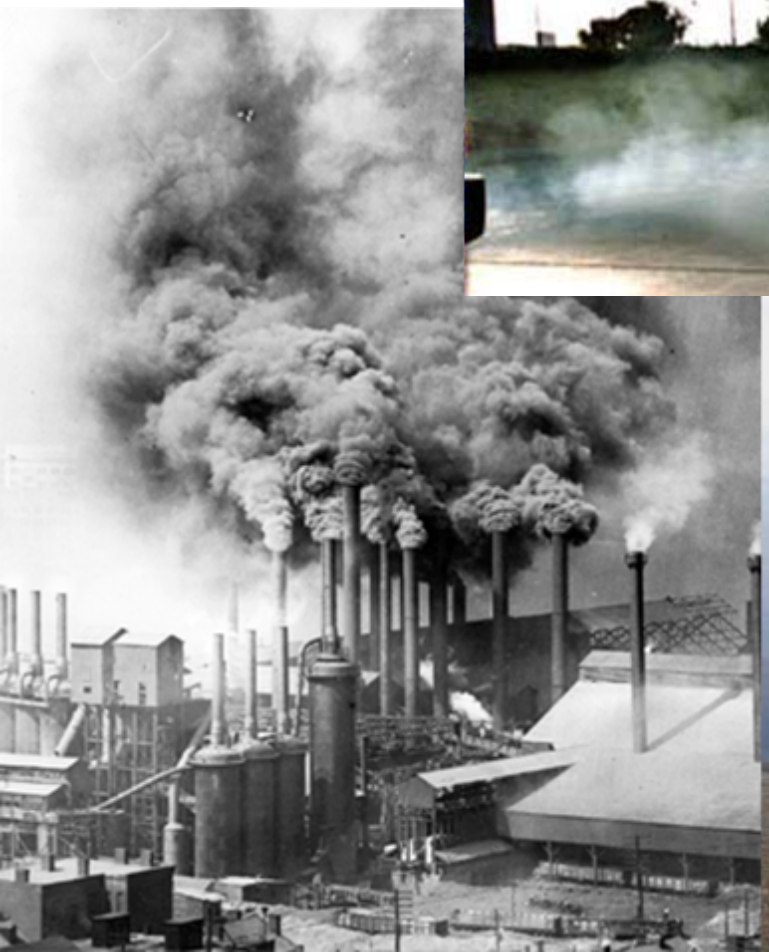
Which PM Components Affect Cardiovascular Health and How Do They Vary by Region?

Terry Gordon

NYU School of Medicine

Ambient Particles Come From Many Sources



What is Particulate Matter?

- Products of combustion, atmospheric reactions, and mechanical processes

- Health Research Concerns for PM
  - Wide range of particle sizes
  - Wide range of physicochemical properties
  - Wide range of health impacts, including cardiopulmonary morbidity and mortality

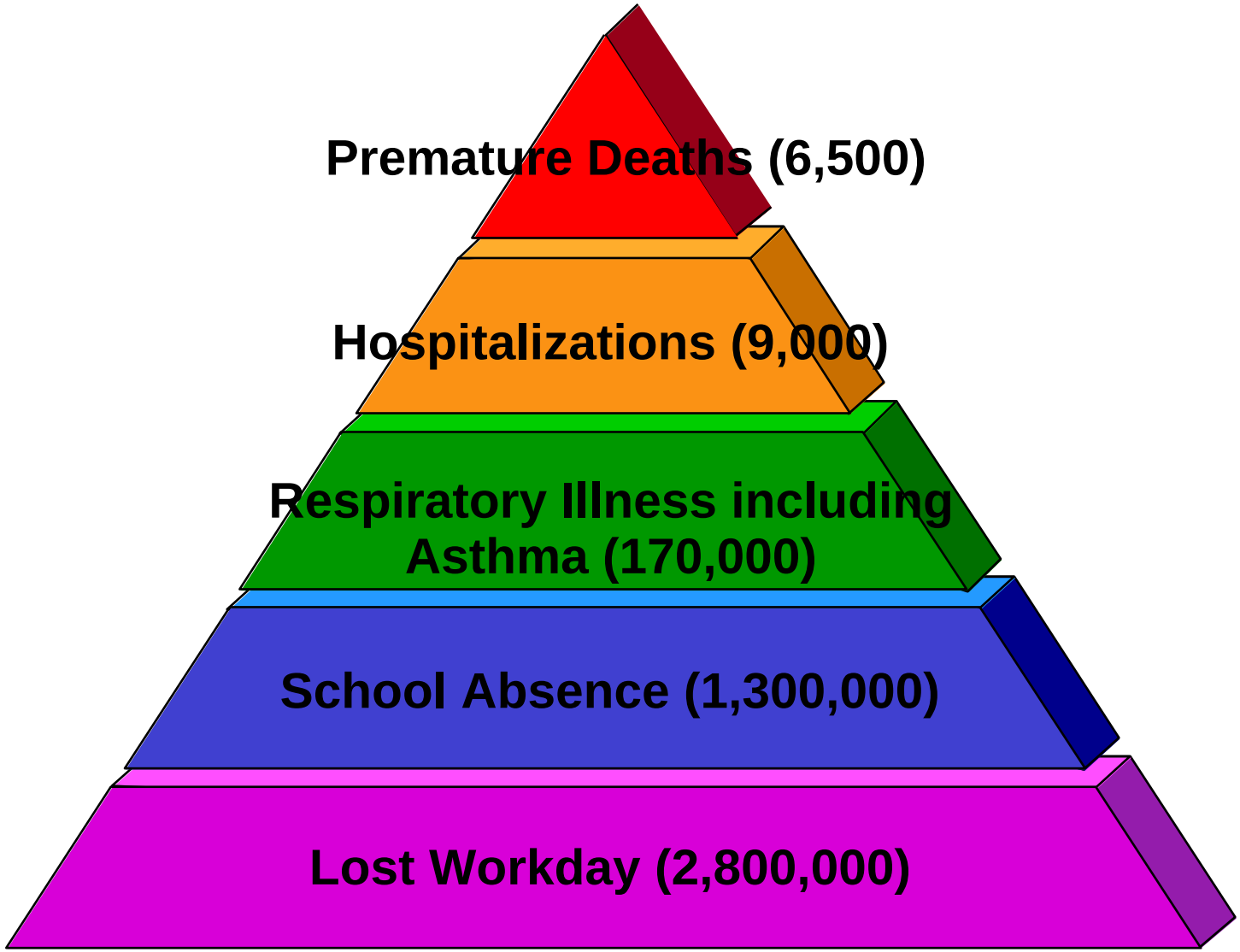
Overview

- Epidemiology and toxicology studies linking PM to cardiovascular disease (CVD)
  - Evidence for role of PM components in CVD
- NYU research
- Current research area
  - Role of particle size, season, region, and components in PM toxicity

PM and CVD

- Specific association of PM with:
  - ischemic heart disease
  - congestive heart failure
  - arrhythmias
- Heart failure deaths make up 10% of all cardiovascular deaths, but account for 30% of cardiovascular deaths related to PM exposure
- Of the 350,000 sudden cardiac deaths in the US per year, 60,000 are related to particulate air pollution

Mortality and Hospital Admissions are the “Tip of the Iceberg” of Pollution's Effects



CARB

Epidemiology

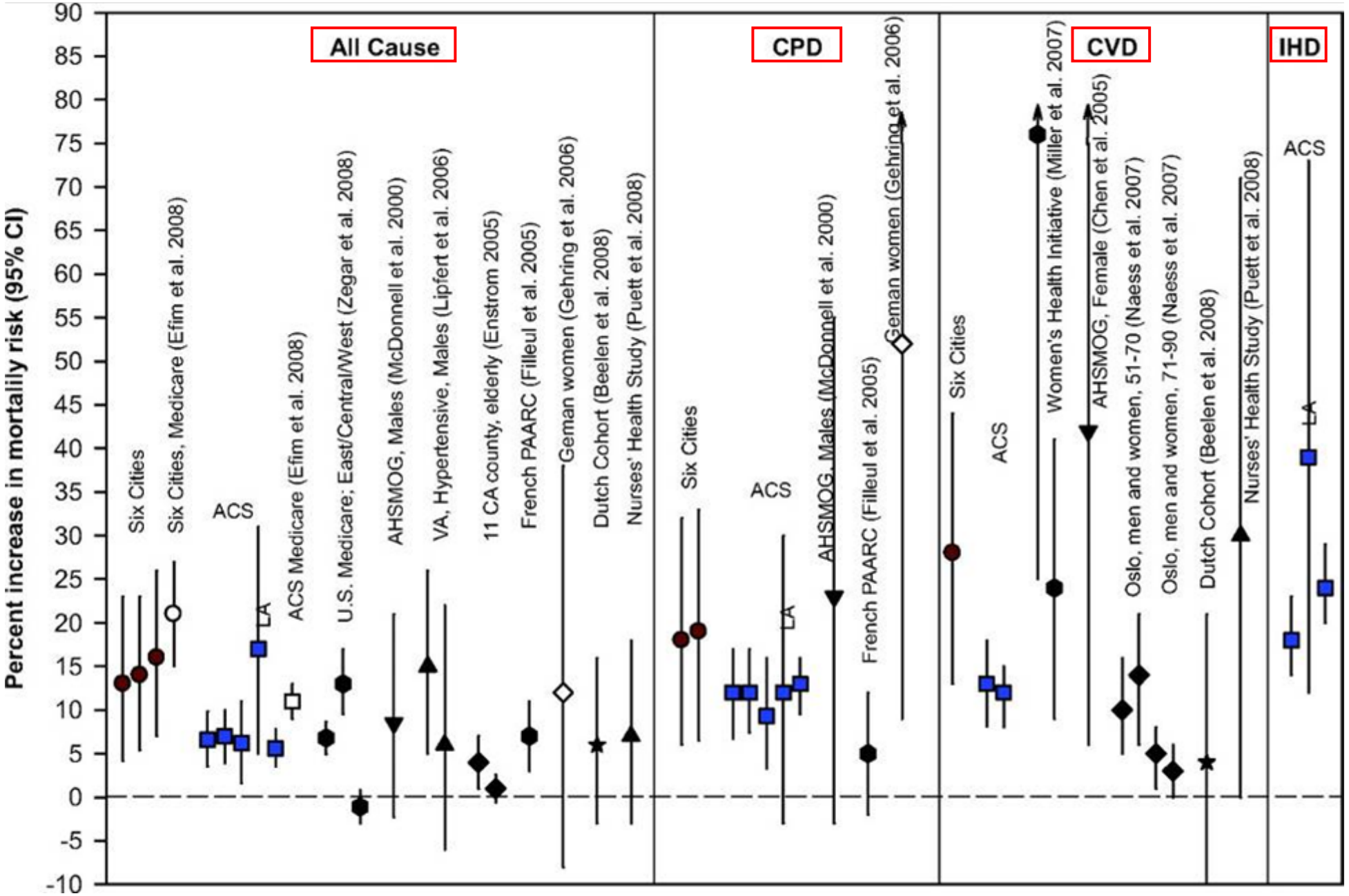
- Epidemiology studies linking PM to CVD
  - Evidence for acute and chronic effects
  - Evidence for role of PM components in CVD

Acute Effects – Time Series Epidemiology

- Throughout the U.S. and Europe
- California

Risk Estimates

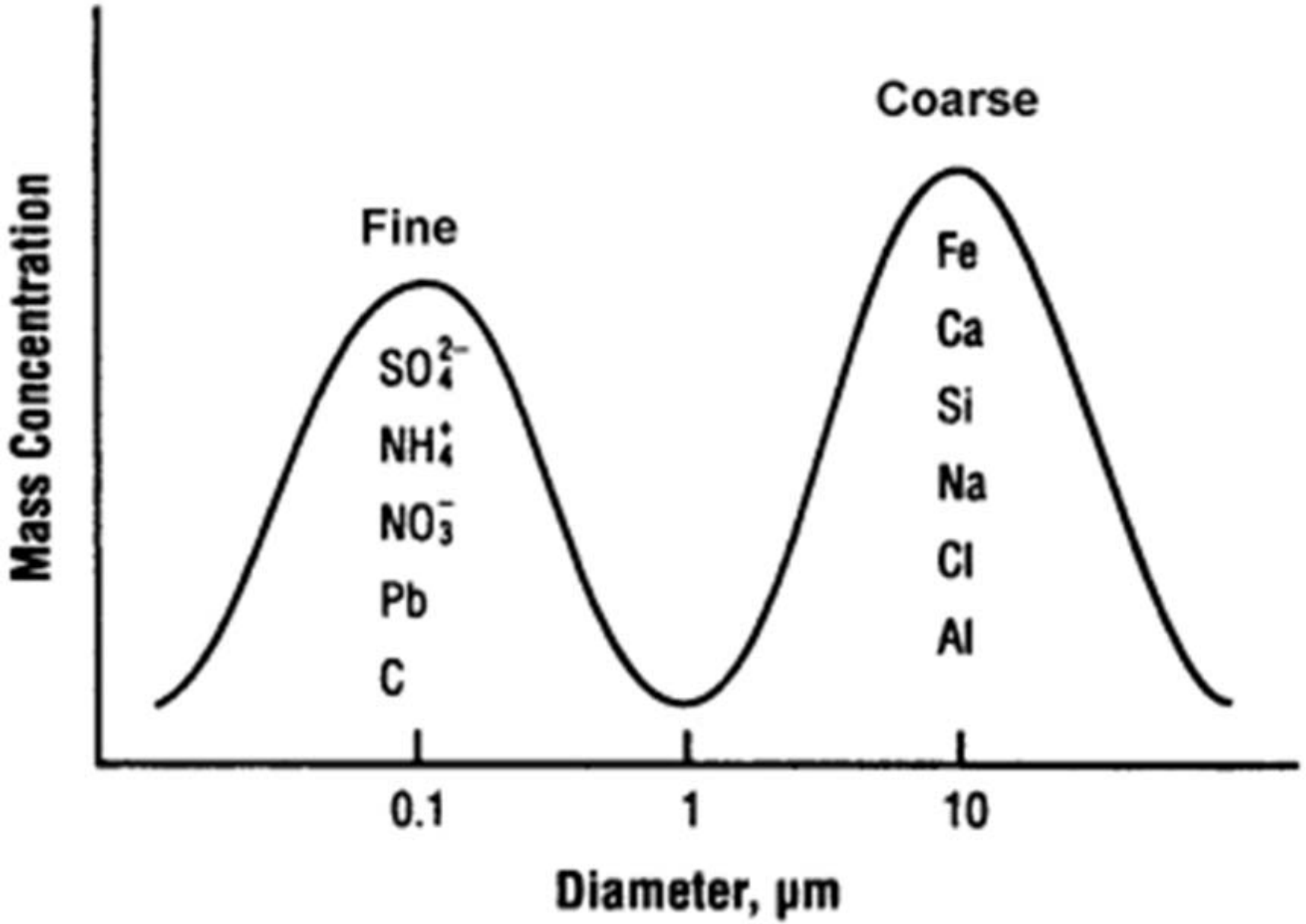
(per increment of 10 μg/m³ in PM2.5 or PM10)



Brook, 2010

Are There Specific Components of PM Associated with Its Adverse Effects?

