Spatial Investigation of Sources, Composition, and Long-Term Health Effects of Coarse PM

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Talk Overview

- Background
- Summary of Data Collected
- Exposure Modeling Progress
  - Mass Modeling
  - Species Modeling
- Preliminary Health Modeling
- Future Plans
Past studies generally focused on PM10 or PM2.5

- Some evidence of cardiovascular and pulmonary effects from coarse particles

- Research on chronic health effects of PM10-2.5 mass and chemical components are very limited
Spatial variation of PM$_{10-2.5}$ can be large due to local sources
Study Aims

1) Characterize spatial variability of PM$_{10-2.5}$ from natural and anthropogenic sources

2) Examine chronic health effects of PM$_{10-2.5}$ on the respiratory and cardiovascular systems
Nested in the Multi-Ethnic Study of Atherosclerosis and Air Pollution

- Population-based prospective cohort
- ~6,000 subjects (aged 45-84 yrs) without clinical CVD at baseline
  - White, African American, Hispanic, and Chinese
- Detailed characterization of PM2.5 through MESA Air
Repeated Spatial Snapshots Collected

- Collected two-week snapshots of PM$_{10-2.5}$ outside homes of ~35 subjects (3 cities/2 seasons)
  - Cities to provide range in PM$_{10-2.5}$ and sources
  - Two seasons with some repeats
  - Mass, chemical species, and endotoxin analyzed and calculated by difference
Short-Term Samples Reasonably Reflect Annual Averages

- Use spatial prediction procedures based on snapshots to assign long-term exposures
April (n=34)

Homes targeted to capture geographic space and variation in local characteristics

August (n=31)
March (n=35)

July (n=30)
January (n=26)

June (n=34)
Within- and Between-City Differences

PM Coarse Concentrations (µg/m³)

- Chicago
  - April
  - Aug
- St Paul
  - Jan
  - June
- Winston Salem
  - March
  - July

Annual Average AQS

PM₁₀-₂₅ (µg/m³)

Average of Two 2-week MESA samples
(1 Summer sample and 1 Winter sample)
PM10-2.5 Can Be Predicted by Spatial Features: Chicago

- Other variables examined included A2, A3, NDVI, commercial land use, residential land use, population density, port, season

- Model selected based on consistency of predictors and CV RMSE

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Partial $R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 in 750m</td>
<td>0.24</td>
</tr>
<tr>
<td>Industry in 750m</td>
<td>0.18</td>
</tr>
<tr>
<td>Nearness to rail yard</td>
<td>0.14</td>
</tr>
<tr>
<td>Nearness to airport</td>
<td>0.05</td>
</tr>
<tr>
<td>Local PM10 emissions</td>
<td>0.04</td>
</tr>
<tr>
<td>Local PM2.5 emissions</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Model based $R^2 = 0.68$
CV $R^2 = 0.61$
Modest Residual Spatial Structure

- Short spatial scale: Range ~600 meters
- LUR: RMSE = 1.22 μg/m³  $R^2 = 0.61$
- UK: RMSE = 1.11 μg/m³  $R^2 = 0.71$
Different Distribution Than PM2.5

PM$_{10-2.5}$

PM$_{2.5}$
**Identified Tracer of Road Dust**

- **Species Mass Fraction**
  - **PMF 3.0**
  - **Enhanced ME-2 (constrained by spatial variables)**

- **PM\textsubscript{10-2.5} from Brake and Tire Wear (\(\mu g/m^3\))**

- **Measured Copper (\(\mu g/m^3\))**
Copper Can Be Predicted by Spatial Features: Chicago

<table>
<thead>
<tr>
<th>Predictor</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 in 400m</td>
<td>0.38</td>
</tr>
<tr>
<td>A2 in 400m</td>
<td>0.05</td>
</tr>
<tr>
<td>Nearness to Large Port</td>
<td>0.05</td>
</tr>
</tbody>
</table>

UK: RMSE=2.6 ng/m³ $R^2=0.64$
LUR: RMSE=2.8 ng/m³ $R^2=0.47$
Exposure Assignment to be Completed for All Cities

- Powered to focus on 3 metropolitan areas with model predictions but also aim to explore associations in 6 metropolitan areas
- To evaluate consistency across regions and ability of models to predict at regulatory monitors
- Assigning exposure based on AQS monitors or covariates
Incident / Progression of Cardiovascular and Pulmonary Outcomes

Coronary Artery Calcium

Intima-Medial Thickness

Lung Density

Clinical Disease/ Events
Other Interesting Outcomes

- Retinal Microvasculature
- Pulmonary Function
- Systemic Inflammation
- Blood Pressure
- Left Ventricular Mass
- Aortic Calcium
- Flow Mediated Dilation
- Heart Rate Variability

Genetic data also available for gene-environment interactions
Retinal Photographs Provide Insight to Microvasculature

- Non invasive, *in vivo*, method to characterize human microvasculature
- Observes retinal vessels 100-300 um
- Hypothesize that PM10-2.5 is associated with narrowed arteriolar diameters
Chicago UK Results: Copper But Not Total Mass Associated with CRAE

