EPA

ACE Task 019 FY14 Product

Near-source air quality in rail yard environments – an overview of recent EPA measurement and modeling findings

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U.S. EPA Office of Research and Development

Outline

- Background
- Three recent studies
  - Cicero Rail Yard Study
    - Project team: Region 5 team members: Mike Rizzo, Chad McEvoy, Jesse McGrath, Marta Fuoco, Loretta Lehrman; ORD team: Gayle Hagler, Eben Thoma
  - Atlanta Rail Yard Study
    - Project team: ORD: Gayle Hagler, Halley Brantley, Eben Thoma; Collaborators (Memorandum of Understanding): Georgia Tech
  - Computational Fluid Dynamics Modeling Study:
    - Project team: ORD: Gayle Hagler; EMVL: Wei Tang, Mike Uhl (Lockheed Martin), Heidi Paulsen (EMVL)

Background

- 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 key past studies to note:
  - CSX Rougemere Rail Yard in Dearborn, MI – Turner, 2009
  - Davis Rail Yard in Roseville, CA – Cahill et al., 2011; Campbell, 2009

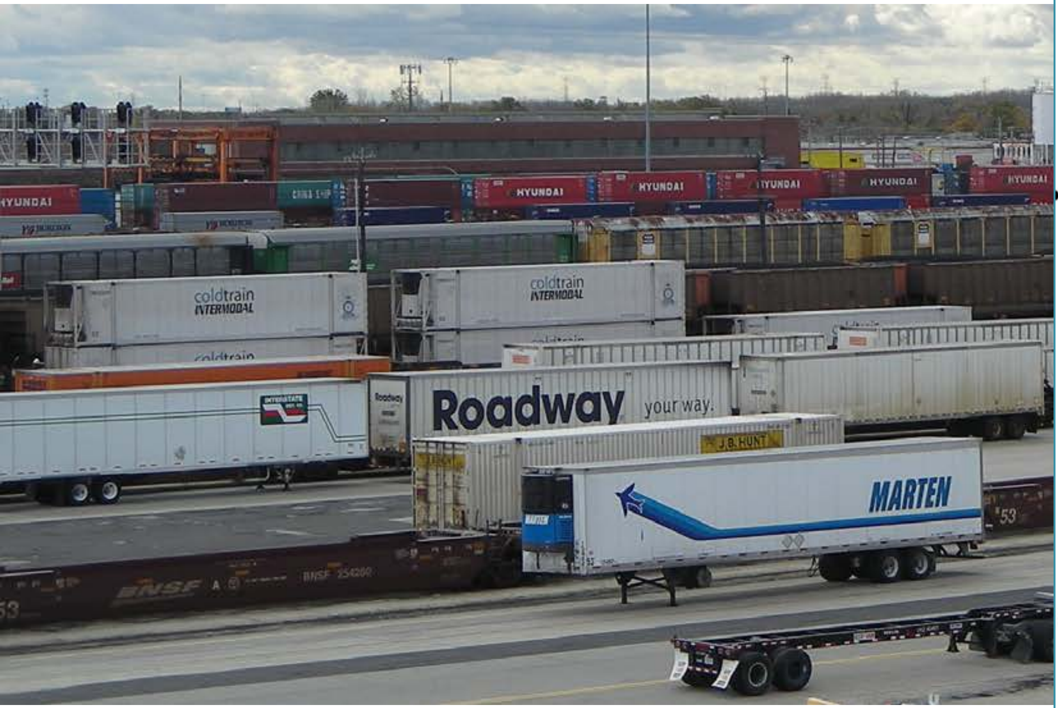
Cicero Rail Yard Study (CIRYS)

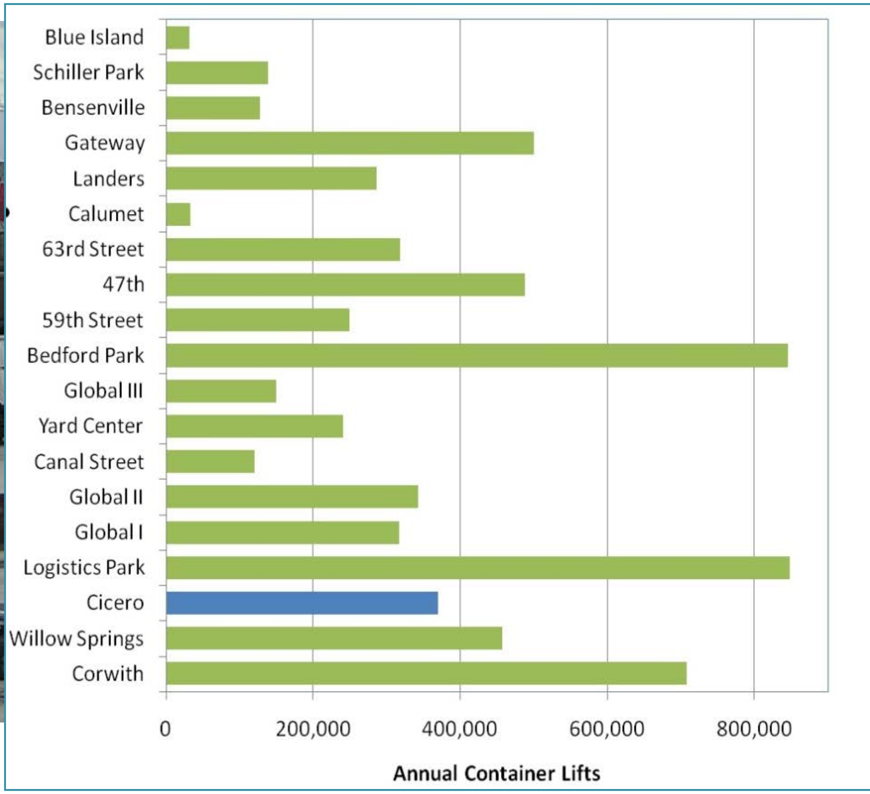
Cicero Rail Yard Study

- Goals:
  - Build upon Phase I of the RARE study, which conducted an emissions inventory, dispersion modeling, and field measurements to study local-scale air pollution from a rail yard in Dearborn, MI.
    - Field measurement portion of the Phase I study was challenged by confounding emissions nearby.
  - Phase II research objective: Field measurements to characterize the degree and spatiotemporal variability of local air pollution related to rail yard emissions
    - Siting criteria:
      - Minimize confounding sources (major roadways, industries)
      - Urban environment
      - Chicago-area
      - Compatible for both stationary and mobile monitoring

CIRYS – rail yard description

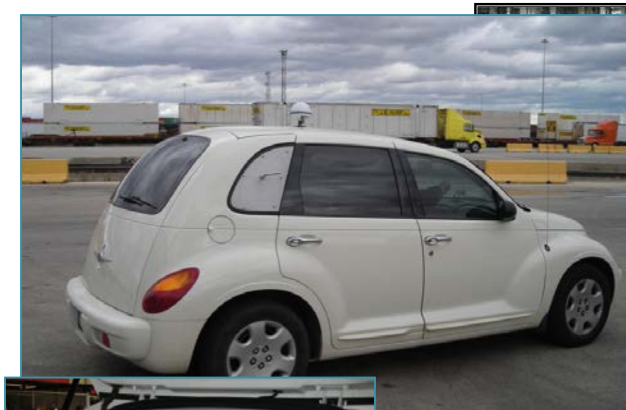
- Cicero Rail Yard is located in densely populated suburb of Chicago
- Intermodal rail yard; emission sources include: trucks, cranes, switcher locomotives, trains passing through (commuter and freight) and idling.
- Estimated container lift volume: 400,000; other Chicago-area intermodal hubs ranging ~100,000-800,000

