

Assessment of Near-Source Air Pollution at a Fine Spatial Scale Utilizing a Mobile Monitoring Approach

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Background

- Ports play a critical role in the United States and global economies.
- The Panama Canal is undergoing an expansion which will double its capacity and allow for larger vessels to pass through. While this is expected to provide a positive economic impact, the environmental impact is uncertain.
- Port facilities service traffic from ocean going vessels (OGV), on-terminal equipment, heavy trucks, and rail, leading to significant emissions of black carbon, particulate, carbon monoxide, and other harmful pollutants.
- Previous research on roadways and railways has shown significant elevation of pollutant concentration above background within several hundred meters of emission sources.

Research Objectives

- Early efforts to investigate how ports could impact local-scale air quality (within several hundred meters from the port facilities).
 - Mobile monitoring campaign conducted around the Port of Charleston in South Carolina
 - Measurement data supplemented with modeling results from AERMOD and RLINE
- Use data to isolate the port contribution from other source contributions (e.g. roadways) and control for confounding variables (e.g. meteorological conditions)

Study Overview



Wando Welch Terminal

Source:

<http://www.scspace.com/>



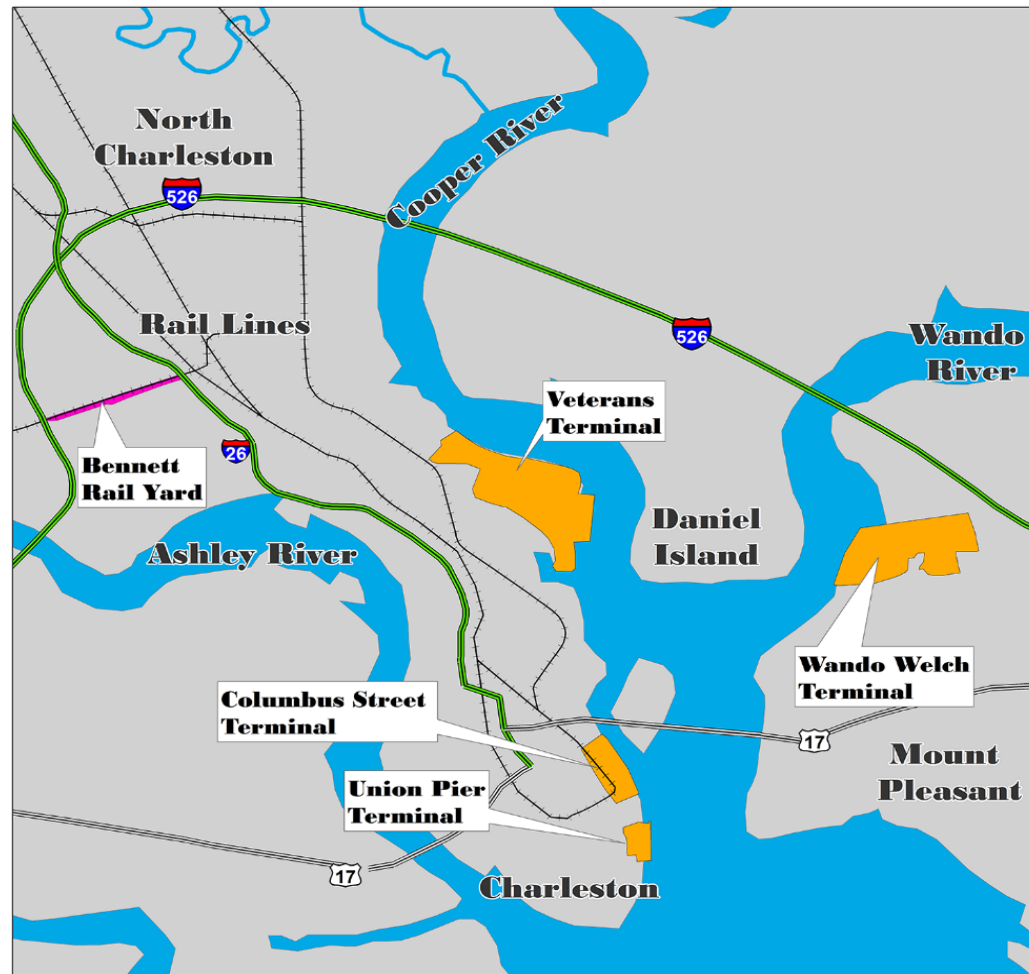
GMAP Vehicle

- Mobile monitoring campaign
 - February and March, 2014
 - Port of Charleston area in South Carolina