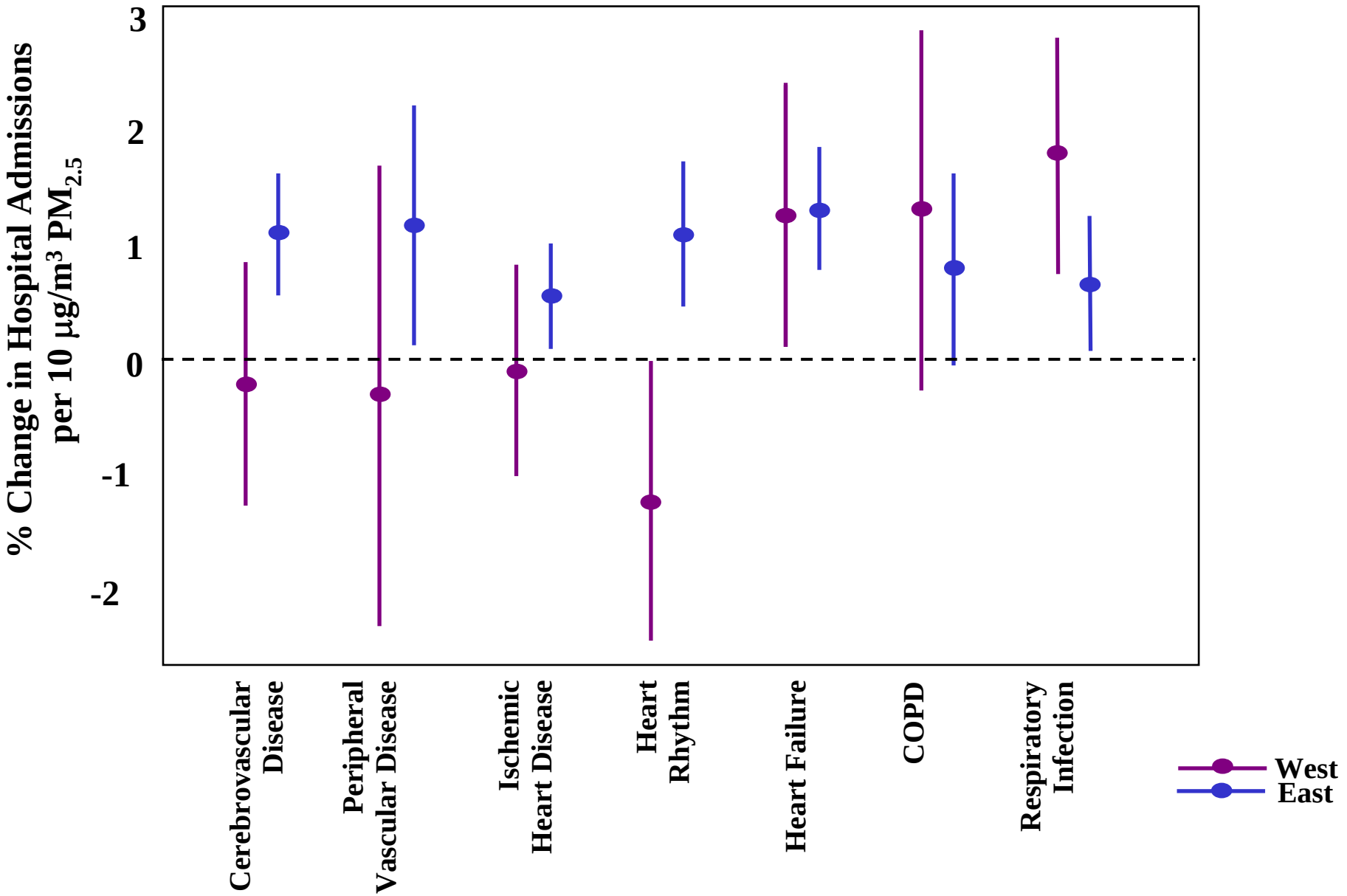
- **Different chemical components vary by PM size**
- **PM size varies bydifferent sources**



Are There Regional Differences in PM's Effects?

- If so, it would imply a role for:
  - Source
  - Components

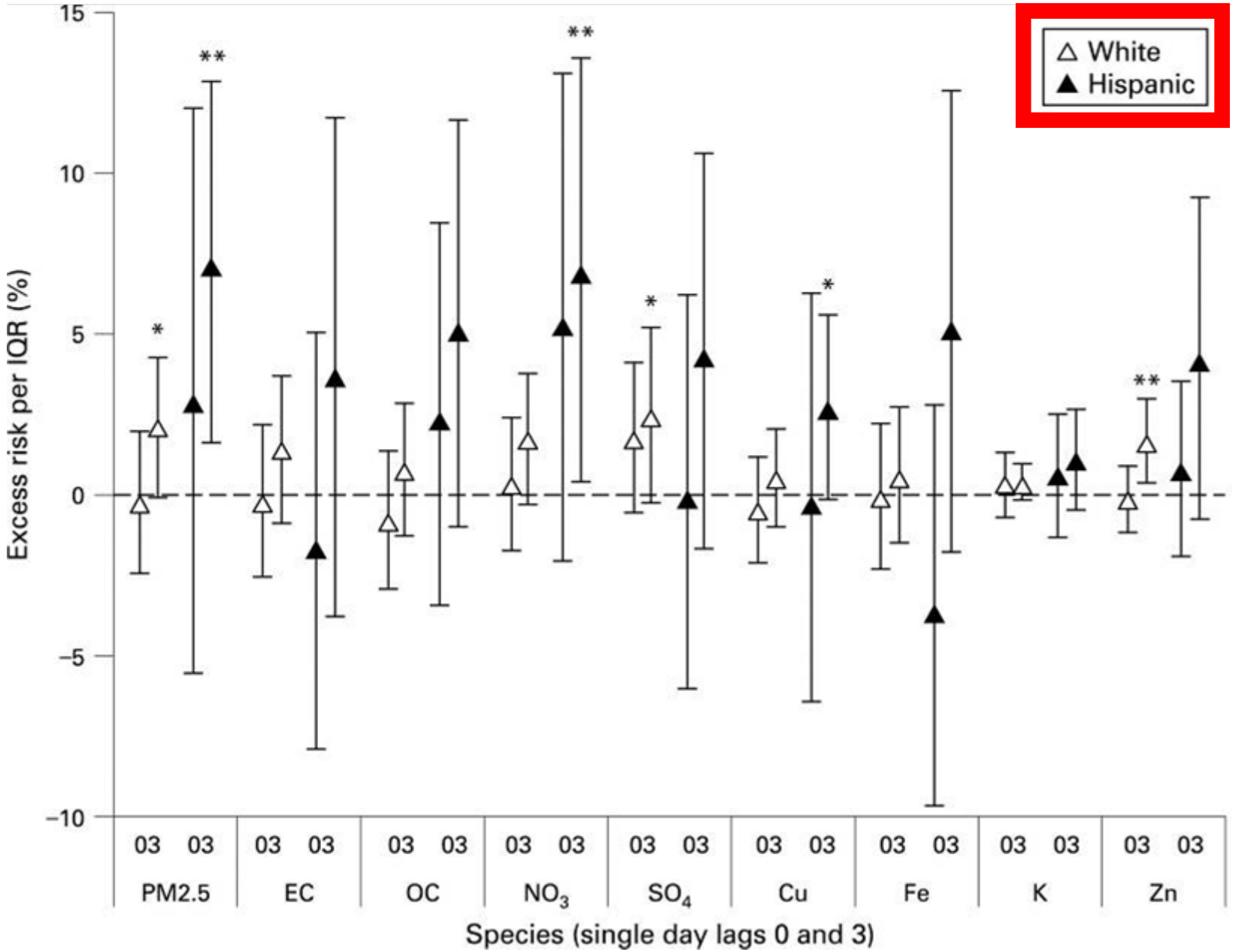
$PM_{2.5}$ and Medicare Hospital Admissions



Dominici, *JAMA* 2006

Excess Risk of Cardiovascular Mortality in CA

(interquartile range increase in PM2.5 mass and selected PM2.5 components)



Ostro B D, 2008

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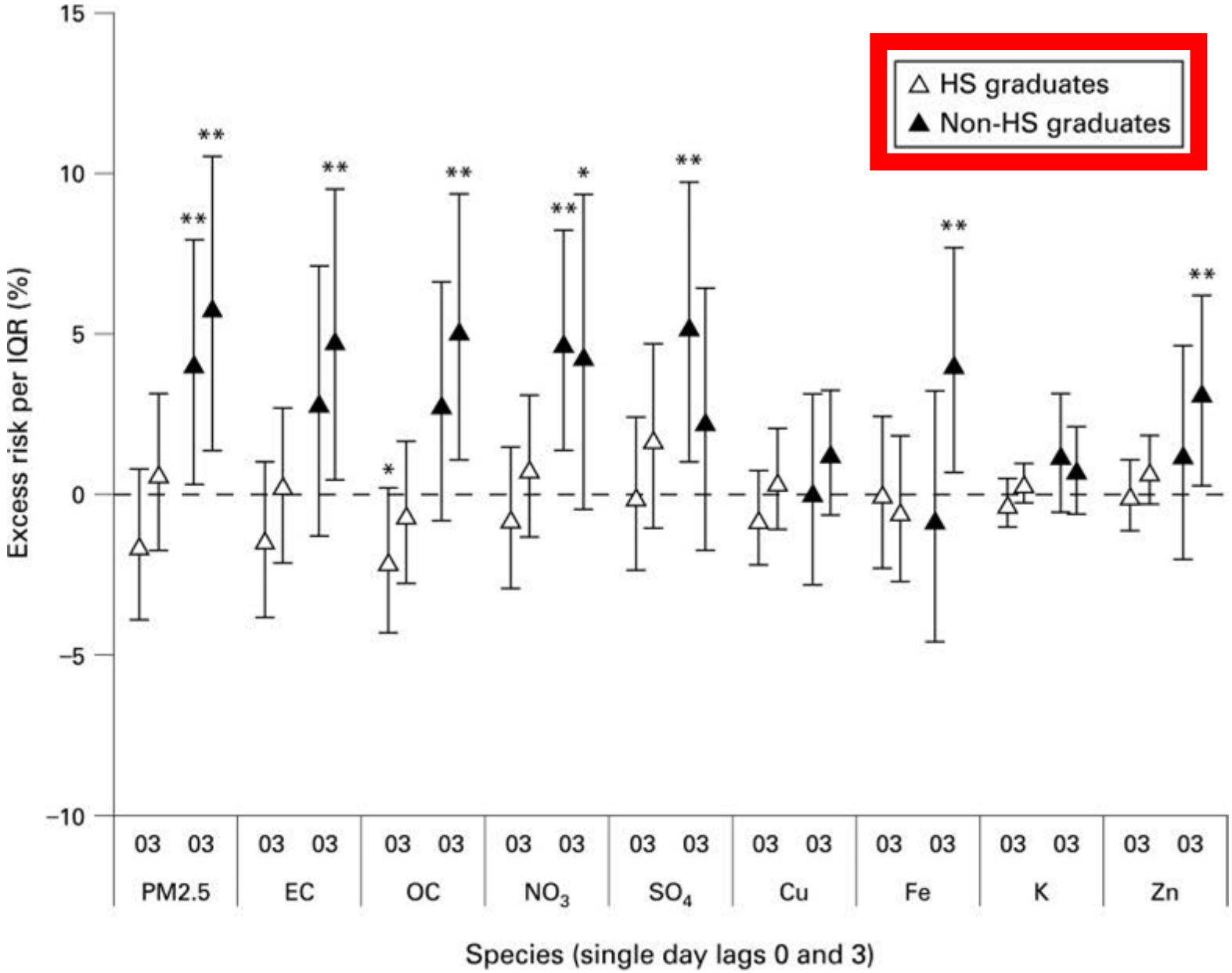
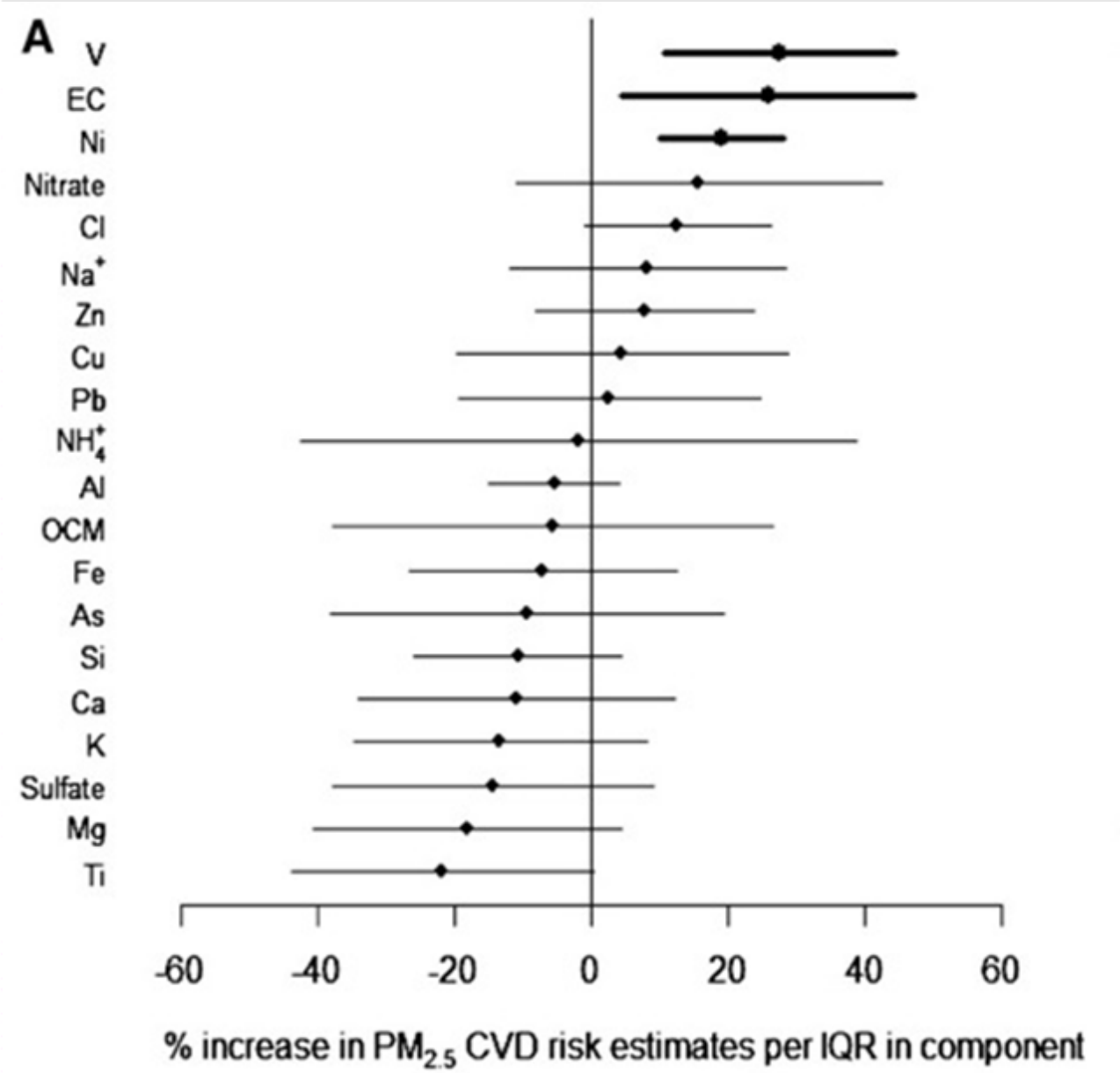


Ostro B D, 2008

Percent increase in health effects estimates for PM2.5 lag 0 and risk of cardiovascular hospitalizations per IQR increase in the fraction of PM2.5 total mass for each component