Controlled for traditional risk factors and PM$_{2.5}$ mass.
Independent negative association for copper and “near road” indicator.
Summary

- Successful monitoring campaign
  - Approximately 200 homes sampled across 3 cities and 2 seasons
  - Analyzed for mass, species, and endotoxin
- Preliminary modeling shows that coarse mass and components can be predicted using covariates and spatial structure
- Early health analyses suggest that there might be impacts of coarse mass, especially from traffic sources
Next Steps

- Finalize spatial modeling
  - Create predictions for St Paul and Winston Salem
  - Evaluate other species and source profiles
  - Identify indicators of PM10-2.5 mass and species
  - Evaluate performance in unmeasured areas

- Examine associations with various health endpoints
Anticipated Contributions

- Unique characterization of within-city variation of PM$_{10-2.5}$ and its sources
  - Spatial prediction models
  - Supplements existing MESA Air exposure assessment

- Explore chronic health effects
  - Clinical and subclinical
  - Ability to evaluate potentially sensitive subpopulations
Thank you for your attention. Any questions?
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Consistent with AQS Data

PM Coarse Concentrations (µg/m³)
Good Agreement with AQS
Copper Highly Correlated with Mass

Copper vs. PM$_{2.5}$
($\rho = 0.82$)

Copper vs. PM$_{10-2.5}$
($\rho = 0.70$)
### Clinical Events Power

- 80% power to detect RR = 1.15 among all cities and RR = 1.28 among three cities

<table>
<thead>
<tr>
<th>Study Name</th>
<th>Relative Risk Per 10µg/m³ (95% CI)</th>
<th>Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Six Cities Study (PM_{15-2.5})³</td>
<td>1.43 (0.83 to 2.48)</td>
<td></td>
</tr>
<tr>
<td>Veteran’s Cohort (PM_{10-2.5})¹⁵</td>
<td>1.07 (1.01 to 1.13)</td>
<td>M</td>
</tr>
<tr>
<td>AHSMOG (PM_{10-2.5})¹⁶</td>
<td>1.05 (0.92 to 1.20)</td>
<td>M</td>
</tr>
<tr>
<td>ACS (PM_{15-2.5})¹⁷</td>
<td>1.00 (0.99 to 1.02)</td>
<td>M</td>
</tr>
<tr>
<td>Coronary Heart Disease</td>
<td>1.38 (1.07 to 1.77)</td>
<td>F</td>
</tr>
<tr>
<td>AHSMOG (PM_{10-2.5})¹⁸</td>
<td>1.19 (0.88 to 1.62)</td>
<td>M</td>
</tr>
<tr>
<td>Non-Malignant Respiratory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AHSMOG (PM_{10-2.5})¹⁶</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Sub-clinical Change Power

**IMT**
- 80% power to detect 2.5% of statin effect in all areas and 3% of effect in 3 areas

**Lung Density**
- 99% power to detect 1% of total change in MESA in all areas and 80% power to detect 1% change in 3 areas
## Good Variation in Geographic Features

<table>
<thead>
<tr>
<th></th>
<th>Baltimore</th>
<th>Chicago</th>
<th>Los Angeles</th>
<th>New York</th>
<th>St Paul</th>
<th>Winston-Salem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean NDVI (SD) USGS Reports NDVI $\times 10^4$</td>
<td>5900 (1600)</td>
<td>2500 (2100)</td>
<td>3200 (1400)</td>
<td>3900 (2100)</td>
<td>6200 (800)</td>
<td>7500 (390)</td>
</tr>
<tr>
<td>Mean Meters to Subjects from Major Road (SD)</td>
<td>230 (220)</td>
<td>140 (120)</td>
<td>230 (200)</td>
<td>60 (65)</td>
<td>160 (140)</td>
<td>390 (490)</td>
</tr>
<tr>
<td>Rural Land Use (%in Zip Code)</td>
<td>9</td>
<td>26</td>
<td>26</td>
<td>8</td>
<td>66</td>
<td>69</td>
</tr>
<tr>
<td>Comm/ Industr (% in Zip Code)</td>
<td>13</td>
<td>29</td>
<td>21</td>
<td>34</td>
<td>8</td>
<td>2</td>
</tr>
</tbody>
</table>
Reproducible Results

Mean RPD = 18%
$R^2 = 0.8$
Subclinical Respiratory Outcomes

Alveoli with emphysema

Microscopic view of normal alveoli

© ADAM, Inc.
Vacuum Pump
PM$_{2.5}$
PM$_{10}$

3-Way Valve

Vacuum Pump

3-Way Valve

PM$_{2.5}$
PM$_{10}$

Elapsed Timer
00000.0 Hrs

120V AC

Endotoxin

Mass, reflectance, and metals
Nearest Monitor Approach: Results Driven by Winston-Salem
Spatial Features

A1

A2

Industry

Port

Rail yard

PM10

PM25
Some Differences at Cohort Locations

\[ \rho = 0.64 \]

PM\textsubscript{10-2.5} (\(\mu g/m^3\))
(Coefficient of Variation = 16%)

PM\textsubscript{2.5} (\(\mu g/m^3\))
(Coefficient of Variation = 6%)