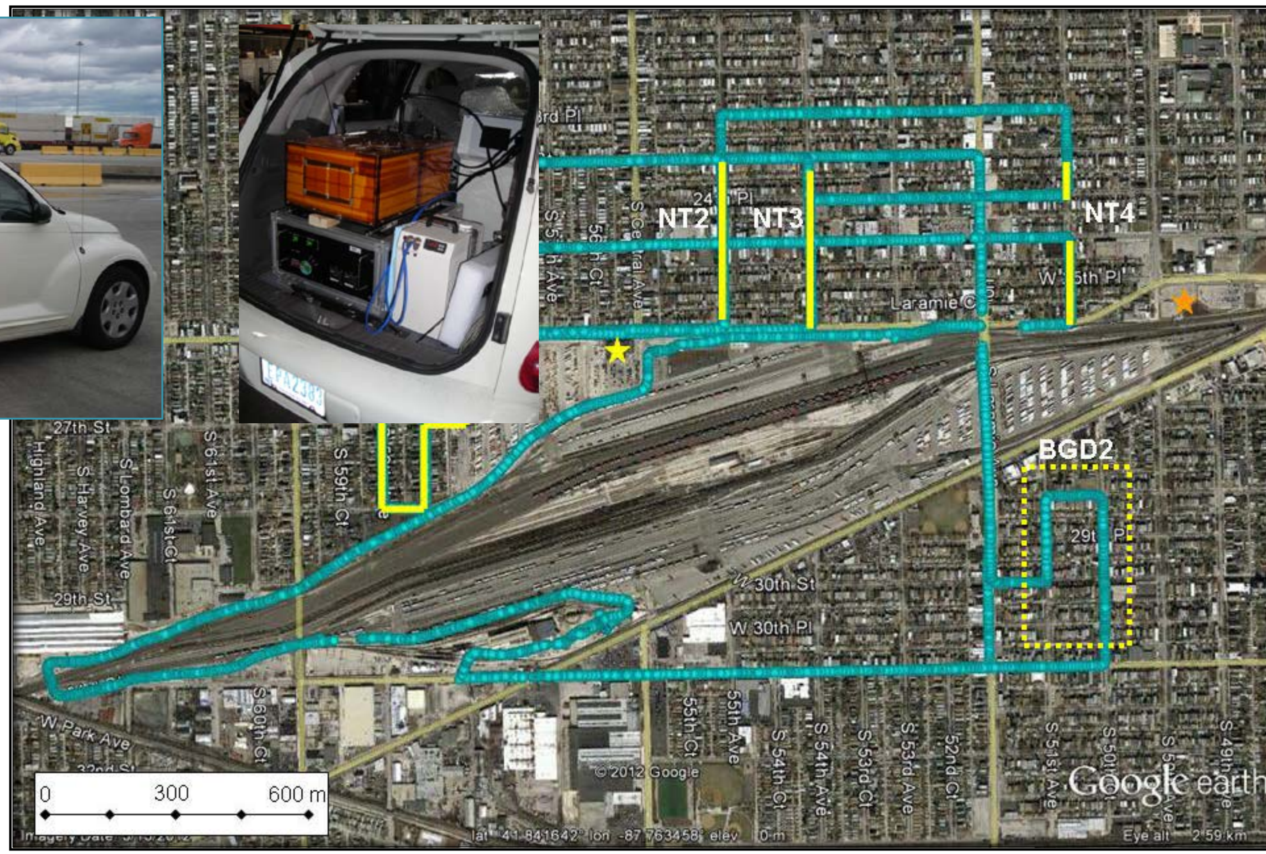




CIRYS – field study

- Monitoring approach:
  - Combined mobile monitoring sessions (1 month) and continuous monitoring at a stationary location, 2010-2011
  - Mobile sessions during early morning, mid-day, evening



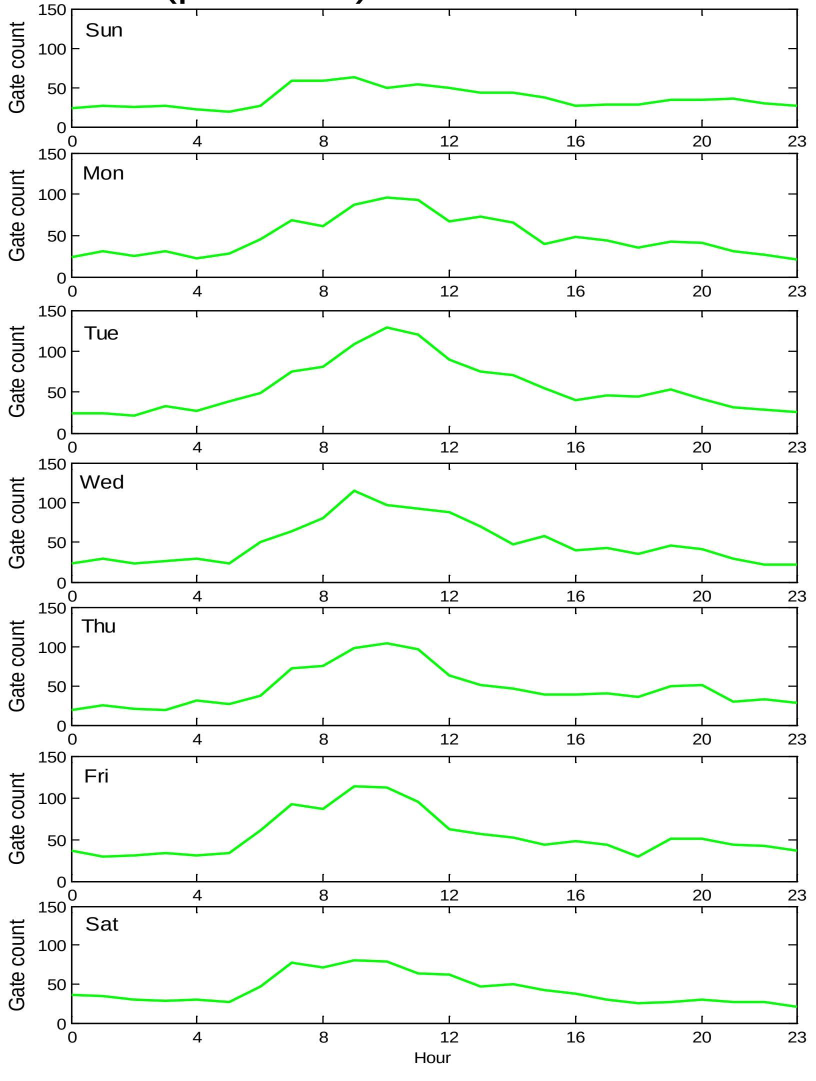


CIRYS – field study

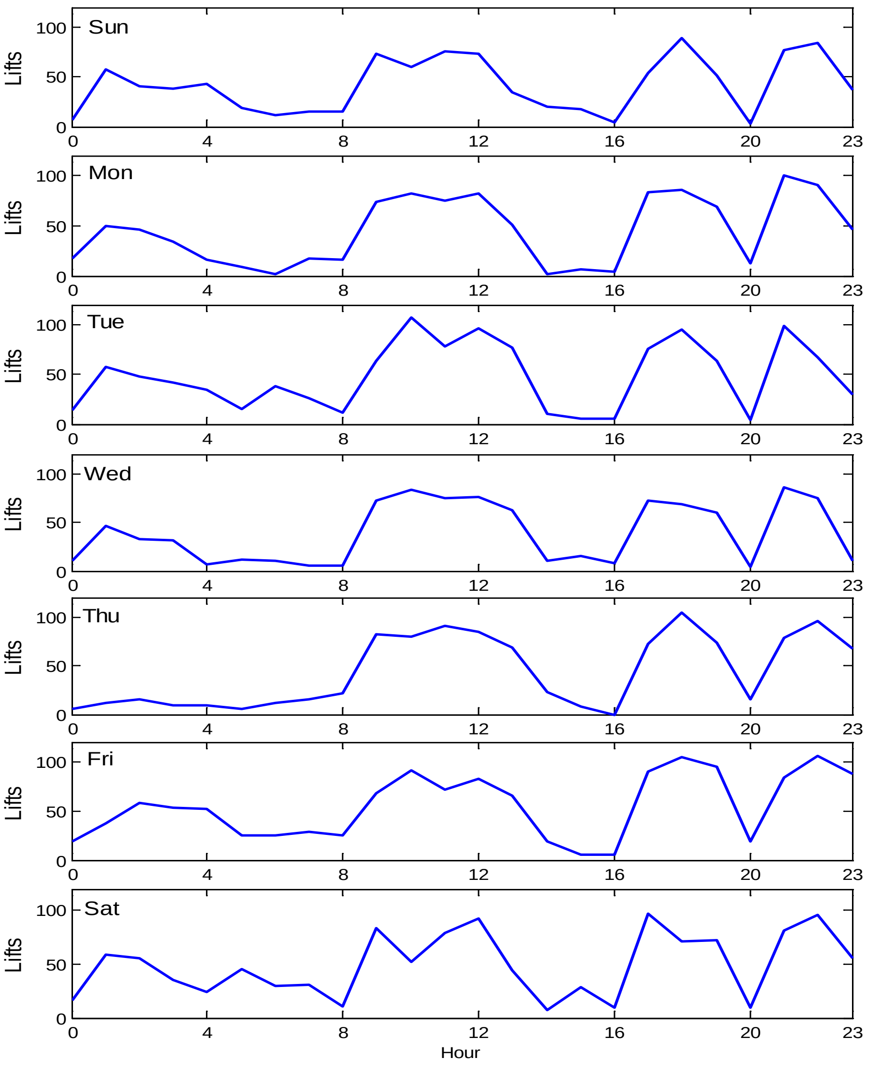
	Mobile Monitoring Vehicle	Stationary Monitoring Site
	Sampling times	
Time span	October-November, 2010	October, 2010 – October, 2011
Measurement rate	1-10 seconds, driving sessions of approximately 3 hours	5 minutes, continuous data
	Measurement techniques	
Fine particulate matter	Aerodynamic sizing, light scattering detection, mass-estimation from size-resolved number counts	Beta-attenuation through particle-laden filter, with an inlet cut at 2.5 microns (FEM)
Ultrafine particles	Electrical mobility sizing, detection by electrometer	N/A
Black carbon	Light absorption (880 nm) through particle-laden filter	Light absorption (880 nm) through particle-laden filter
Carbon monoxide	Quantum cascade laser	Nondispersive infrared detector (FRM)
Sulfur dioxide	Quantum cascade laser	Pulsed fluorescence (FEM)
Oxides of nitrogen	N/A	Chemiluminescence (FRM)