Bell M, 2009

Chronic Effects - Epidemiology

PM and Carotid Intima-Media Thickness

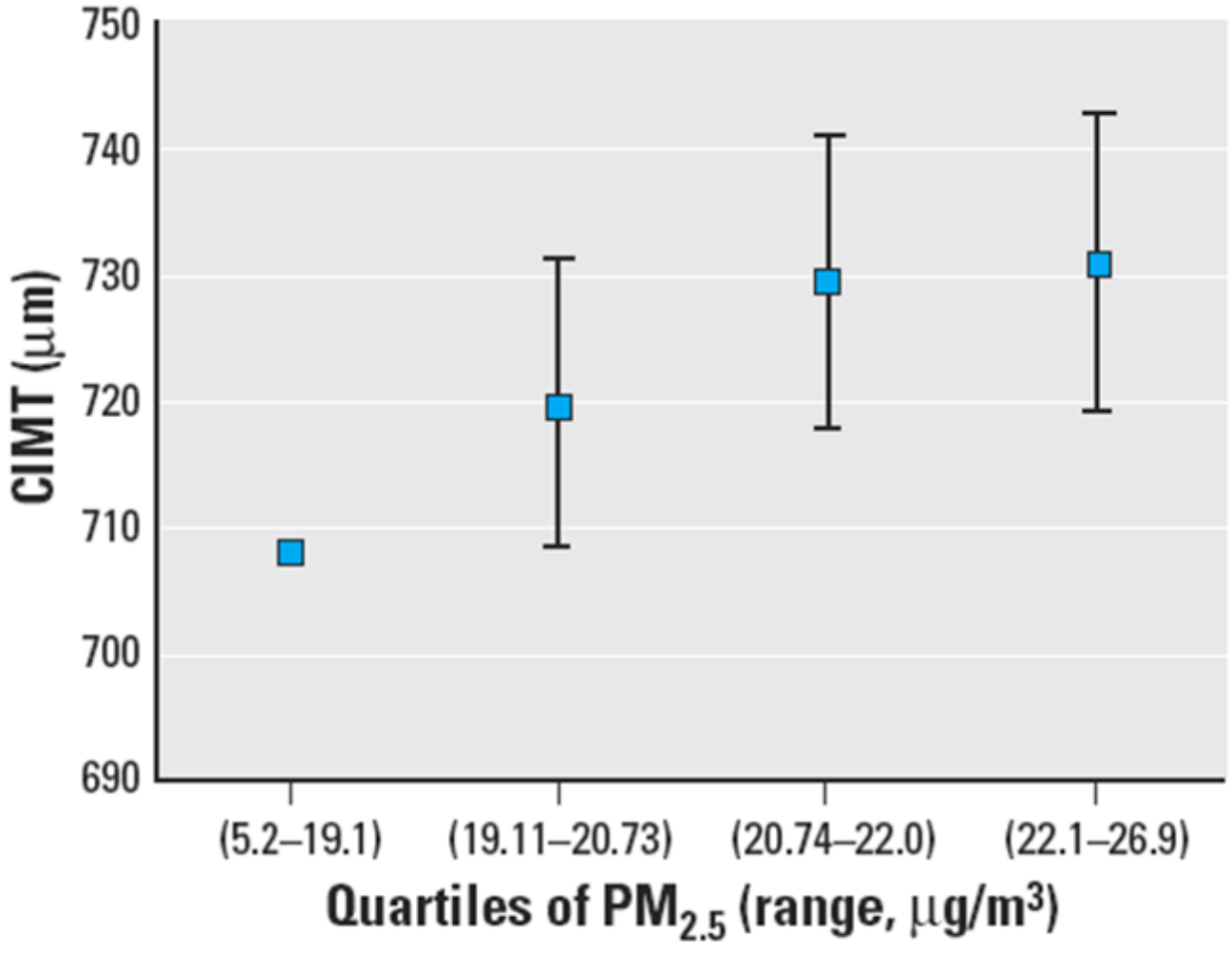
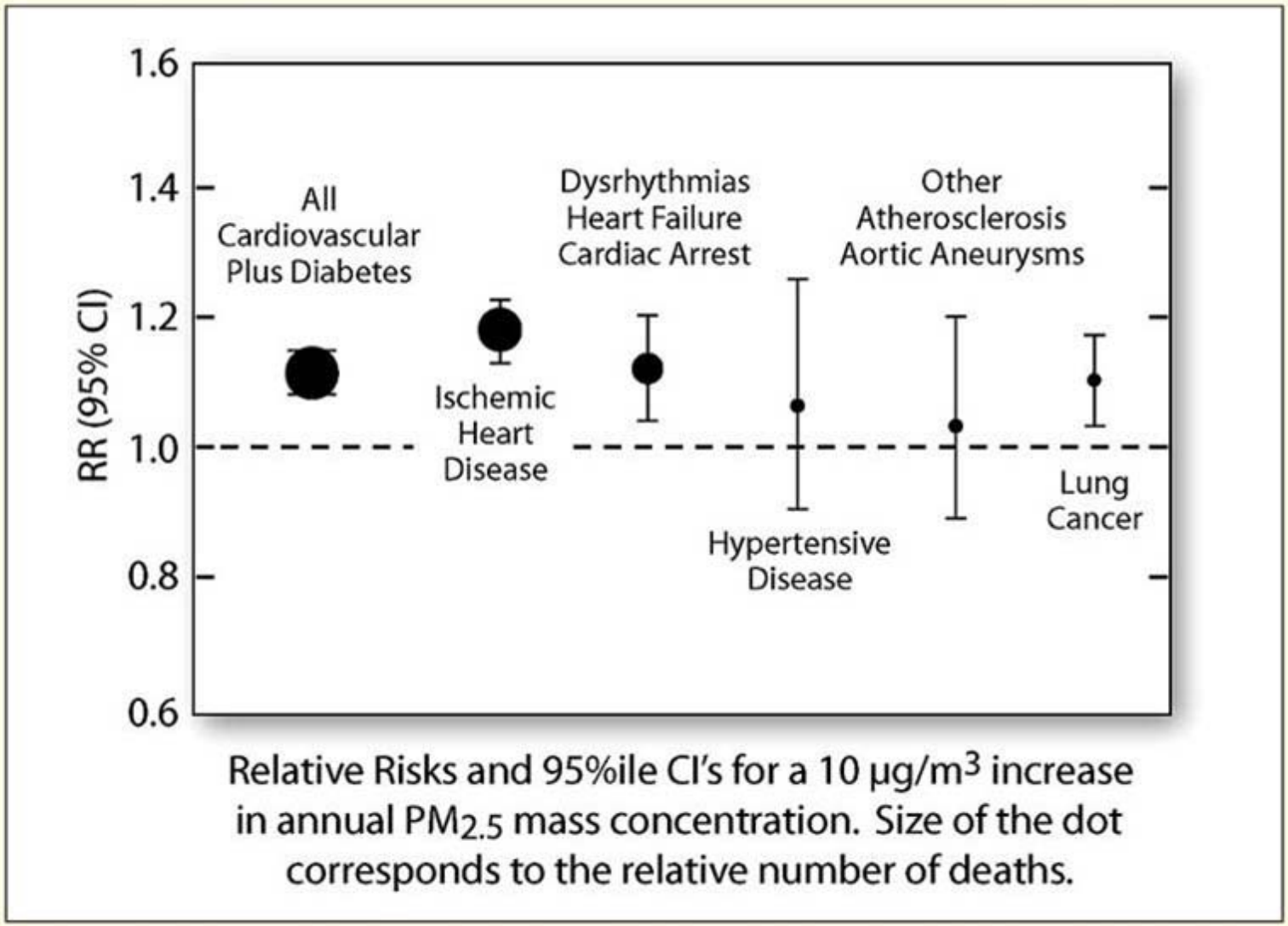


Figure 2. Mean CIMT ± 1 SE among quartiles of the $PM_{2.5}$ distribution. The *y*-axis shows mean CIMT levels at the population average of the adjustment covariates (age, sex, education, and income). The first quartile is the reference group.

Cardiovascular Mortality and Lung Cancer Affected by Long-Term Fine Particulate Matter



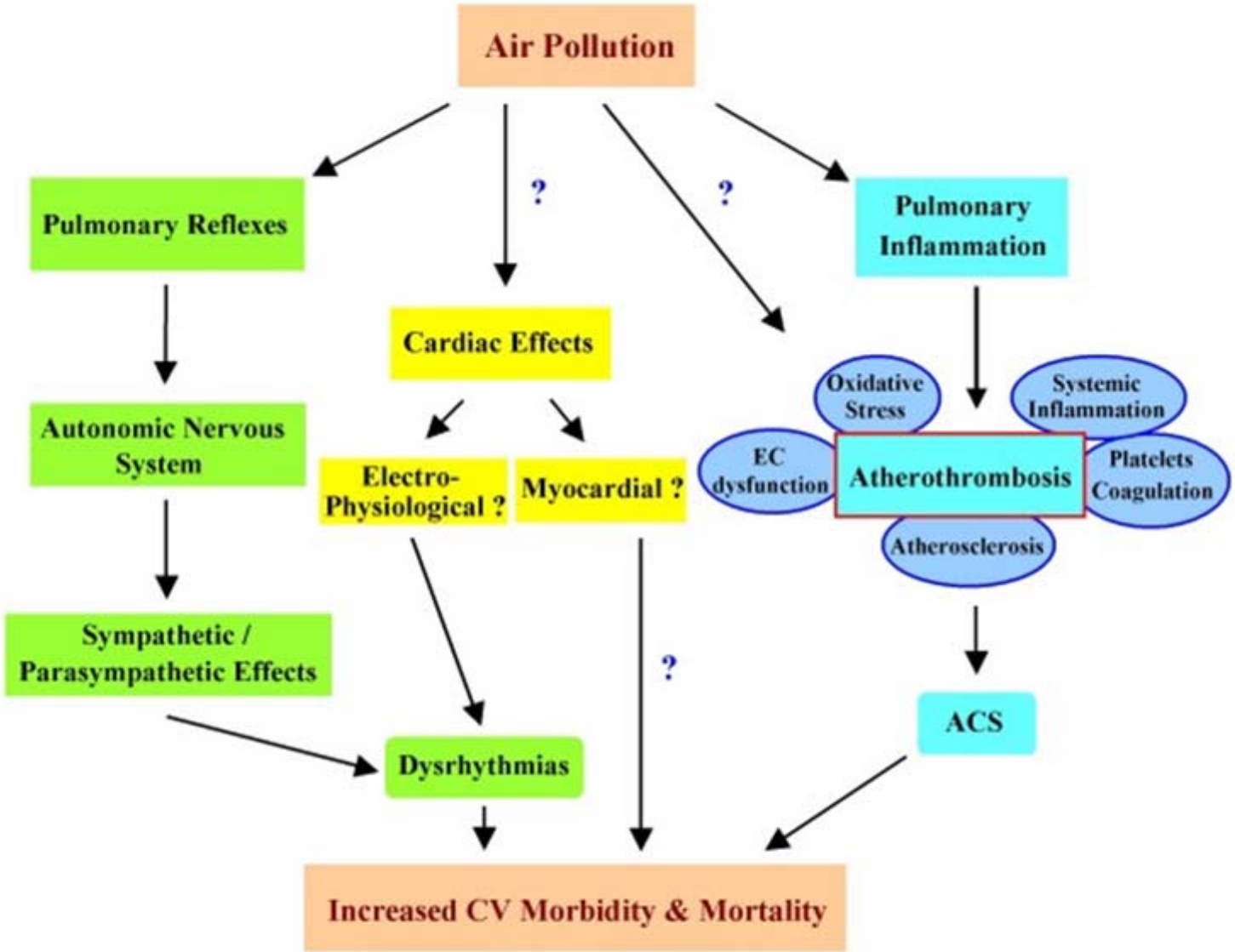
Relative Risks and 95%ile CI's for a 10 μg/m^3 increase in annual $PM_{2.5}$ mass concentration. Size of the dot corresponds to the relative number of deaths.

Pope, JAMA, 2002

Range of Cardiovascular effects of PM

- Disruption of autonomic nervous system activity by decreased heart rate variability
- Arterial vasoconstriction
- Cardiac arrhythmias in patients with implantable defibrillators
- Cardiac events such as myocardial infarction
  - Elevated concentration of $PM_{2.5}$ transiently elevate the risk of MI within a few hours and 1 day after exposure
- Exacerbation of ST-segment changes in animal models of myocardial infarction
- Increased generation of CRP, white cell counts, fibrinogen, and plasma viscosity
- Increased CIMT

Potential Pathways for PM's Effect on Cardiovascular System



Bottom Line

- How can PM cause adverse cardiovascular effects even in the absence of pulmonary effects?

Sub-clinical pulmonary effects

or

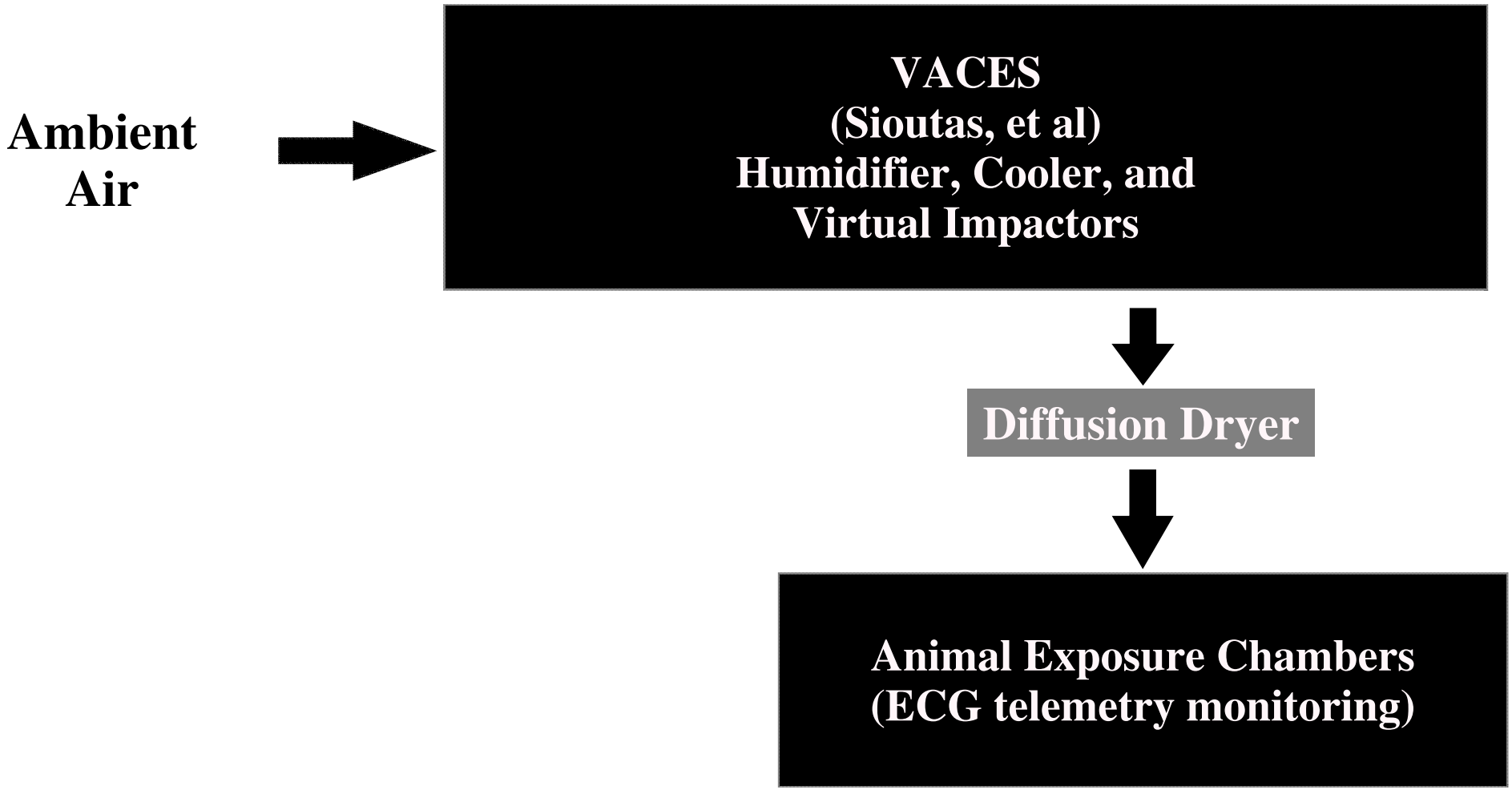
Soluble factors (or ultrafine PM) are transported to the cardiovascular system

