MESA Coarse: Characterizing Long-Term Exposure to $PM_{10-2.5}$ and Health

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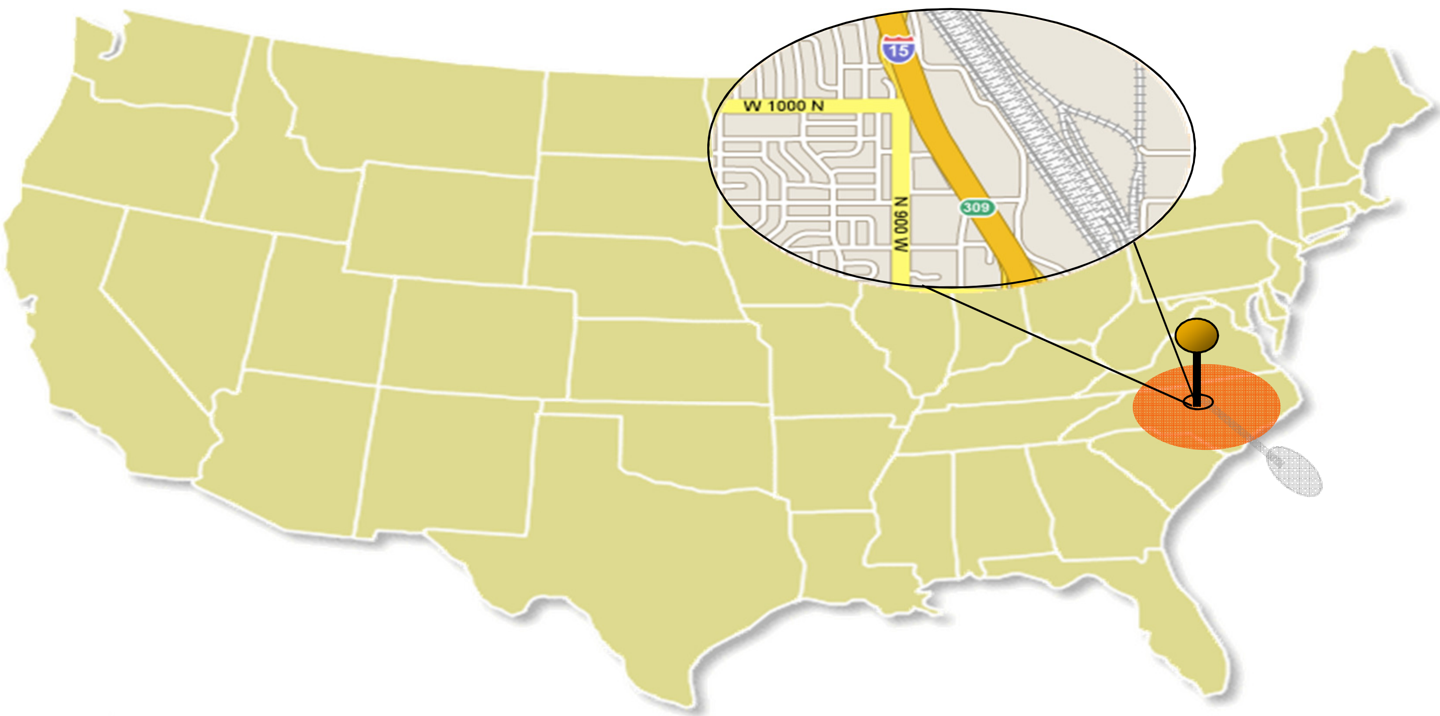
March 18, 2013

Motivations

- There is some suggestive evidence of cardiovascular and pulmonary health effects from $PM_{10-2.5}$ particles
- Data regarding long-term health effects of $PM_{10-2.5}$ particles are very limited

Exposure Assignment for Long-Term Health Effects Can Be Difficult

- Variation of $PM_{10\text{-}2.5}$ across different locations can be large due to local sources



Little Information Available on Source-Specific Health Effects

- Limited speciation data with which to characterize local variability of different sources
  - Natural sources of windblown dust
  - Suspended dust from traffic and other man-made particles

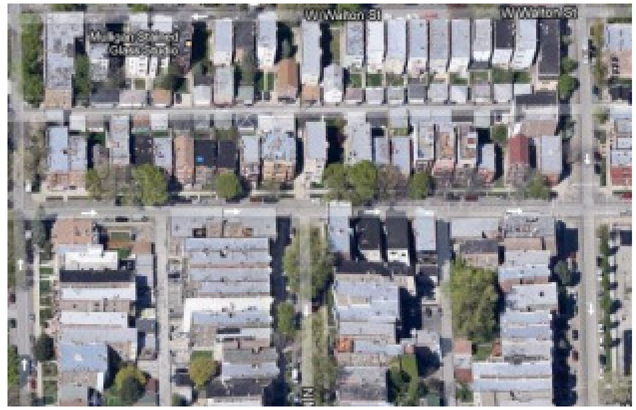
Study Aims

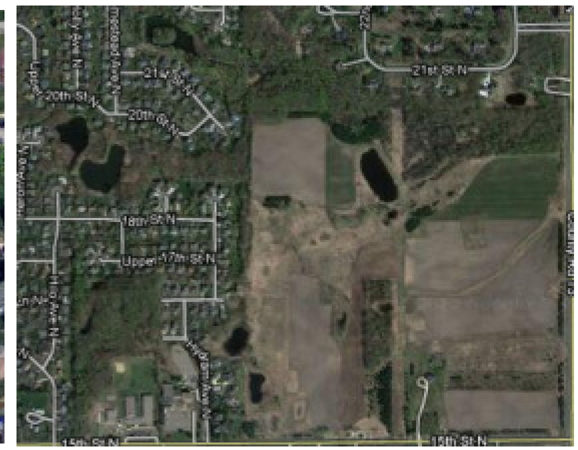
1) Characterize fine-scale spatial variability of $PM_{10-2.5}$ from natural and man-made sources

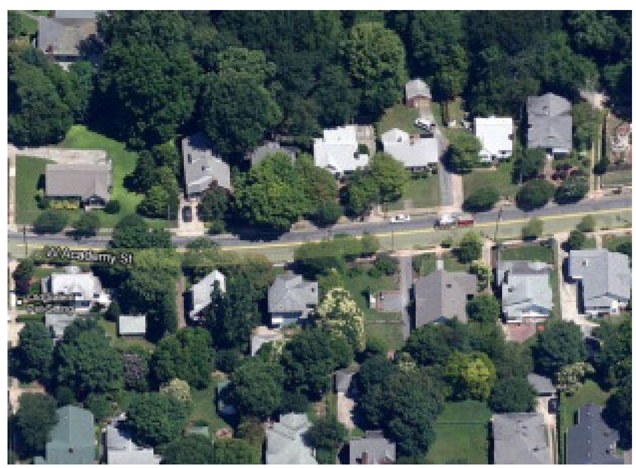
2) Examine long-term health effects of $PM_{10-2.5}$ on the respiratory and cardiovascular systems

Nested in the Multi-Ethnic Study of Atherosclerosis (MESA)

- Population-based prospective cohort
- >6,000 subjects (aged 45-84 yrs) without clinical CVD at baseline
- Followed since 2000
- Detailed characterization of PM2.5 in MESA Air