CIRYS – ancillary data from BNSF: minute-by-minute activity data on trucks and containers

Trucks (per hour)



Containers (per hour)



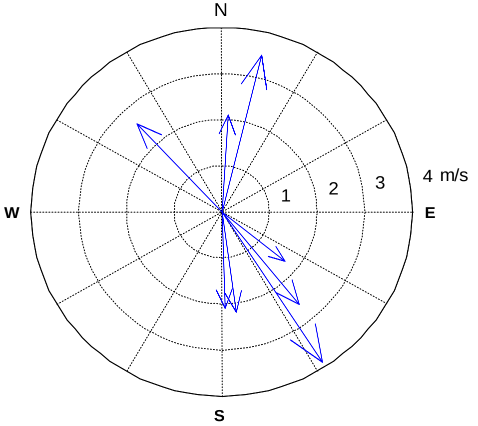
CIRYS – mobile monitoring sessions

Session	Start time	End time	U, scalar (m/s)	U, vector (m/s)	θ^a (deg)	$\sigma_\theta{}^b$ (deg)	Category
1	10/27/2010 9:16	10/27/2010 13:05	8.0	7.4	236	33	SW
2	10/28/2010 18:53	10/29/2010 2:00	3.1	2.5	294	41	NW
3	10/29/2010 18:45	10/29/2010 23:45	4.6	4.5	208	9	SW
4	10/30/2010 8:52	10/30/2010 13:15	6.4	5.7	232	32	SW
5	10/31/2010 3:52	10/31/2010 8:25	2.4	2.2	352	18	N
6	11/1/2010 19:18	11/2/2010 0:10	1.9	1.7	70	13	NE
7	11/3/2010 11:50	11/3/2010 16:25	4.0	3.6	230	29	SW
8	11/4/2010 4:10	11/4/2010 8:42	4.1	3.9	327	14	NW
9	11/5/2010 9:00	11/5/2010 14:30	5.1	4.7	338	22	NW
10	11/6/2010 3:52	11/6/2010 8:15	1.8	1.7	309	17	NW
11	11/7/2010 19:40	11/7/2010 23:56	1.9	1.7	184	11	S
12	11/8/2010 19:00	11/9/2010 0:10	2.1	2.0	175	16	S
13	11/10/2010 9:10	11/10/2010 14:00	3.6	3.3	164	25	SE
14	11/11/2010 4:00	11/11/2010 9:40	2.2	2.1	184	21	S
15	11/12/2010 10:00	11/12/2010 15:05	3.1	2.8	44	24	NE
16	11/13/2010 4:00	11/13/2010 8:40	2.8	2.6	137	21	SE
17	11/15/2010 19:30	11/16/2010 1:05	2.7	2.5	192	17	S
18	11/16/2010 18:55	11/17/2010 1:30	2.0	1.9	304	21	NW
19	11/17/2010 9:45	11/17/2010 14:37	2.9	2.3	280	48	W
20	11/18/2010 3:58	11/18/2010 8:42	2.7	2.6	321	16	NW
21	11/19/2010 3:52	11/19/2010 8:30	3.7	3.5	194	21	S
22	11/20/2010 3:57	11/20/2010 9:49	2.2	2.1	358	19	N
23	11/21/2010 19:02	11/22/2010 0:09	8.4	8.3	212	9	SW

23 sampling sessions

Categorized by time of day and prevailing wind direction

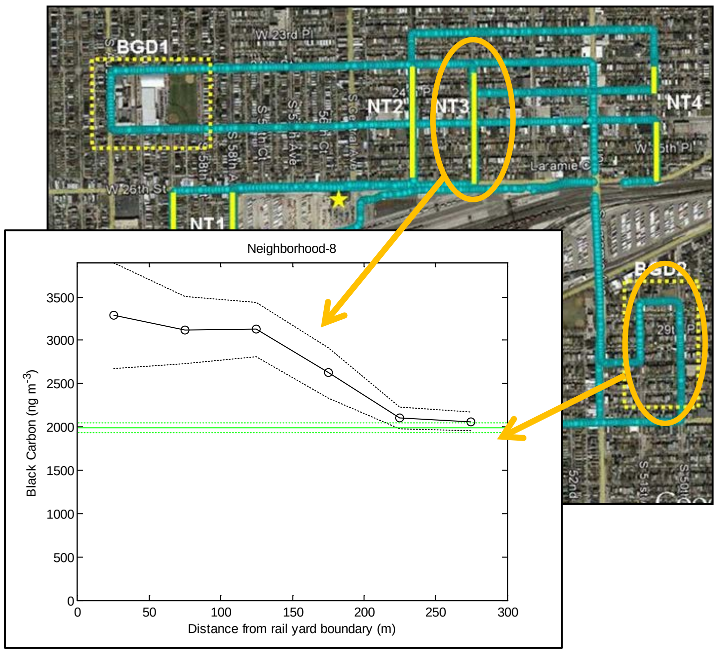
e.g., early morning mean wind direction / speed per session



CIRYS – data analysis

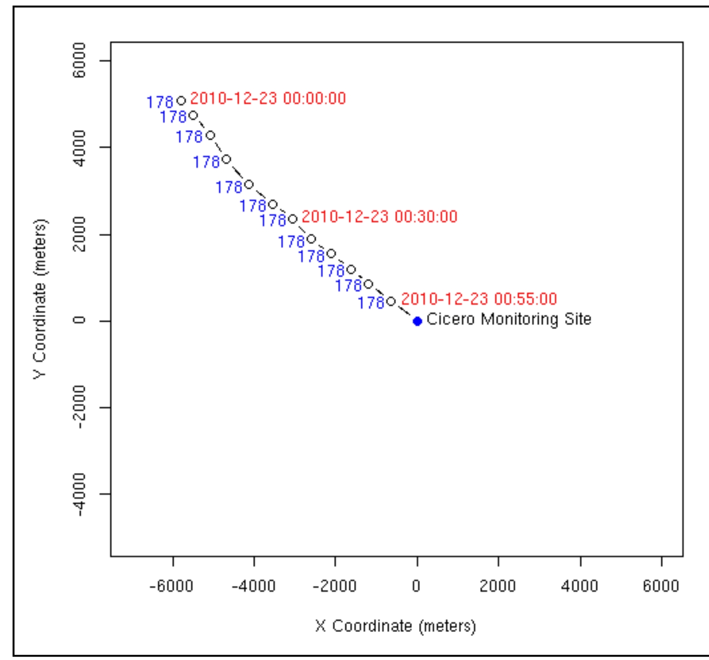
Data analysis approaches:

Mobile: Comparison of upwind / downwind concentrations in residential areas



Stationary: Wind directional trends, inverse modeling using non-parametric trajectory analysis (NTA, NERL model)

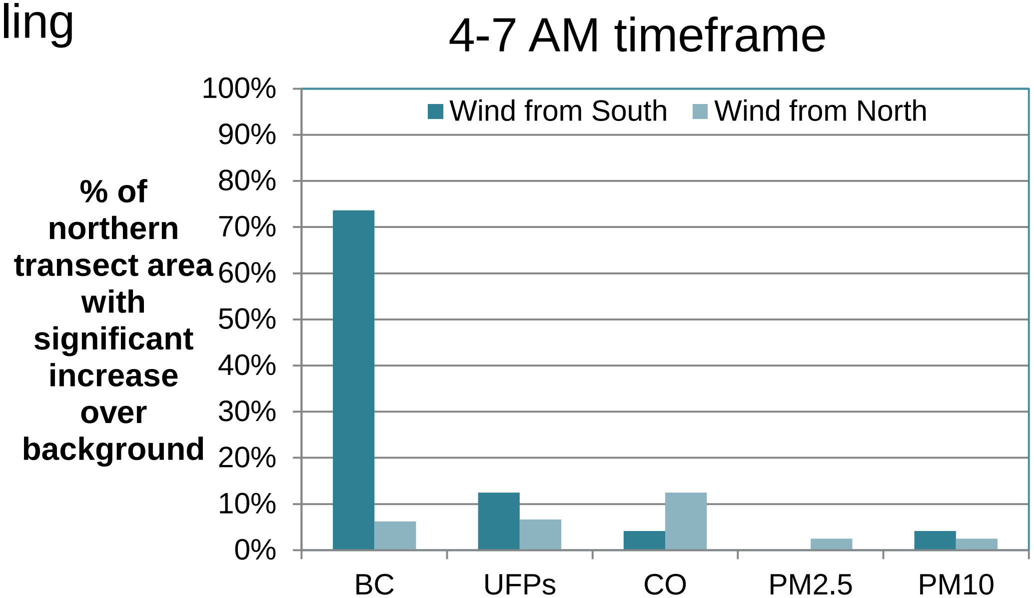
Tracing 5-min concentration back along near-field air mass trajectory



