Atlanta Rail Yard Study: Evaluation of local-scale air pollution trends using stationary and mobile monitoring

Gayle Hagler¹, Halley Brantley¹, Boris Galvis², Scott Herndon³, Eben Thoma¹, Armistead Russell⁴, Michael Bergin⁴, Paola Massoli³, Edward Fortner³, Jon Franklin⁵, Lu Xu⁴, Nga Lee Ng⁴

¹US EPA, Office of Research and Development, Research Triangle Park, NC
²Universidad De La Salle, Colombia
³Aerodyne Research, Billerica, MA
⁴Georgia Institute of Technology, Atlanta, GA
⁵Massachussetts Institute of Technology, Boston, MA
Purpose of this talk

• Provide an overview of research field measurements to evaluate multipollutant air pollution trends near a major rail yard in Atlanta, GA
Air pollution in close proximity to rail yards is not well understood and a challenging issue to study
  - Significant variety of rail yards - size, operations, surrounding environment, local meteorology
  - Emissions vary spatially and temporally, over large geographic area
  - Confounding sources often nearby – highways, manufacturing

Some large rail yards are in very close proximity to residential areas; environmental justice concerns

Several recent studies to note:
  - CSX Rougemere Rail Yard in Dearborn, MI – Turner, 2009
  - Davis Rail Yard in Roseville, CA – Cahill et al., 2011; Campbell, 2009
  - Cicero Rail Yard Study in Cicero, IL – Rizzo et al., 2014
• CSX and Norfolk Southern co-located rail yards, Tilford and Inman Yards, are in a non-attainment or maintenance area for PM$_{2.5}$

• State of GA received $44.9M in CMAQ and HPP* funding to support low-emission switch-duty locomotives in Georgia ($36M for Atlanta area rail yards, remainder for Macon and Rome)

• CMAQ funding also supported local monitoring upwind and downwind by Georgia Tech (Galvis, 2013)

*Middle Georgia Clean Air Coalition for Congestion Mitigation and Air Quality Improvement High Priority Projects (HPP)
Field study

- Monitoring near rail yard

Two independent monitoring studies (Georgia Tech, EPA) – developed official Memorandum of Understanding (MOU) to collaborate and share data.
Mobile field study

• 19 sampling runs conducted in May 2012

Wind conditions during sampling (measured on Georgia Tech rooftop)

★

Georgia Tech sites (initiated in 2010): PM$_{2.5}$, BC, CO$_2$
Field study

Aerodyne Mobile Lab
ARYS 2012

**Roof**
- Sun Photometer
- Anemometer
- GPS

**NO₂**
- CAPS

**NOₓ**
- Chemiluminescence

**O₃**
- UV Absorption

**CO₂**
- Licor N.D. IR

**SMPS**
- Multi-angle absorption photometer (MAAP)
- Condensation Particle Counter
- CAPS extinction monitor

**SP-AMS**
- Aerosol Mass Spec
  - Size Resolved Composition
    - 35 nm - 1 μm
    - NO₃⁻, SO₄²⁻, NH₄⁺
    - Organic Carbon, BC

