Identification and Characterization of Pollutant Hot Spots Integrating Probe Vehicle, Traffic and Land Use Data

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Identification and Characterization of Pollutant Hot Spots
Integrating Probe Vehicle, Traffic and Land Use Data

By
Katherine E. Bell, P.E.
Miguel A Figliozi, Ph.D.

FRIDAY SEMINAR
January 17, 2014
OUTLINE

I. Introduction & Background

II. Available and Collected Data

III. Statistical Analysis

IV. Conclusions & Future Research
BACKGROUND

• Motor Vehicle Emissions – CO2, CO, HC, NOX, MSATs

• Fine Particulate Matter (PM$_{2.5}$) – noncombustion & combustion
  - Carcinogenic
  - Heart problems
  - Respiratory problems

• Volatile Organic Compounds (VOC) – ozone precursors, carcinogens

• **HOT SPOT:** Subsection of corridor that consistently has an average pollutant concentration above the 85$^{th}$ percentile when compared to all other subsections on the corridor.
Background

**HUMAN HAIR**
50-70 μm (microns) in diameter

*PM₂.₅*
Combustion particles, organic compounds, metals, etc.
< 2.5 μm (microns) in diameter

*PM₁₀*
Dust, pollen, mold, etc.
< 10 μm (microns) in diameter

**FINE BEACH SAND**
90 μm (microns) in diameter

Image courtesy of the U.S. EPA
STUDY AREA – SE Powell Boulevard

- 4.6 miles – SE 7th Ave to I-205
- Multi-modal

- 2-lanes each direction
- Variety of land uses
OBJECTIVES

• Develop an efficient method to identify hot spot locations
  
  o **Better understand which variables are most related to variability in pollutant levels**
  
  o **Better understand the variability of exposure levels along a corridor**

• **Long-term**: Better inform personal exposure models and health analyses
LITERATURE REVIEW

1) Air Quality Health and Environmental Concerns
2) Air Quality Modeling and Measurements
3) Powell Boulevard Research
4) Land Use Regression
LITERATURE REVIEW

1) Air Quality Health and Environmental Concerns
2) Air Quality Modeling and Measurements
3) Powell Boulevard Research
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Background
Data
Analysis
Conclusions
LITERATURE REVIEW

1) Air Quality Health and Environmental Concerns
2) Air Quality Modeling and Measurements
3) Powell Boulevard Research
4) Land Use Regression

Mobile
Tailpipe
In Vehicle
Outside Vehicle
Stationary

Background Data Analysis Conclusions
AVAILABLE & COLLECTED DATA

- Probe Vehicle Data
- Traffic Data
- Land Use Data
- Meteorology

PM$_{2.5}$ Concentrations
## Data Collection

**Probe Vehicle**

### Data Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Equipment</th>
<th>Description</th>
<th>Measurement Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS Data</td>
<td>iPhone 4 - &quot;MyTracks&quot; Application</td>
<td>Location of probe vehicle</td>
<td>1 second</td>
</tr>
<tr>
<td>Video Footage</td>
<td>4 CountingCars digital video cameras</td>
<td>Front, Right, Left and Rear of Probe Vehicle</td>
<td>Continuous</td>
</tr>
<tr>
<td>PM&lt;sub&gt;2.5&lt;/sub&gt; (µg/m&lt;sup&gt;3&lt;/sup&gt;)</td>
<td>2 DustTrak DRX Aerosol Monitors (TSI Model 8533)</td>
<td>Outside probe vehicle passenger windows, left and right</td>
<td>1 second</td>
</tr>
<tr>
<td>VOC (ppb)</td>
<td>2 Ion-Science PhoCheck Tiger devices</td>
<td></td>
<td>1 second</td>
</tr>
</tbody>
</table>
AVAILABLE DATA

Data Type | Data Source | Measurement Frequency
--- | --- | ---
Meteorological | DEQ Station | 5 minutes
Traffic | Wavetronix | 10 seconds
SCATS | 15 minutes
Land Use | PortlandMaps | n/a
Portland Metro RUIS* | n/a

SCATS (Adaptive Traffic Signal) Data
Wavetronix SmartSensor HD Systems
Oregon DEQ Air Quality Monitoring Station
A West End of Study Area
B East End of Study Area
Multiple Regression – ALL DAY

Data

- Linear Model: Adjusted $R^2 = 36$
- Log-Linear Model: Adjusted $R^2 = 52$

Background

Data Analysis

Conclusions
CONCLUSIONS

• Hot Spot Identification
  • Consistency, magnitude and distance impacted
  • AM vs. PM: analyze together AND separately