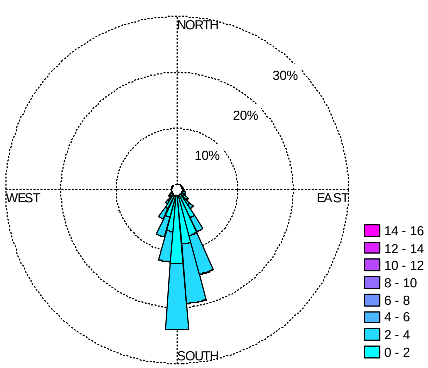
CIRYS – findings

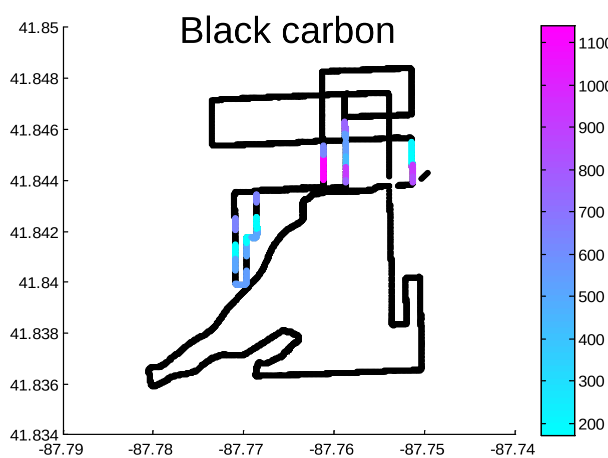
Example findings from mobile sampling

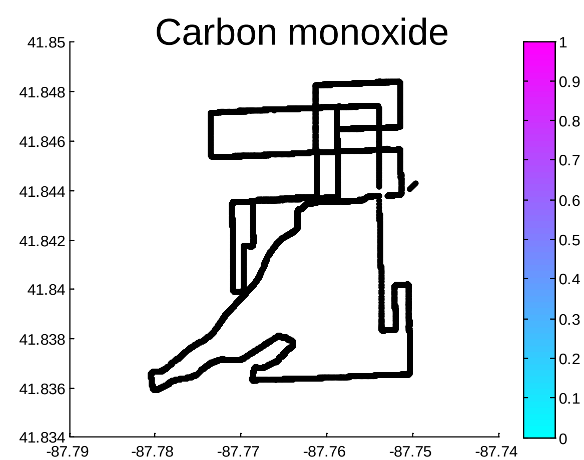
For 3 early morning sessions with wind from S: "…excess concentration of 0.3-0.6 µg m^{-3} BC, 30-40% higher total BC concentrations relative to the urban background (background ranged 0.8-2.0 µg m^{-3} BC). The other measurements shown – UFPs, CO, $PM_{2.5}$, and PM_{10} – do not show the same upwind/downwind trend of excess levels."



e.g., early morning session

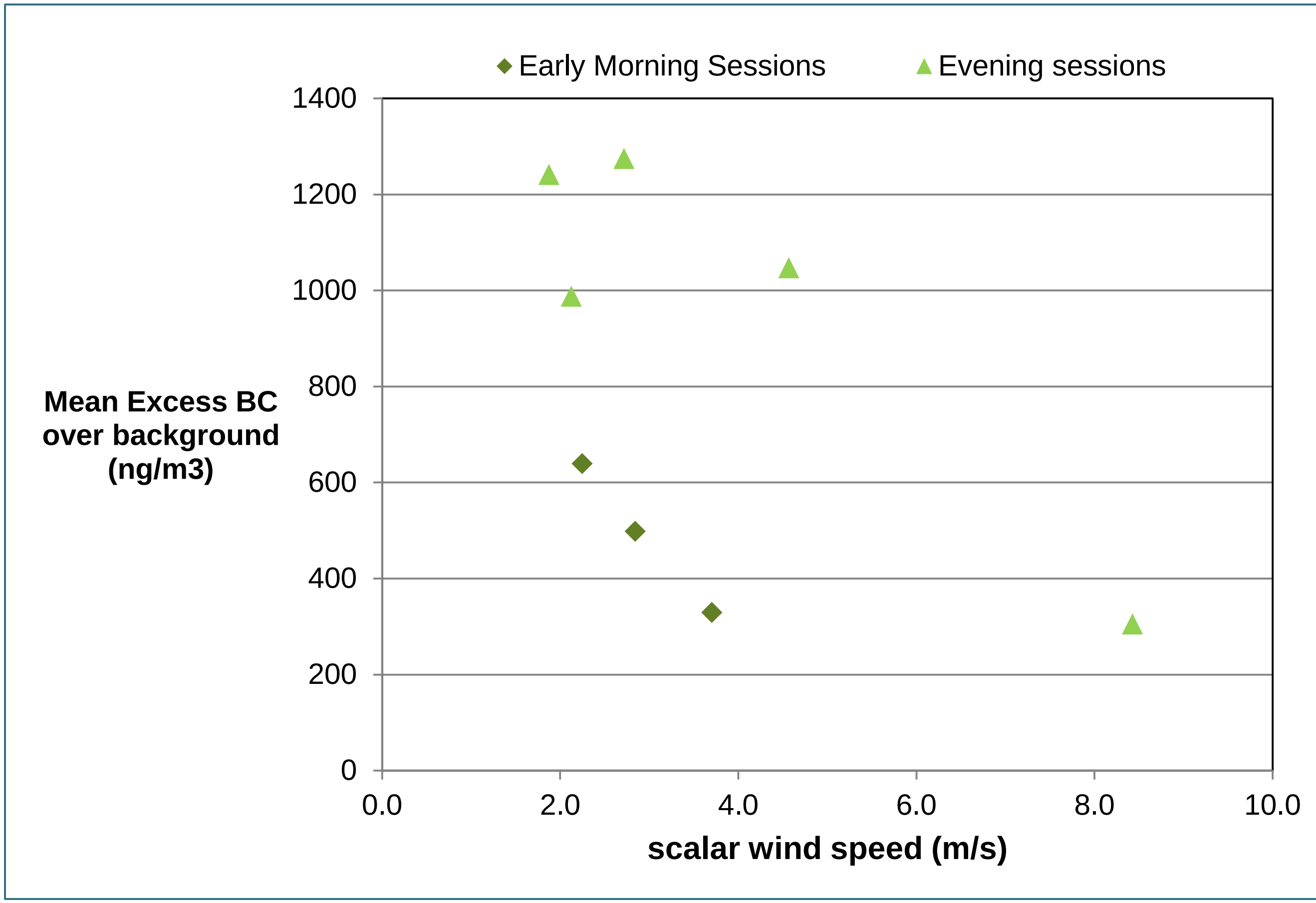






CIRYS – findings

Black carbon levels downwind of rail yard a function of wind speed and time of day