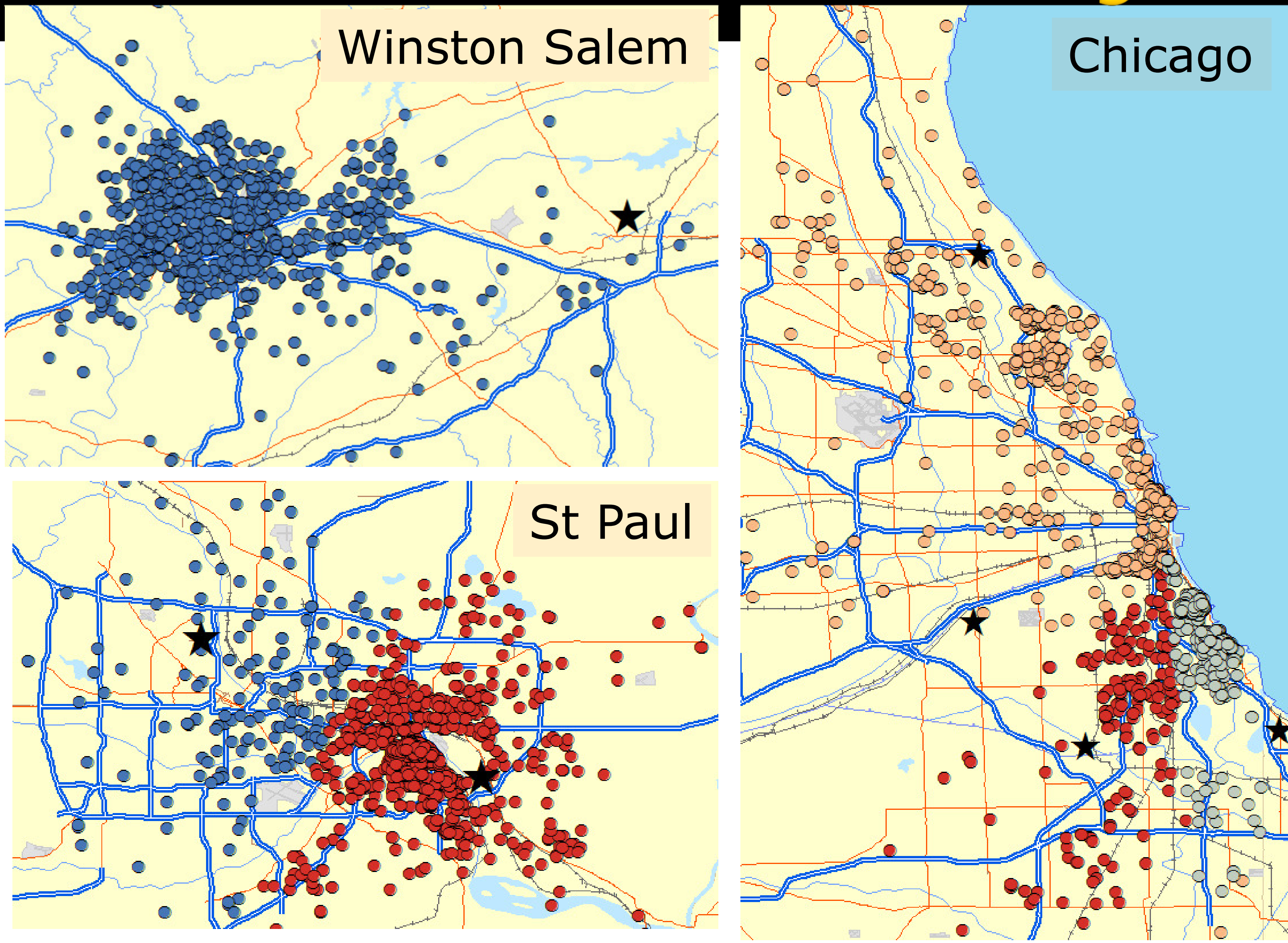






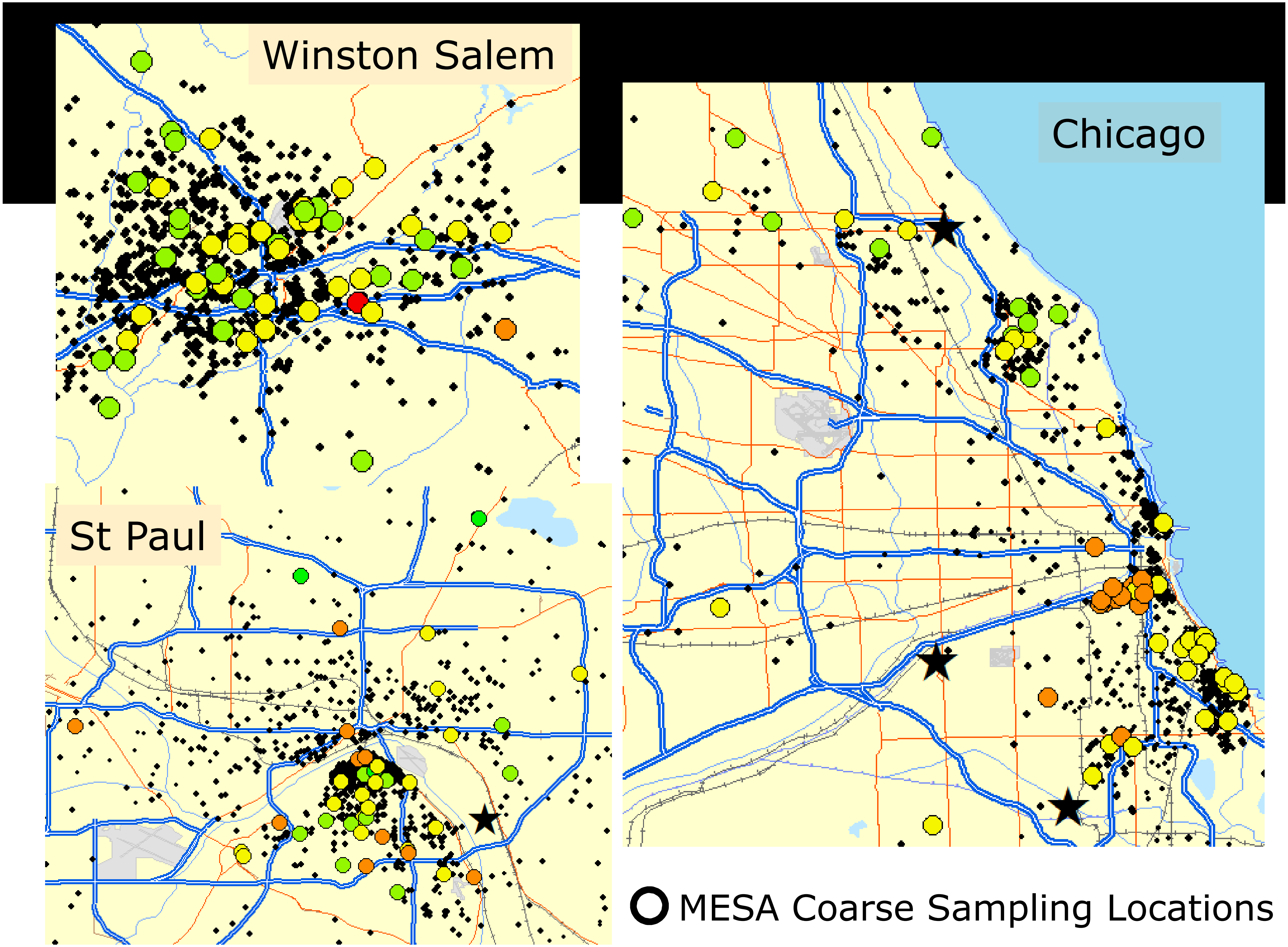
Satellite images from Google

Nearest Monitor Approach Has Major Limitations for PM10-2.5



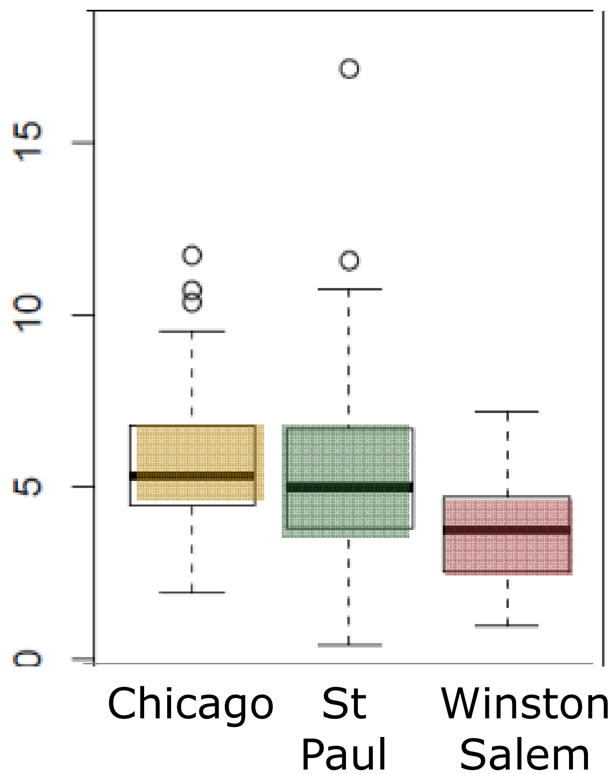
Intensive Air Sampling Campaigns in the 3 MESA Coarse Cities

- Collected >200 samples from 121 locations, ~40 per city
- Simultaneous sample collection in each city, during each of 2 seasons (+ 1 pilot study in Chicago)
- Mass and species concentrations estimated by difference

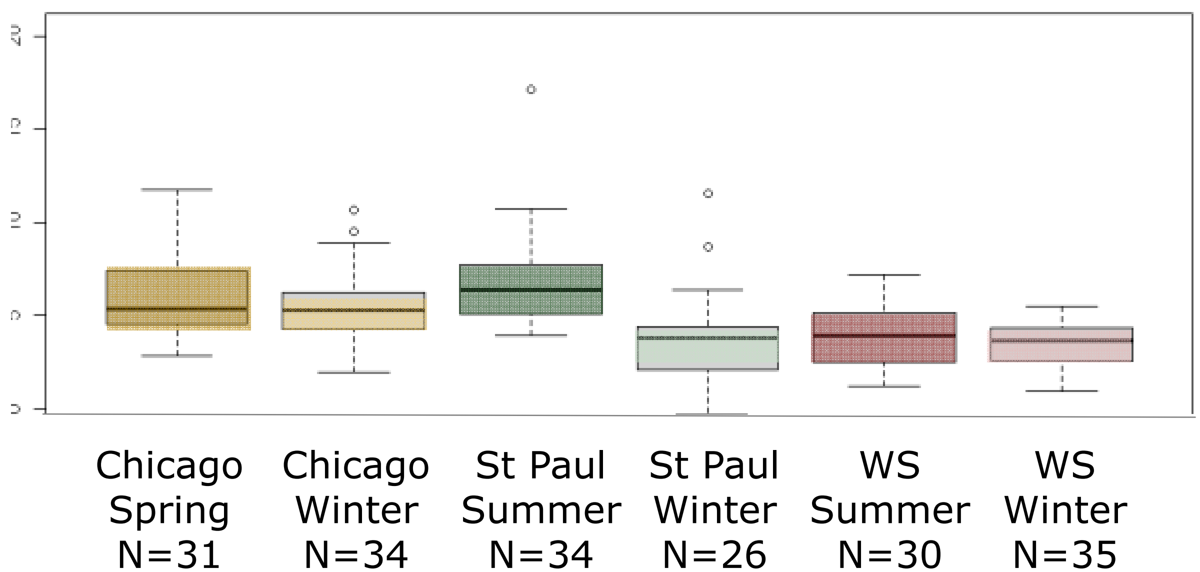

Winston Salem
Chicago
St Paul
MESA Coarse Sampling Locations

Limited Large Scale Differences and Seasonal Variability

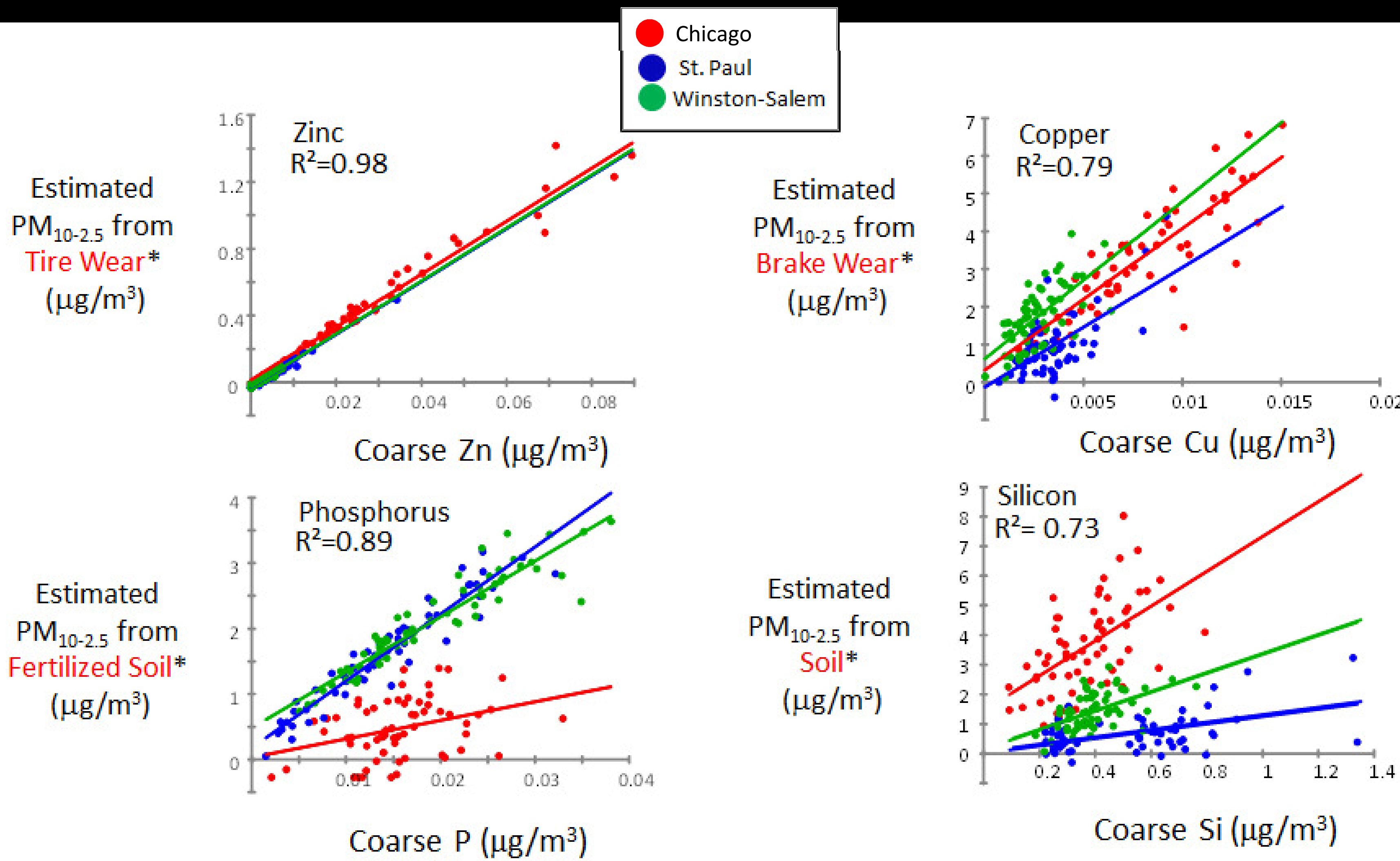
Overall (μg/m³)