NYU Research Collaborations

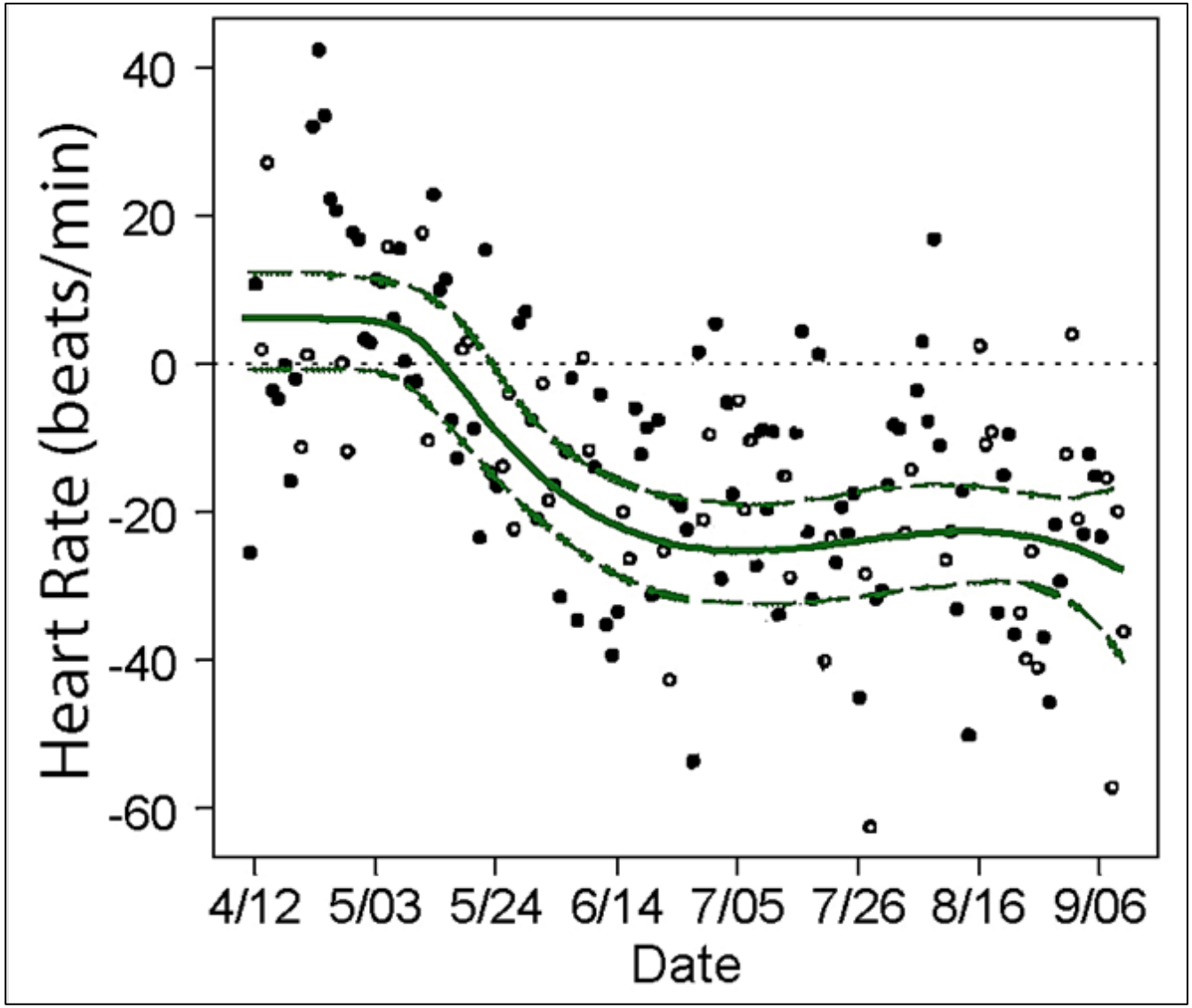
- Does long term exposure to $PM_{2.5}$ cause cumulative damage to cardiovascular, pulmonary, and other tissues?

- What is the relationship between the temporal variations in PM concentration or composition and acute changes in cardiac function?

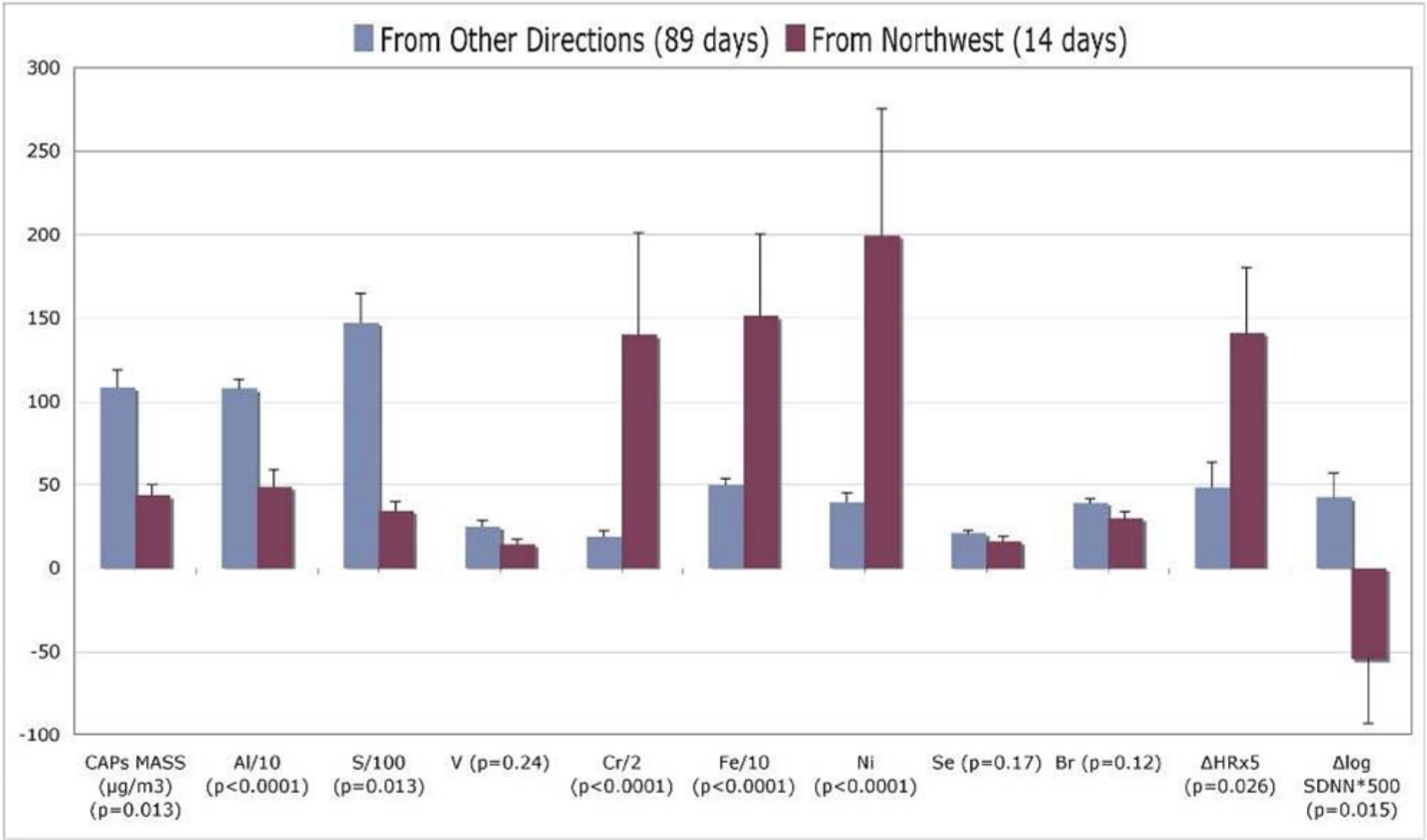
Ambient Particle Concentrating and Animal Exposure System



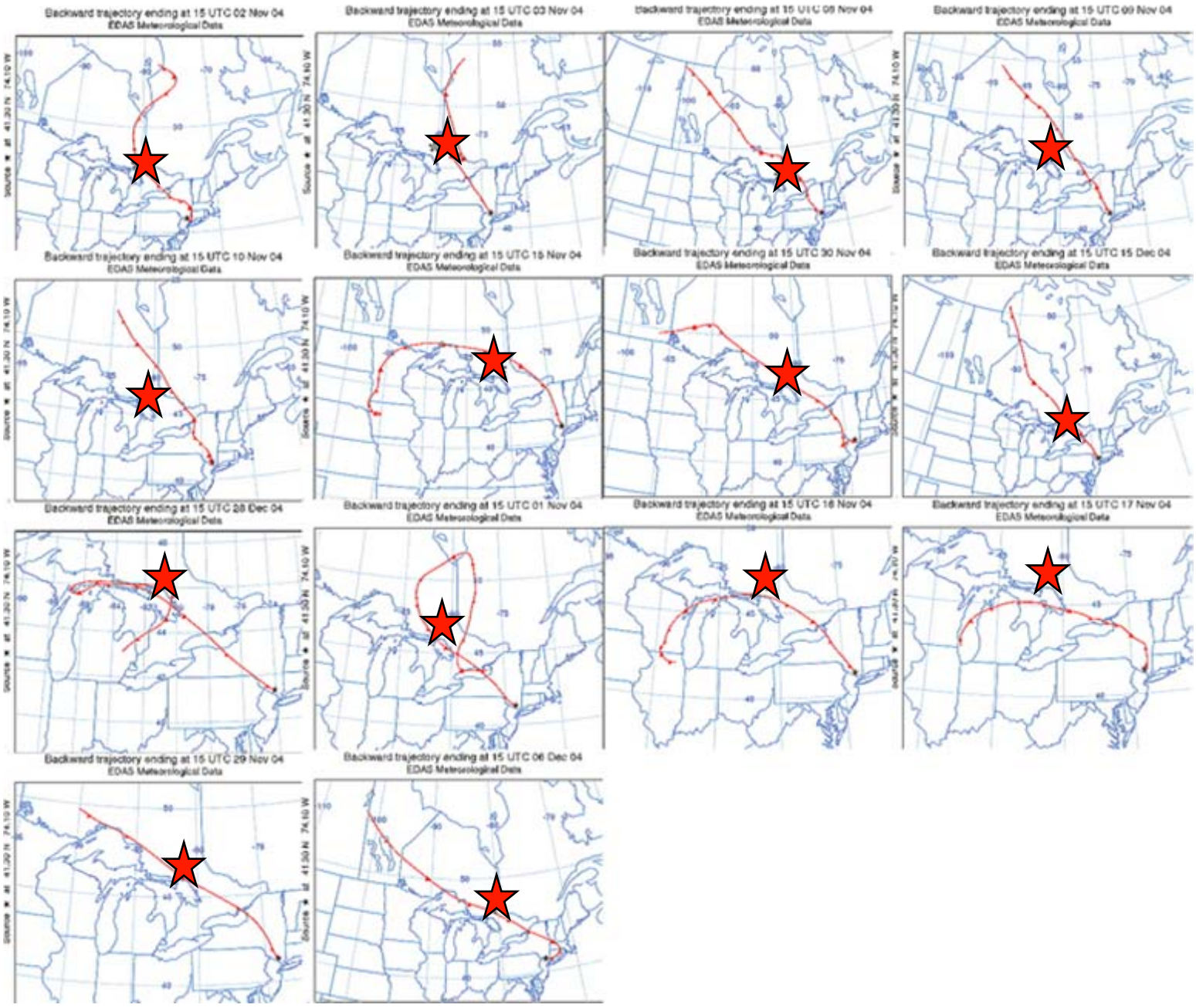
Effect of Subchronic Exposures to Concentrated PM on Heart Rate in Mice



Unusual changes in HR and HRV were associated with Ni, Cr, and Fe in Concentrated PM