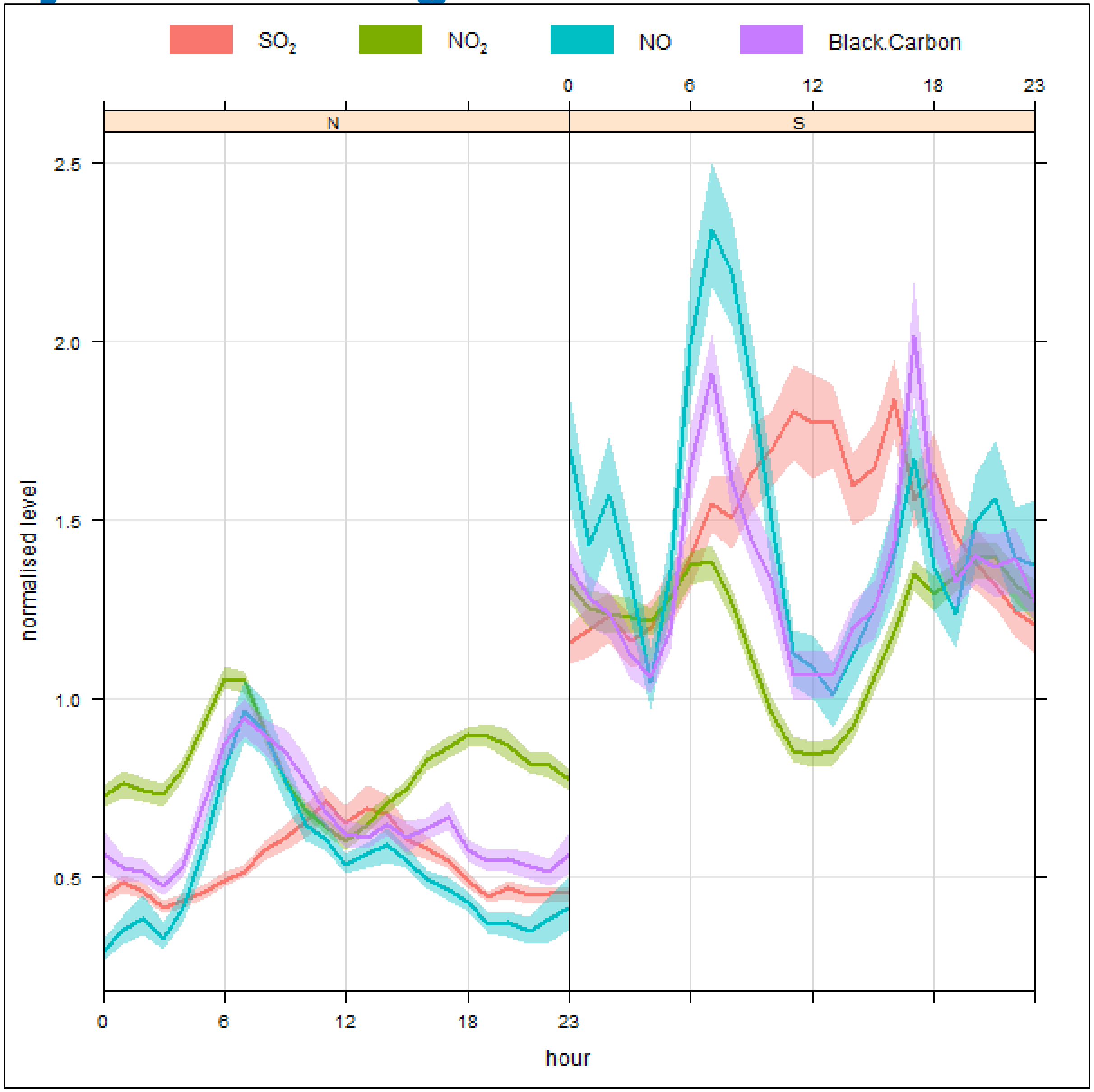
CIRYS – stationary site findings

Table 3-6. Summary statistics for 5-minute pollutant data (NOx and SO_2 in ppb, BC in ng m^{-3})

Case	Pollutant	N	Mean	Standard deviation	Lower 95th CI	Upper 95th CI	Percentiles 25th	50th	75th	90th	95th
All data	NO_2	38253	20.9	12.7	20.7	21.0	11.2	18.5	28.6	38.4	45.0
	NO	38253	16.8	25.5	16.5	17.0	3.0	7.7	18.6	43.8	66.2
	NO_x	38253	37.6	35.6	37.3	38.0	15.7	26.8	46.9	80.2	108.5
	SO_2	50085	2.8	3.3	2.7	2.8	1.0	1.6	3.2	6.2	9.2
	Black carbon	47067	635.5	690.5	629.3	641.7	235.4	433.0	796.0	1330.0	1811.0
Wind from SE (angles: 105 - 215)	NO_2	8274	24.6	12.7	24.3	24.9	15.2	23.2	32.7	42.5	47.4
	NO	8274	24.4	32.2	23.7	25.1	3.7	12.0	32.1	63.8	92.1
	NO_x	8274	48.9	41.5	48.0	49.8	21.2	36.8	63.8	104.2	134.2
	SO_2	8310	4.8	3.8	4.7	4.9	2.3	3.6	5.8	9.9	12.5
	Black carbon	7652	819.1	737.0	802.6	835.6	378.0	618.0	1011.0	1580.0	2079.5
Wind from SW (angles:215 - 266)	NO_2	7156	27.6	15.6	27.3	28.0	15.4	26.8	38.2	48.0	54.0
	NO	7156	30.8	34.7	30.0	31.6	6.4	18.8	43.4	74.8	101.1
	NO_x	7156	58.5	47.8	57.4	59.6	23.7	46.9	80.4	119.4	151.4
	SO_2	7176	3.5	3.7	3.4	3.6	1.3	2.1	4.3	8.2	10.9
	Black carbon	6791	815.9	726.6	798.6	833.1	359.0	630.0	1031.5	1610.0	2092.0
Wind from N (angles: 300 - 60)	NO_2	13212	16.8	9.7	16.6	16.9	9.6	14.7	22.5	31.1	35.1
	NO	13212	8.5	11.2	8.3	8.7	2.4	5.3	10.1	18.8	27.8
	NO_x	13212	25.3	19.1	24.9	25.6	13.2	20.5	32.0	48.2	59.8
	SO_2	13248	1.3	1.0	1.3	1.3	0.8	1.1	1.5	2.4	3.1
	Black carbon	12235	333.6	327.5	327.8	339.4	143.3	243.0	419.0	662.0	858.3

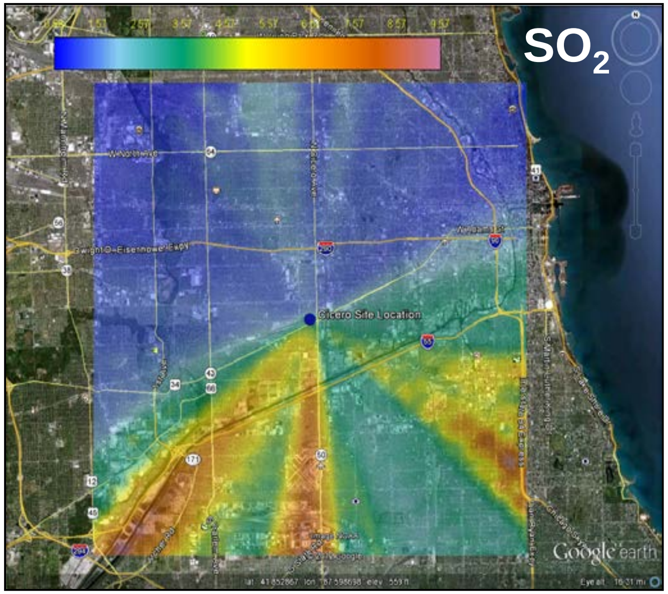
CIRYS – stationary site findings

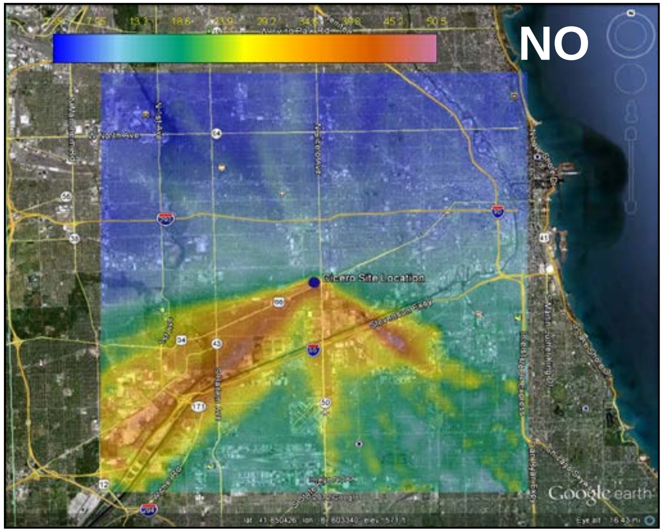
Diurnal trends during winds from the North (left) and winds from the South (right)