**Relative Humidity**

**Pressure**

**Temperature**

**Velocity**

**Cyclone**
- < 2.5 μm

**isokinetic sample splits**

**CO₂**
- Licor N.D. IR

**Video Camera**

**cw-QCL**
- Quantum Cascade Laser
  - CH₄, C₂H₂

**PTR-MS**
- Proton-Transfer Mass Spec
  - Selected VOCs

**cw-QCL**
- Quantum Cascade Laser
  - CO, N₂O, H₂O

**QCL**
- Quantum Cascade Laser
  - NO₂ and HCHO
<table>
<thead>
<tr>
<th>Measurement</th>
<th>Rate</th>
<th>Instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide (CO2)</td>
<td>0.9 s</td>
<td>Licor 6262 (2) and Licor 820</td>
</tr>
<tr>
<td>Carbon Monoxide (CO)</td>
<td>1 s</td>
<td>Quantum Cascade Laser System (2230 cm(^{-1}))</td>
</tr>
<tr>
<td>Nitric Oxide (NO)</td>
<td>1 s</td>
<td>Thermo 42i Chemiluminescence</td>
</tr>
<tr>
<td>Nitrogen Dioxide (NO(_2))</td>
<td>1 s</td>
<td>Quantum Cascade Laser System (1600 cm(^{-1}))</td>
</tr>
<tr>
<td>Nitrogen Dioxide (NO(_2))</td>
<td>5 s</td>
<td>Cavity Enhanced Phase Shift</td>
</tr>
<tr>
<td>Oxides of Nitrogen (NOy)</td>
<td>1.4 s</td>
<td>Thermo 42i with external inlet-tip Mo Converter</td>
</tr>
<tr>
<td>Black Carbon PM (&lt; 2.5 μm)</td>
<td>3 s</td>
<td>Multi-Angle Absorption Photometer</td>
</tr>
<tr>
<td>Black Carbon PM (70 nm - 1.5 μm)</td>
<td>1 s (variable)</td>
<td>SP-AMS with laser-on mode</td>
</tr>
<tr>
<td>Non-refractory PM coating on Black Carbon (70 nm – 1.5 μm)</td>
<td>1 s (variable)</td>
<td>SP-AMS with laser-on mode;</td>
</tr>
<tr>
<td>Particle Extinction</td>
<td>3 s</td>
<td>Cavity Enhanced Phase Shift</td>
</tr>
<tr>
<td>Particle Number Density</td>
<td>1.8 s</td>
<td>Condensation Particle Counter</td>
</tr>
<tr>
<td>Number based Size Distribution</td>
<td>2 minutes</td>
<td>Differential Mobility Analyzer with Condensation Particle Counter</td>
</tr>
<tr>
<td>Various Aromatics and Oxygenates such as:</td>
<td>1.4 s</td>
<td>Proton Transfer Reaction Mass Spectrometer</td>
</tr>
<tr>
<td>Benzene, Toluene, Xylene, Acetone, Acetaldehyde</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alkanes, Selected Alkenes and Aromatics</td>
<td>Hourly</td>
<td>Gas Chromatogram with Flame Ionization Detector</td>
</tr>
</tbody>
</table>
Example plume event

Nitrogen oxide

Nitrogen dioxide

Carbon monoxide

Ultrafine particles

Black carbon

Particle extinction
Research question #1

Are there statistically significant differences in air pollutant concentrations downwind of the rail yard relative to upwind air?
Results

50 m median UFP concentrations by wind category (N > 5)

Wind from the Southwest

- UFPs (cm$^3$):
  - 1400 - 3110
  - 3120 - 4100
  - 4110 - 4440
  - 4450 - 4930
  - 4940 - 5440
  - 5450 - 6110
  - 6120 - 6830
  - 8940 - 13100

Wind from the Northeast

- UFPs (cm$^3$):
  - 1400 - 3110
  - 3120 - 4100
  - 4110 - 4440
  - 4450 - 4930
  - 4940 - 5440
  - 5450 - 6110
  - 6120 - 6830
  - 8940 - 13100

Source: DigitalGlobe, GeoEye, Inc., USGS, AEX, GeoEye, Inc., USGS, AEX, GeoEye, Inc.
Results

Median concentrations by 50 m segment and wind category

Points represent means and 95% CL

[Map and graphs showing concentration data by wind direction and distance to railyard]
Results

- NO (ppb)
  - Winds from Northeast: Western 2.5, Within 4.7, Eastern 2.3
  - Winds from Southwest: Western 5.3, Within 4.9, Eastern 6.1

- CO (ppb)
  - Winds from Northeast: Western 246, Within 255, Eastern 229
  - Winds from Southwest: Western 205, Within 189, Eastern 213

- NO$_2$ (ppb)
  - Winds from Northeast: Western 18.9, Within 23.4, Eastern 10.6
  - Winds from Southwest: Western 9.4, Within 16, Eastern 19.8

- NO$_3$ (ppb)
  - Winds from Northeast: Western 17.5, Within 23.7, Eastern 11.3
  - Winds from Southwest: Western 11, Within 19, Eastern 20.7
Results

Example BC stationary data:

General agreement between mobile and stationary data indicating downwind excess BC / light-absorbing particles

Figure from Galvis et al., 2013. Fuel-based fine particulate and black carbon emission factors from a railyard area in Atlanta. JAWMA
Results

Correlation of 50m medians, all wind directions

R = 0.63  
R = 0.64  
R = 0.49  
R = 0.44  
R = 0.32

R = 0.64  
R = 0.49  
R = 0.44  
R = 0.30  
R = 0.34

R > 0.5
Summary

• Detectable upwind/downwind shift in local air pollution levels in neighborhoods surrounding the yard.
  o Statistically significant increase in: UFPs, BC, particle extinction, NO₂, NOy
  o Albedo shift towards more light-absorbing particulate mixture in downwind areas

• Next steps
  o Compare in situ emission factors developed by Galvis et al. stationary data and mobile data sets for BC, PM₂.5
Acknowledgements

- EPA Office of Research and Development
- EPA Region 4
- Georgia Department of Natural Resources, Environmental Protection Department