Seasonal Variability (μg/m³)

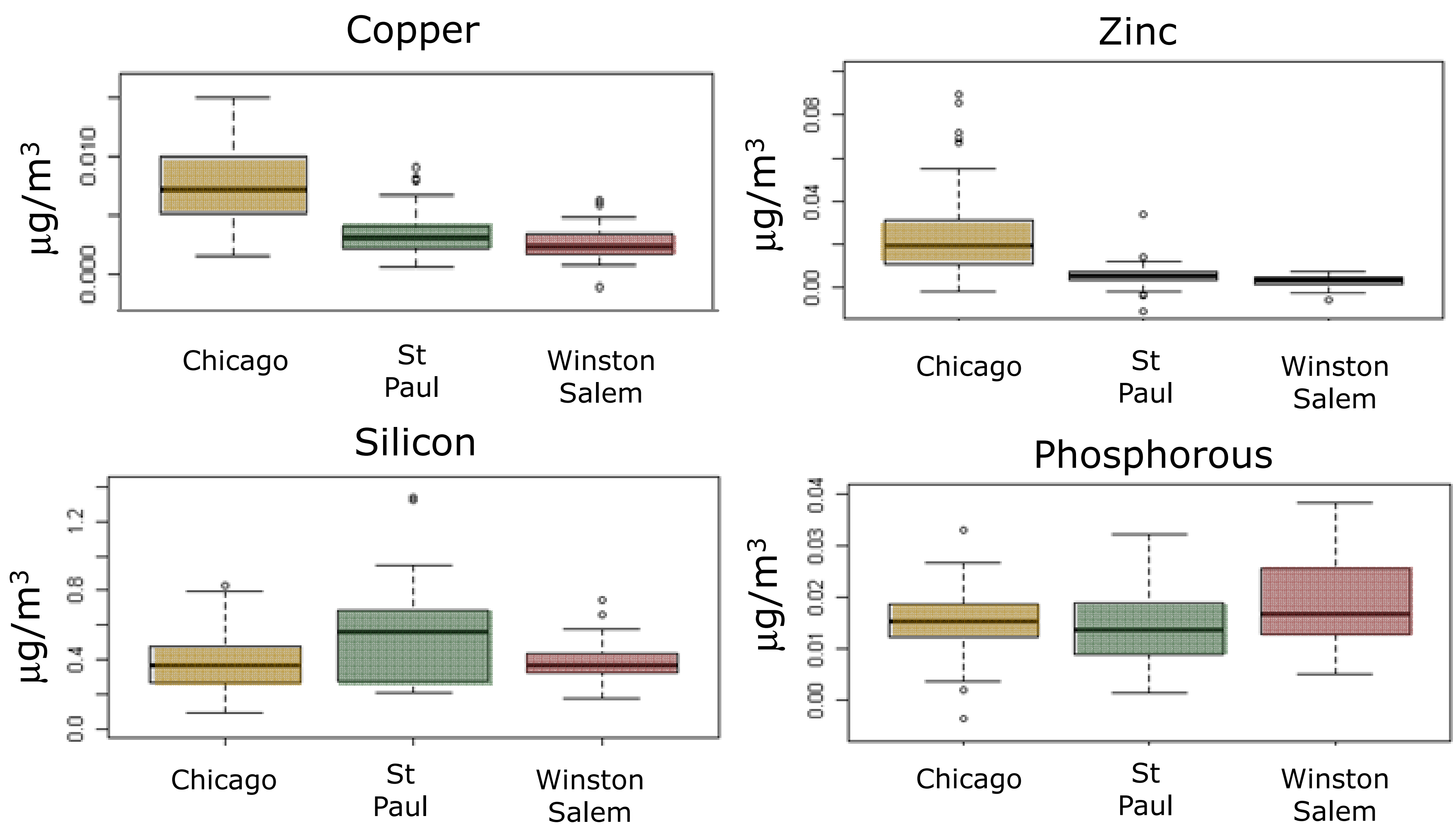


Components Serve as City-Specific Indicators of Select Sources



* Estimated by Constrained Positive Matrix Factorization

More Cu and Zn in Chicago, P and Si More Evenly Distributed



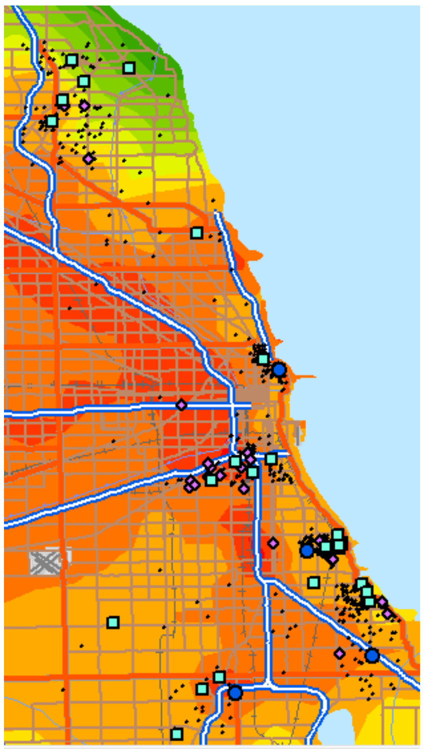
Conducted Spatial Prediction Modeling for Mass and Components

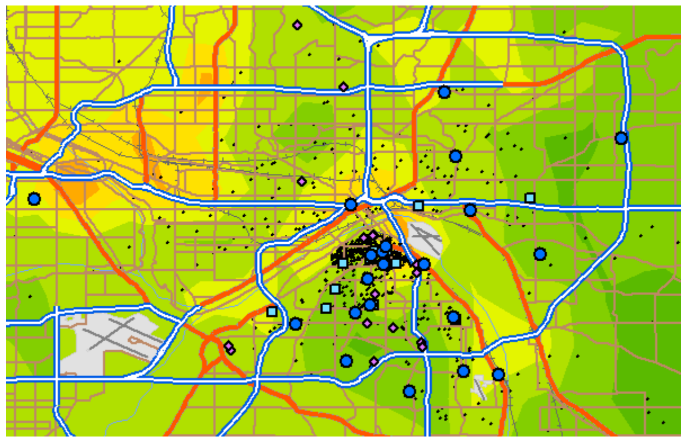
	$PM_{10-2.5}$		Copper		Zinc		Silicon		Phosphorous	
	R^2	RMSE	R^2	RMSE	R^2	RMSE	R^2	RMSE	R^2	RMSE
Chicago	0.68	1.16	0.65	2.29	0.73	10.63	0.68	0.08	0.50	3.88
St Paul	0.51	2.33	0.86	0.68	0.40	4.40	0.93	0.07	0.68	4.14
Winston Salem	0.41	1.09	0.51	0.93	0.36	1.89	0.48	0.07	0.76	3.95

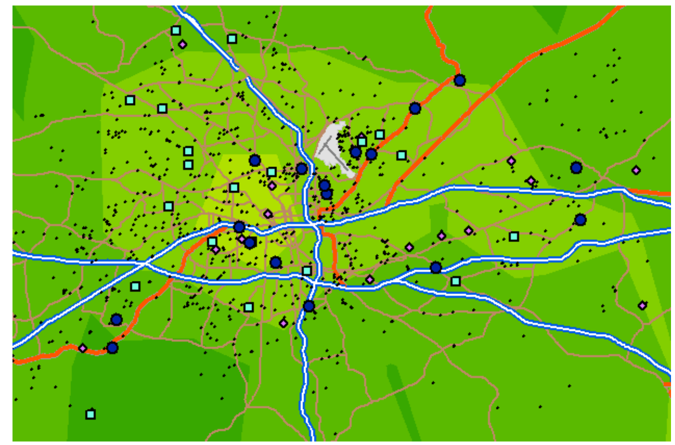
- Roadways and intensity of land use generally important in all cities, vegetation and water more important in Winston Salem and St Paul, respectively
- No evidence of residual spatial correlation after control for geographic features

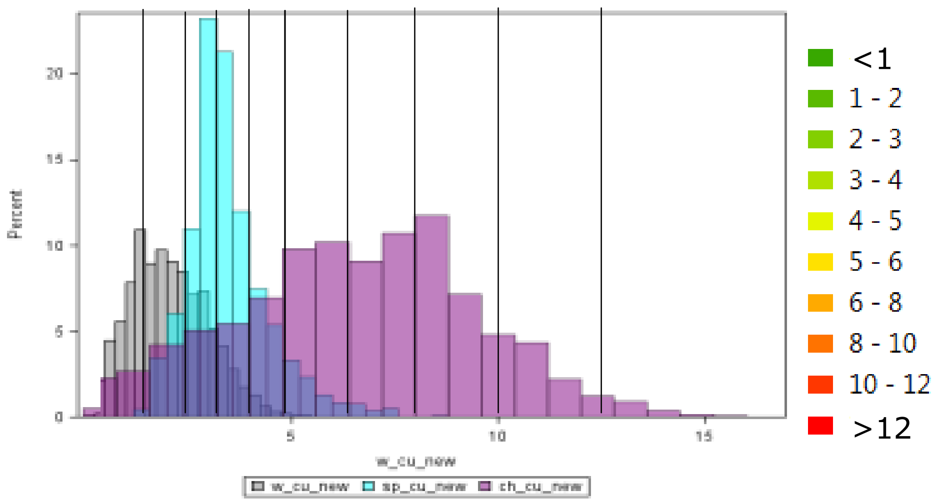
Predicted Coarse Copper Levels Track with Roadways and Urbanicity