 - Conducted using EPA's Geospatial Measurement of Air Pollution (GMAP) vehicle
- GMAP vehicle
 - all-electric
 - measures real-time (1 Hz) concentrations of BC, NO₂, particulate matter, CO, and CO₂
 - on-board GPS records geospatial coordinates
 - 3 to 4 hour range
 - Repeated laps at various times of day and week near different port terminals
- Meteorological conditions recorded with nearby stationary sampling

GMAP Vehicle Instrumentation

Measurement	Sampling Rate	Instrument	Stationary/ Mobile
NO ₂	1 s	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

Port of Charleston



Driving Routes

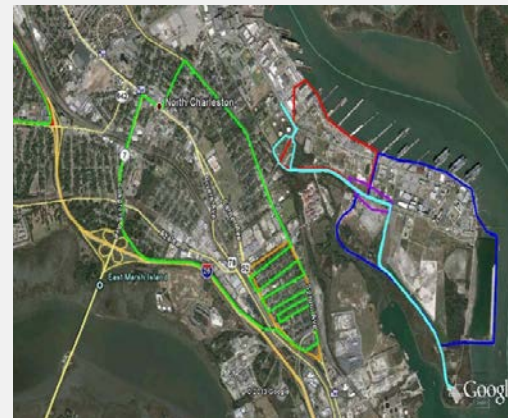
- Sampling at each occurred over 3-4 hour periods on multiple days
- Measurement start times were selected to cover a wide range of port operational times
- Driving routes shown in green.
- Port terminals outlined in red.



Wando Welch Terminal
(10 sampling days)



Columbus Street Terminal
(6 sampling days)



Veteran's Terminal
(4 sampling days)



Bennett Rail Yard
(4 sampling days)

Spatially Averaged Concentration

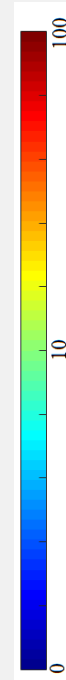
- Each point represents an average of all PM_{2.5} concentrations ($\mu\text{g}/\text{m}^3$) measured within 20 m radius.
- High concentrations observed along major roadways (significant non-port impact)
- Analysis will focus on measurements within neighborhood zones (outlined in yellow)



Wando Welch Terminal



Columbus Street Terminal



Spatially Averaged Concentration

- Spatially averaged PM_{2.5} concentrations ($\mu\text{g}/\text{m}^3$) at Veteran's Terminal and Bennett Rail Yard