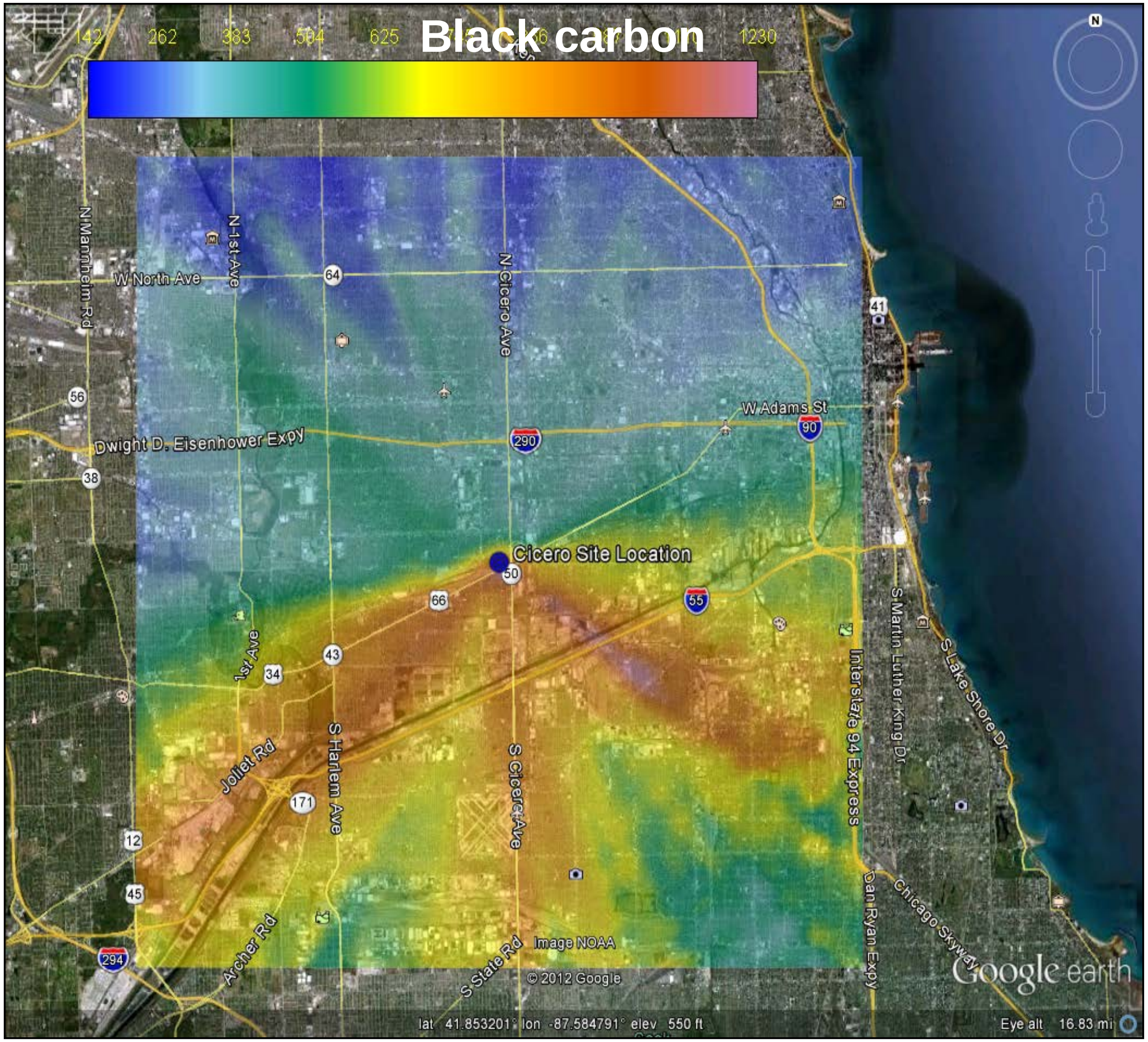


CIRYS – stationary site findings

Inverse modeling







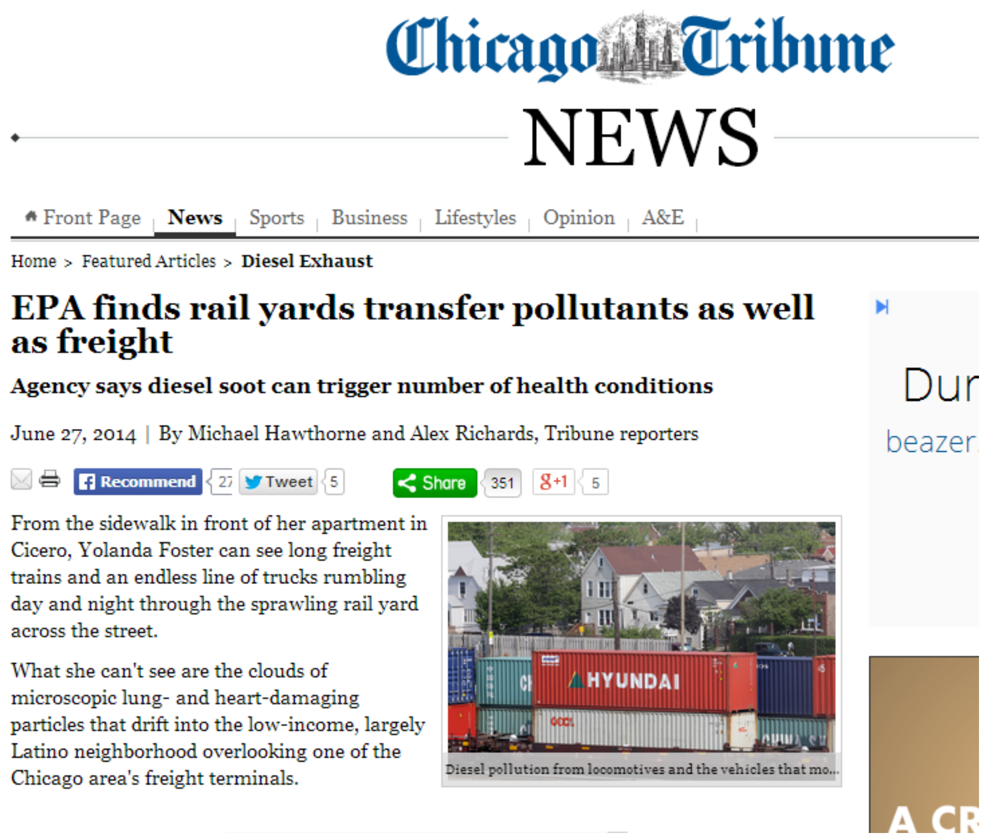
CIRYS – report released in spring 2014

Full report available at: http://nepis.epa.gov/Adobe/PDF/P100IVT3.pdf

Report review process: internal peer review, QA review, management review, external peer review

Media reaction: ORD and Region 5 interviewed by Chicago Tribune in mid-June

Article tweeted by Inbound Logistics, which has >20,000 followers



Chicago Tribune

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Home > Featured Articles > Diesel Exhaust

EPA finds rail yards transfer pollutants as well as freight

Agency says diesel soot can trigger number of health conditions

June 27, 2014 | By Michael Hawthorne and Alex Richards, Tribune reporters

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From the sidewalk in front of her apartment in Cicero, Yolanda Foster can see long freight trains and an endless line of trucks rumbling day and night through the sprawling rail yard across the street.

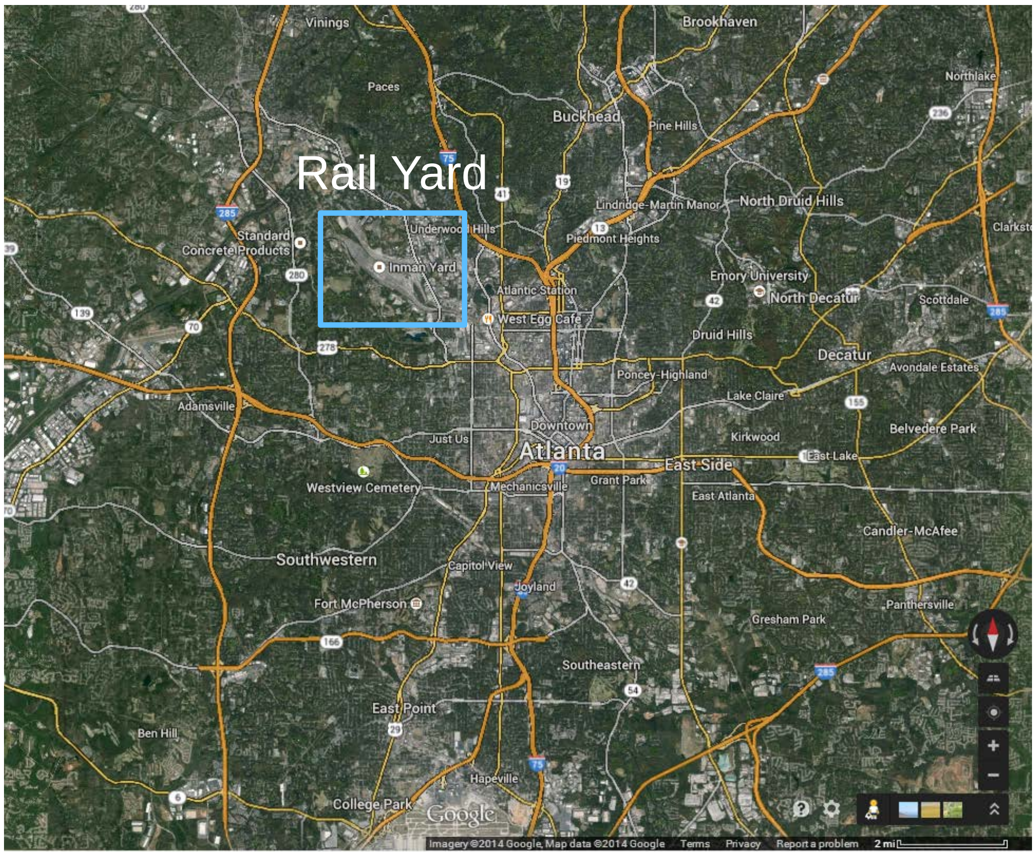
What she can't see are the clouds of microscopic lung- and heart-damaging particles that drift into the low-income, largely Latino neighborhood overlooking one of the Chicago area's freight terminals.

Diesel pollution from locomotives and the vehicles that mo...