Chicago St Paul Winston Salem



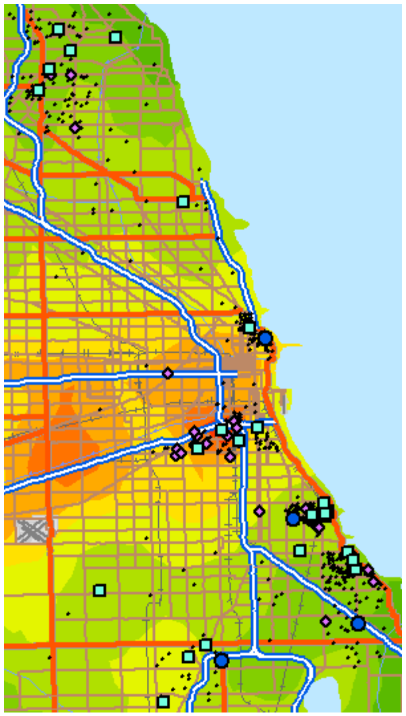




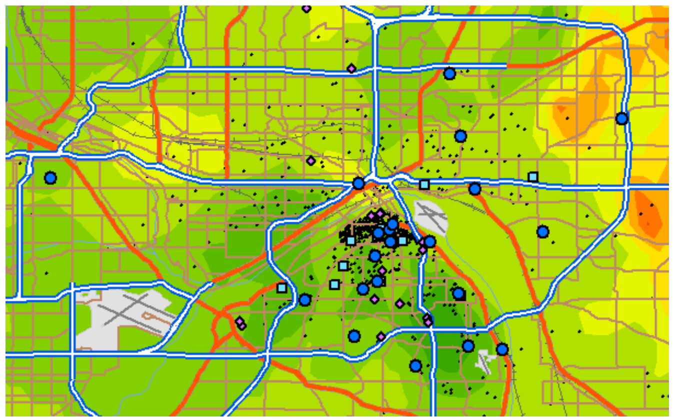


Predicted Coarse Phosphorous Levels Show Different Patterning

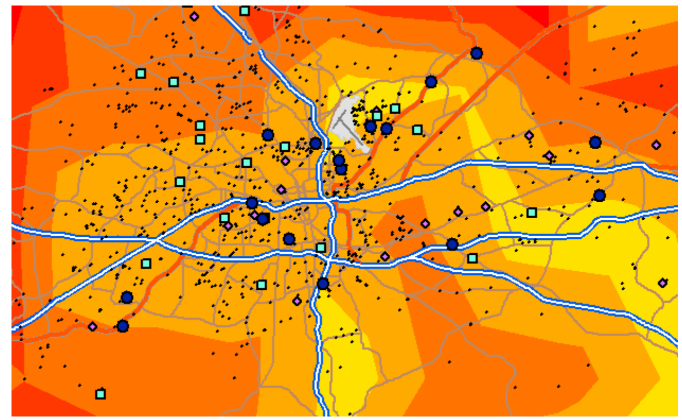
Chicago

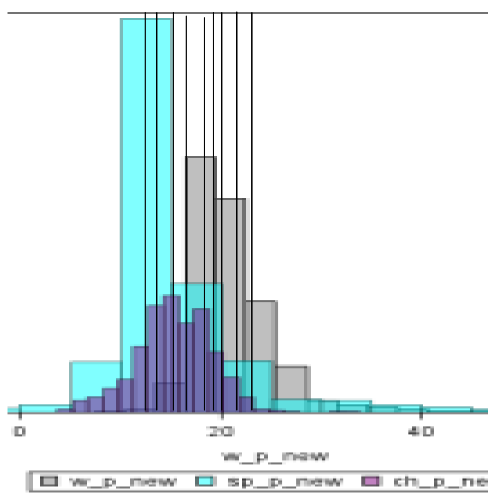


St Paul



Winston Salem





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- 10 - 12
- 12 - 14
- 14 - 16
- 16 - 18
- 18 - 19
- 19 - 20
- 20 - 21
- 21 - 22
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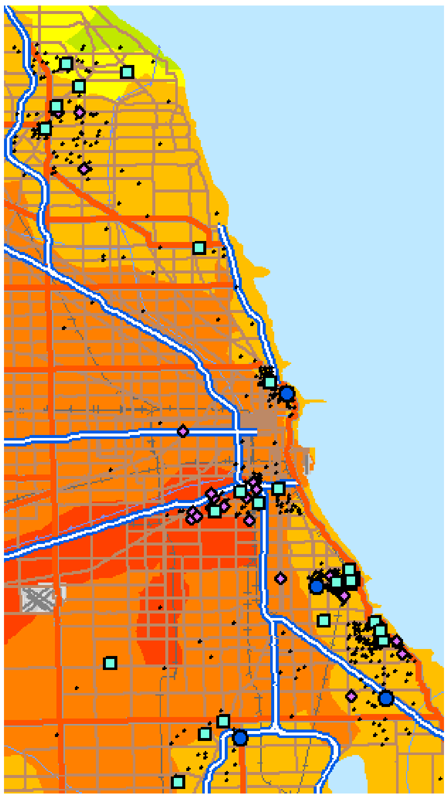
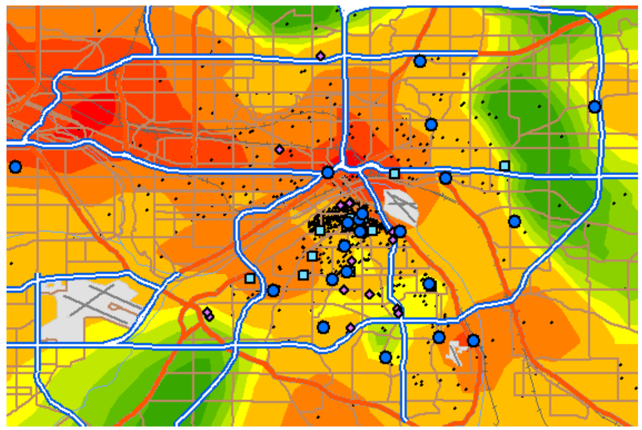
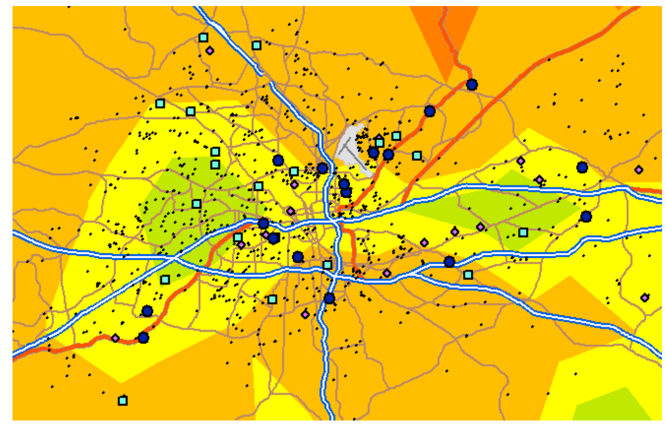
Tails trimmed for presentation

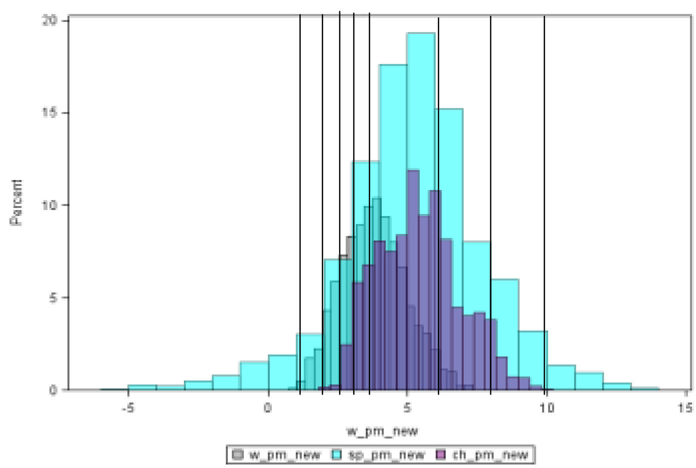
PM10-2.5 Mass Patterning

Chicago | St Paul | Winston Salem









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- 1 - 2
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- 10 - 12
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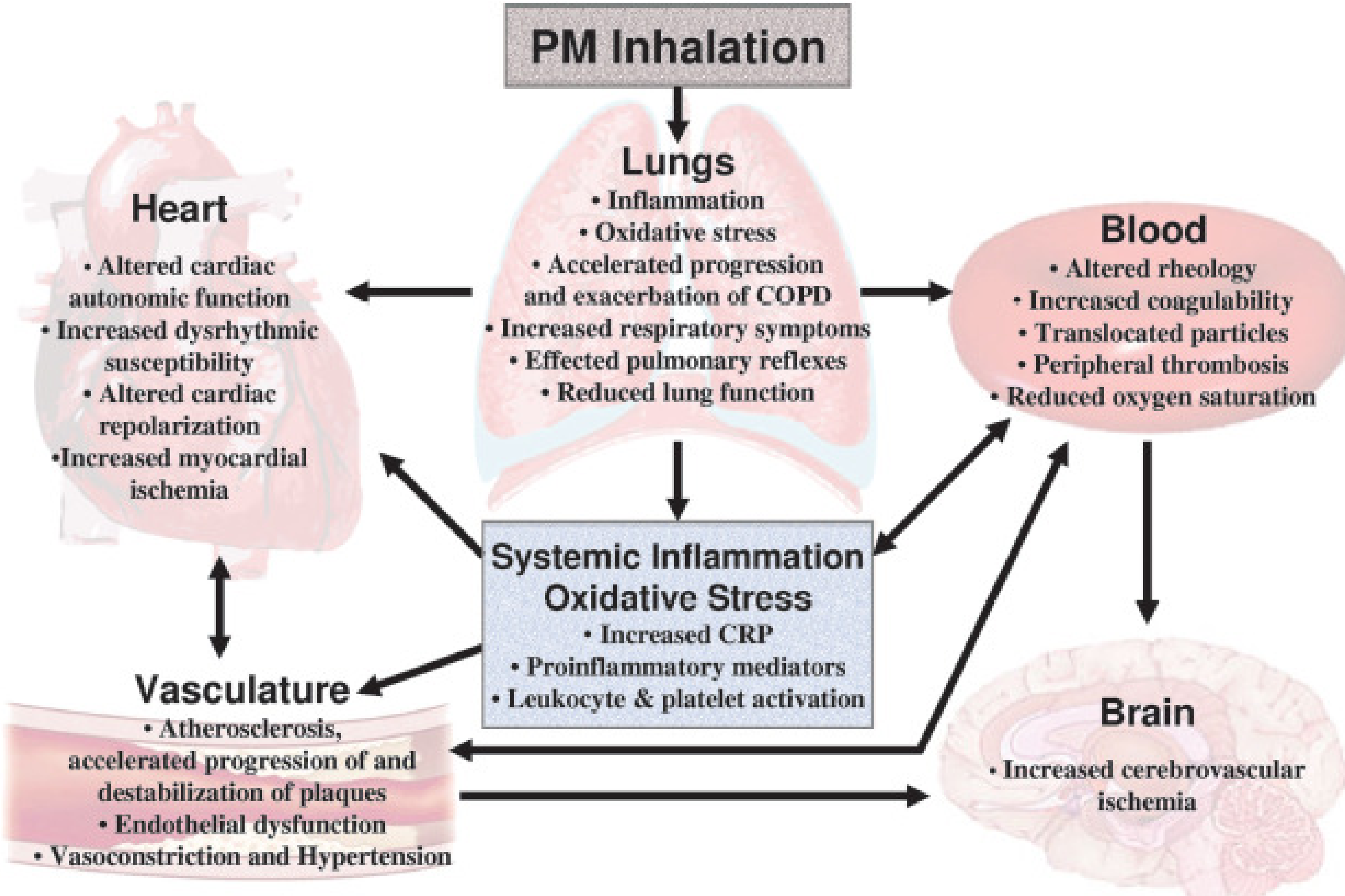
Summary of Findings for Aim 1

