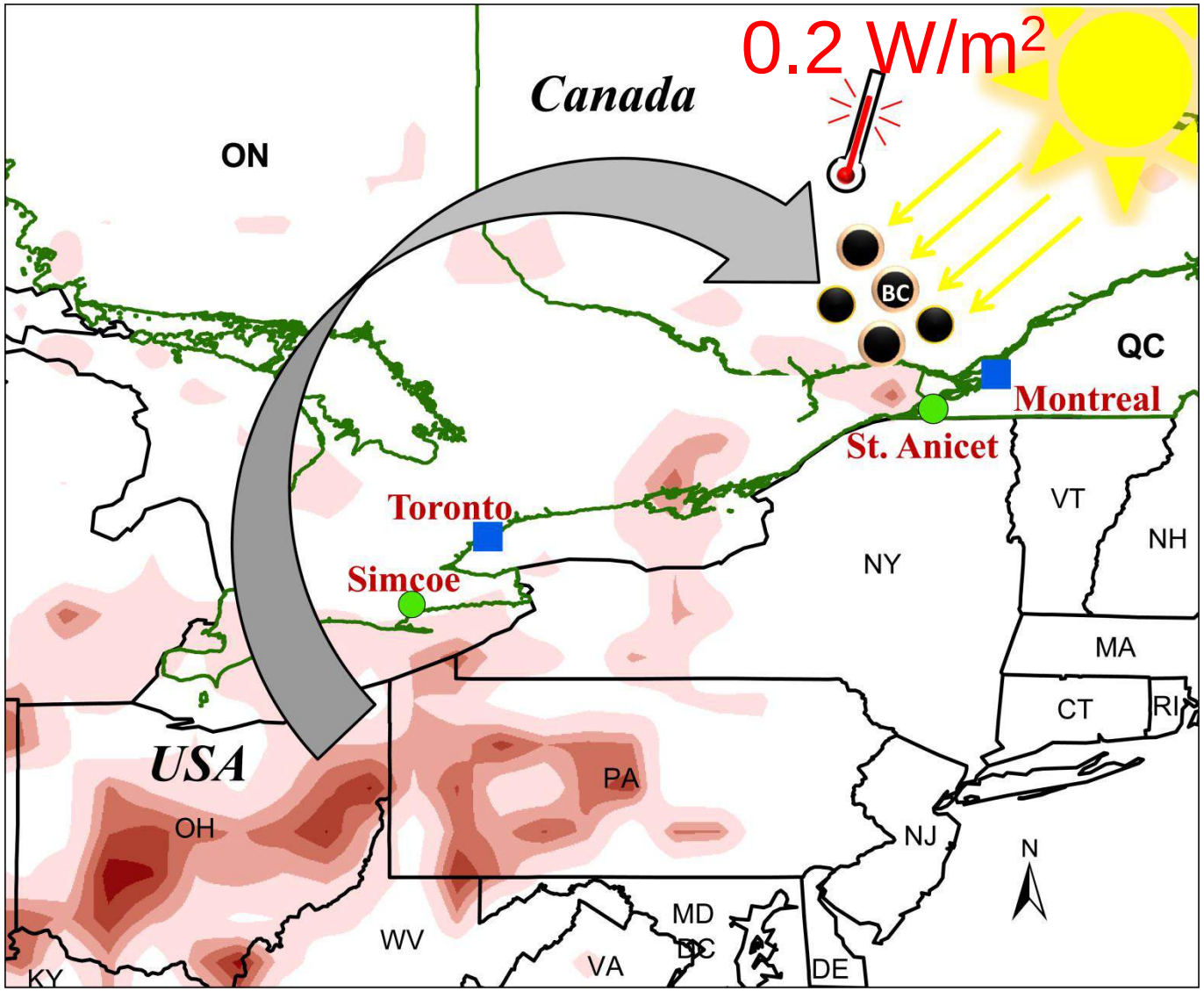
- Similar amounts of black carbon in rural sites as in cities
- Suggests that it is not all due to traffic

Locations of Black Carbon sources

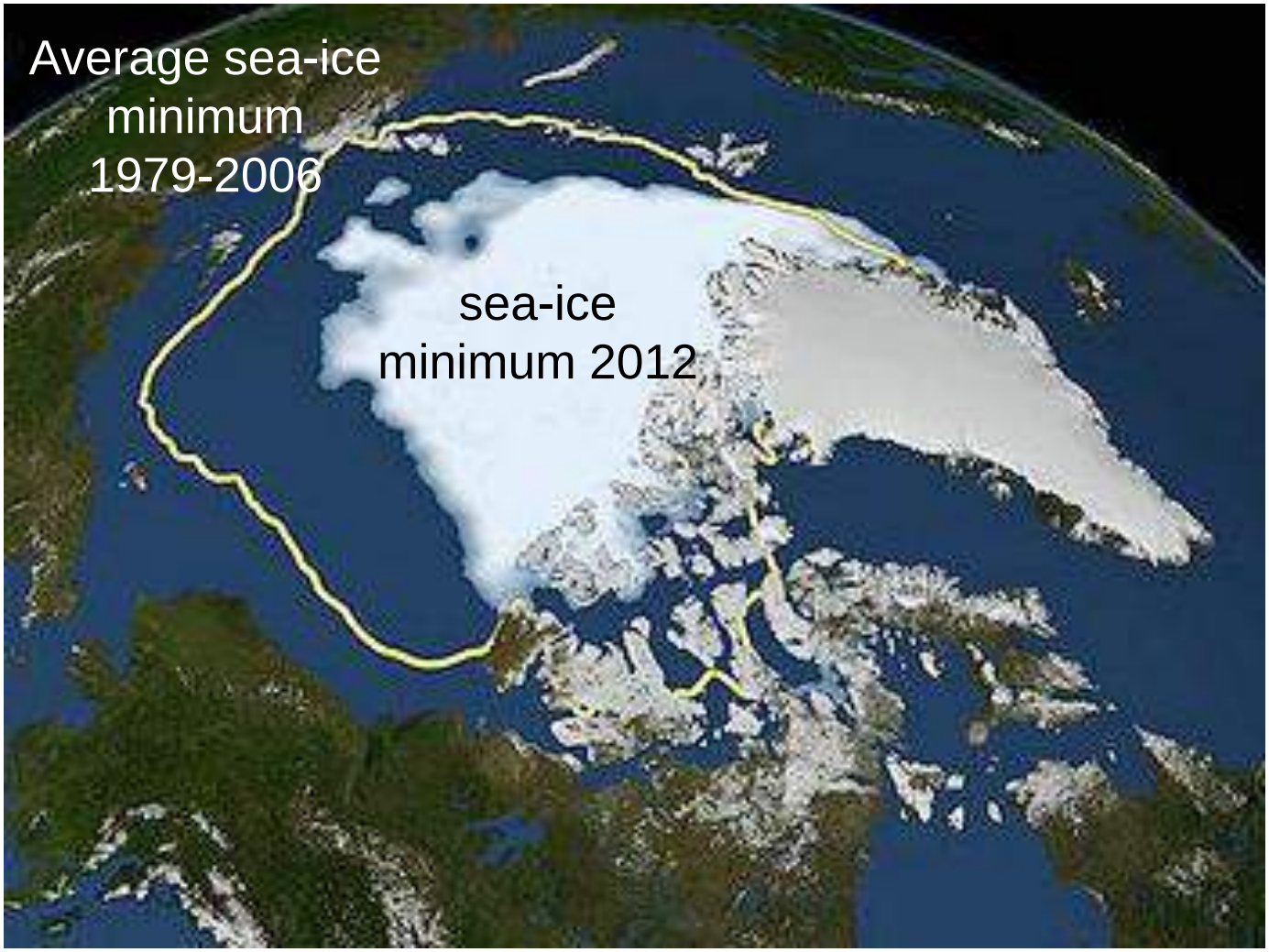


Why do we care about Black Carbon ?