Atlanta Rail Yard Study (ARYS)

Atlanta Rail Yard Study (ARYS)

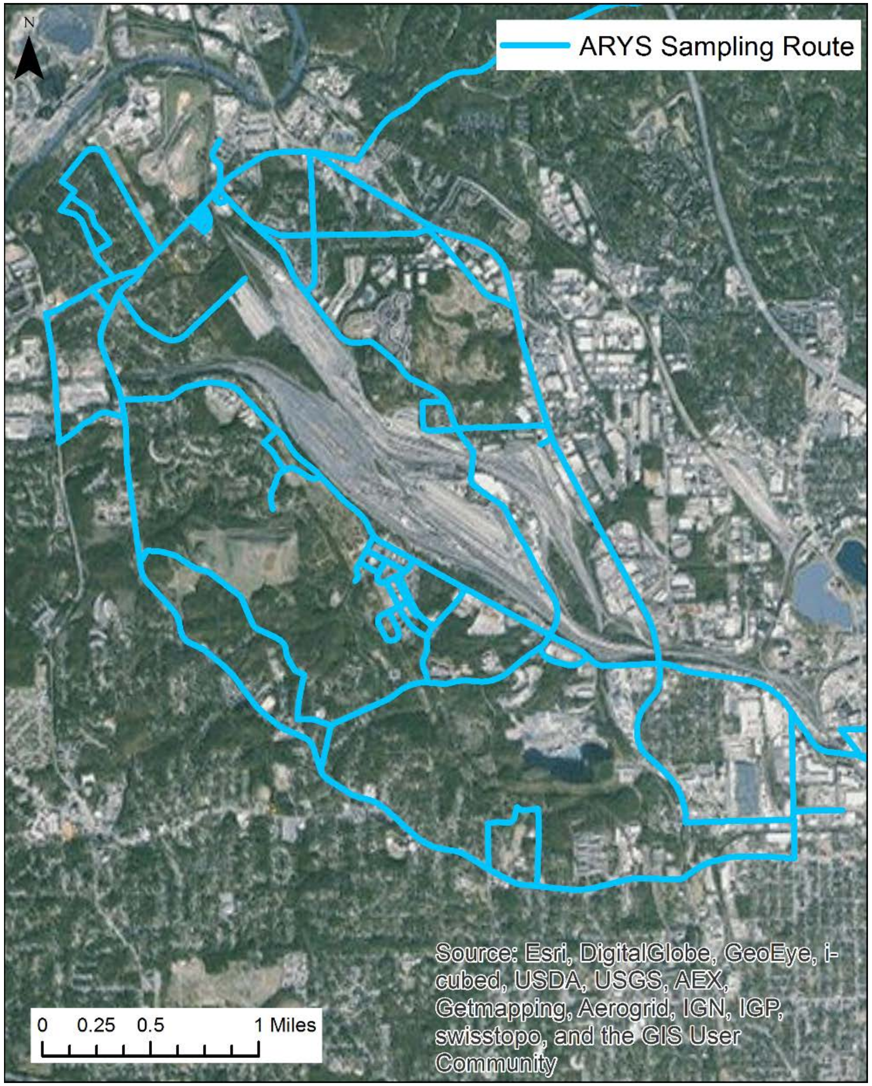
- CSX and Norfolk Southern co-located rail yards, Tilford and Inman Yards, are in a non-attainment area for $PM_{2.5}$



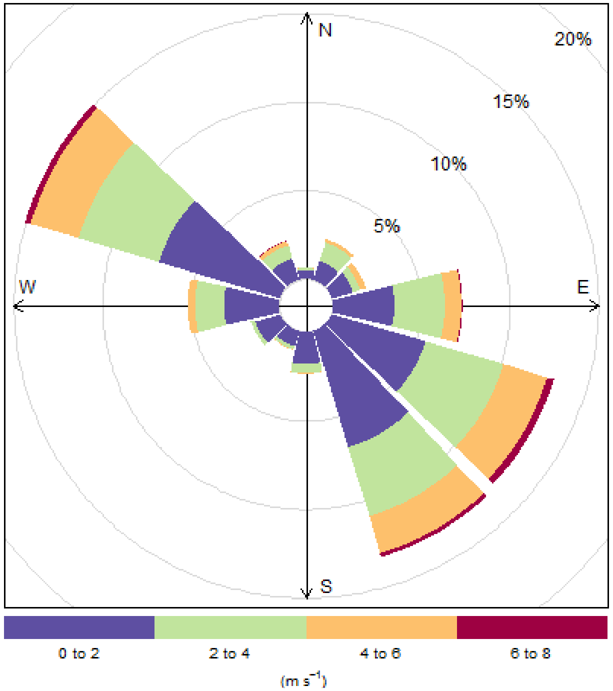
- State of GA funding for rail yards to reduce emissions
- Local monitoring upwind and downwind by Georgia Tech (Galvis, 2013).