- $PM_{10\text{-}2.5}$ particle levels vary over short distances, with different patterning by city and species

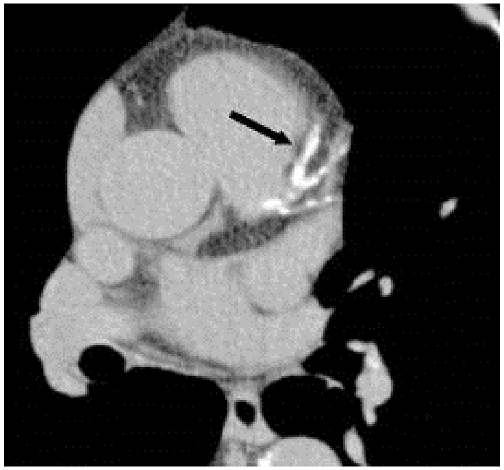
- Intensive monitoring and spatial modeling allows for fine-scale mapping of $PM_{10\text{-}2.5}$ mass and components
  - Less measurement error for long-term epidemiology
  - Distinguishes the impacts of different sources

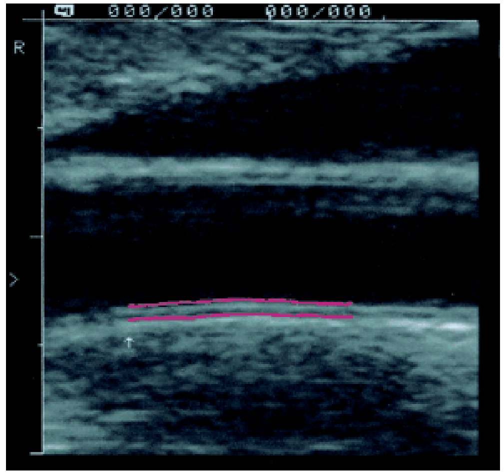
PM10-2.5 Impacts May Include Lungs, Heart, and Vasculature

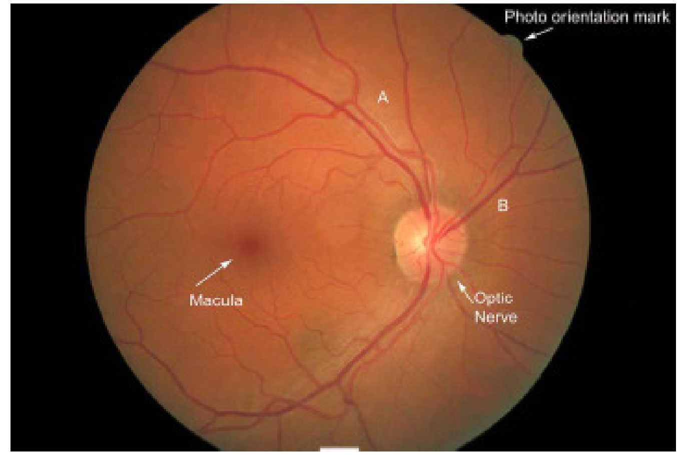


Pope and Dockery. JAWMA. 2006

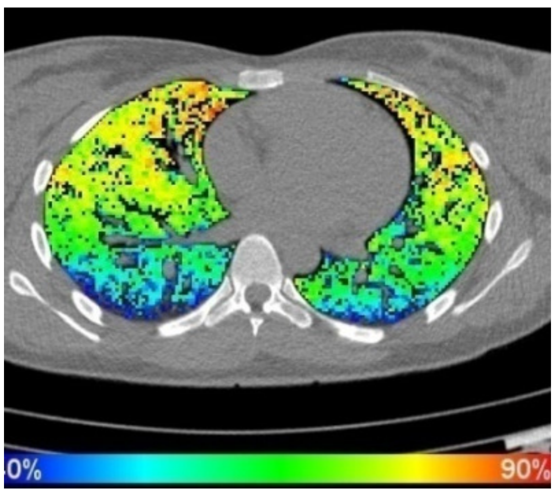
Extensive Health Outcomes Available Through MESA







Drbeck.com



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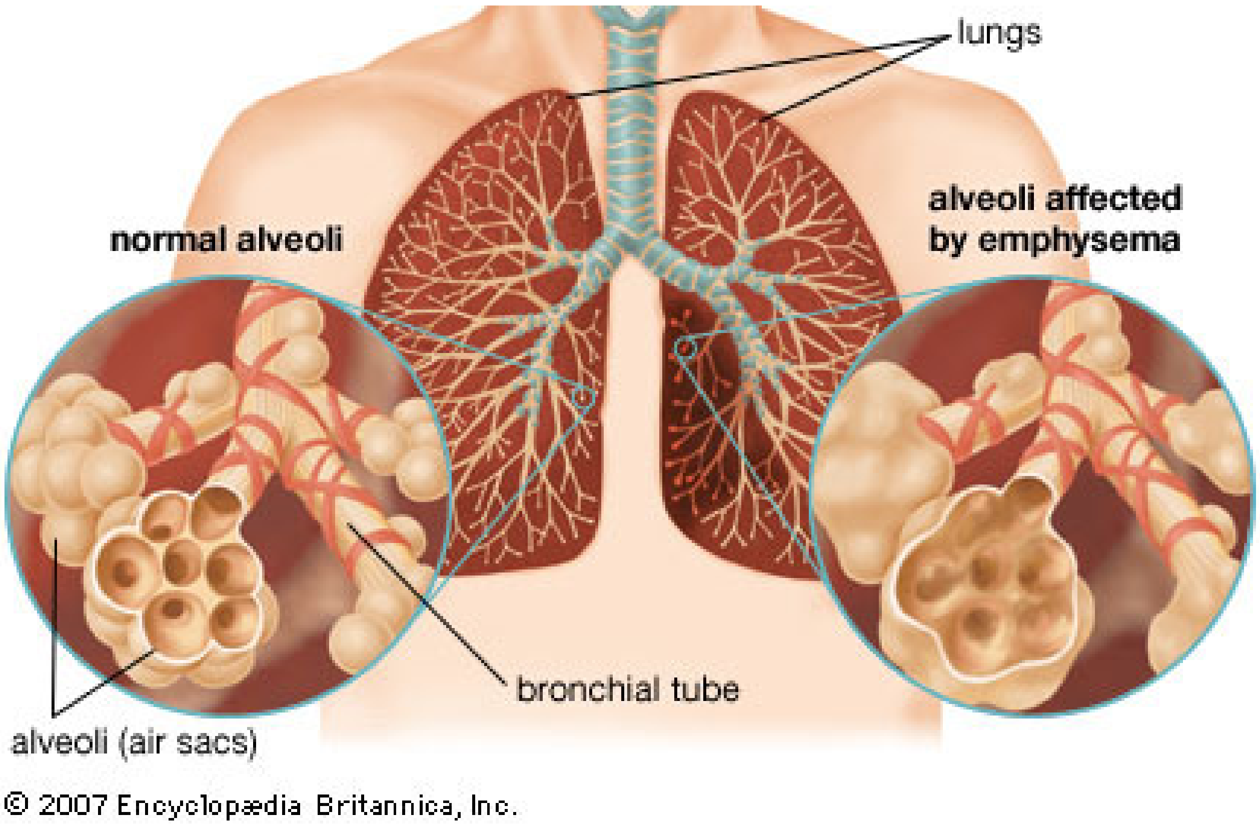
Today to Highlight Respiratory Findings