• Statistical Analysis
  • Strongest (+) Relationships: Relative Humidity, Background PM$_{2.5}$ Concentrations, Presence of “High Emitters”
  • Strongest (-) Relationships: Temperature, Wind Speed, Traffic Speed
  • Land Use variables also have statistically significant relationships with PM$_{2.5}$ concentrations
  • Multiple Regression models can be adjusted depending on data available

• Mobile Outside Vehicle Measurements + Land Use Regression
  • Valuable tool to better understand relationships between hot spot locations and other variables
FUTURE RESEARCH

• Cold Spots – *study potential predictors*
• VOC – *perform regression analysis*
• Predictors of Hot Spot Frequency
• Study “outliers”
• Other variables
  o *Construction*
  o *Underpasses*
  o *Vehicle Classifications (more detailed)*
ACKNOWLEDGEMENTS

Oregon Transportation Research and Education Consortium (OTREC) & National Institute for Transportation and Communities (NITC)

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Alex Bigazzi, Adam Moore (PSU)
QUESTIONS

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Portland State University

Related Masters Thesis will be available at http://www.its.pdx.edu/publications.php
Data

- Pollutant Concentration – $PM_{2.5}$ and VOC
- Probe Vehicle Behavior – Location, Speed, Standard deviation of speed, Percent time accelerating, Stopped time
- Traffic – Queue length, Queue adjacent, Volume, Distance to major intersection, # of high emitters
- Meteorological – Wind Speed/Direction, Background $PM_{2.5}$, Relative humidity, Temperature
- Zoning – Commercial, Residential, Industrial, Open-space
- Buildings & Businesses – Drive-through business (i.e., McDonalds) Gas station, Building height, Building footprints
- Elevation Changes – Flat, Uphill, Downhill, High point, Low point
AVAILABLE DATA

- **Traffic** – *Wavetronix & SCATS*
- **Land Use** – *PortlandMaps & RLIS*
- **Meteorological** – *DEQ Air Quality Monitoring Station*
STATISTICAL ANALYSIS

1) Mann-Whitney-Wilcoxon Test
2) Simple Regression Analysis
3) Multiple Regression Analysis

Skewed distribution
Time-Space-Air Quality Diagram

Speed (mph)
- D-5
- >=5-10
- >=10-20
- >=20-30
- >=30

PM2.5 (ug/m³)
- 0.4
- >=4.8
- >=8.12
- >=12.16
- >=16.20
- >=20

Above Primary NAAQS (for annual mean, averaged over 3 years)
Simple Regression - Traffic

- Time of Day
- Mean Speed
- Stdev Speed
- Stopped Time
- Queue Length
- Queue Adjacent
- Traffic Volume
- Distance to Major Intx
- # Of High Emitters

R-square and correlation sign

-40% -30% -20% -10% 0% 10% 20%

AM Only
PM Only
AM & PM
Simple Regression

Zoning
- Industrial
- Residential
- Commercial

Buildings
- Frontage Profile Height
- Building Height
- Building Footprint
- Distance to Gas Station (Far Side)
- Distance to Gas Station
- Distance to Drive Through (i.e., McD's)
- Mostly Flat
- Mostly Uphill
- Temperature
- Mean Speed

R-square and correlation sign

-40% -30% -20% -10% 0% 10% 20%

AM Only
PM Only
AM & PM
Simple Regression - Traffic

- Time of Day
- Mean Speed
- Stdev Speed
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- Queue Length
- Queue Adjacent
- Traffic Volume
- Distance to Major Intx
- # Of High Emitters

R-square and correlation sign

-40% -30% -20% -10% 0% 10% 20%

AM Only
PM Only
AM & PM
Simple Regression

Meteorology

- Temperature
- Wind Speed
- Wind Direction Sin
- Wind Direction Cos
- Background PM2.5
- Relative Humidity
- Time of Day

Traffic

- Mean Speed
- # Of High Emitters
- Queue Adjacent

R-square and correlation sign

AM Only
PM Only
AM & PM

Introduction  Literature Review  Data  Analysis  Conclusions
Simple Regression

Zoning
- Industrial
- Residential
- Commercial

Buildings
- Frontage Profile Height
- Building Height
- Building Footprint
- Distance to Gas Station (Far Side)
- Distance to Gas Station
- Distance to Drive Through (i.e., McD's)
- Mostly Flat
- Mostly Uphill
- Temperature
- Mean Speed