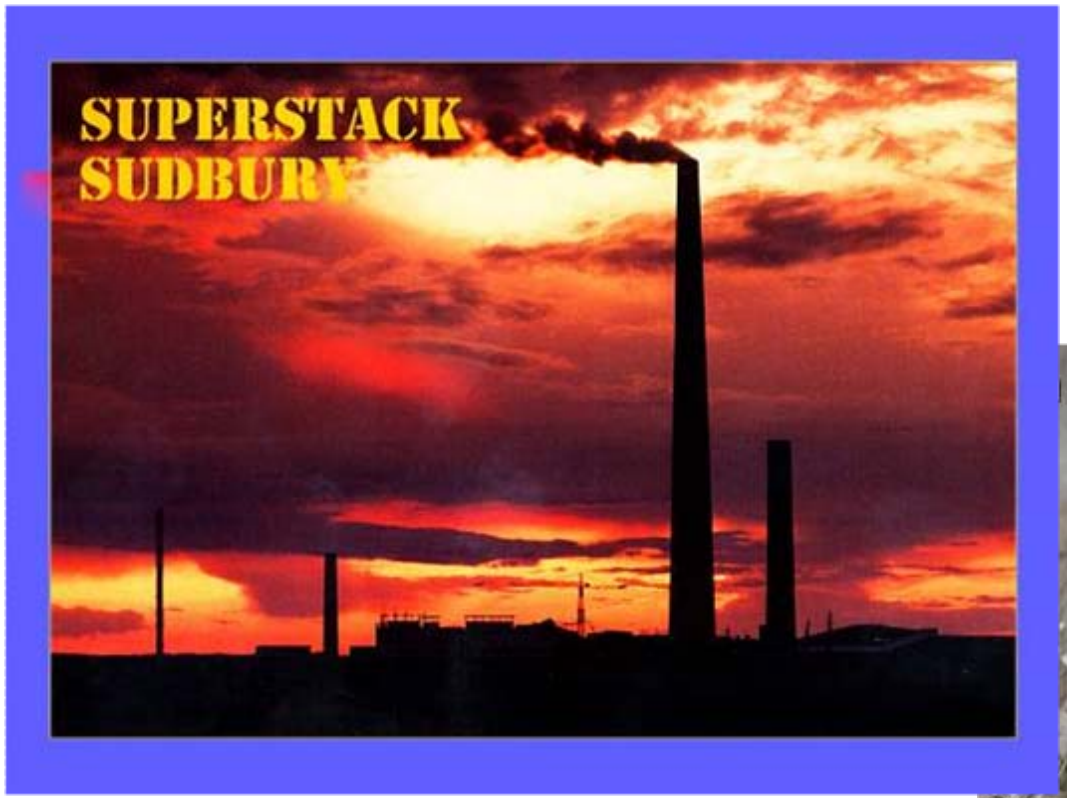


PM that caused changes in HR and HRV was coming from the Northwest



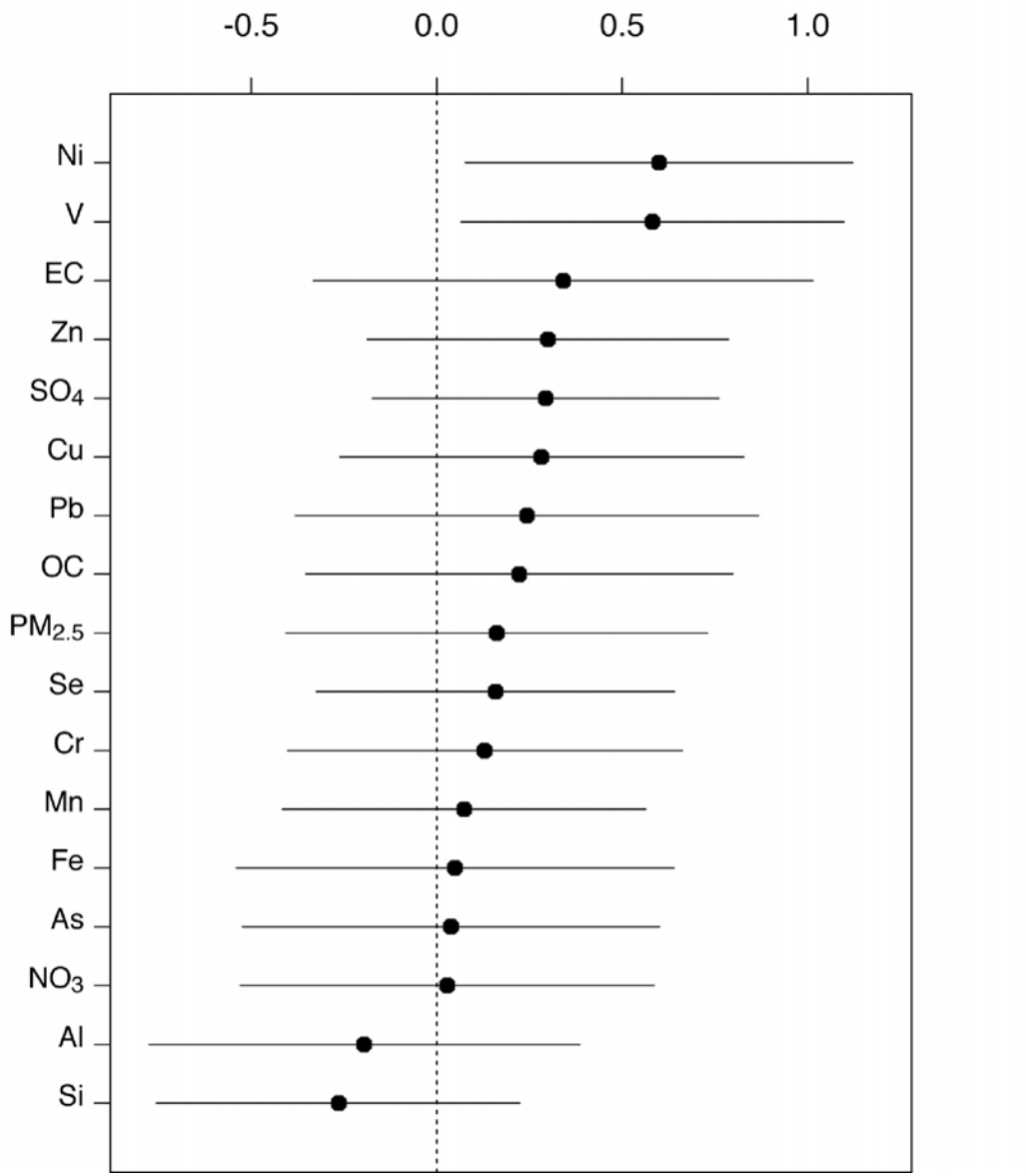
Super Stack

Sudbury, Ontario Canada



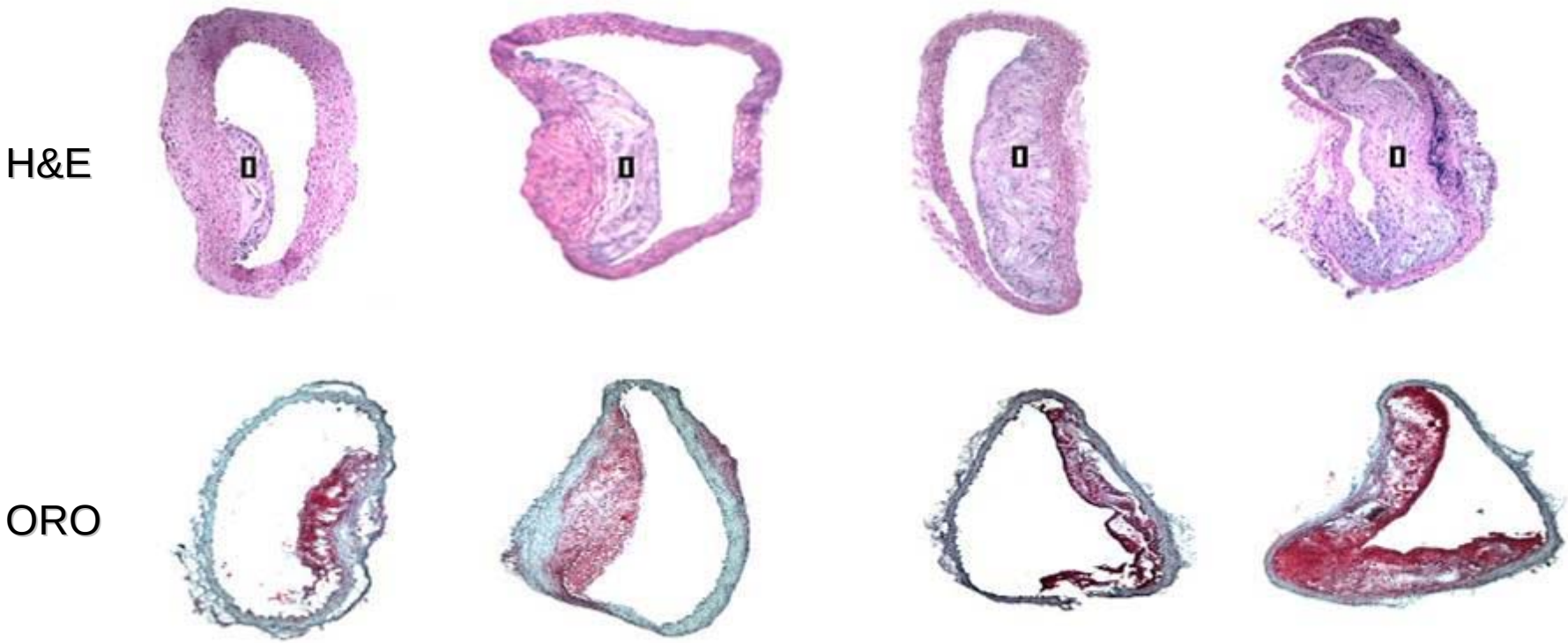
Does the effect of nickel and vanadium hold up in an epidemiology study?

Nickel and Vanadium were only $PM_{2.5}$ components significantly associated with daily PM_{10} mortality coefficients for 60 U.S. Cities



Lippmann, 2006

CAPs exposure enhanced atherogenesis in mice fed a high fat chow, with accompanied increases in lipid content (ORO staining)

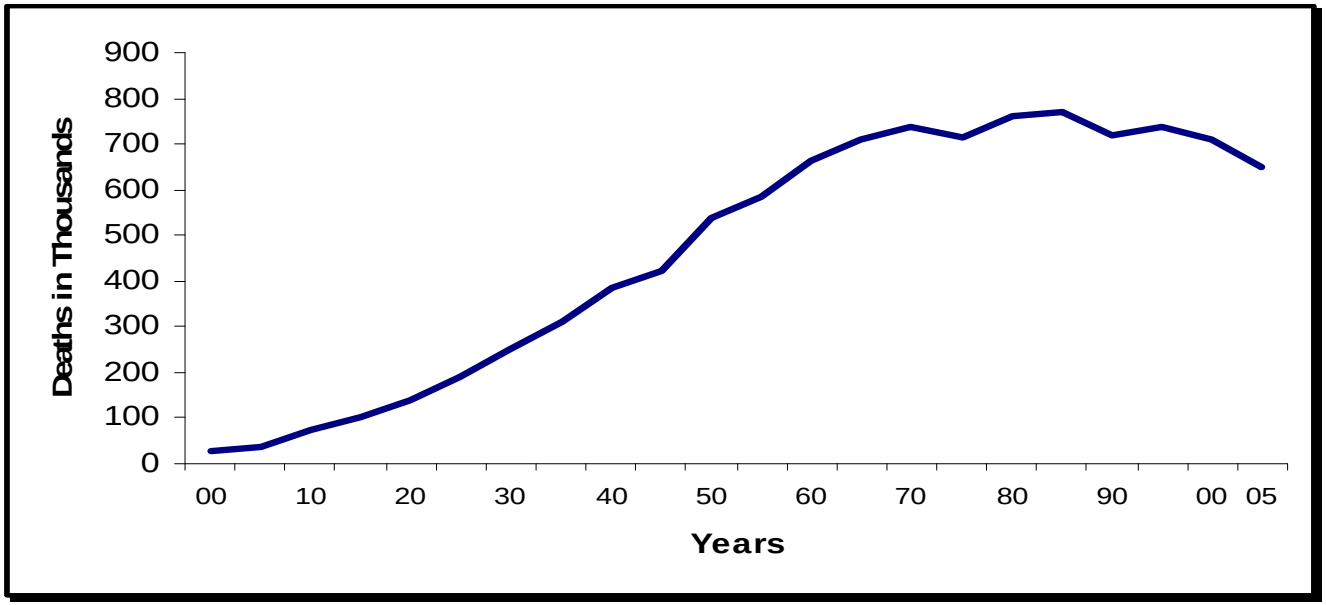


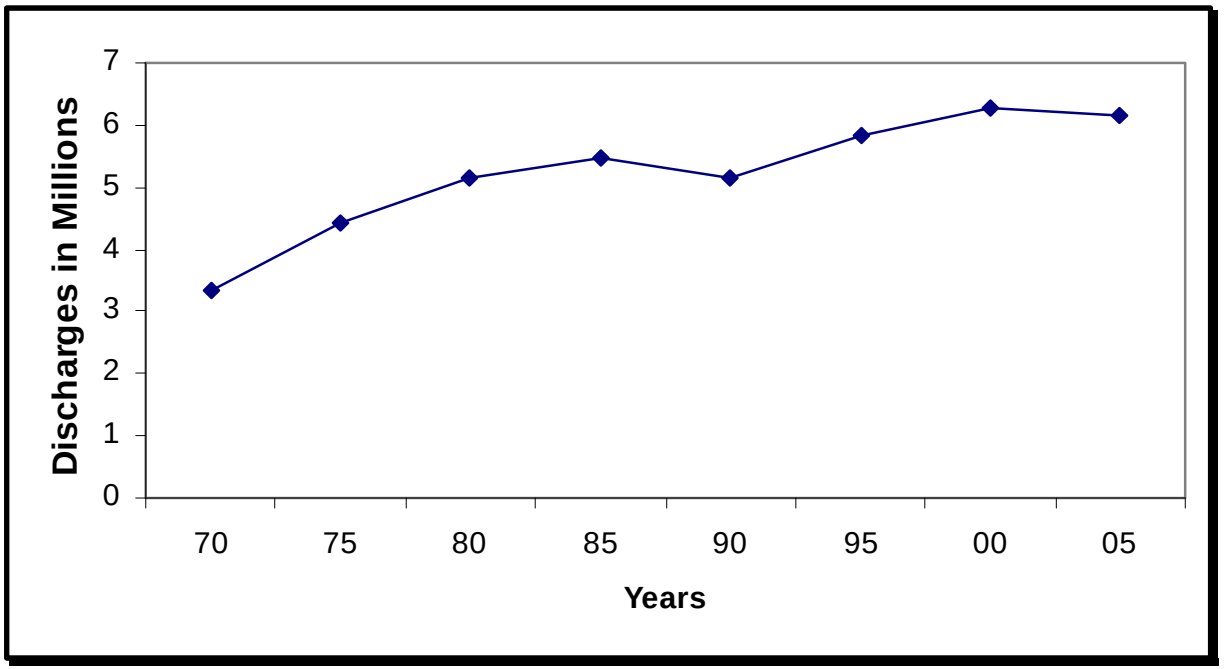
Summary

PM is associated with significant increases in adverse cardiovascular effects

But how important are these changes?

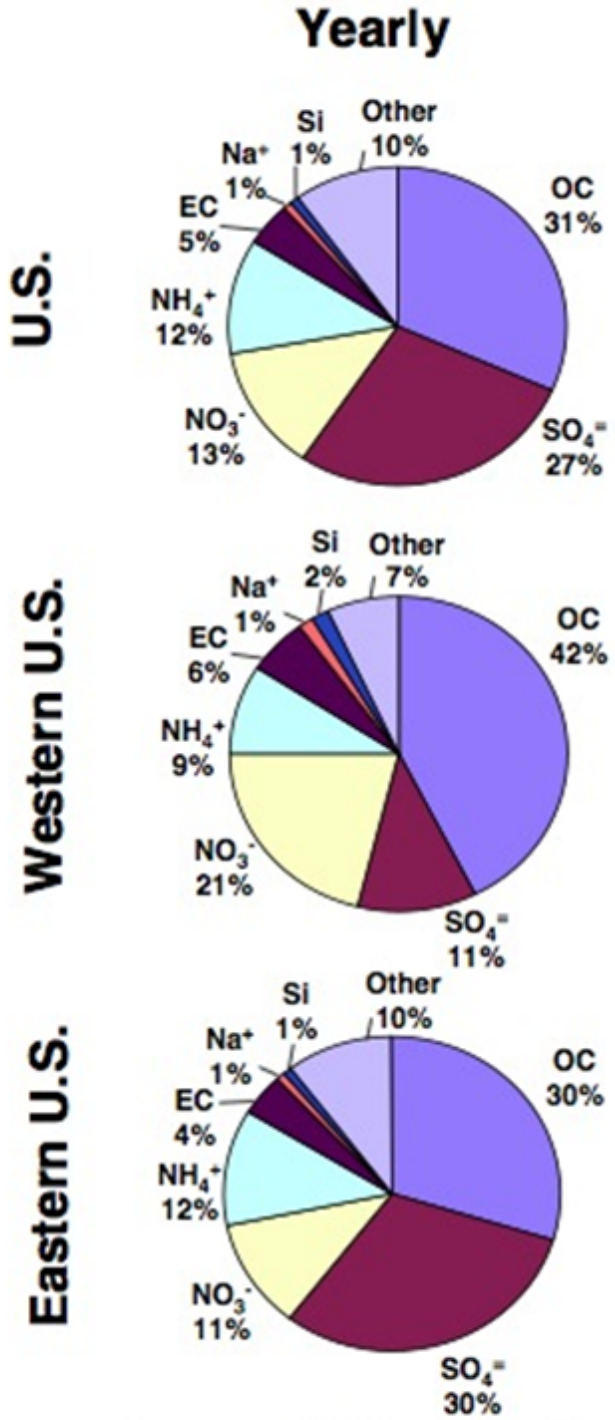
Why is a PM-driven small per cent increase in cardiovascular morbidity and mortality so important?



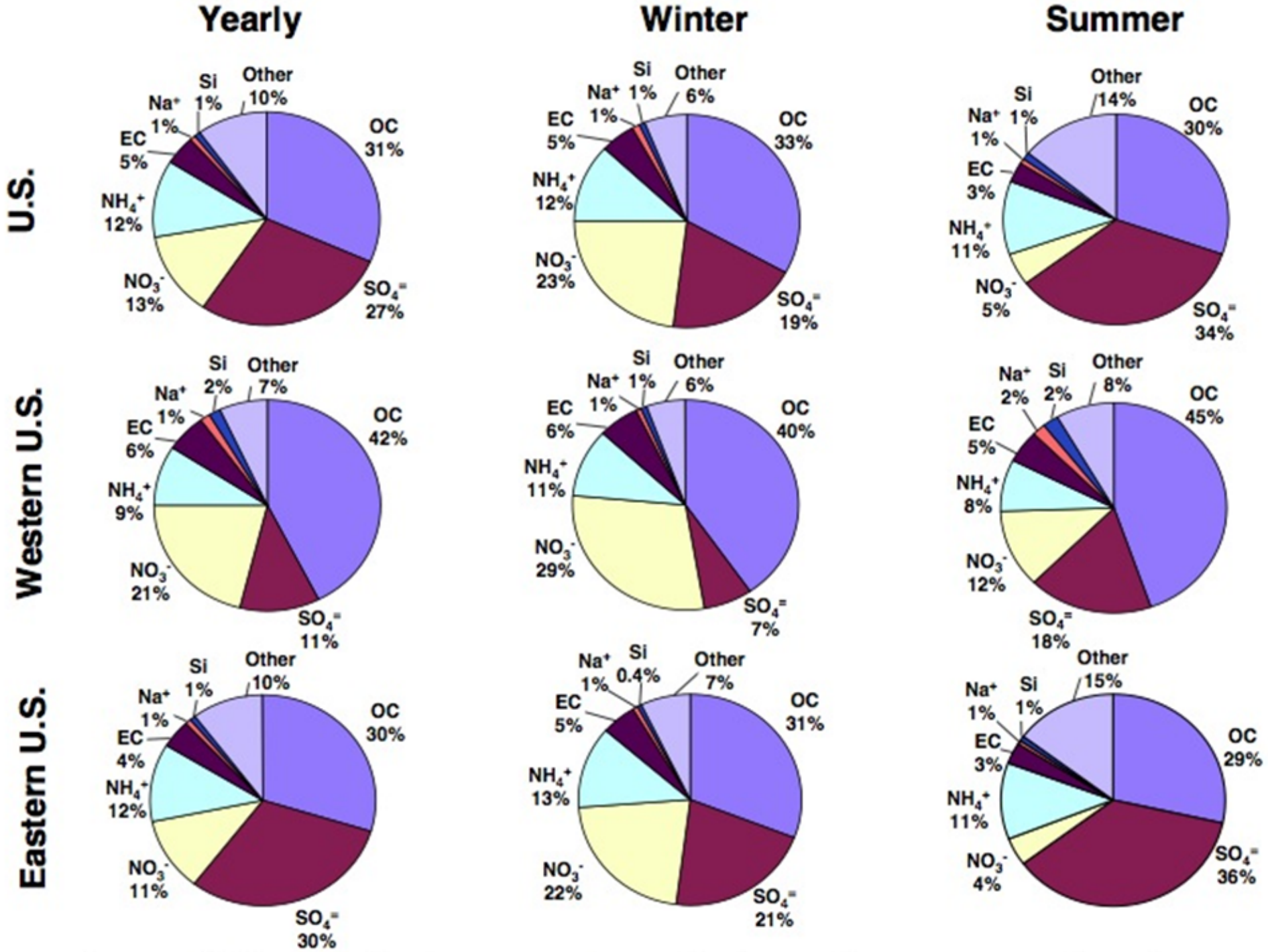


Deaths and hospital discharges from diseases of the heart (U.S.: 1900–2005).