Radiative Forcing due to BC Source



Impacts Of Aerosol: Arctic Ice



SOCAAR

Local Scale

Traffic Related Air Pollution

Population Living Near a Major Road

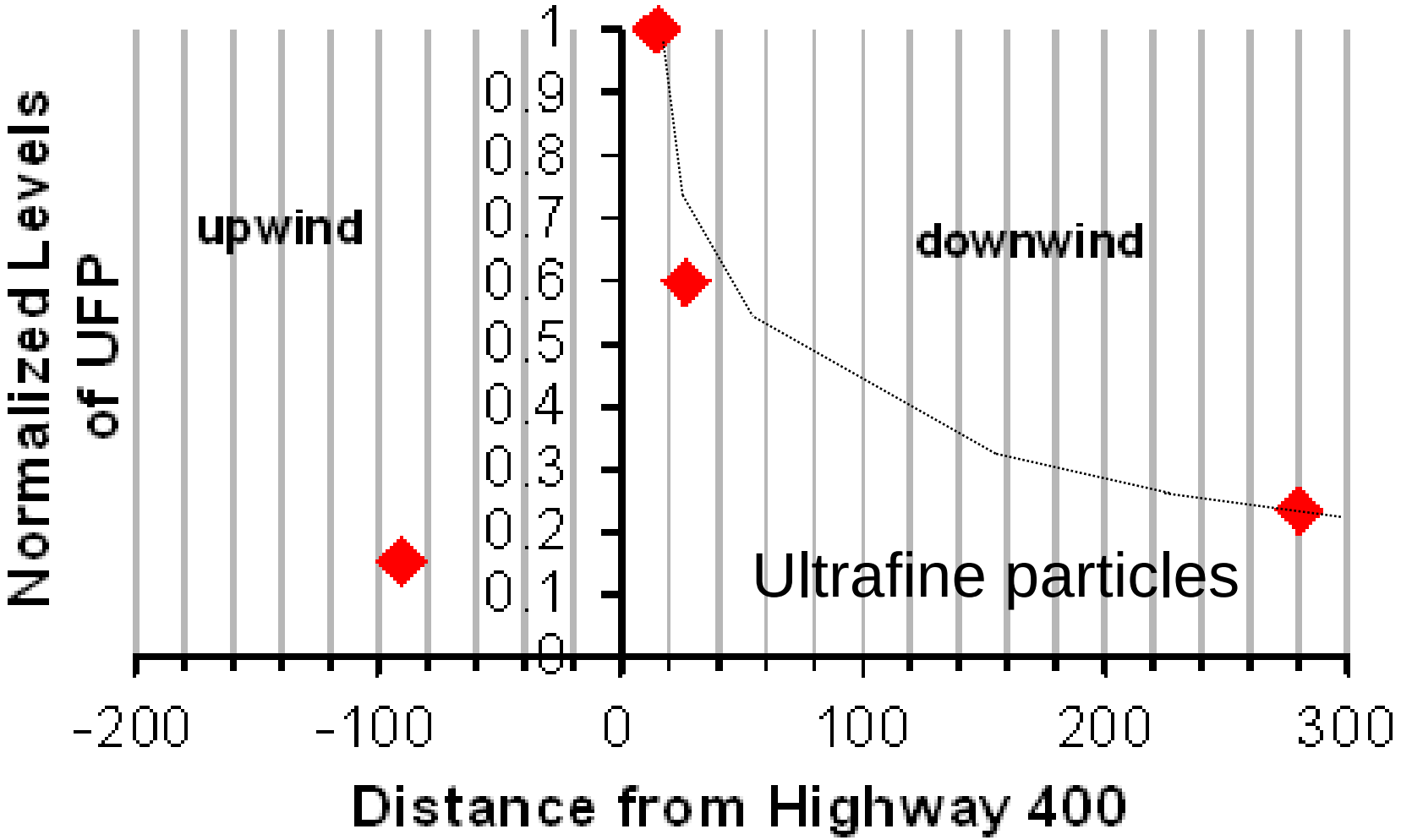
Location	Distance from Road (m)	
	100	250
Toronto	**1,240,000 (24%)**	**2,825,000 (56%)**
Montreal	312,975 (9%)	888,160 (24%)
Vancouver	442,225 (21%)	1,030,320 (49%)
Ontario	2,370,785(19%)	5,622,845 (46%)
Canada	4,090,000 (13%)	10,260,000 (32%)

Number of people (percent)

10 million Canadians live within 250 m of a major road

Evans et al ***Design of a Near-Road Monitoring Strategy for Canada***
Report to Environment Canada 2011

Gradients Beside Major Roads FEVER 2010



Gradients Beside Major Roads

Morbidity of Lung Transplant Recipients and Proximity to Traffic

Bhinder S. Chen H. et al *J. Transplantation* 2014

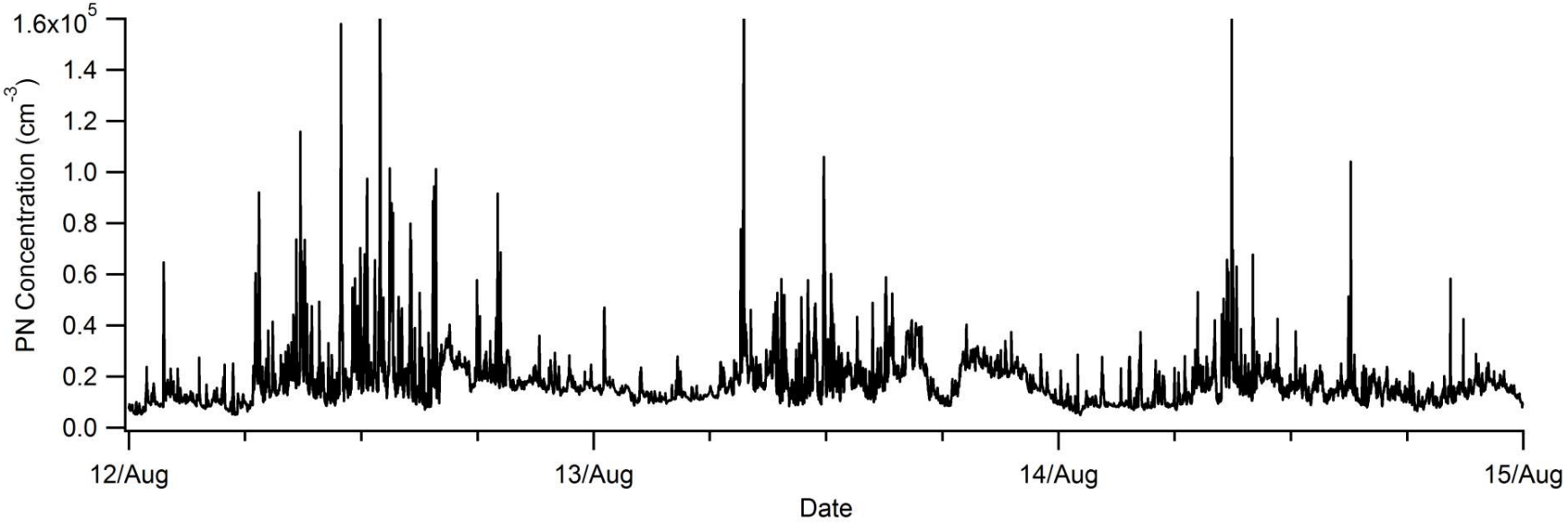
Density of Road Within	n	HR	95% Upper	95% Lower
500 m	397	1.25	1.05	1.48
300 m	397	1.26	1.07	1.48
200 m	397	1.30	1.07	1.58