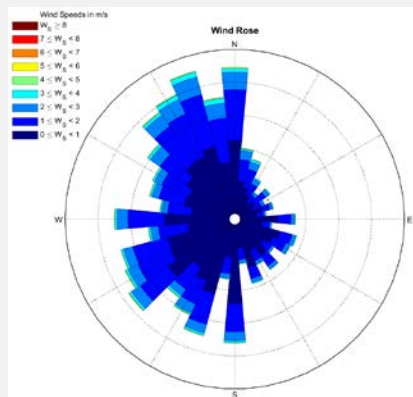


Veteran's Terminal

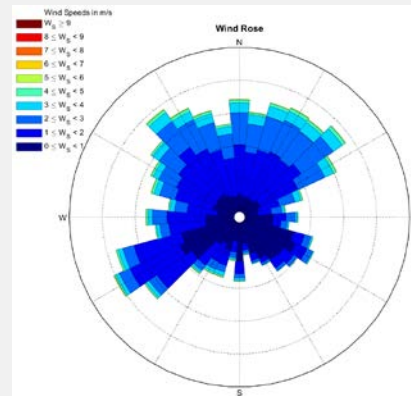


Bennett Rail Yard

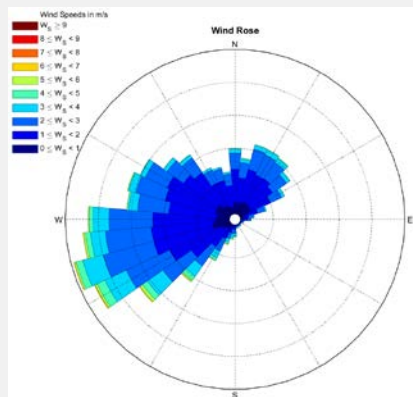
Wind Roses



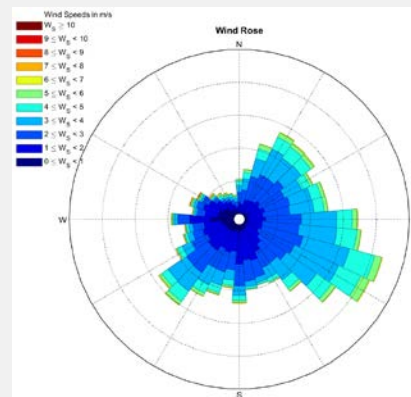
Wando Welch Terminal



Columbus Street Terminal



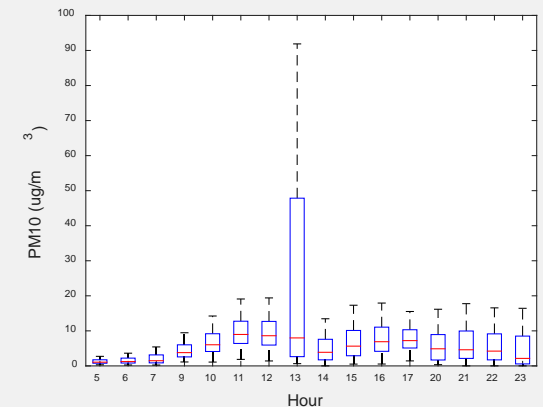
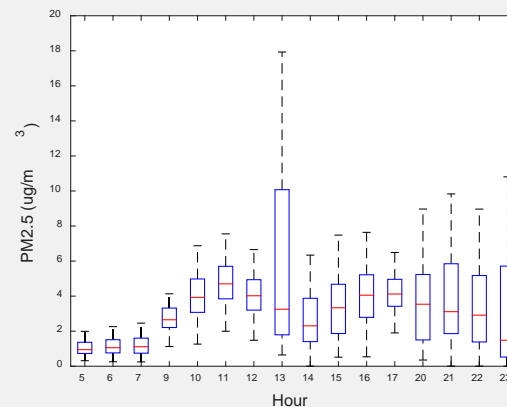
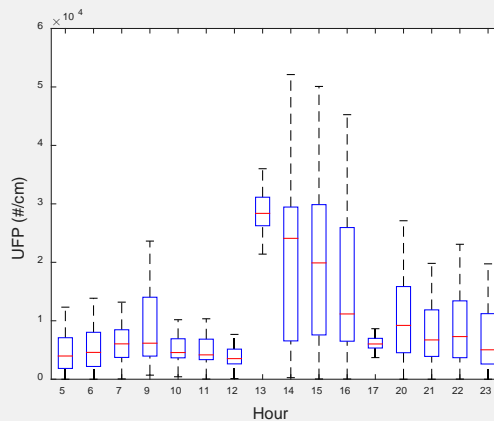
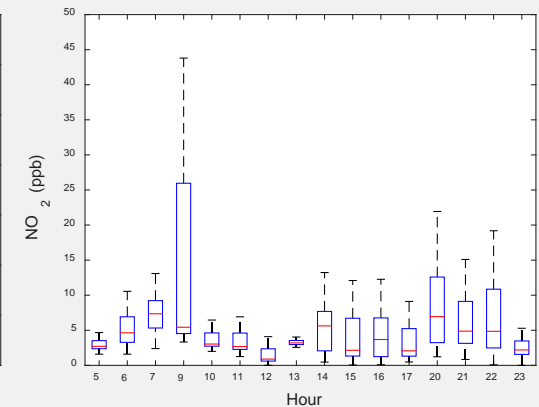
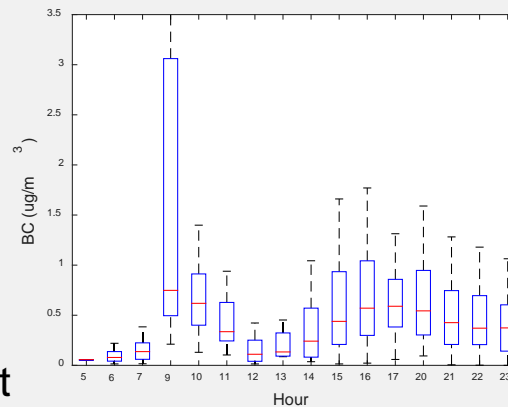
Veteran's Terminal