Current Research - Gordon Lab



Percent of $PM_{2.5}$ composition by component for yearly, winter, and summer averages, by region



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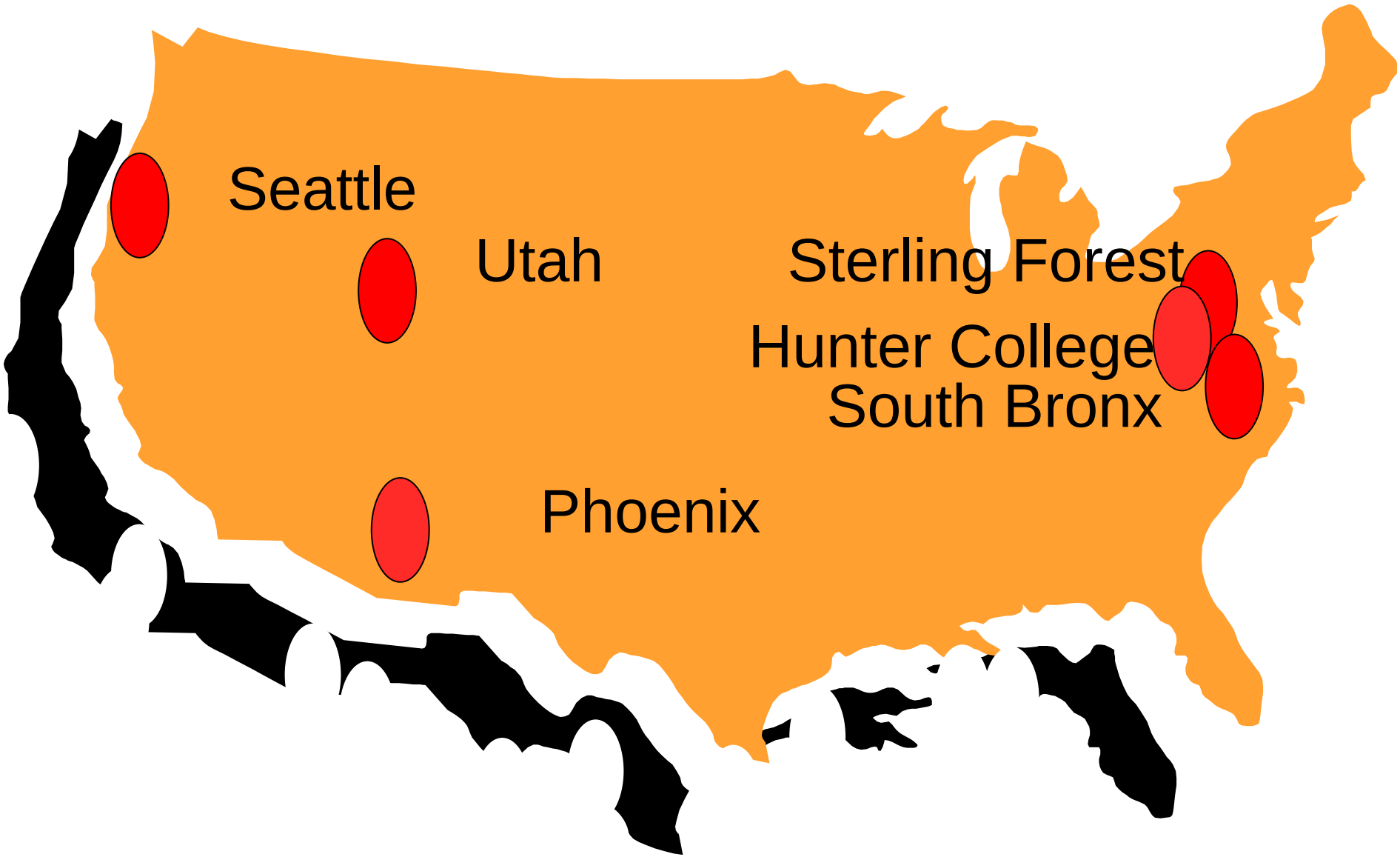
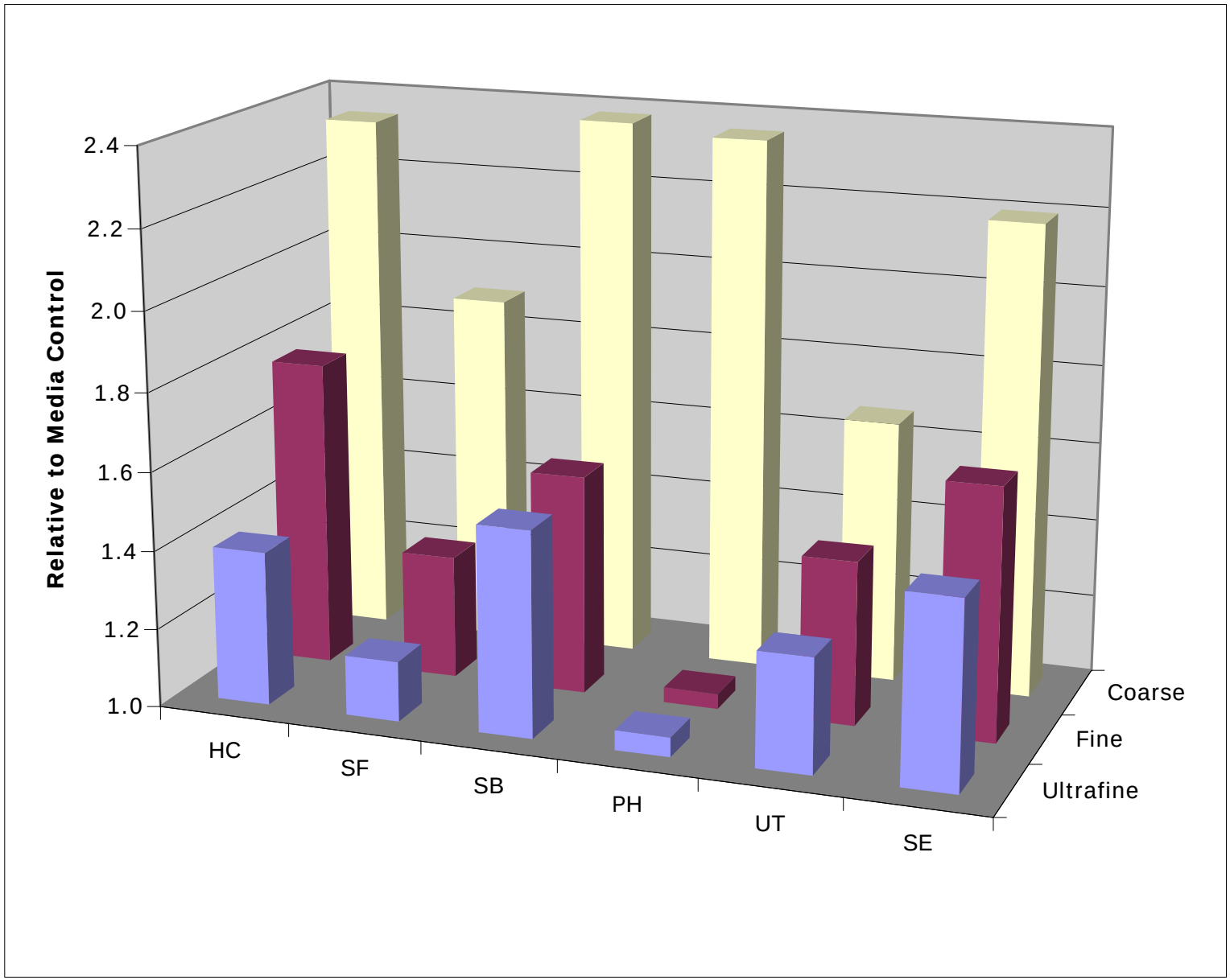
The Multi-City Ambient PM Study (MAPS)



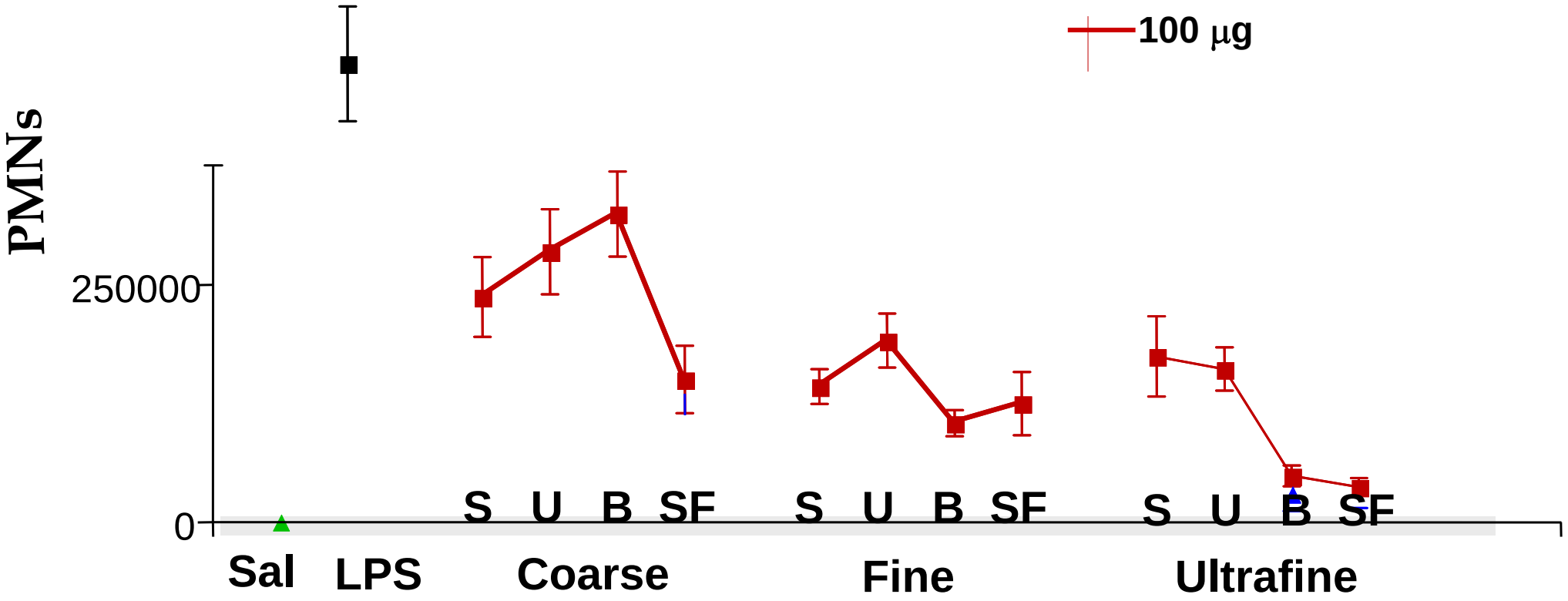
Effect of PM on Reactive Oxygen Species Production in Airway Epithelial Cells



Dose = 50 µg/ml

HC: Hunter College
SF: Sterling Forest
SB: South Bronx
PH: Phoenix
UT: Utah
SE: Seattle

Effect of Aspirated PM in Mice



S = Seattle
U = Utah
B = Bronx
SF = Sterling Forest

Gilmour, 2007

Comparative toxicity of coarse particles

PI: Terry Gordon

Co-I: Kaz Ito, Mort Lippmann, Lung Chi Chen

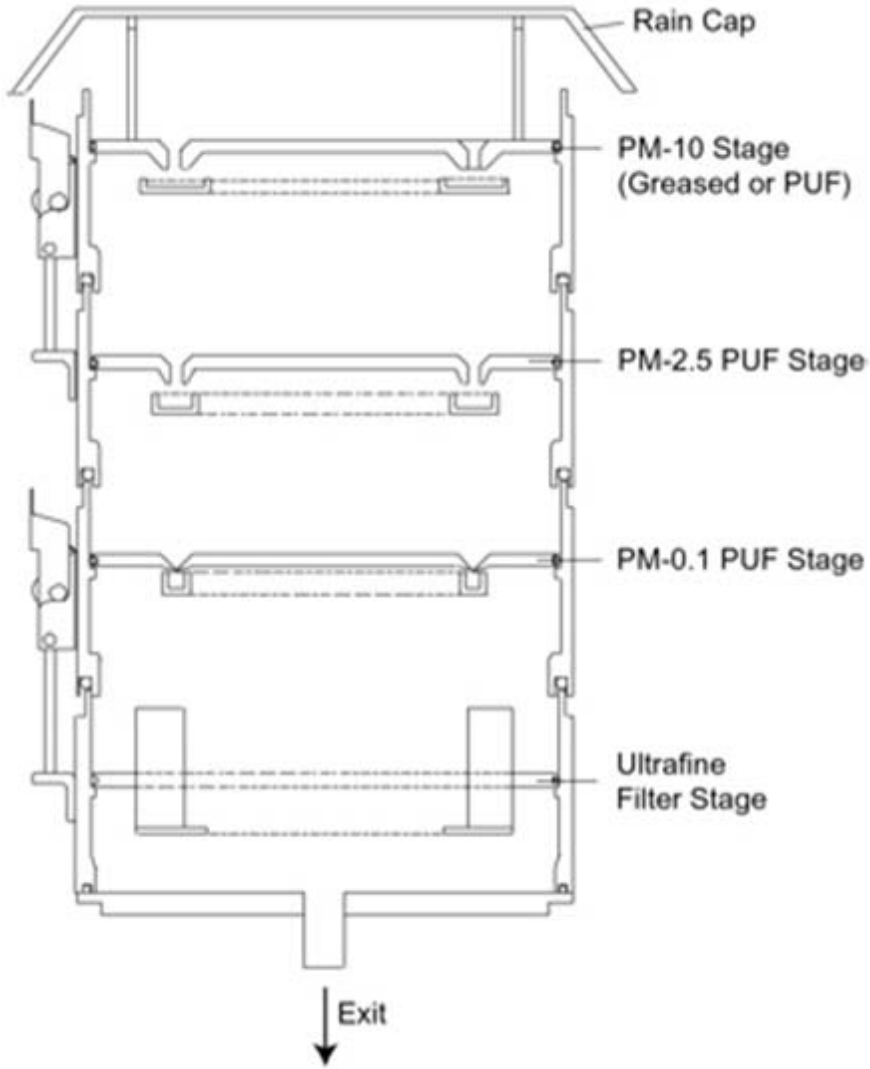
Objective

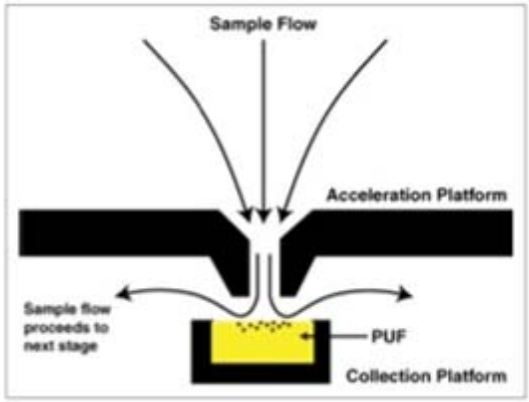
- To determine the contribution of coarse particles to the adverse effects associated with exposure to ambient PM
- We hypothesize that differences in the toxicity of coarse PM ($PM_{10-2.5}$) samples are due to the source contributions of the particles

Experimental Design

- Design was copied from European scientists (Netherlands/Germany)
- Measure the differential toxicity of coarse particles both *in vitro* and *in vivo*
- Identify whether coarse particles from urban and rural sources differ in toxicity.