Incidence of Bronchiolitis Obliterans Syndrome

SOCAAR

1. Evaluated Excess Air Pollution

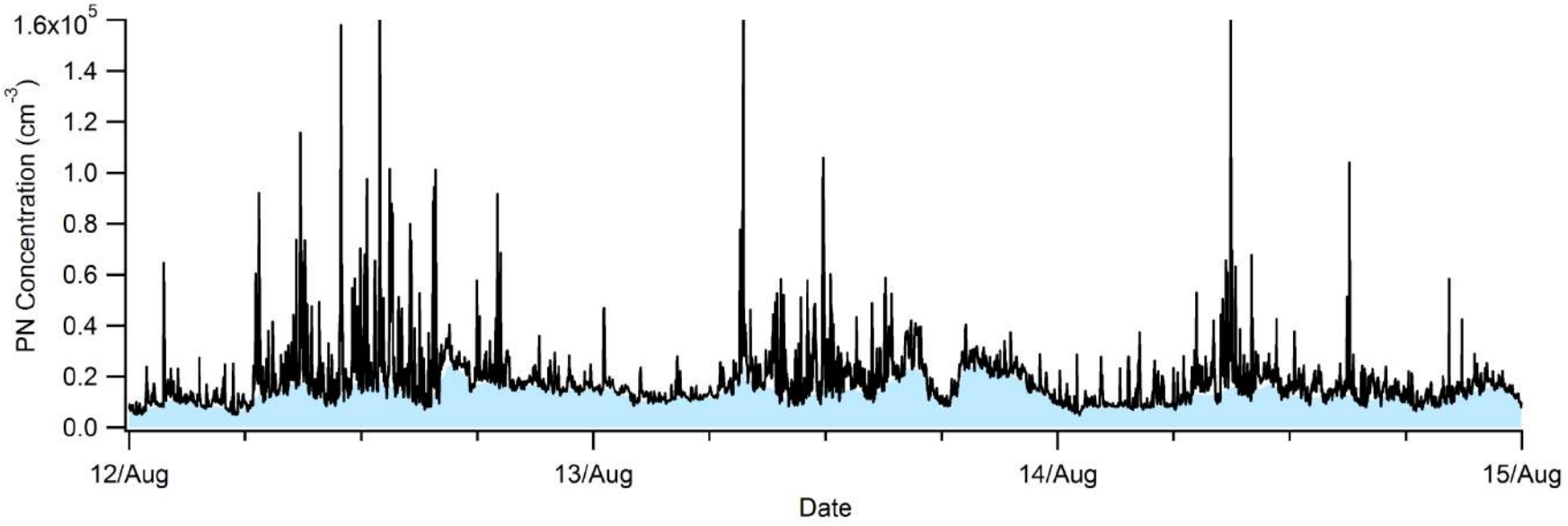
Temporal differences: **rapid vs slow variations**



Ultrafine particles on College Street

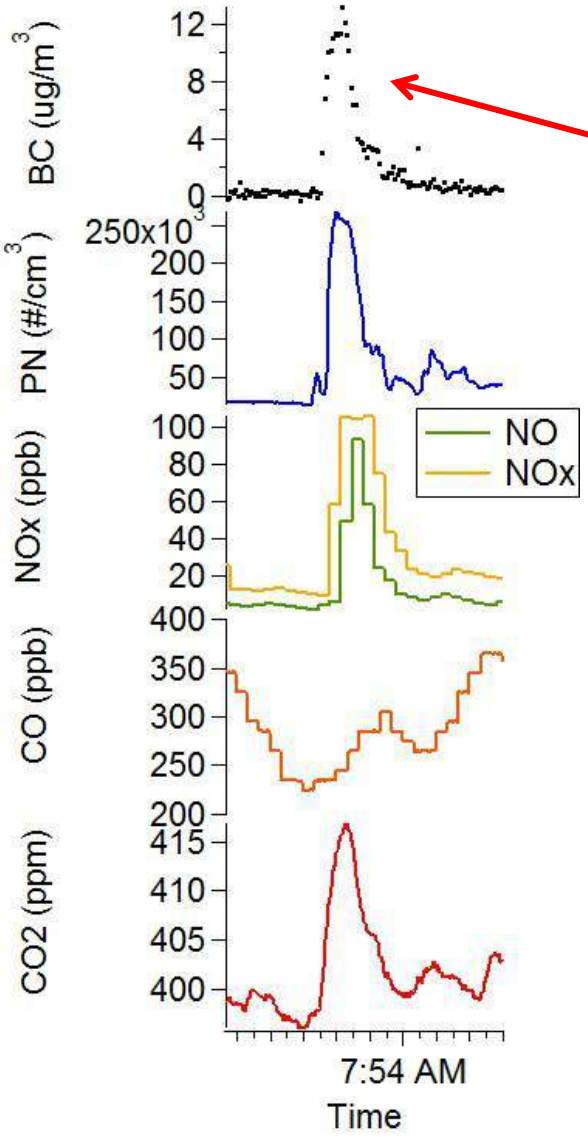
1. Evaluated Excess Air Pollution

Temporal differences: **local vs regional signal**



Ultrafine particles on College Street

Measurement of Emissions Factors

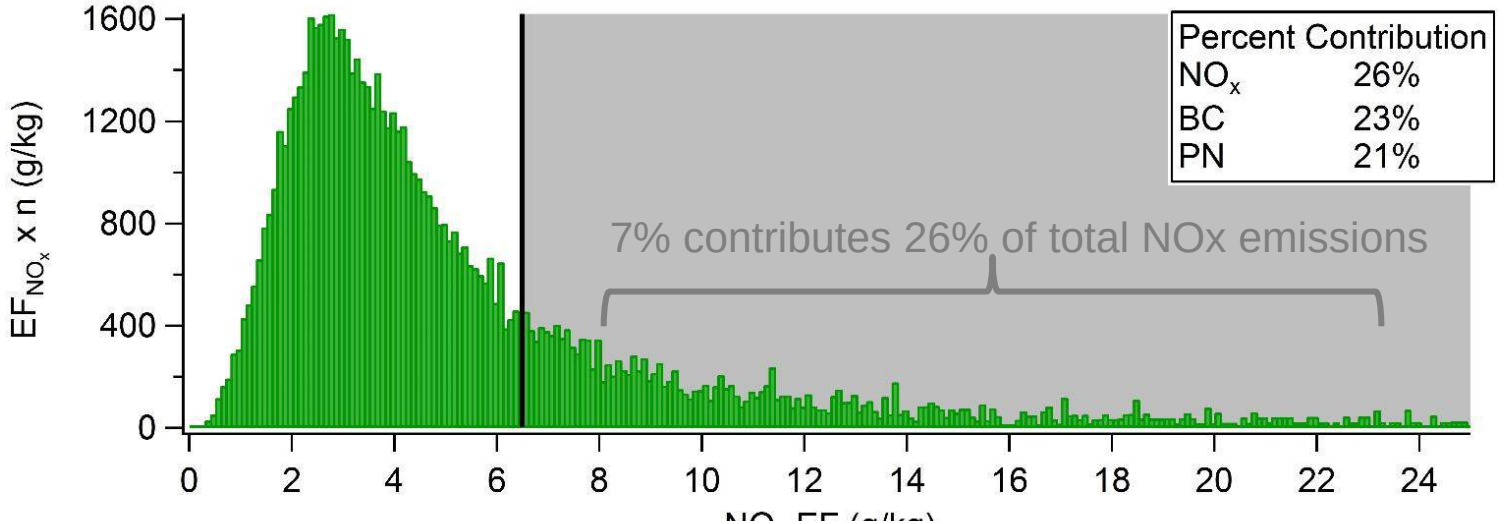


Pollutant	Unit	EF
BC	g/kg	0.39
CO	g/kg	9.5
NO	g/kg	6.0
NOx	g/kg	19
Particles	10^{15} #/kg	18