Change in Pulmonary Function Over Time

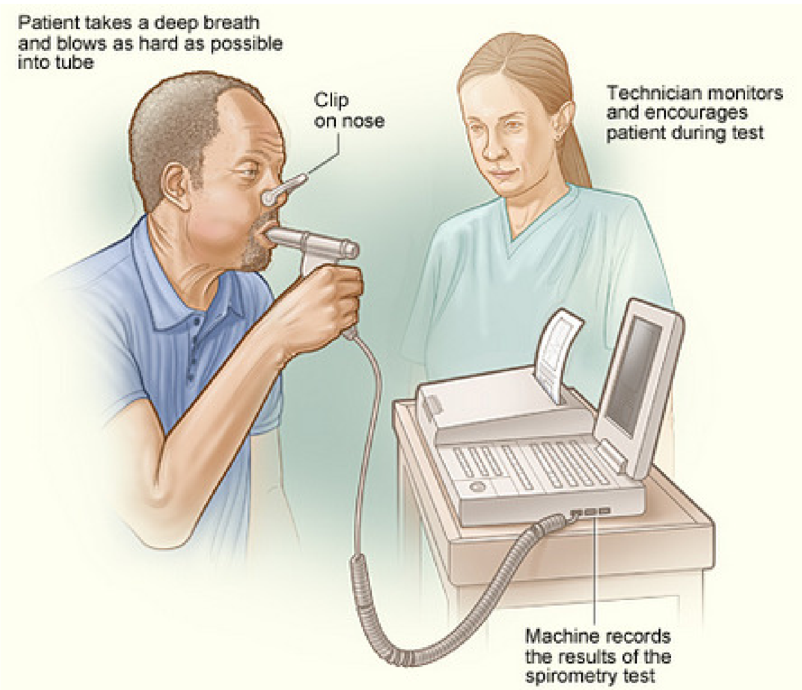
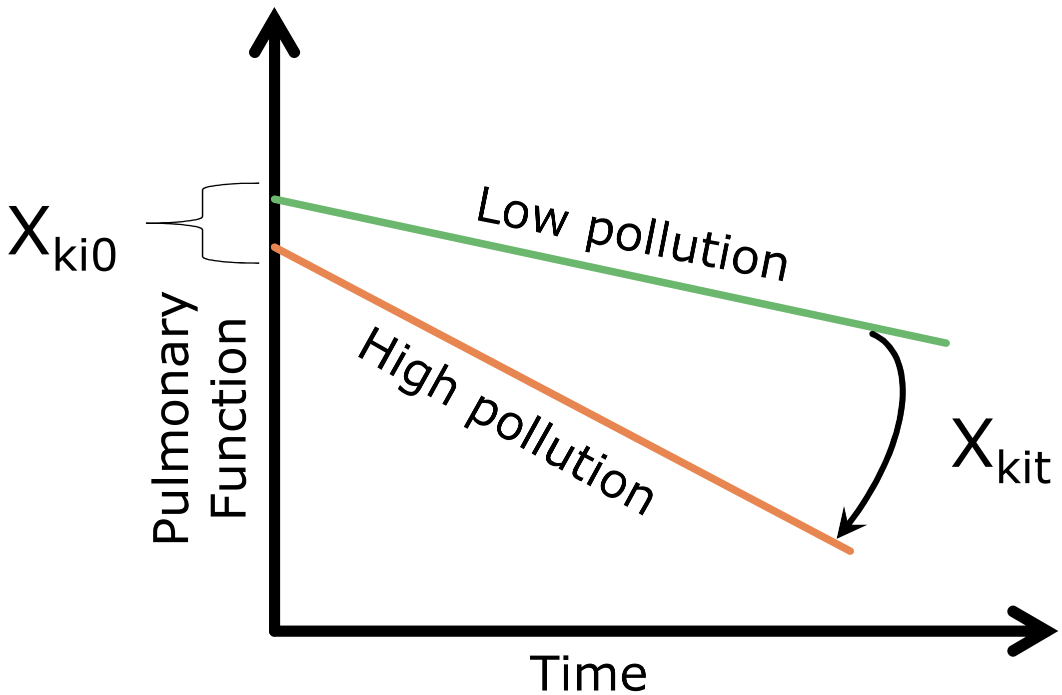


Photo from NHLBI

- Measurements of spirometry collected from a subset of the cohort during exams 3 or 4 and 5
- Focused on changes in FEV_1 and FVC over time
- Hypothesized steeper reductions over time with increasing concentrations

Statistical Modeling



$$Y_{kit} = \{\alpha_0 + a_{ki} + X_{ki0}\alpha_1 + Z_{ki0}\alpha_2\} + [\beta_o + b_{ki} + X_{kit}\beta_1 + W_{kit}\beta_2 + R_{ki0}\beta_3]\, t + (U_{kit}\gamma) + \varepsilon_{kit}$$

Covariate Control

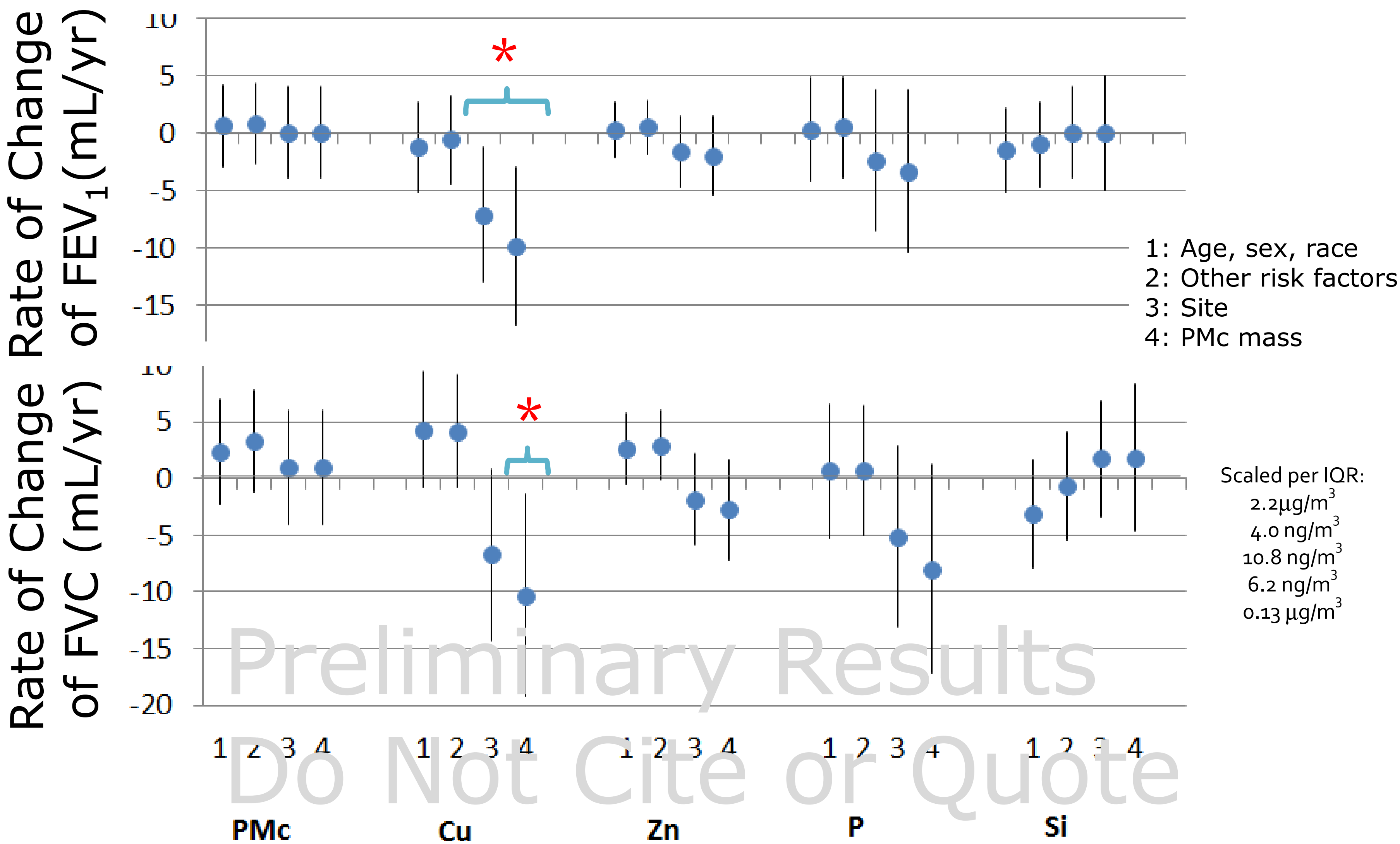
- Constructed models with increasing control for potential confounders to investigate sensitivity

  1) Age, race/ethnicity, sex
  2) + Risk factors including education, neighborhood income, smoking, passive smoke, body size, workplace exposure, hay fever, family history of COPD, early asthma
  3) + Site
  4) + $PM_{10-2.5}$ (for components)

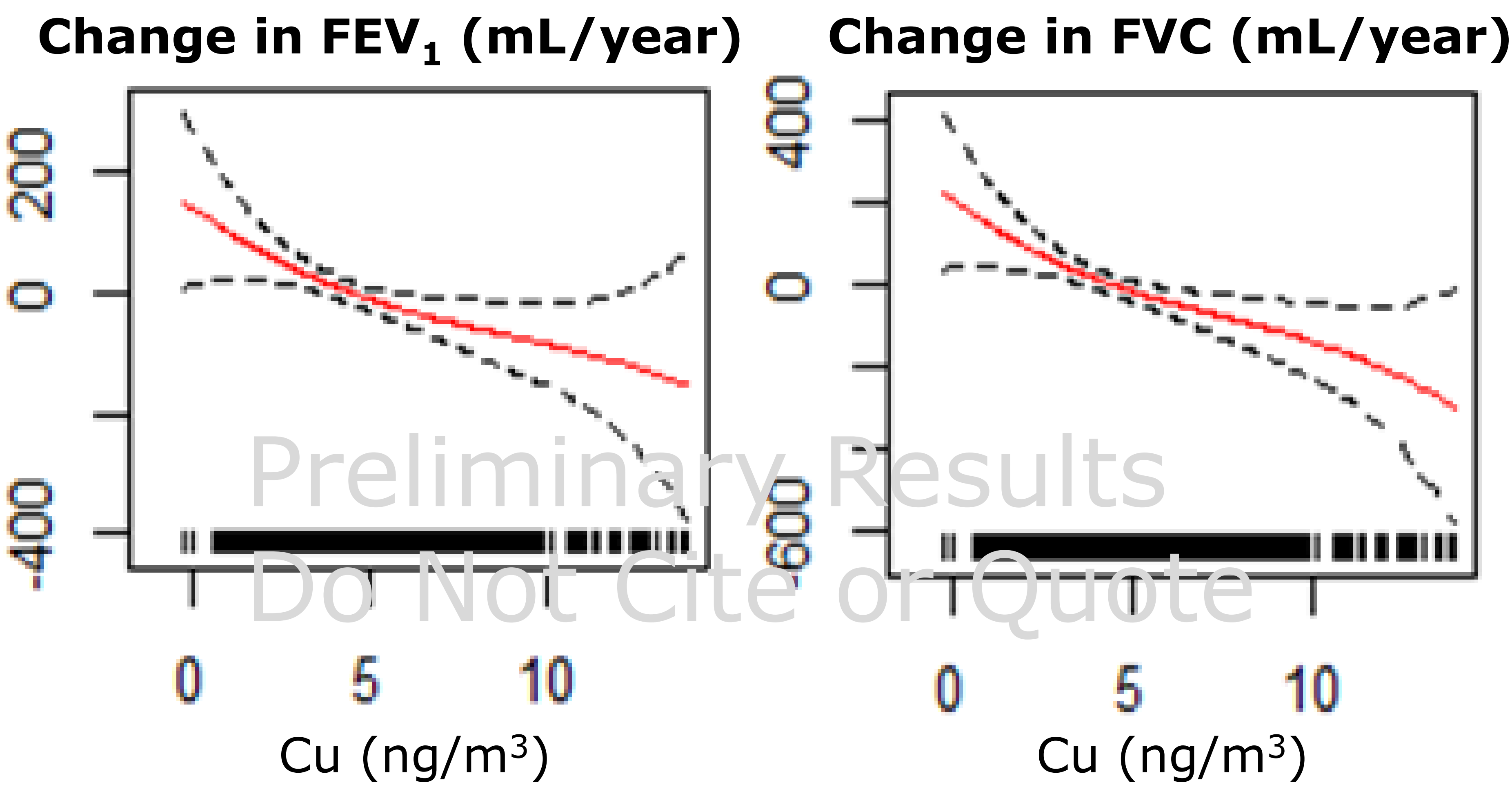
- Sensitivity analyses explored control for $PM_{2.5}$, LAC, NO_x

