Assessment of Near-Port Air Pollution Combining a Mobile Monitoring and Modeling Approach

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Introduction

- Summarizes early study to investigate the effect of ports on local-scale air quality
- Ports are complex multi-modal facilities - ocean going vessels, on-terminal equipment, trucks, and rail
- These sources can emit high quantities of multiple pollutants such as carbon monoxide, particulates and black carbon[1]
- Pollutant levels may be elevated up to several hundred meters from a source[2]
- Numerous negative health effects from port emissions including cardiac and respiratory diseases[3]
- Synthesis of novel measurement and modeling techniques
  - Mobile Monitoring using EPA's Geospatial Monitoring of Air Pollution (GMAP) vehicle[4]
  - Modeling using AERMOD, R-LINE, and C-PORT models

Wando Welch Terminal, Port of Charleston, South Carolina
Source: http://www.scspa.com/

Mobile Monitoring Study

Study Design Consideration:

- Port activity hours – 7 am to 7 pm when ships are being loaded/unloaded
- Facilities of interest: Wando Welch Terminal; Downtown terminals; Veterans Terminal; Bennett Rail Yard
- Electric vehicle
  - 3-4 hour range depending on route to be driven, laps, and road speed
  - Real-time air monitoring instruments of multiple pollutants (see Table)
- Approximately 30 minute driving routes allow for multiple laps per sampling day
- Stationary sampling of nearby meteorological conditions
- Avoidance of sample start times coinciding with typical commute hours
- Sample start times – Week 1: 4 AM; Week 2: 1:30 PM; Week 3: 9 AM

GMAP Vehicle

Measurement	Sampling Rate	Instrument	Stationary/ Mobile
NO_2	1s	Visible (450 nm) absorption Cavity Attenuated Phase Shift Spectroscopy (CAPS, Aerodyne Research, Inc., Billerica, MA, USA)	Mobile
Carbon monoxide (CO)	1 s	Quantum cascade laser (QCL, Aerodyne Research, Inc., Billerica, MA, USA)	Mobile
Carbon dioxide (CO_2)	1 s	Li-COR 820 non-dispersive infrared (NDIR), (LI-COR, Lincoln, Nebraska USA)	Mobile
Particle number concentration (size range 5.6-560 nm, 32 channels)	1 s	Engine Exhaust Particle Sizer (EEPS, Model 3090, TSI, Inc., Shoreview, MN, USA)	Mobile
Particle number concentration (size range 0.5-20 µm, 52 channels)	1 s	Aerodynamic Particle Sizer (APS, Model 3321, TSI, Inc., Shoreview, MN, USA)	Mobile
Black carbon	1-5 s	Single-channel Aethalometer (Magee Scientific, AE-42, Berkeley, CA, USA)	Mobile
Longitude and latitude	1 s	Global positioning system (Crescent R100, Hemisphere GPS, Scottsdale, AZ, USA)	Mobile
3D wind speed and direction	1 s	Ultrasonic anemometer (RM Young, Model, Traverse City, MI, USA)	Stationary
SO_2	1 s	Ecotech 9850 (Ecotech, Knoxfield Victoria, 3180, Australia)	Stationary

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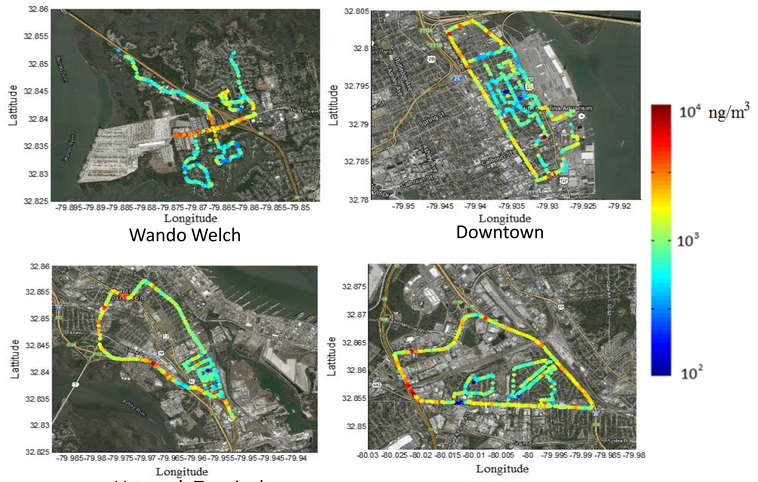
Mobile Measurement Results