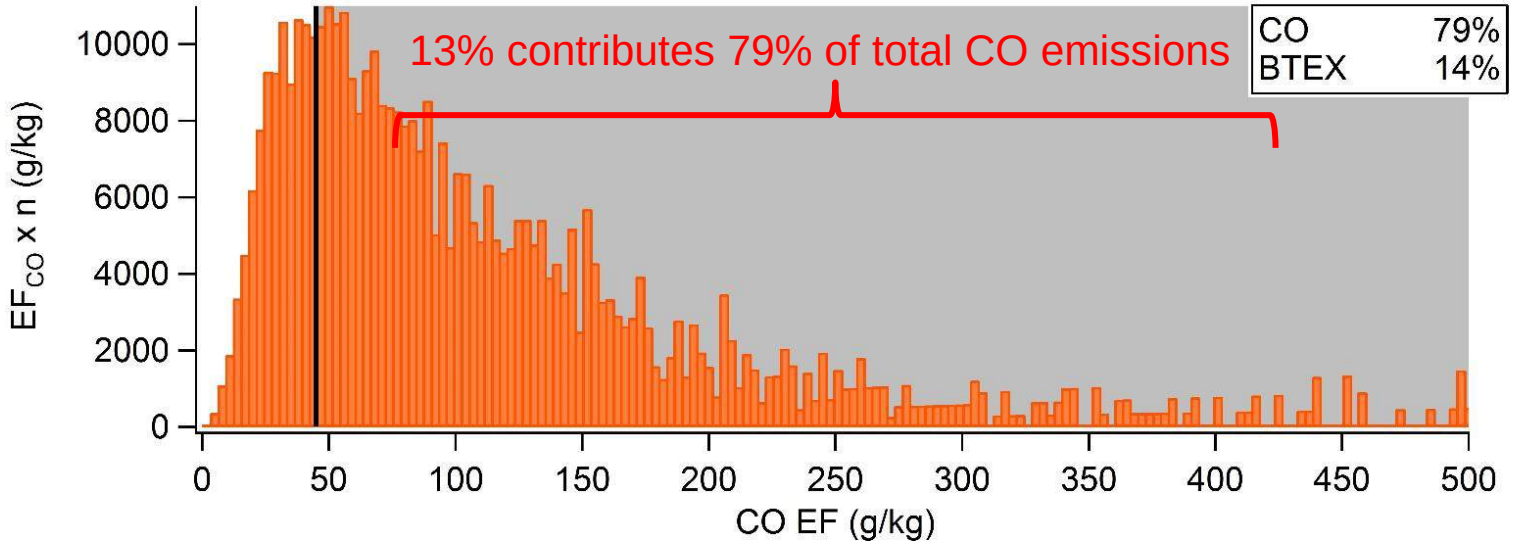
Fleet Emission Factors:
155,000 vehicle plumes in four season