Bennett Rail Yard

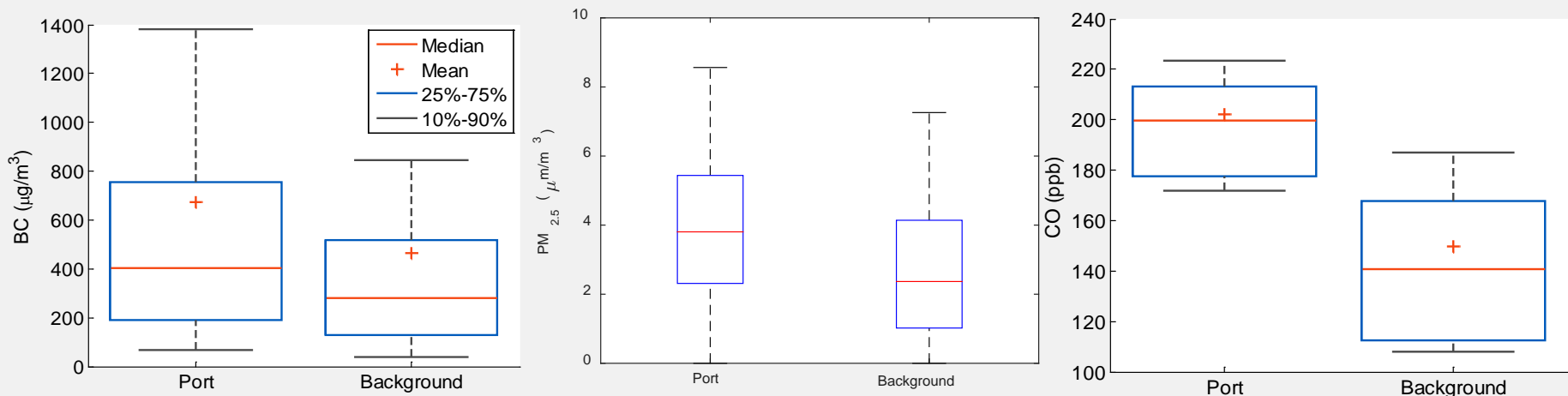
Time of Day

- Distributions of concentration at Wando Welch show high temporal variability in measurement
- Higher concentrations observed in the morning and afternoon – likely caused by morning and evening rush hour periods.
- Very heavy diesel truck traffic observed moving into and out of port in early morning.



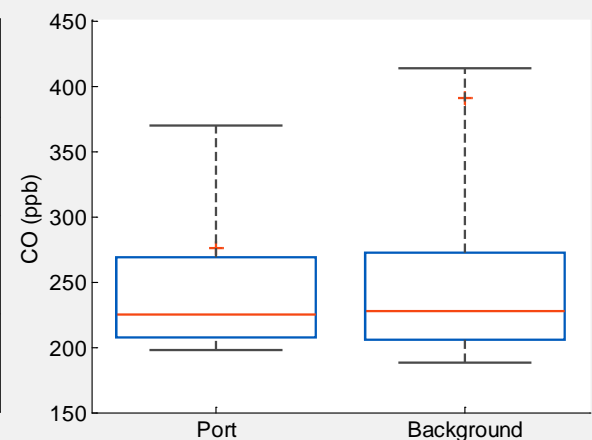
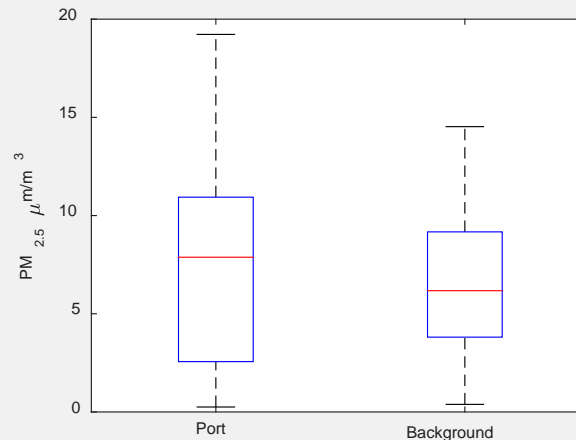
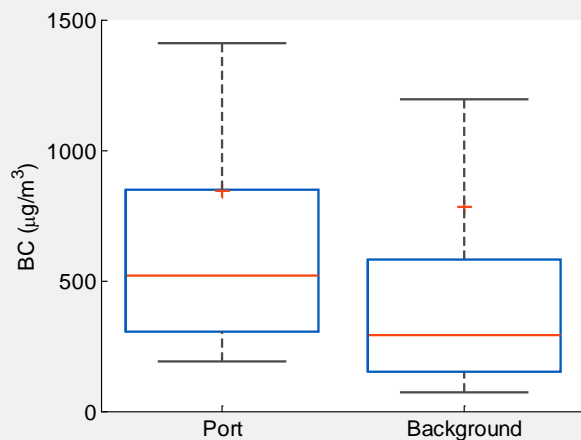
Wando Welch Terminal