Collection Apparatus



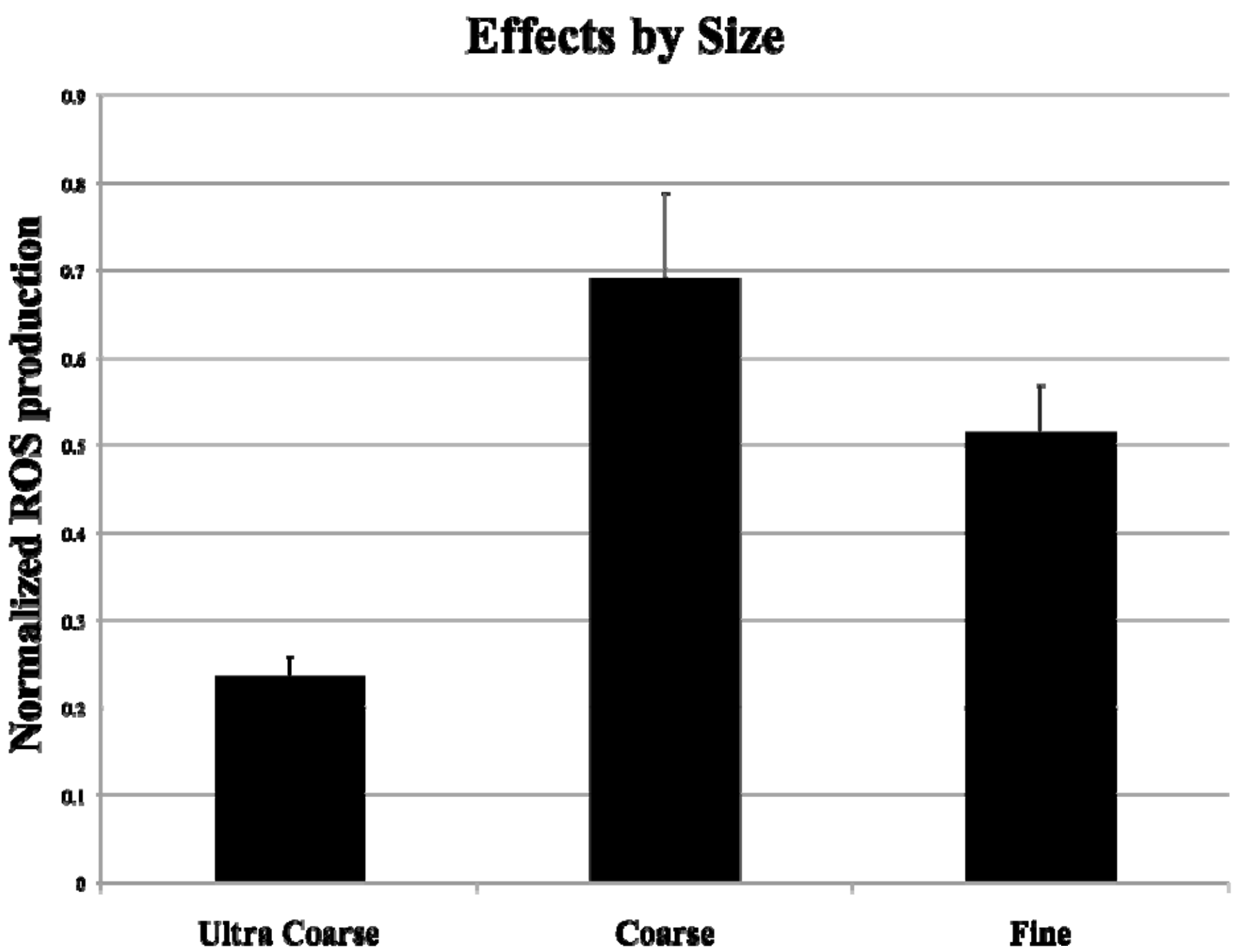


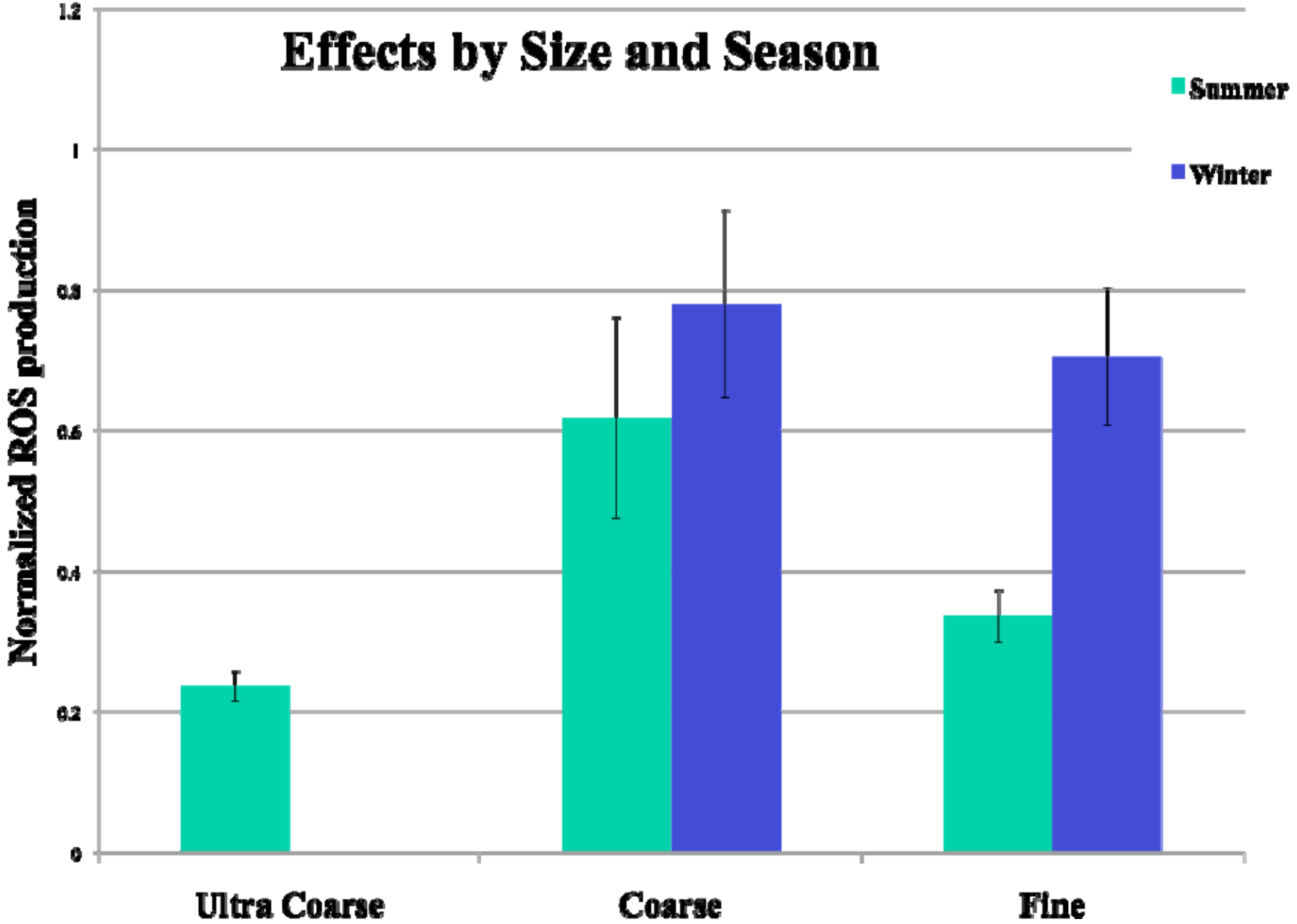
Foam Impaction Stage

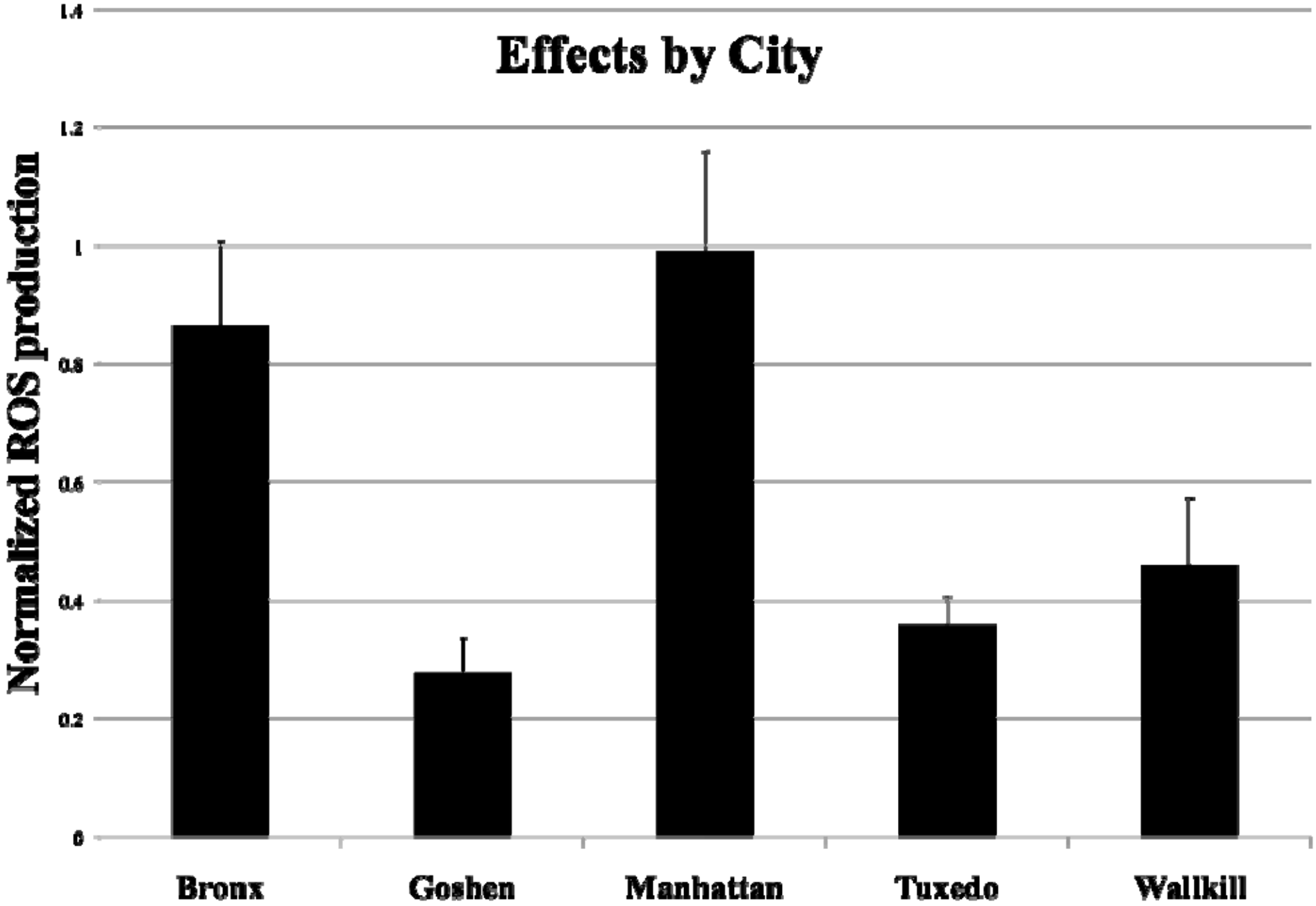
Study Design (cont….)

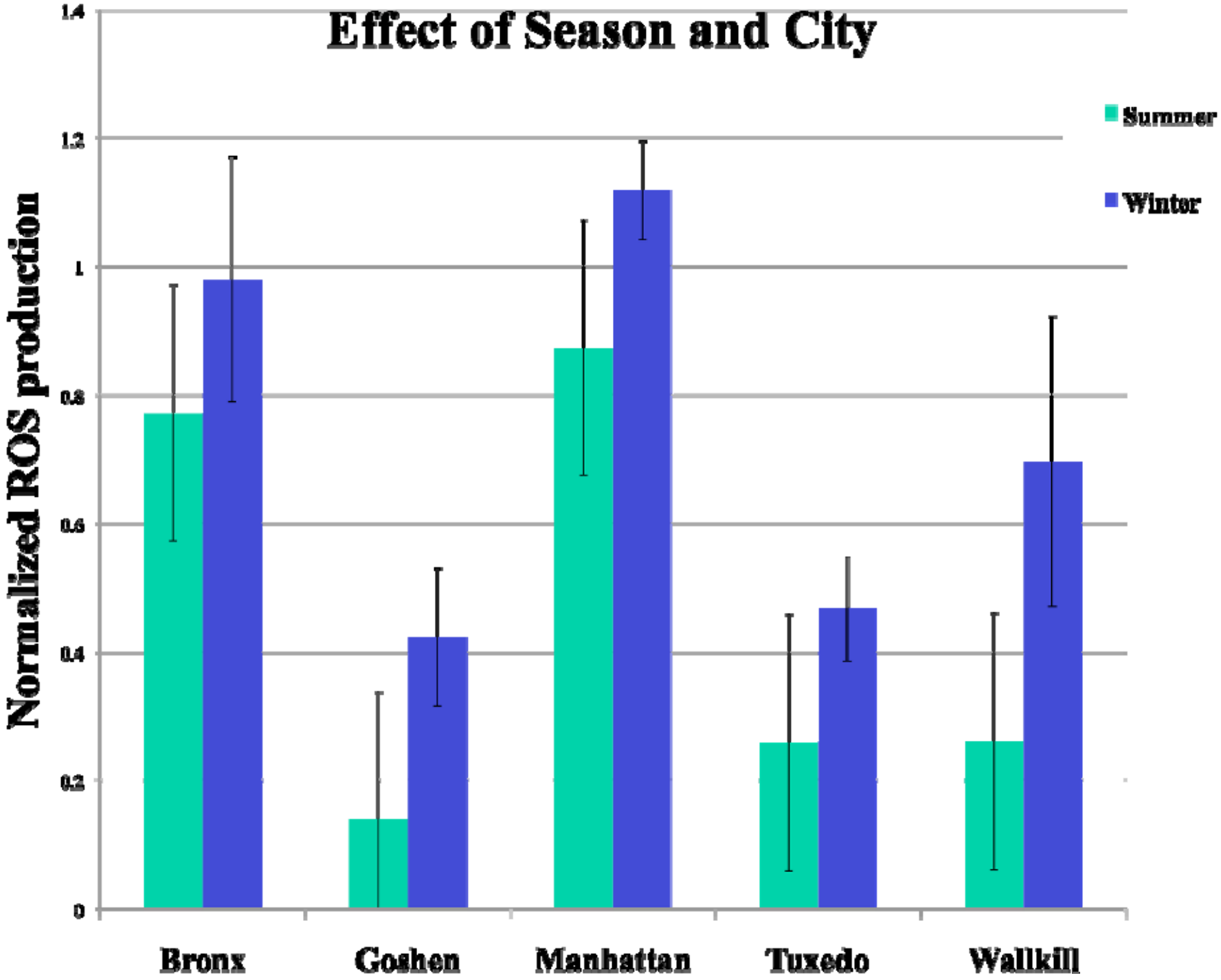
- Several sites in urban and rural NY and Central California
- Winter and summer
- 2 particle sizes (coarse and fine/UF)
  - Co-located teflon and quartz filter samples
- *In vivo* bioassay - mouse
- *In vitro* bioassay - 3 cell types
  - epithelial, vascular endothelial, cardiac myocytes