	All (N=1624)	Winston Salem (N=466)	St Paul (N=480)	Chicago (N=678)
Age (years)	62 (10)	63 (10)	60 (11)	62 (10)
Male (%)	48	47	49	47
Race/Ethnicity (%)				
White	52	53	57	48
Black	24	47	0	26
Chinese	9	0	0	26
Hispanic	14	0	43	0
<HS Education (%)	11	8	19	7
Smoking Status (%)				
Former	40	41	40	38
Current	14	14	16	11
FEV1 (L)	2.5 (0.8)	2.4 (0.7)	2.7 (0.8)	2.3 (0.8)
FVC (L)	3.3 (1.0)	3.2 (0.9)	3.6 (1.0)	3.1 (1.0)
Change in FEV1 (mL/yr)	-70 (120)	-60 (130)	-90 (110)	-60 (120)
Change in FVC (mL/yr)	-60 (160)	-50 (170)	-100 (160)	-30 (150)
Follow-Up Time (yrs)	5.1 (0.8)	5.0 (0.6)	5.2 (0.8)	5.2 (0.8)

Higher Cu Associated with Steeper Declines in FEV1 & FVC Over Time

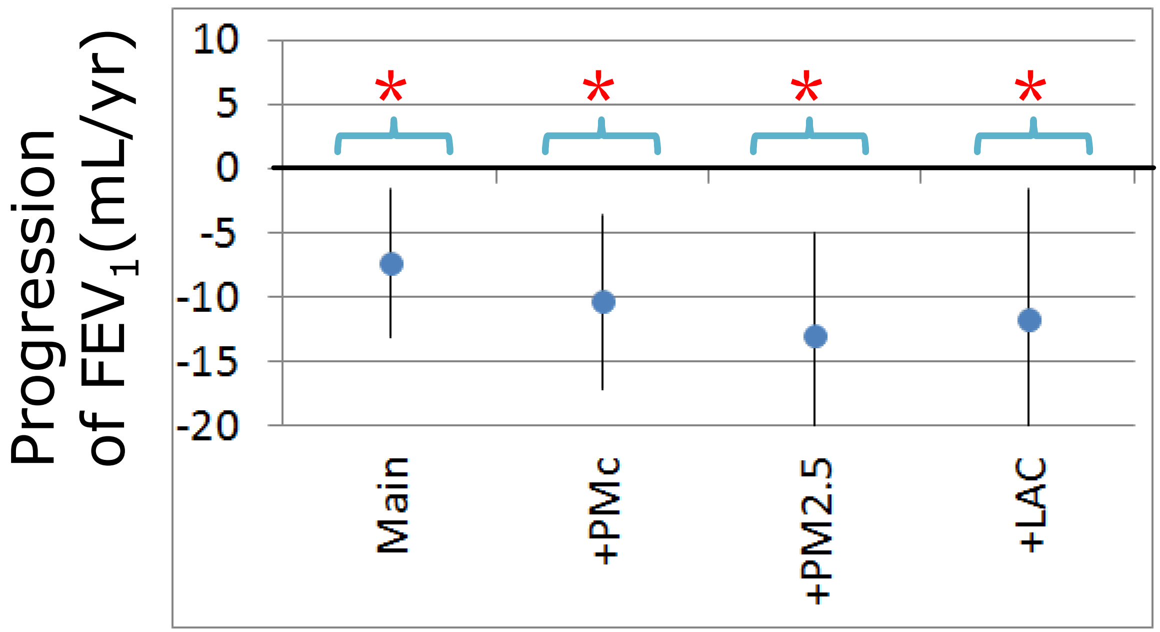


Associations Appear Linear

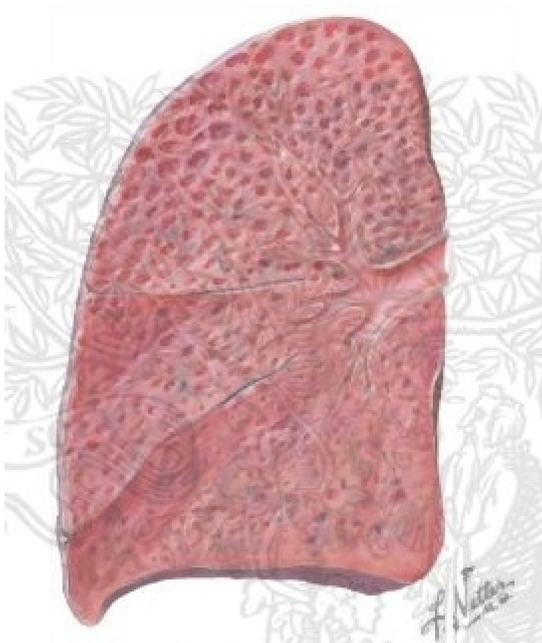


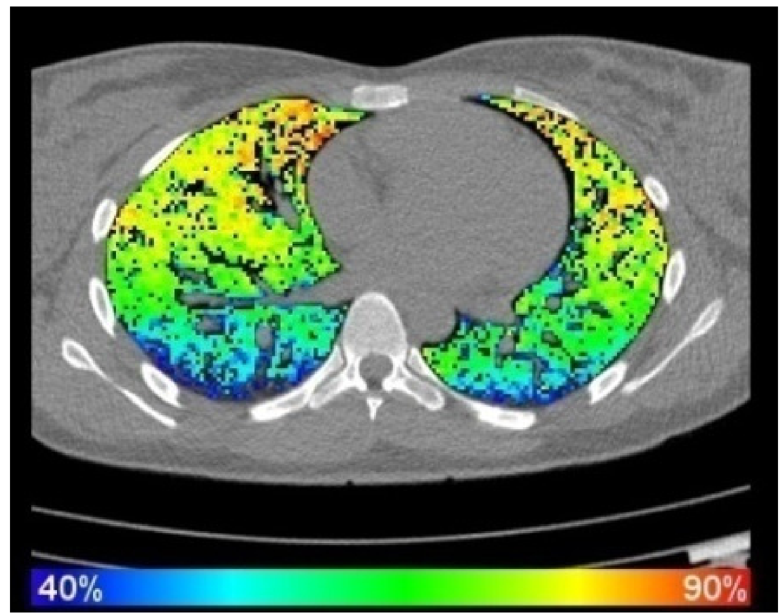
Cu Associations Likely Not Due to Correlated Combustion Emissions

- Average correlation with PM2.5 = 0.32
- Average correlation with LAC = 0.66



Lung Density on CT a Novel Method to Assess % Emphysema





$$\text{Percent emphysema} = \frac{\text{number voxels} < -910\ \text{HU}}{\text{total voxels}}$$

Can be classified for different regions of the lungs

Threshold corrected for attenuation of air on each scan

Descriptive Statistics

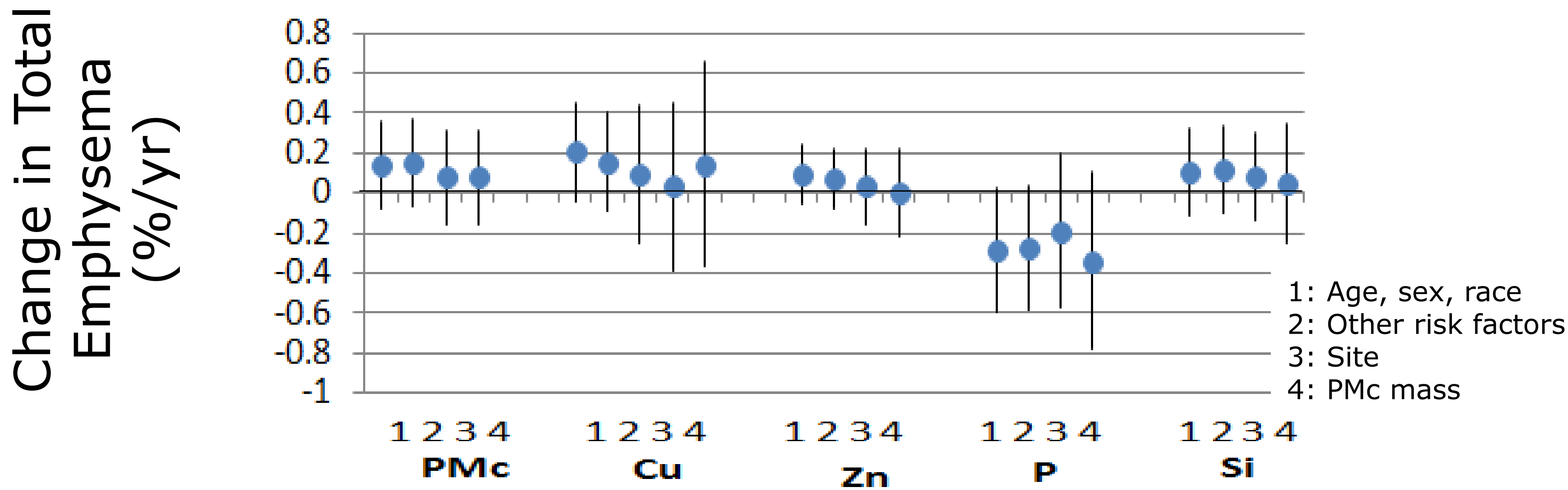
	All (N=2741)	Winston Salem (N=856)	St Paul (N=873)	Chicago (N=1012)
% Emphysema	20 (13.5)	21 (14.9)	18 (13.0)	21 (12.3)
Δ % Emphysema (%/yr)	2 (9.6)	0 (9.6)	3 (10.3)	2 (8.8)
AB Ratio	2 (6.4)	2 (5.7)	1 (2.2)	2 (8.9)
Δ AB Ratio (1/yr)	-0.2 (2.1)	-0.1 (1.5)	-0.2 (2.6)	-0.2 (2.2)
Follow-Up Time (yrs)	3.5 (1.0)	3.5 (0.9)	3.6 (0.9)	3.4 (1.1)

- Each participant contributed 1-2 scans between Exams 1 and 4

Covariate Control

- Constructed models with increasing control for potential confounders to investigate sensitivity
  - Age, race/ethnicity, sex
  - + Risk factors including height, education, neighborhood income, smoking, passive smoke, CT scanner, body size
  - + Site
  - + Total $PM_{10-2.5}$ for species
- Sensitivity analyses explored control for $PM_{2.5}$, LAC, NOx