- Local background concentration is taken by selecting periods where wind is from a direction away from the port (from the South at Wando for lower neighborhoods)
- This is 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)
- A significant effect from the port is observed in all measured pollutants



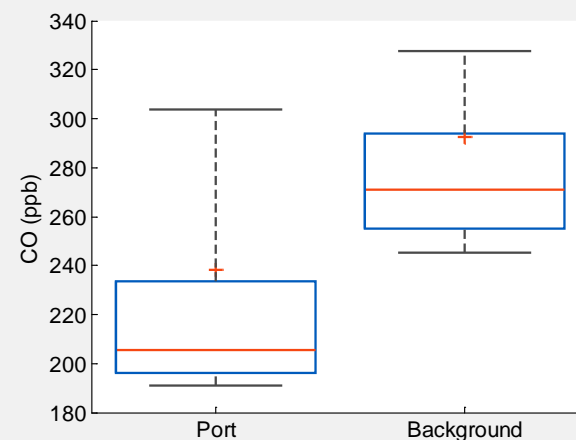
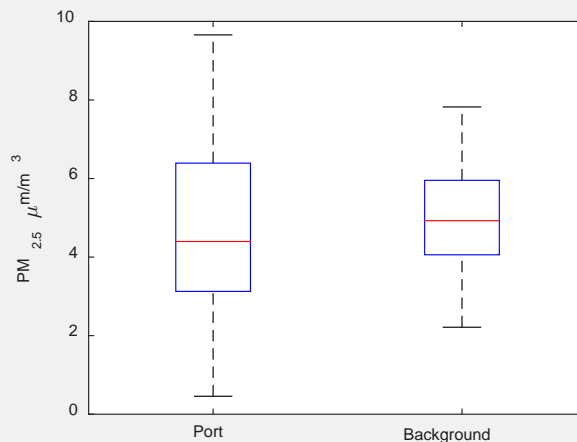
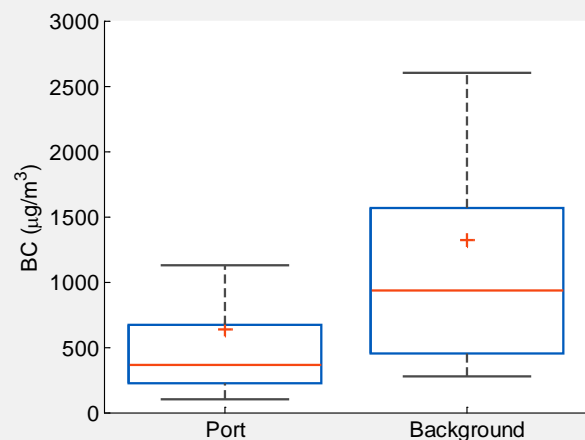
Columbus Street Terminal

- Only small (if any) port influence is observed at the Columbus Street terminal
- Many confounding sources in the vicinity make it difficult to isolate port effect