SOCAAR

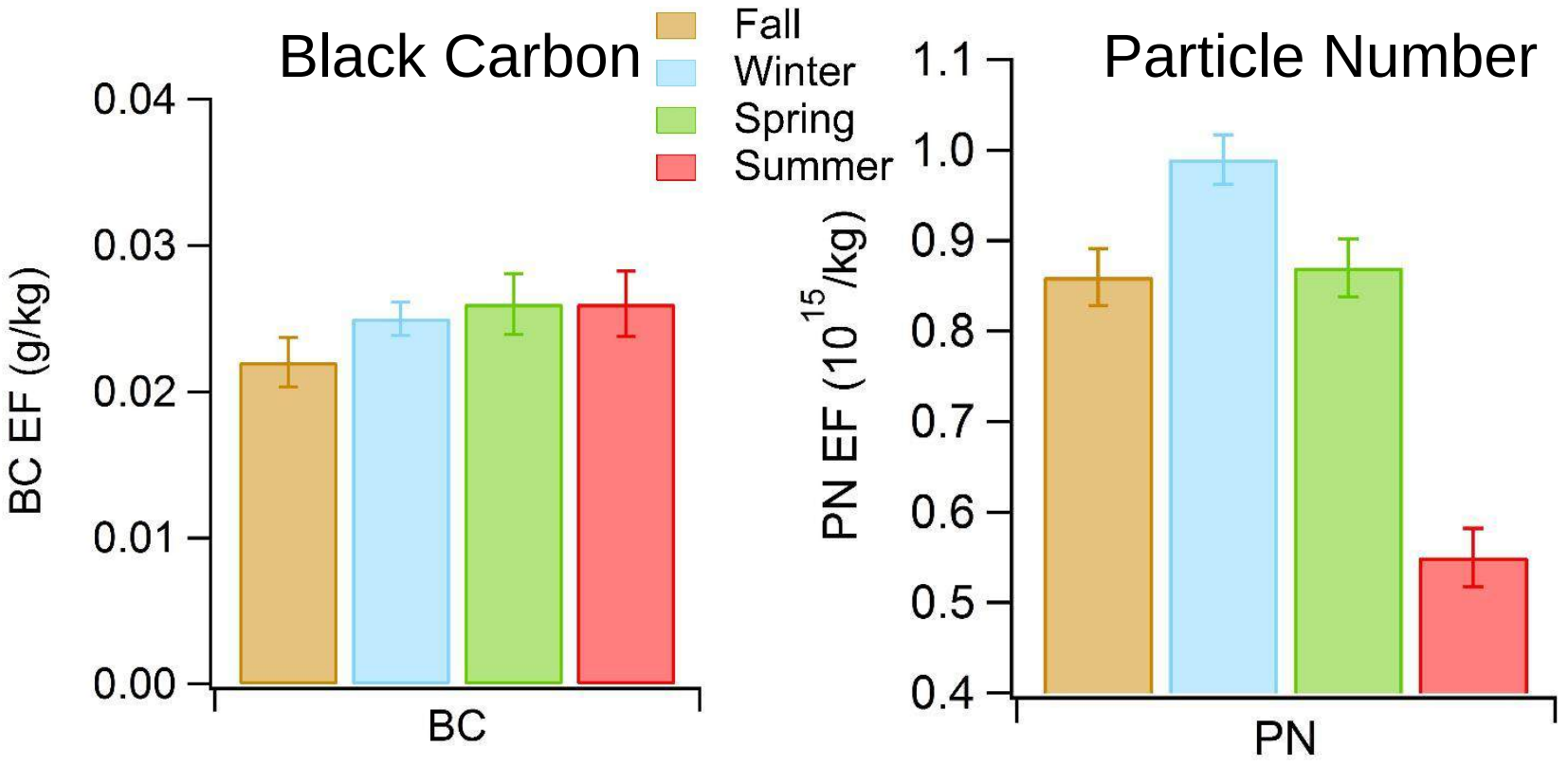
18% plumes had undetectable NOx



72% plumes had undetectable CO



Particle Emission Factors: Fleet mean values

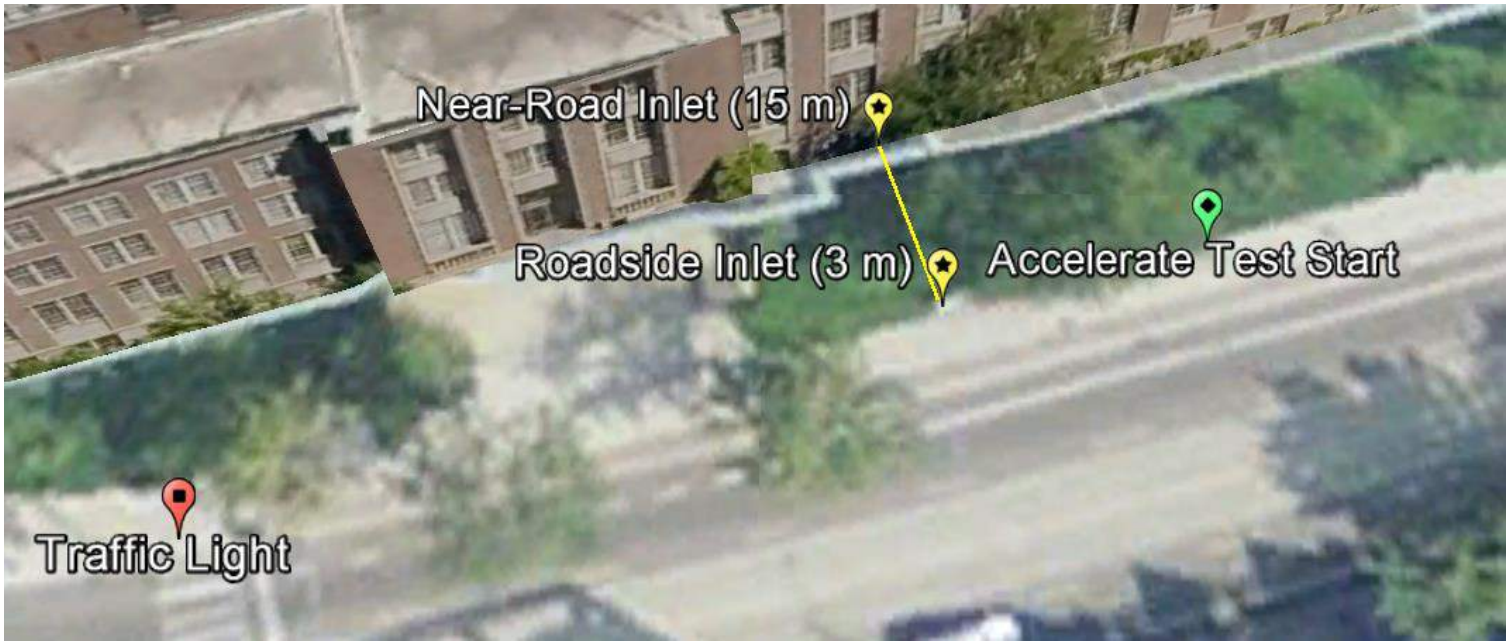


Highest **5%** of vehicles emit:

64% of black Carbon and 37% of particles

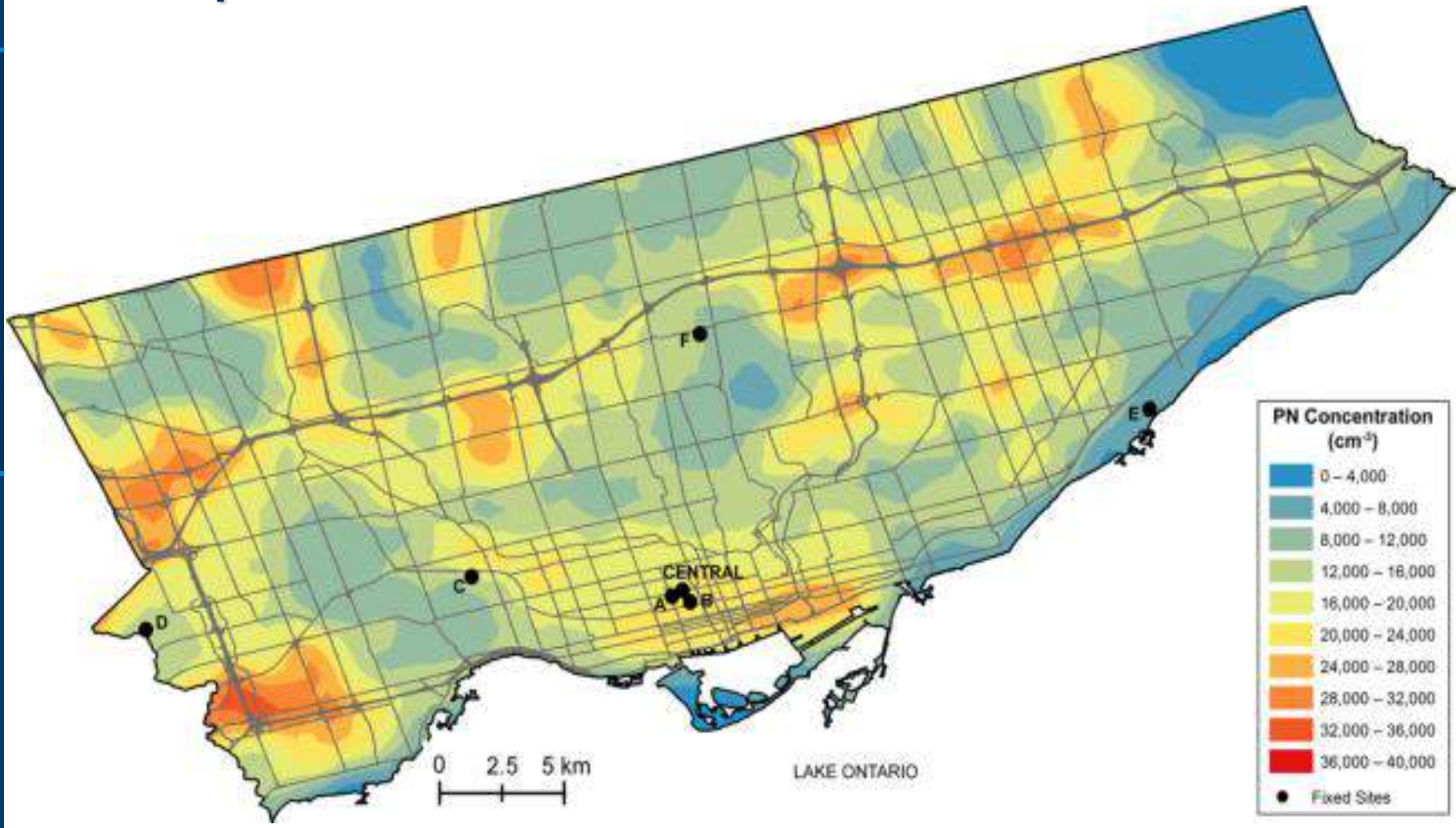
Drive by Testing

Can detect vehicle plume ~50% of the time



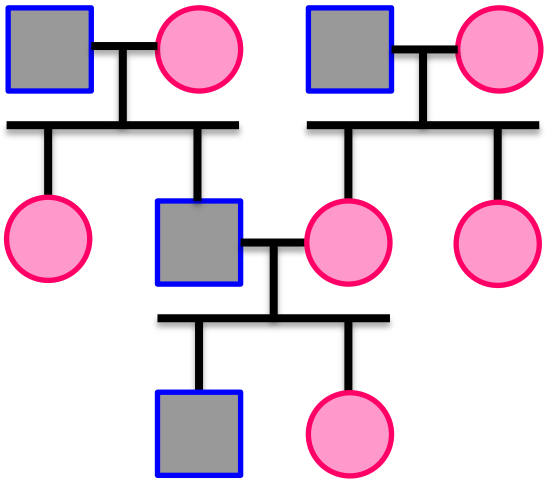
- **New Gasoline Direct Injection (GDI) cars emit ~10 times more UFP**
- **Fuel additives vary seasonally and summer additives (e.g. toluene) increase UFP emissions**