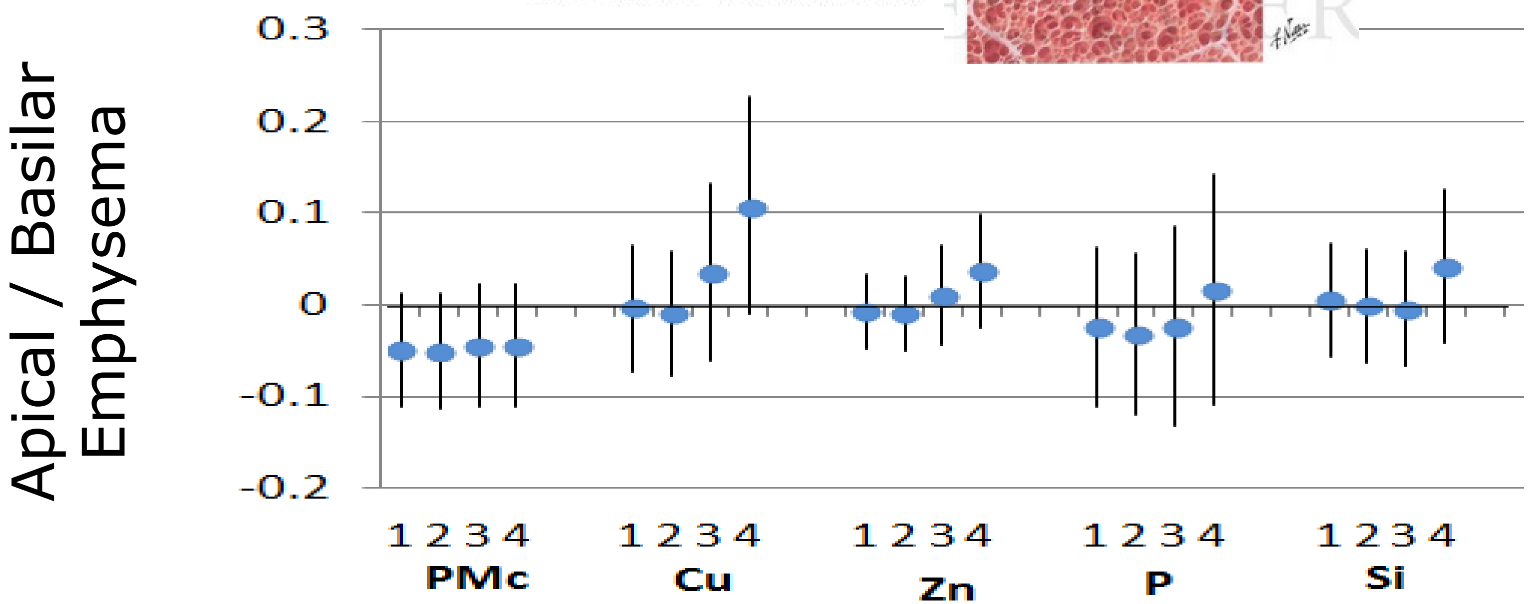
No Associations with Total Emphysema



Scaled per IQR:
2.2µg/m³
4.0 ng/m³
10.8 ng/m³
6.2 ng/m³
0.13 µg/m³

Cu Also Suggestive of More Apical Emphysema

1: Age, sex, race
2: Other risk factors
3: Site
4: PMc mass

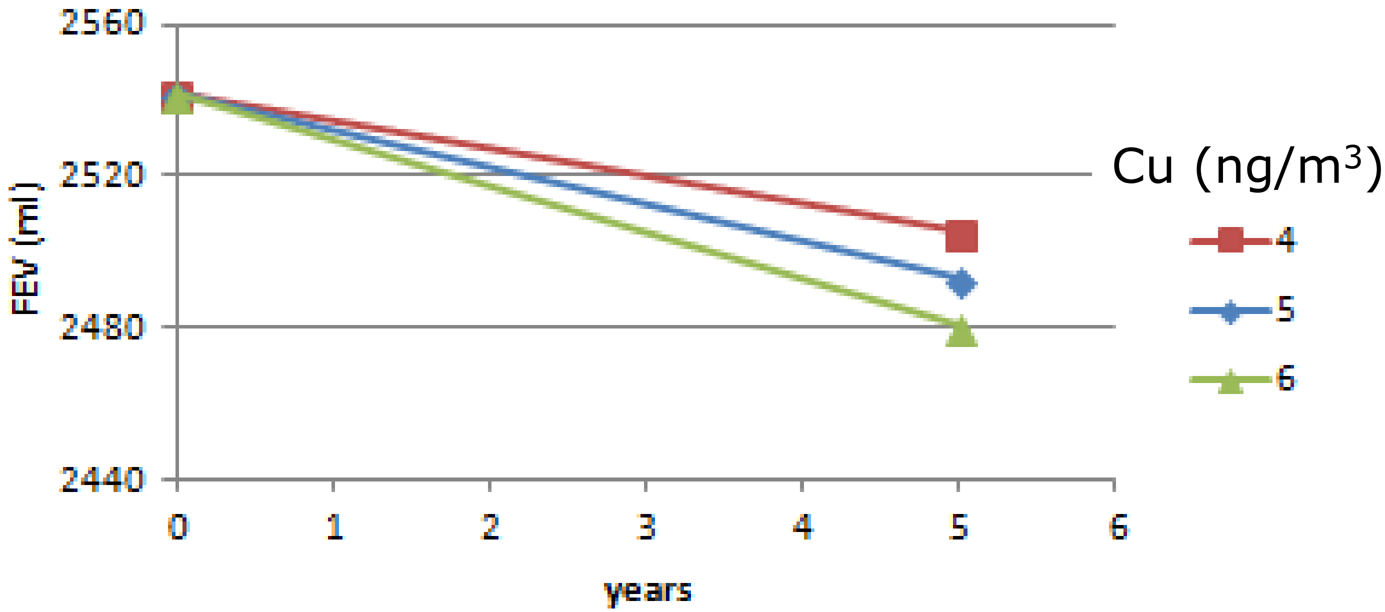


Scaled per IQR:
2.2μg/m^3
4.0 ng/m^3
10.8 ng/m^3
6.2 ng/m^3
0.13 μg/m^3

Summary of Findings: Respiratory Endpoints

- Associations observed between $PM_{10-2.5}$ copper but not $PM_{10-2.5}$ mass and the decline in lung function over time
- Similar associations observed in all 3 cities and associations were robust to control for $PM_{2.5}$, NO_x, and LAC
- No strong associations with emphysema by lung CT though suggestive associations between copper and apical/basilar ratio

Decline in Lung Function with Cu on Par with Aging 1-2 Years



- Findings suggest over a 10 year time span, people's lungs will "age" an additional 2 to 3 years as a result of a 4 ng/m^3 higher Cu level (Fletcher and Peto: BMJ1977;i:1645-8)

Overall Summary

- Variability in $PM_{10-2.5}$ mass and components within cities can be estimated using localized monitoring and spatial prediction modeling
- Certain components of $PM_{10-2.5}$ are associated with adverse health
- $PM_{10-2.5}$ mass may be insufficient to fully characterize health impacts

Future Work

- Extending exposure and health modeling to explore source profiles and endotoxin
- Exploring the utility of satellite data to refine and extend spatial prediction models to other cities
- Leveraging existing exposure predictions for new research in MESA Coarse cities

The content of this presentation was the responsibility of the grantees and does not necessarily represent the official views of the EPA.

- *Amanda Gassett*
  Tim Sturtz
  Lianne Sheppard
  Mark Davey
  Tim Gould
  Adam Szpiro
  Cynnie Curl
  Kayleen Williams
  Karen Stukovsky
  Joel Kaufman

- Jennifer D'Souza
  Kai Zhang
  Kari Mendelsohn-Victor
  Laura Elkayam
  Yeh-Hsin Chen
  Jordan Jahnke

National Heart Lung and Blood Institute

MESA Graham Barr, Gregory Burke, Martha Daviglus, David Jacobs

Source apportionment of coarse particulate matter ($PM_{10-2.5}$) and selected trace elements using positive matrix factorization with selected prior constraints
Timothy M. Sturtz, Sara Adar, Timothy Gould, Timothy Larson

Characterizing spatial patterns of airborne coarse particulate ($PM_{10-2.5}$) mass and chemical components in three cities: The Multi-Ethnic Study of Atherosclerosis (MESA)
Kai Zhang, Sara Adar, Amanda Gassett, Adam A. Szpiro, David Jacobs, Martha Daviglus, Gregory Burke, Joel Kaufman, Timothy V. Larson

Airborne coarse particulate matter ($PM_{10-2.5}$) and lung function and structure: The Multi-Ethnic Study of Atherosclerosis and Airborne Coarse Particulate Matter (MESA Coarse)
Sara D. Adar, Timothy Larson, Jennifer D'Souza, Amanda Gassett, Eric Hoffman, Lianne Sheppard, Kai Zhang, Joel D. Kaufman, R. Graham Barr

Long-term concentrations of airborne coarse particulate matter ($PM_{10-2.5}$), inflammation, and coagulation in the Multi-Ethnic Study of Atherosclerosis (MESA)
Sara D. Adar, Jennifer D'Souza, Kari Mendelsohn-Victor, David Jacobs, Lianne Sheppard, Mary Cushman, Ana V. Diez Roux, Joel Kaufman, Timothy V. Larson

Airborne coarse particulate matter ($PM_{10-2.5}$) and subclinical indicators of atherosclerosis: The Multi-Ethnic Study of Atherosclerosis and Airborne Coarse Particulate Matter (MESA Coarse)
Sara D. Adar, Jennifer D'Souza, Amanda Gassett, Lianne Sheppard, Joseph F. Polak, James H. Stein, Ana Diez Roux, David Jacobs, Gregory L. Burke, Martha Daviglus, Joel D. Kaufman, Timothy V. Larson

Long-term exposures to ambient coarse particulate matter ($PM_{10-2.5}$) and right ventricle end-diastolic volume, mass, and ejection fraction: The Multi-Ethnic Study of Atherosclerosis and Coarse Particle Study (MESA Coarse)
Laura R. Elkayam, Steven Kawut, Timothy V. Larson, Kai Zhang, Lianne Sheppard, R. Graham Barr, Victor Van Hee, Joel Kaufman, Sara D. Adar

Long-term Exposure to Coarse Particulate Air Pollution and Change of Blood Pressure Over Time: The Multi-Ethnic Study of Atherosclerosis (MESA)
Yeh-Hsin Chen, Timothy Larson, Marie S. O'Neill, Ana Diez-Roux, Amy Auchincloss, Adam Szpiro, David Jacobs, Martha Daviglus, Gregory Burke, Joel Kaufman, Sara Adar

Airborne coarse particulate matter ($PM_{10-2.5}$) and the retinal microvasculature in humans: The Multi-Ethnic Study of Atherosclerosis and Airborne Coarse Particulate Matter (MESA Coarse)
Sara D. Adar, Jennifer D'Souza, Ronald Klein, Barbara Klein, Amanda Gassett, Kai Zhang, Adam Szpiro, Tien Wong, Marie S. O'Neill, Sandi Shrager, David Siscovick, Martha Daviglus, Joel D. Kaufman, Timothy V. Larson

Thank you for your attention.
Any questions?