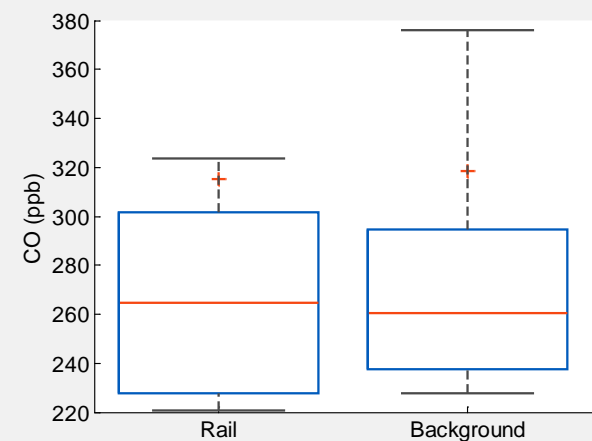
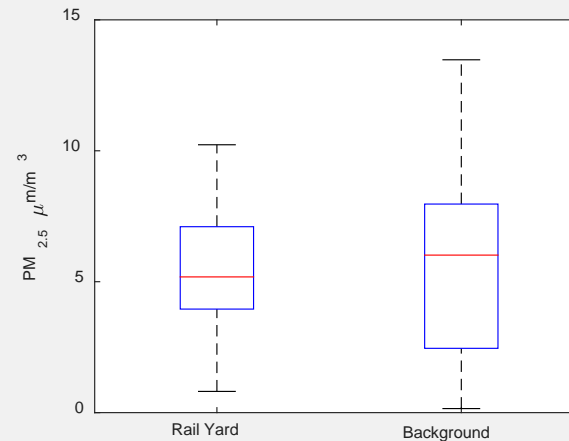
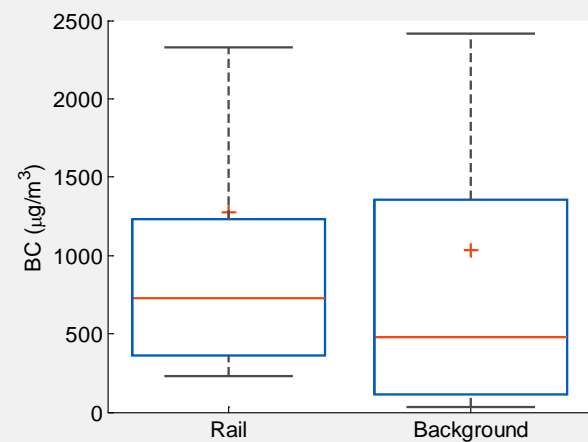
Veteran's Terminal

- “Background” is observed to be higher near Veteran’s Terminal
- Port is further away from neighborhood reducing its impact
- Major highway immediately on the far end of the neighborhood causing much higher concentration when wind is blowing from that direction



Bennett Rail Yard

- Little difference observed between rail and background
- Very strong influence from major roadways in all directions



Port Activity

- Port activity data (crane counts and ship counts) supplied at Wando Welch for most sampling periods
- Cranes are electric, but assumed to be representative of overall port activity including diesel trucks and other on-terminal equipment, and hoteling OGVs.
- Percent increase over background concentration observed (absolute values vary strongly with regional background)
- Weak trend observed between crane counts and PM2.5 concentration. ($r^2 = 0.36$)

Sampling Day	Ship Count	Crane Count	PM2.5 Concentration Percent Increase
2/21	3	8	15.5
2.25	1	1	5.6
2/27	2	2	4.9
3/2	2	4	8.2
3/5	3	7	19.3
3/7	2	4	18.7
3/13 AM	1	2	18.2
3/13 PM	3	6	20.8