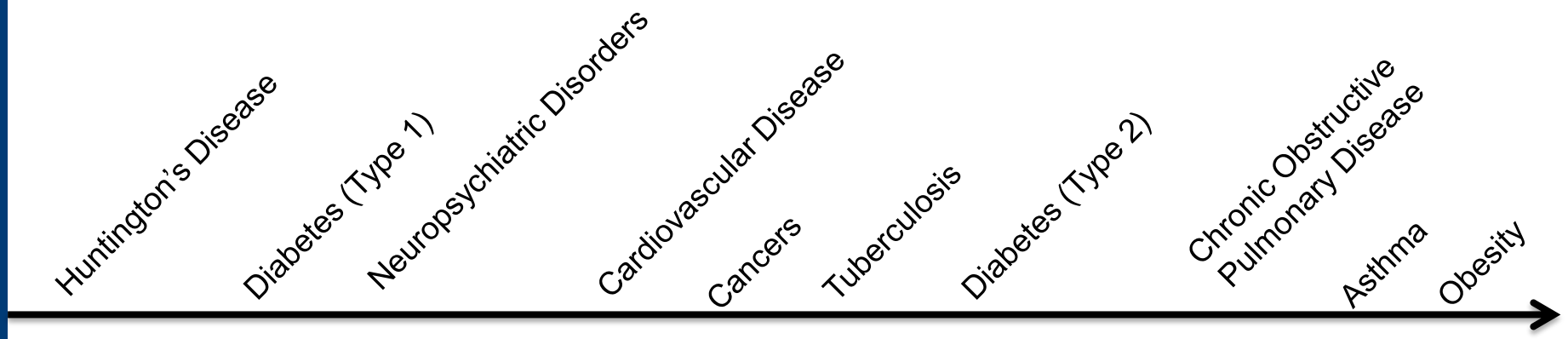
Map of Ultrafine Particles in Toronto



Sabaliauskas et al. unpublished

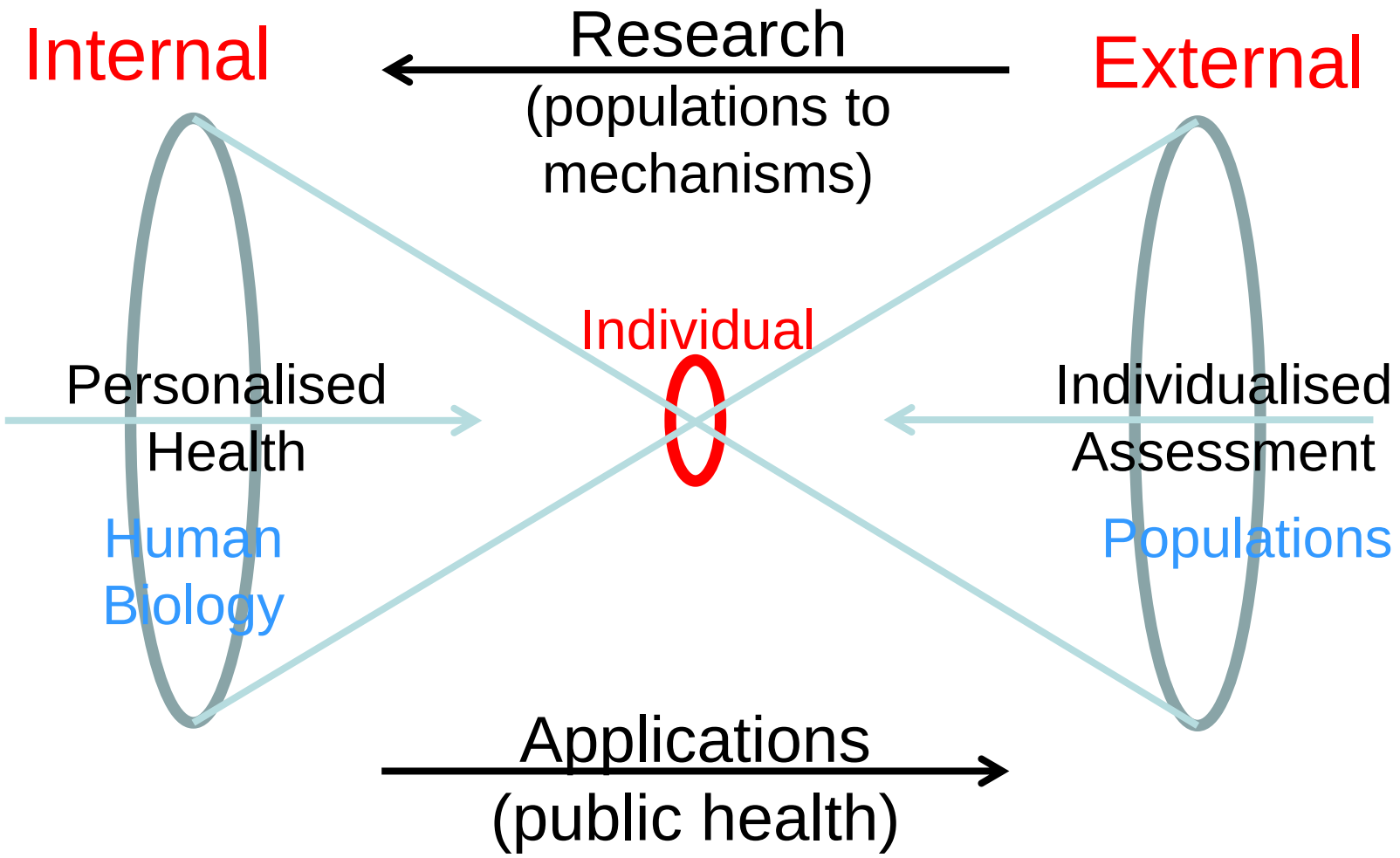
Individual Level: *Gene X Environment*





WHO, 2006

Through the lens of individuals..