R-square and correlation sign

- AM Only
- PM Only
- AM & PM

Data Analysis

Introduction Literature Review Data Analysis Conclusions
Multiple Regression - % Contribution to Baseline

**All Day Model - Example**

Y = 18.14 – 0.21(Temperature) + 2.00[sin(Wind Direction)] + 0.22(# of high emitters) + 1.41(Time w queue adjacent) - 0.01(% Residential zoning) - 0.12(Distance to gas station)
Multiple Regression  \[ Y_i = \beta_0 + \beta_1 X_{1i} + \ldots + \beta_k X_{ki} + \varepsilon \]

- R Step() function – *uses AIC criteria*
- p-value < 0.05
- Variance inflation factor (VIF) < 5

\[ VIF_j = \frac{1}{1 - R^2_j} \]

- Correlations
- Log-linear Models
## Correlations

<table>
<thead>
<tr>
<th>$R^2$</th>
<th>ResTotal</th>
<th>ResNear</th>
<th>GasDistFar</th>
<th>H200AvgTotal</th>
<th>ResFar</th>
<th>GasDistAll</th>
<th>H200AvgNear</th>
<th>IndTotal</th>
<th>H200Total</th>
<th>IndNear</th>
<th>IndFar</th>
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<td>0.19</td>
<td>0.18</td>
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</table>
## Simple Regression

### Introduction

- **Literature Review**
- **Data**
- **Analysis**
- **Conclusions**

### Analysis

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>AM &amp; PM</th>
<th>AM only</th>
<th>PM only</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Change</td>
<td>p-value</td>
<td>R-sq</td>
</tr>
<tr>
<td>Time</td>
<td>TOD</td>
<td>0.0000</td>
<td>30.55%</td>
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<tr>
<td>Probe Vehicle Behavior</td>
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<tr>
<td>Mean Speed</td>
<td>-</td>
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<td>5.28%</td>
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<td>Percent Accel</td>
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<tr>
<td>Queue Length</td>
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<tr>
<td>Mean Q Adj</td>
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<tr>
<td>Volume</td>
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<tr>
<td>Dist To 4 Way</td>
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<td>0.0043</td>
<td>1.11%</td>
</tr>
<tr>
<td>Vol Over Dist</td>
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<td>0.0442</td>
<td>0.55%</td>
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<tr>
<td>Mean Emitters</td>
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<tr>
<td>Mean Wind Speed</td>
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<tr>
<td>Mean Wind Dir Sin</td>
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<tr>
<td>Mean Wind Dir Cos</td>
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<tr>
<td>Mean Back PM 2.5</td>
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<tr>
<td>Mean RH</td>
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<td>26.62%</td>
</tr>
<tr>
<td>Mean Temp</td>
<td>-</td>
<td>0.0000</td>
<td>32.83%</td>
</tr>
</tbody>
</table>

### Notes

- AM & PM: AM and PM data compared.
- AM only: AM data only.
- PM only: PM data only.
- Change: Percentage change in PM concentration.
- Sig: Statistical significance of the change.
- R-sq: Coefficient of determination.
## Analysis

### Land Use - Zoning

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>AM &amp; PM</th>
<th>AM only</th>
<th>PM only</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Change</td>
<td>p-value</td>
<td>R-sq</td>
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<tr>
<td>CommNear</td>
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</tr>
<tr>
<td>ResNear</td>
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<td>2.28%</td>
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<tr>
<td>IndNear</td>
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<td>0.0045</td>
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<tr>
<td>OpenNear</td>
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<td></td>
</tr>
<tr>
<td>CommFar</td>
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<td>-</td>
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<td>OpenFar</td>
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<td>0.58%</td>
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<td>+</td>
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</tr>
<tr>
<td>OpenTotal</td>
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</table>

### Land Use - Buildings and Businesses

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<th>AM &amp; PM</th>
<th>AM only</th>
<th>PM only</th>
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<tbody>
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<td>p-value</td>
<td>R-sq</td>
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</tr>
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<td>1.74%</td>
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<td></td>
</tr>
<tr>
<td>GasDistNear</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>DriveDistFar</td>
<td>+</td>
<td>0.0491</td>
<td>1.06%</td>
</tr>
<tr>
<td>GasDistFar</td>
<td>-</td>
<td>0.0002</td>
<td>1.83%</td>
</tr>
<tr>
<td>DriveDistAll</td>
<td>-</td>
<td>0.0169</td>
<td>0.78%</td>
</tr>
<tr>
<td>GasDistAll</td>
<td>-</td>
<td>0.0004</td>
<td>1.70%</td>
</tr>
</tbody>
</table>