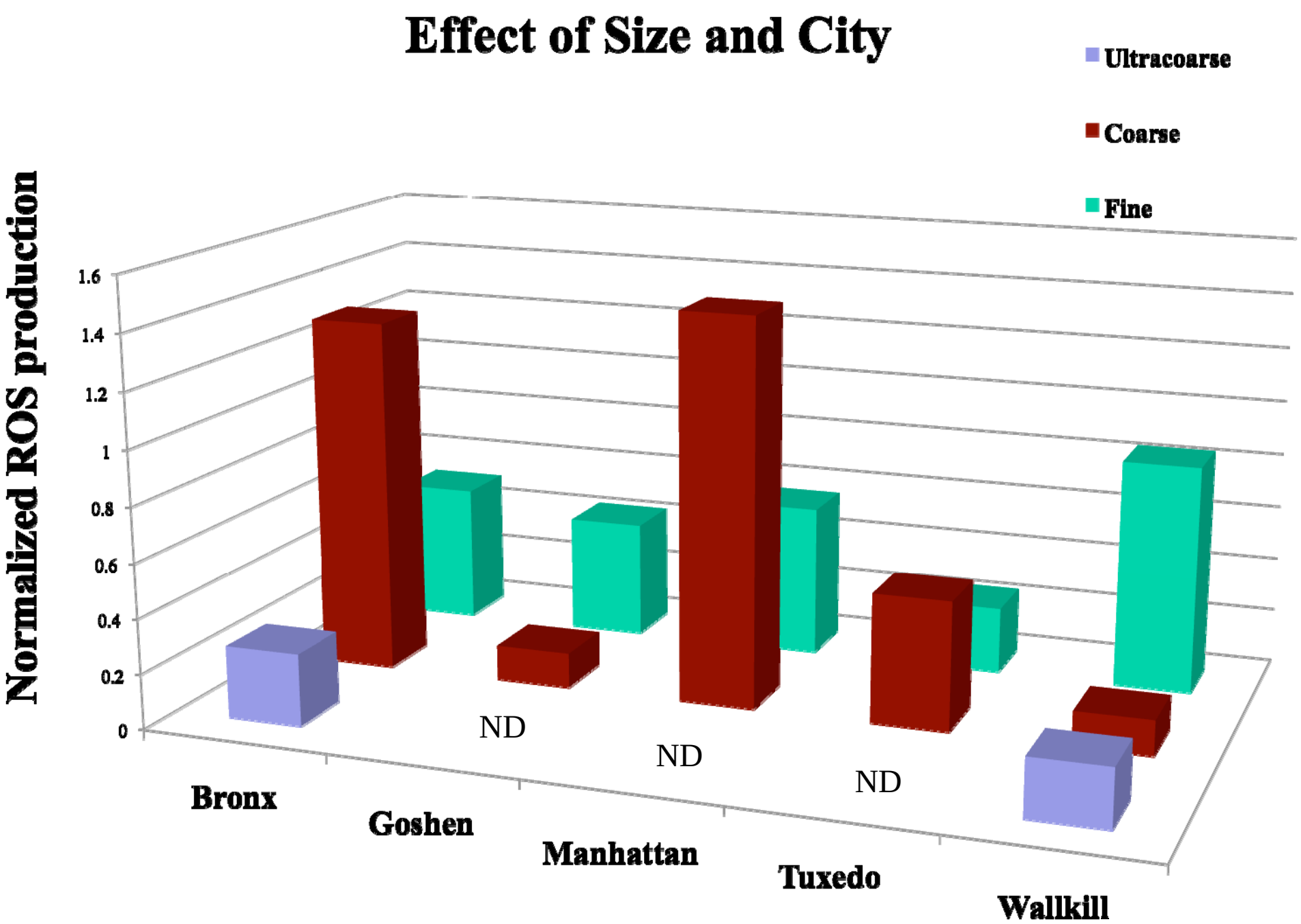
Rural Enough?


Effects by Size
Normalized ROS production
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Ultra Coarse
Coarse
Fine


Effects by Size and Season
Summer
Winter
Normalized ROS production
1.2
1
0.8
0.6
0.4
0.2
0
Ultra Coarse
Coarse
Fine


Effects by City
Normalized ROS production
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Bronx
Goshen
Manhattan
Tuxedo
Wallkill

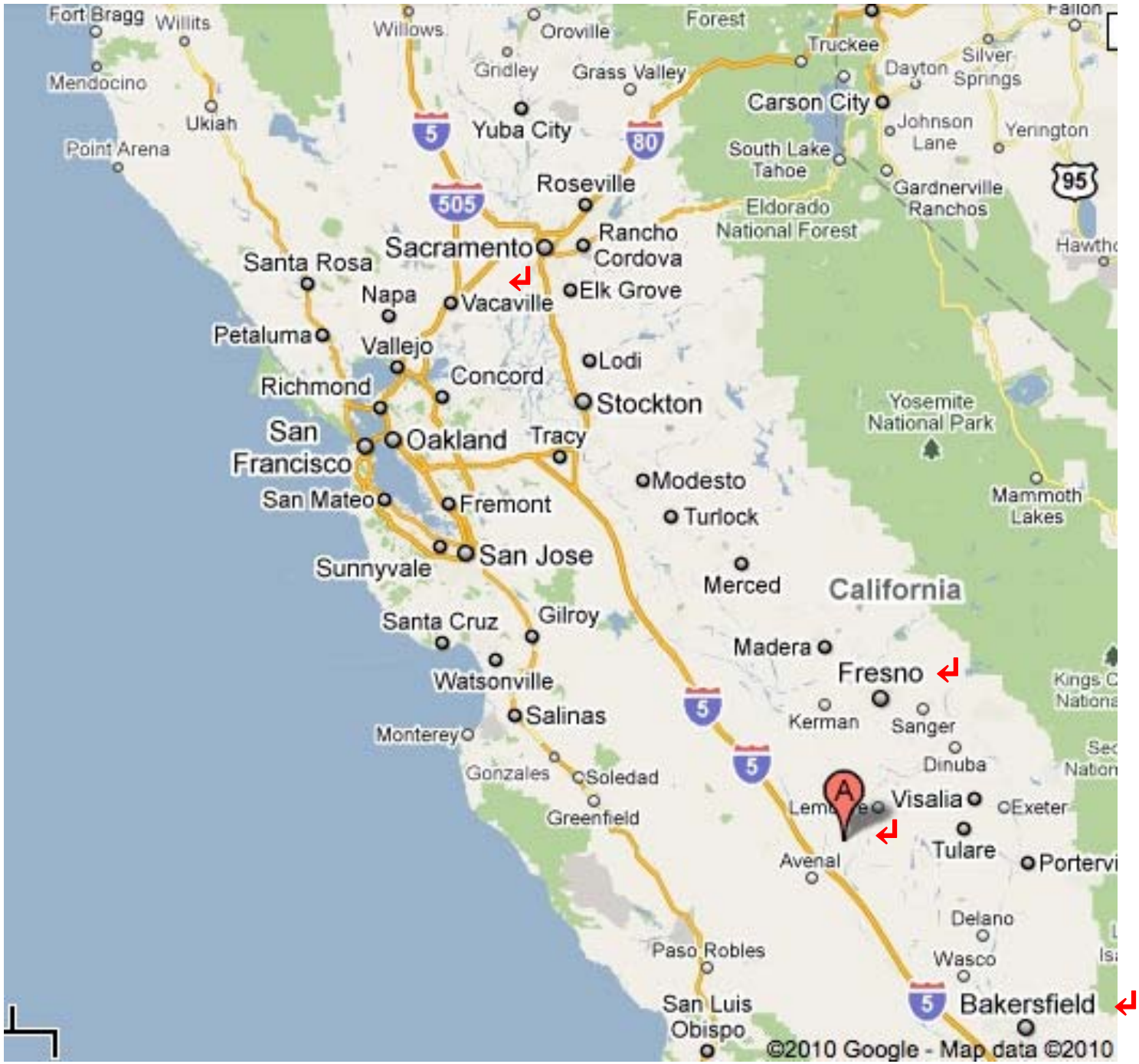

Effect of Season and City
Normalized ROS production
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Summer
Winter
Bronx
Goshen
Manhattan
Tuxedo
Wallkill


Effect of Size and City
Ultracoarse
Coarse
Fine
Normalized ROS production
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
ND
ND
ND
Bronx
Goshen
Manhattan
Tuxedo
Wallkill

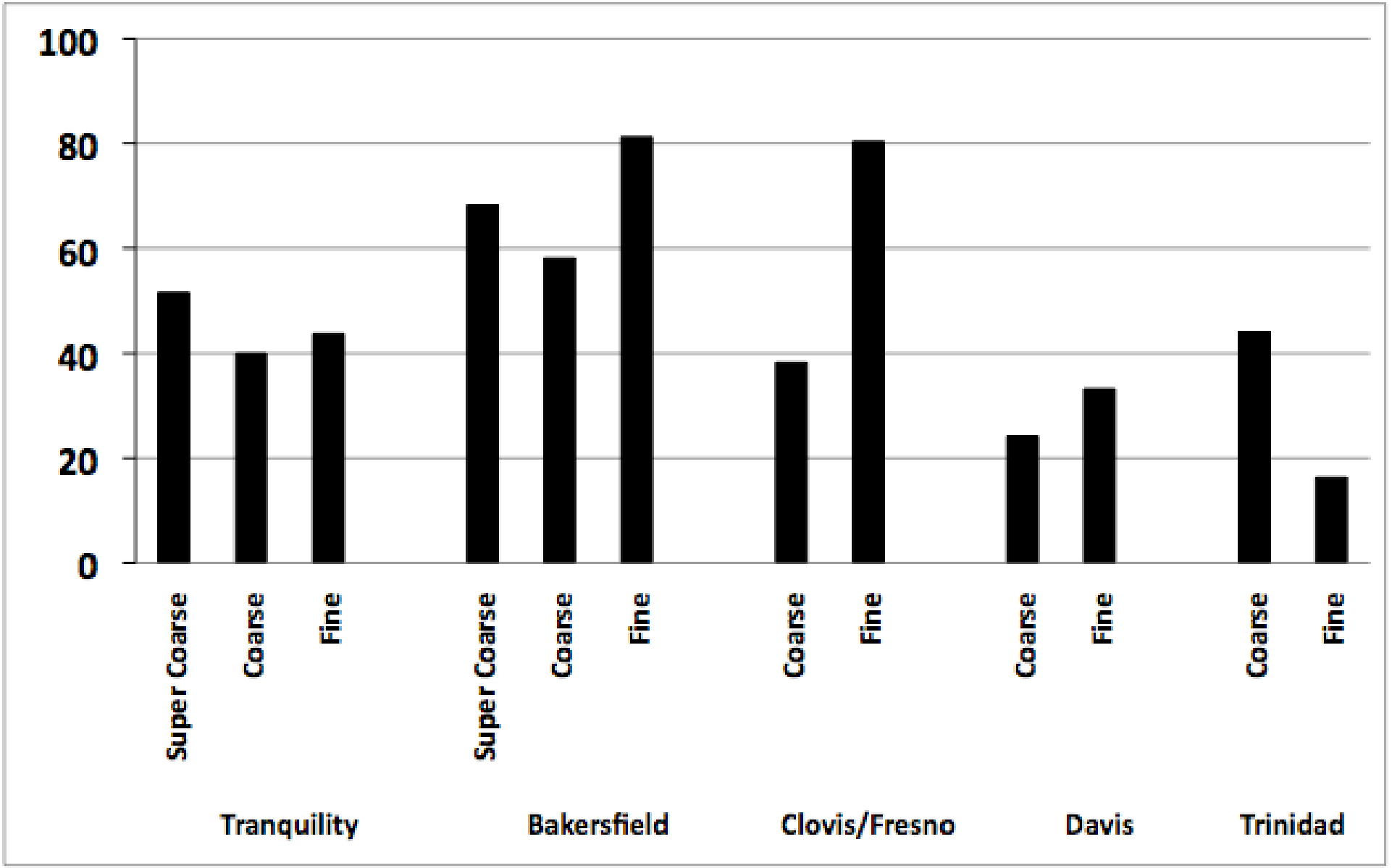
Conclusions (NY only)

- Size, season, and site (urban vs. rural) were shown to be significant factors influencing ROS production *in vitro*.
- Generally, the coarse fraction elicited a greater ROS response than either fine or 'super coarse' PM.
- Generally, coarse PM collected in Winter elicited a greater ROS response than that collected in Summer.
- Generally, urban coarse samples (i.e., Bronx and Manhattan) produced greater effects than rural samples.
- Analysis of PM composition needs to be considered to gain a better understanding of these effects.

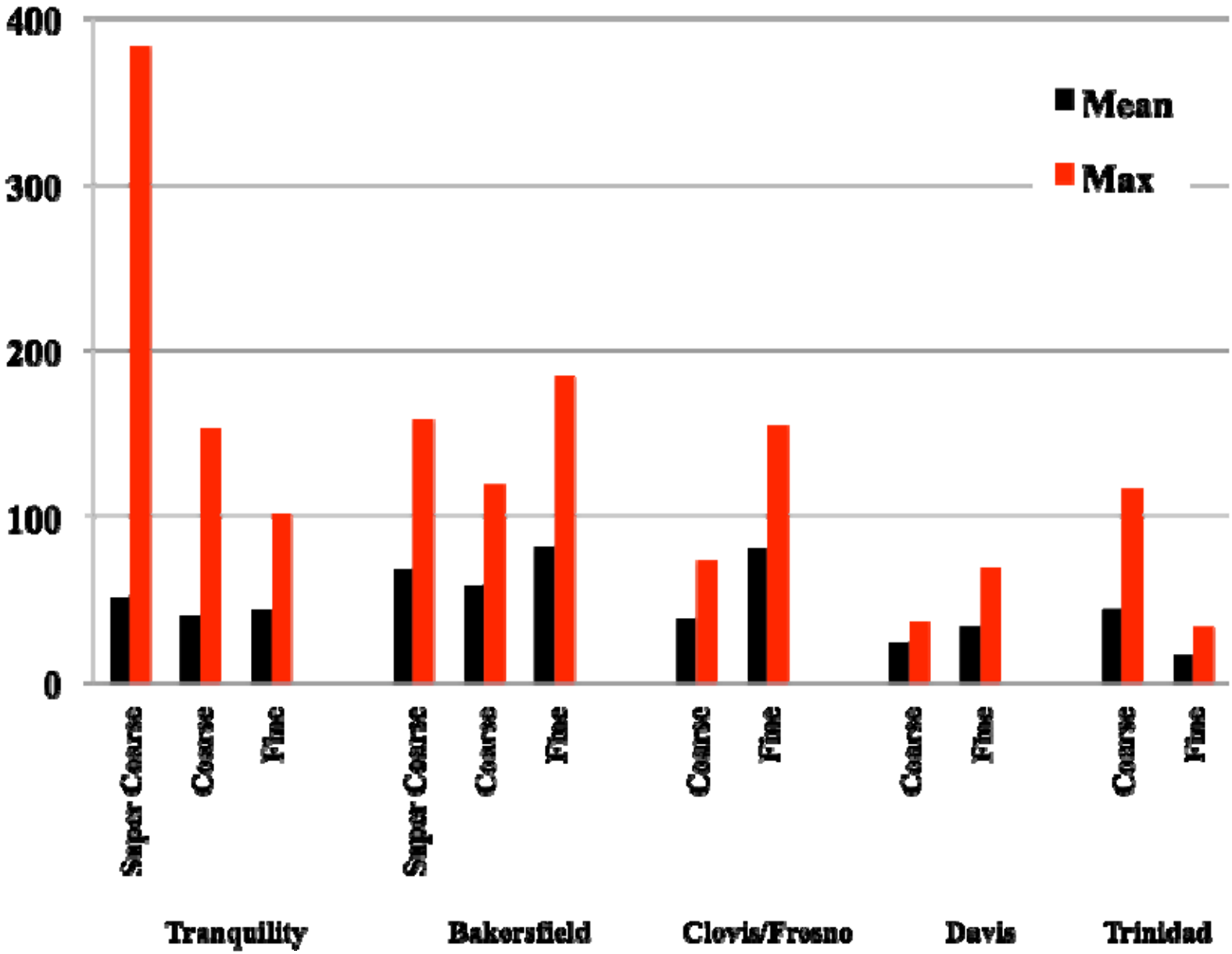
California Sampling Sites



CALIFORNIA AIR SAMPLING
PM COLLECTED (mean per stage over 48 hrs)



CALIFORNIA AIR SAMPLING
MAX PM COLLECTED (per stage over 48 hrs)



Work To Be Completed in the Next Year

- *In vitro* and *in vivo* bioassays on California samples
- Chemical analyses on NY and California samples
- Source apportionment
- Correlation of components and sources with *in vitro* and *in vivo* effects

Health Effects Institute

Collaborators

Tim Larson and Tim Gould - U Wash

Jonathan Allen - Arizona

Delbert Eatough - Utah

Jerry Keeler and Masako Morishita - U Mich

David Lighthall, Tim Tyner, Jaime Contrares, James Sweet, Scott Nester, Corinne Bartlett, Chris Ruehl

Mike Kleeman, Toshihiro Kuwayama, and Kent Pinkerton (UC Davis)

Michael Ives and Brian Vasel (NOAA)

Bob Devlin, Ian Gilmour – U.S. EPA

NYU - Christina Hickey, Lori Horton, Martin Blaustein, Karen Galdanes, Lung Chi Chen, Mort Lippmann, Rick Peltier, Ramona Lall