UofT Sensor Array System

SOCAAR

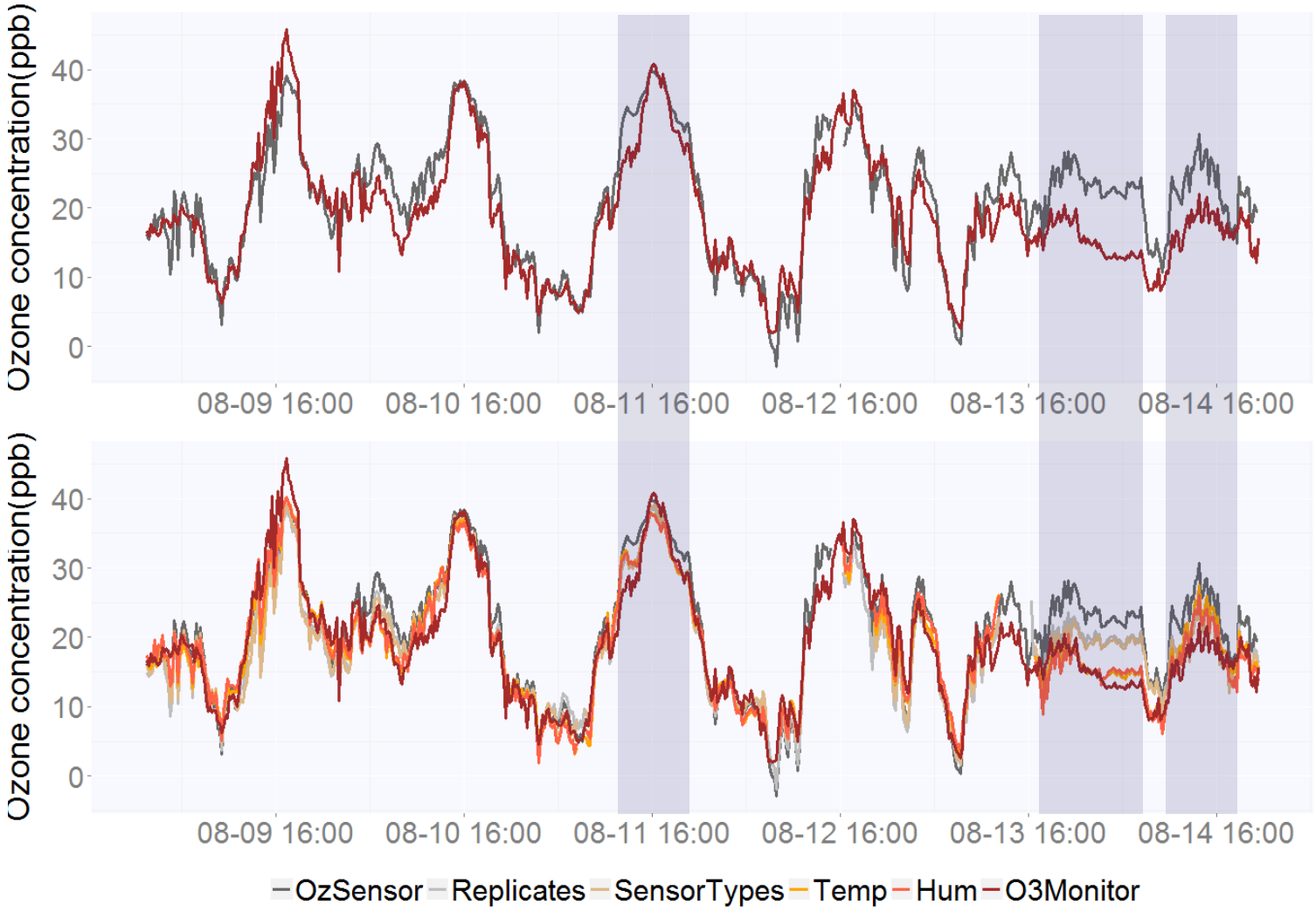
Circuit Board

Manufacture

Deployment

Includes sensors for: CO, NOx, VOC, O3 PM …..