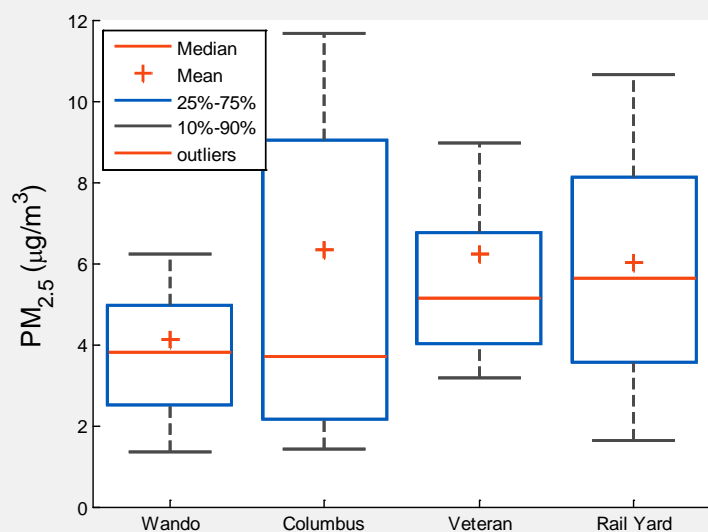
Modeling Analysis



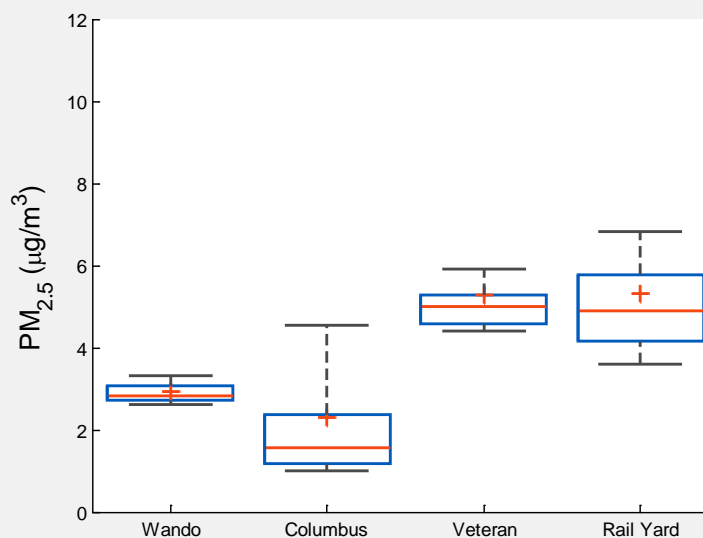
- Model port-related emissions of $PM_{2.5}$ using AERMOD and RLINE
 - AERMOD models port on-terminal sources such as heavy equipment and docked vessels as area source using emissions inventory data
 - RLINE models roadway and railways as line sources using AADT counts
- Receptor grids Uniformly spaced at 270m resolution (8,100 receptors)

Modeling Analysis

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

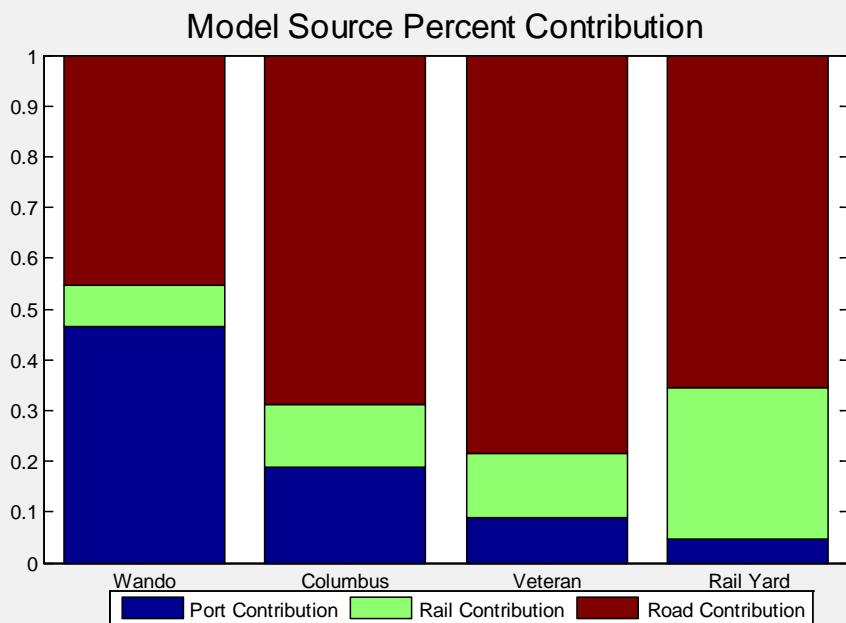


GMAP Data



Model Results

Modeling Analysis



- 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

Summary and Future Work

- Mobile monitoring campaign conducted around the Port of Charleston, South Carolina, using GMAP vehicle.
- Very large amount of data collected – over 55 hours of real-time sampling of multiple pollutants and meteorological conditions.
- Ports are shown to have a potentially significant impact on local air quality (Wando Welch) which quickly diminishes away from the port (Veteran's). This effect can be difficult to isolate as the impact of roadways is generally much higher.
- This work represents an early effort in mapping near-port air quality. More port-related mobile monitoring campaigns may be conducted to facilitate a more comprehensive analysis.

ACKNOWLEDGMENTS

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