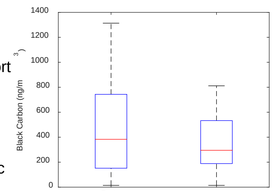


Black Carbon concentrations (ng/m³) along driving routes, spatially averaged over 20 m increments

Port of Charleston Area
Source: http://www.scspa.com

Quantifying Port Effect on Residential Neighborhoods

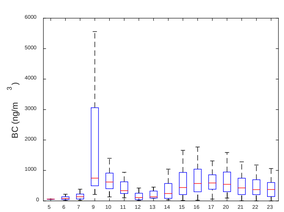
- Local background concentration is taken by selecting periods where wind is from a direction downwind of the port compared to periods where wind is blowing from over the port
- Comparison was confined to periods during normal port operating hours (7 am to 7 pm) during similar atmospheric conditions to control for stability differences
- A significant effect from the port is observed for all measured pollutants



Concentration distributions when wind is blowing from upwind and downwind

Spatial and Temporal Port Effect

- High concentrations observed along major roadways (significant non-port impact)
- Distributions of concentration show high variability in measurement
- Higher concentrations observed in the morning and afternoon (likely traffic related spikes)
- Generally higher concentrations observed during port operational hours (7 AM to 7 PM)
- Significant non-port effect observed – high concentrations outside of port hours

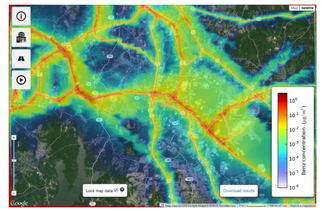


Time of day effect on Black Carbon concentration distributions

Modeling Results

Modeling Tools

- Model ambient pollutant concentrations near ports
- AERMOD models port on-terminal sources such as heavy equipment and docked vessels as area source using emissions inventory data
- RLINE models roadway and railways as line sources using AADT counts
- C-PORT is a reduced form model intended for community use to quickly but accurately gauge impact of ports, roadways, and rail yards on local air quality



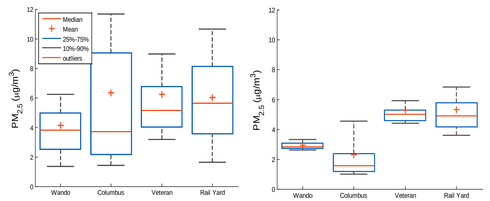
C-PORT Benzene model concentrations around Port of Charleston area

Modeling Comparison

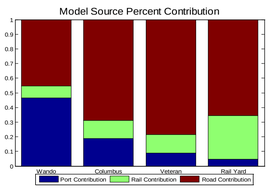
- Differences in sampling times/days, met conditions and distance from source to sampling locations makes it difficult to accurately compare sites
- However, comparison between measurement and model in the neighborhood regions along the four measurement routes for $PM_{2.5}$ shows good qualitative agreement
- Model results for Columbus Street terminal are much lower than measurement, suggesting the model may be missing some major emission source near this location

Source Contribution

- Source apportionment is difficult with measurements but easier with models
- Modeling complements measurement data by filling in knowledge gaps
- Isolating percent contribution from the three source types shows that roadway sources dominate port and rail source everywhere except Wando Welch terminal
- Measurement route near Veteran's terminal is further away than other terminal routes, explaining minor port impact
- Port contribution only relates to on-terminal activity. Part of road and rail contribution would also be attributable to port activity



Comparison of measurement (left) and modeling (right) concentrations at each location of interest



Percent contribution of different sources at locations of interest from AERMOD and RLINE models

Summary

- Mobile monitoring campaign conducted around the Port of Charleston, South Carolina, using GMAP vehicle.
- This work represents an early effort to understand the impact of port emissions on near-port air quality. More port-related mobile monitoring campaigns may be conducted to facilitate a more comprehensive analysis.
- More port-related mobile monitoring campaigns are needed to generate more comprehensive analysis.
- Ports are shown to have a potentially significant impact on local air quality which quickly diminishes away from the port. This effect can be difficult to isolate as the impact of roadways is generally much higher.
- AERMOD and RLINE modeling shows generally strong agreement with measurement study.

References:
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2. Zhou, Y.; Levy, J. 2007. Factors influencing the spatial extent of mobile source air pollution impacts: a meta-analysis. *BMC Public Health*. 7(1), 89.
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