Sensor Array Strategy

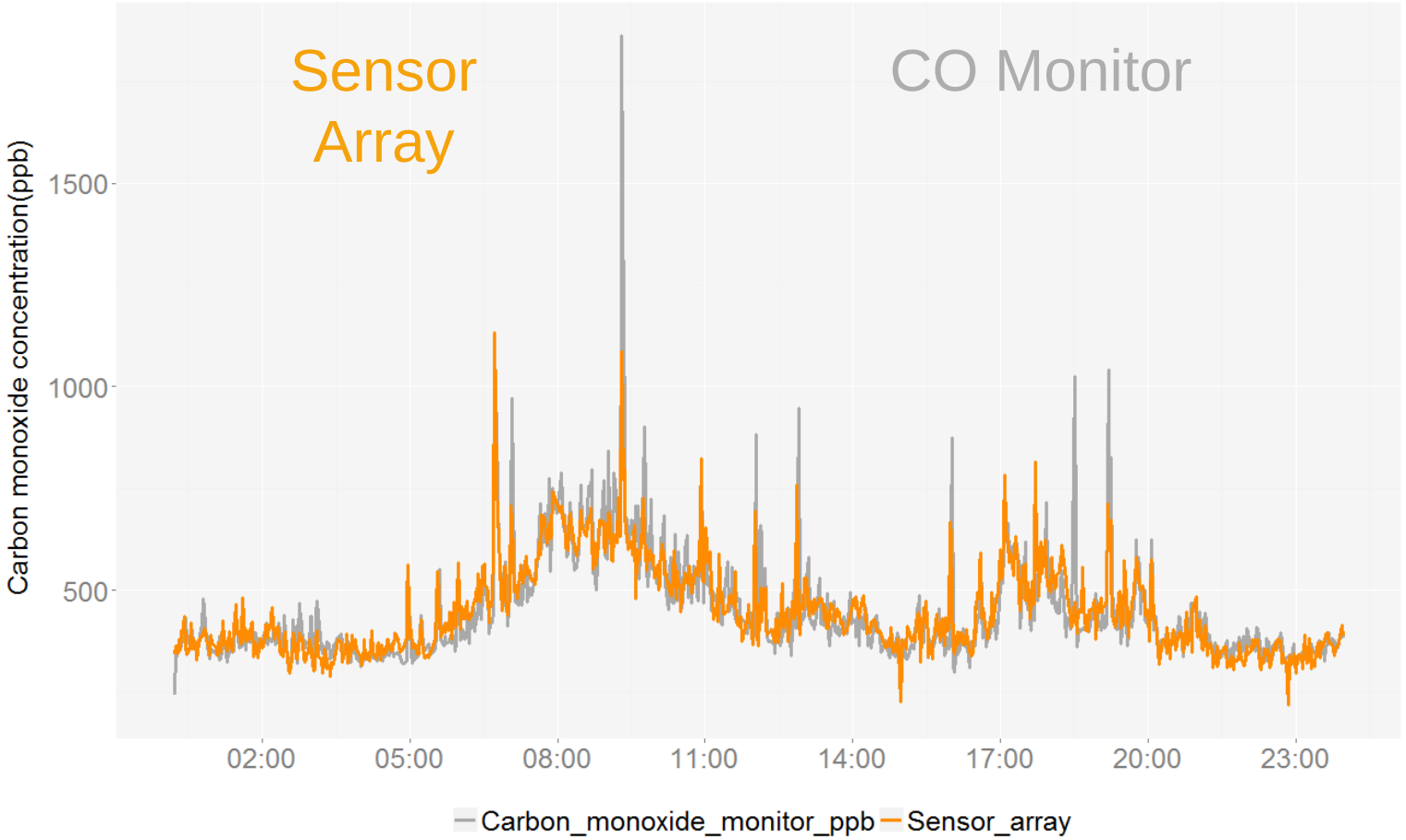


SOCAAR

UNIVERSITY *of* TORONTO

Training the array to measure CO concentrations

CO estimated based on array sensor, trained using data from this same day

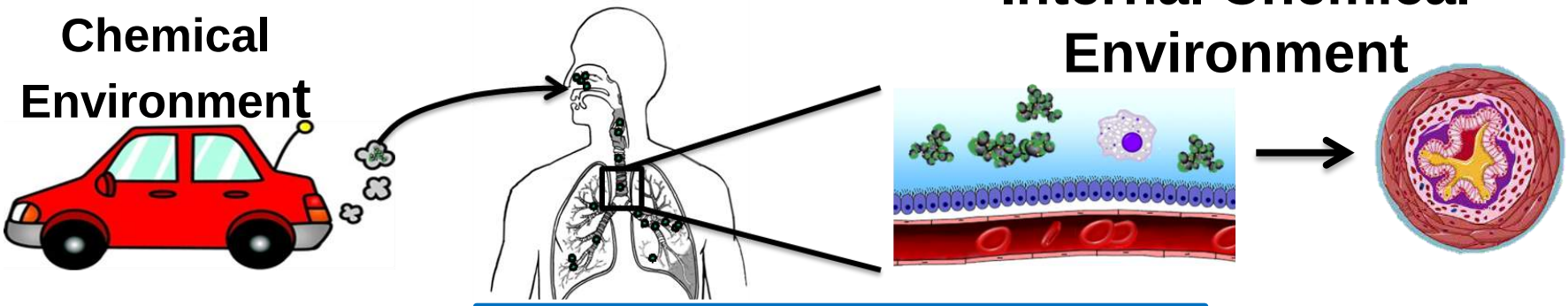


Exposome: A way to link pollutants to chronic disease

External Chemical Environment

Exposure

Internal Chemical Environment



Pollutant Emission

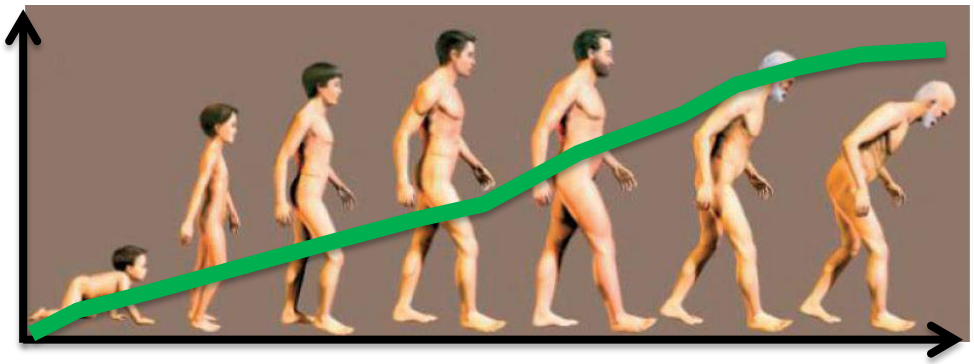
Internalised Pollutant

Intermediate Phenotype/ Biomarkers

Chronic Disease

Exposome

Environmental Exposure, Multiple Pollutants



Time

Summary

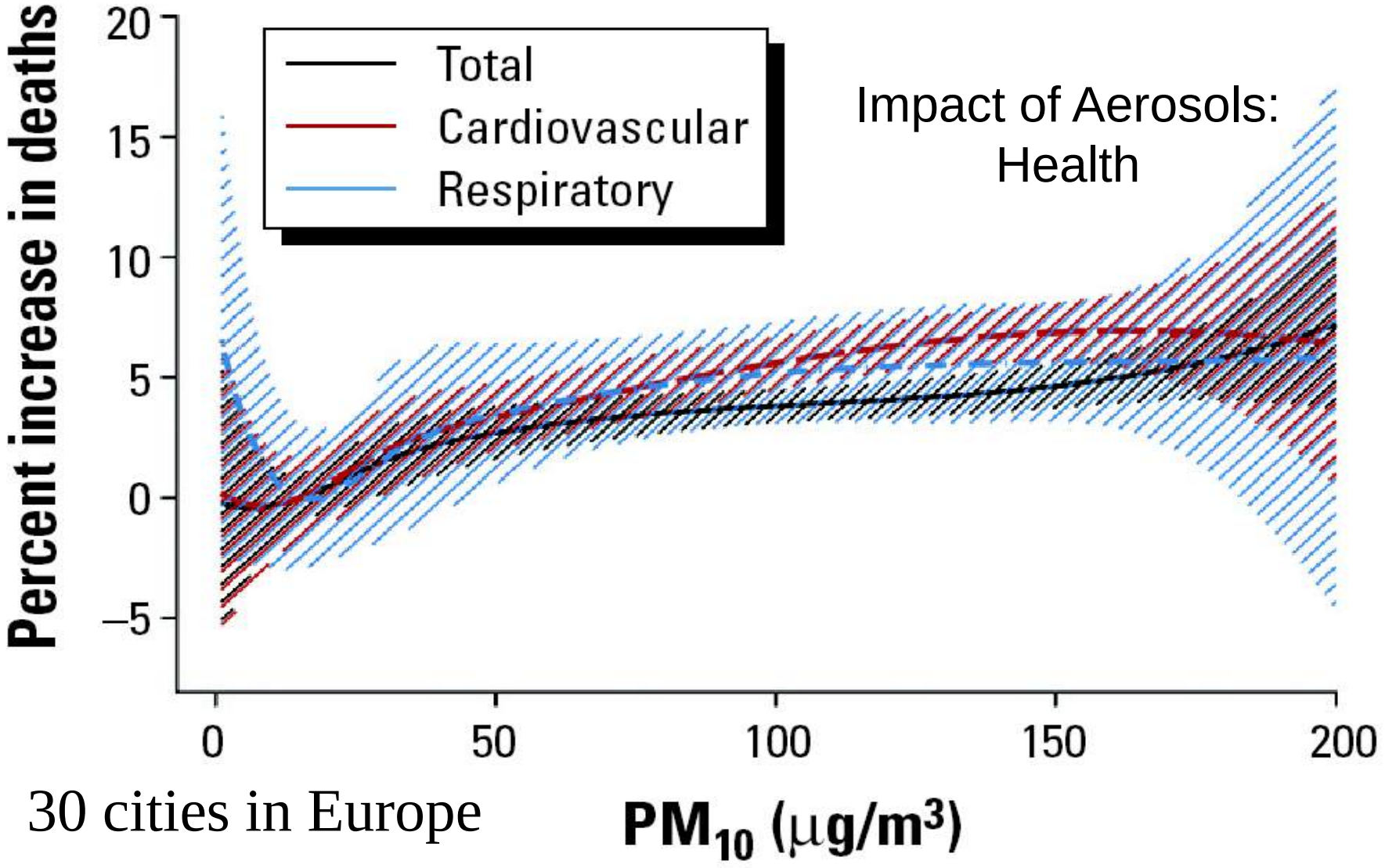
- Particles are strongly linked to global disease yet they come from many sources and are all different; we treat them as being the same
- Emissions are strongly linked to energy use. We need to monitor how changes in energy use alter air quality
- People are all different; we treat them as being the same. Coupling of gene and environment means we need to examine health impacts through the lens of individuals
- Measurements are essential to identifying their evolving impacts of health and climate

Thank You

www.socaar.utoronto.ca

UNIVERSITY *of* TORONTO

Southern Ontario Centre for Atmospheric Aerosol Research



Impact of Aerosols: Health

30 cities in Europe

Estimating the Exposure–Response Relationships between Particulate Matter and Mortality within the APHEA Multicity Project

Evangelia Samoli,[1] Antonis Analitis,[1] Giota Touloumi,[1] Joel Schwartz,[2] Hugh R. Anderson,[3] Jordi Sunyer,[4] Luigi Bisanti,[5] Denis Zmirou,[6] Judith M. Vonk,[7] Juha Pekkanen,[8] Pat Goodman,[9] Anna Paldy,[10] Christian Schindler,[11] and Klea Katsouyanni[1]

Salt Lake City

Jan 23 2013

image courtesy of University of Utah/TimeScience.