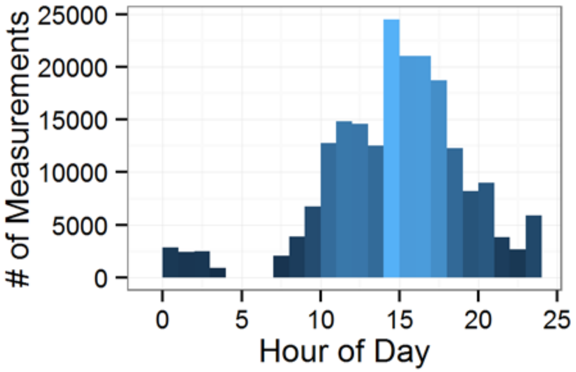
ARYS Field Study

- 19 sampling runs conducted in May 2012

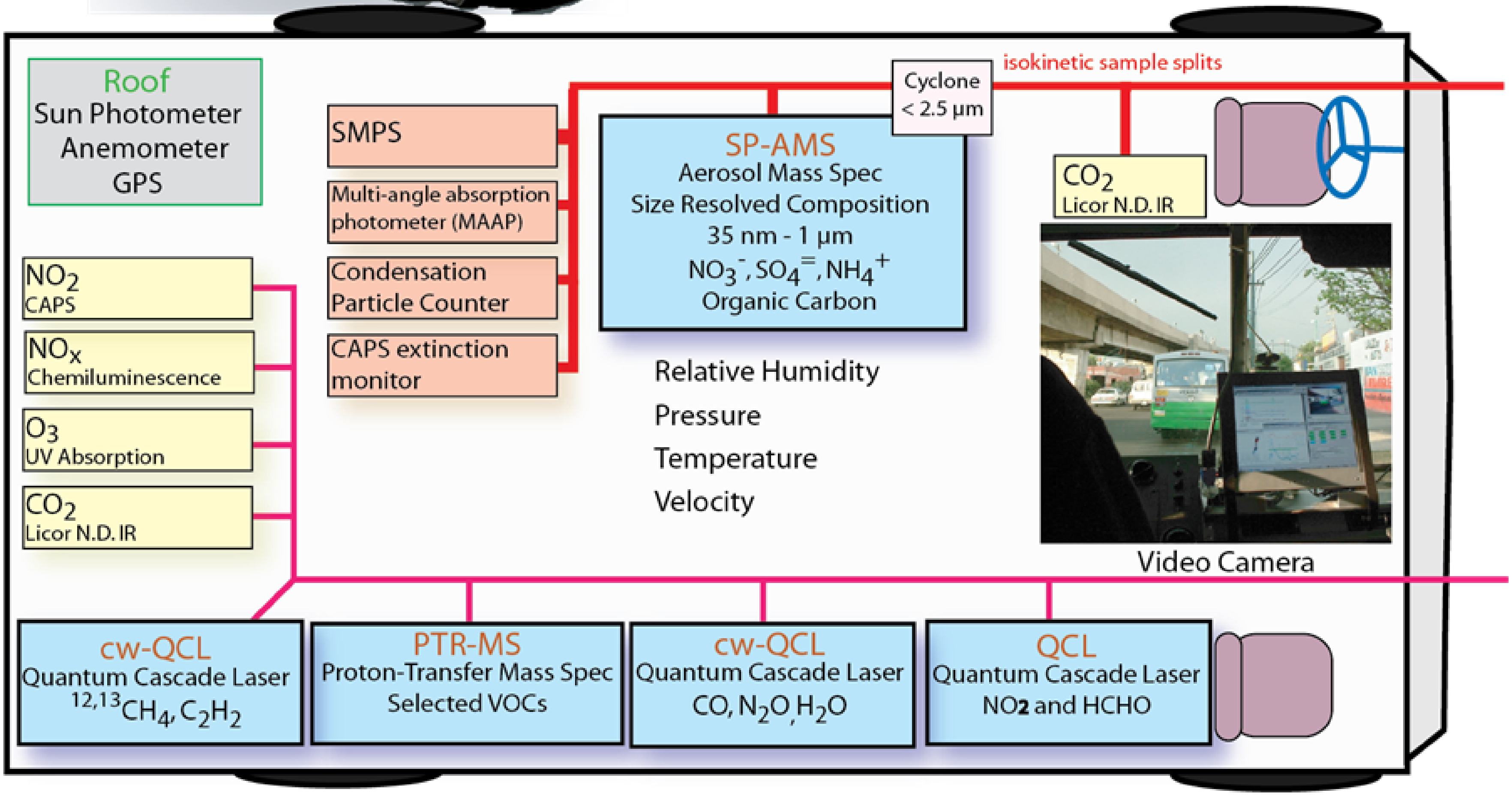


Wind conditions during sampling





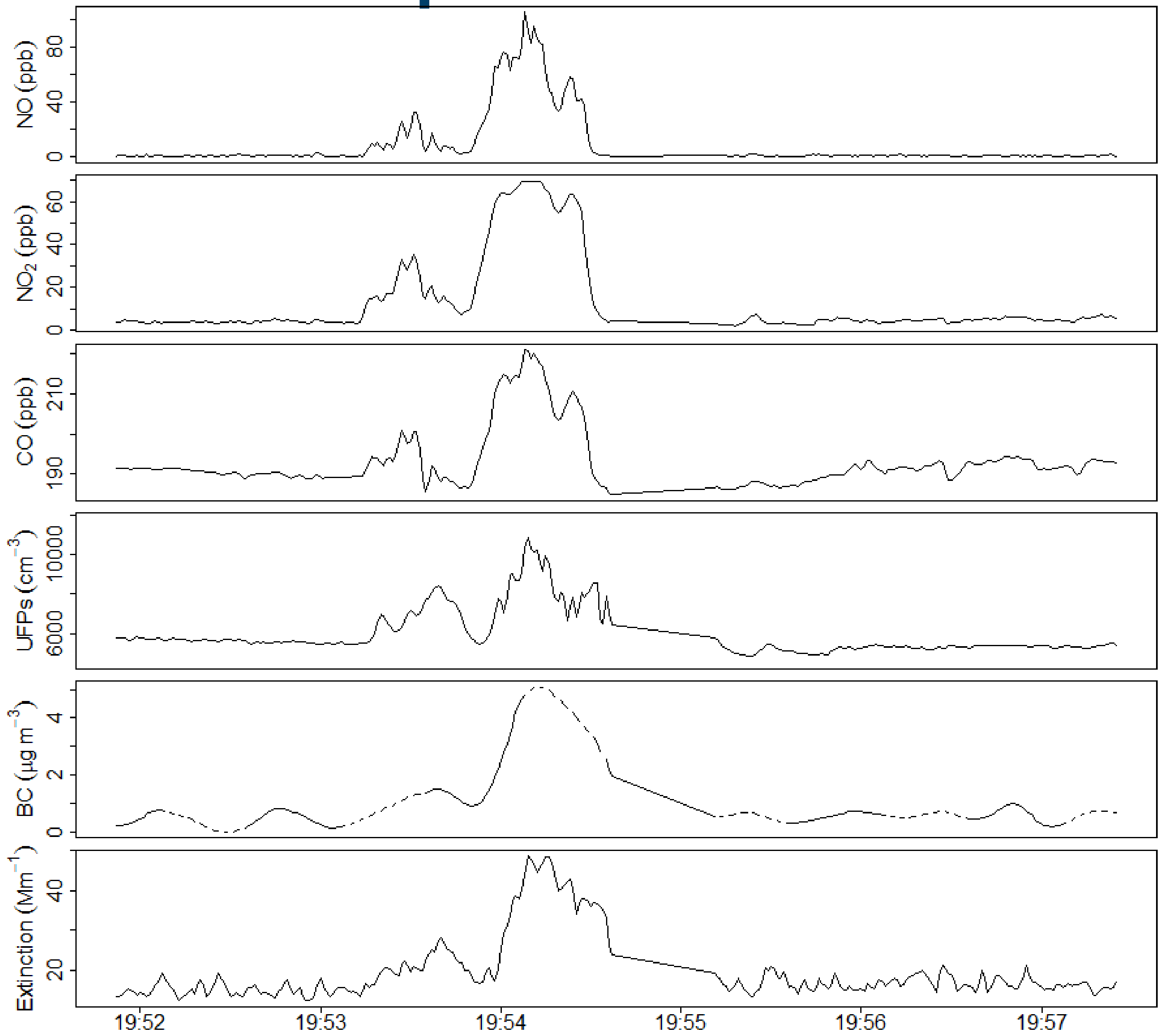
Aerodyne Mobile Lab
ARYS 2012



Measurements

Measurement	Rate	Instrument
Carbon Dioxide (CO_2)	0.9 s	Licor 6262 (2) and Licor 820
Carbon Monoxide (CO)	1 s	Quantum Cascade Laser System (2230 cm-1)
Nitric Oxide (NO)	1 s	Thermo 42i Chemiluminescence
Nitrogen Dioxide (NO_2)	1 s	Quantum Cascade Laser System (1600 cm-1)
Nitrogen Dioxide (NO_2)	5 s	Cavity Enhanced Phase Shift
Oxides of Nitrogen (NO_y)	1.4 s	Thermo 42i with external inlet-tip Mo Converter
Black Carbon PM (< 2.5 μm)	3 s	Multi-Angle Absorption Photometer
Black Carbon PM (70 nm -1.5 μm)	1 s (variable)	SP-AMS with laser-on mode
Non-refractory PM coating on Black Carbon (70 nm – 1.5 μm)	1 s (variable)	SP-AMS with laser-on mode;
Particle Extinction	3 s	Cavity Enhanced Phase Shift
Particle Number Density	1.8 s	Condensation Particle Counter
Number based Size Distribution	2 minutes	Differential Mobility Analyzer with Condensation Particle Counter
Various Aromatics and Oxygenates such as: Benzene, Toluene, Xylene, Acetone, Acetaldehyde	1.4 s	Proton Transfer Reaction Mass Spectrometer
Alkanes, Selected Alkenes and Aromatics	Hourly	Gas Chromatogram with Flame Ionization Detector

Example Train Plume

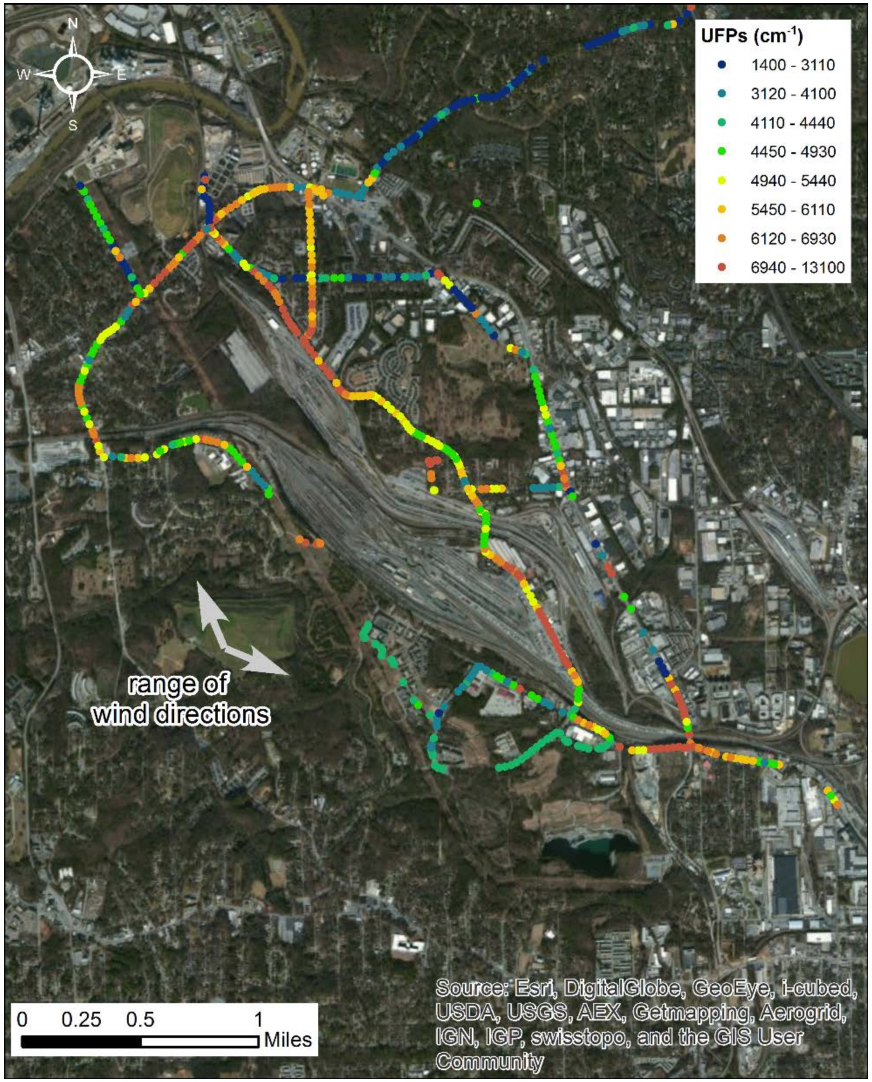


Research Questions

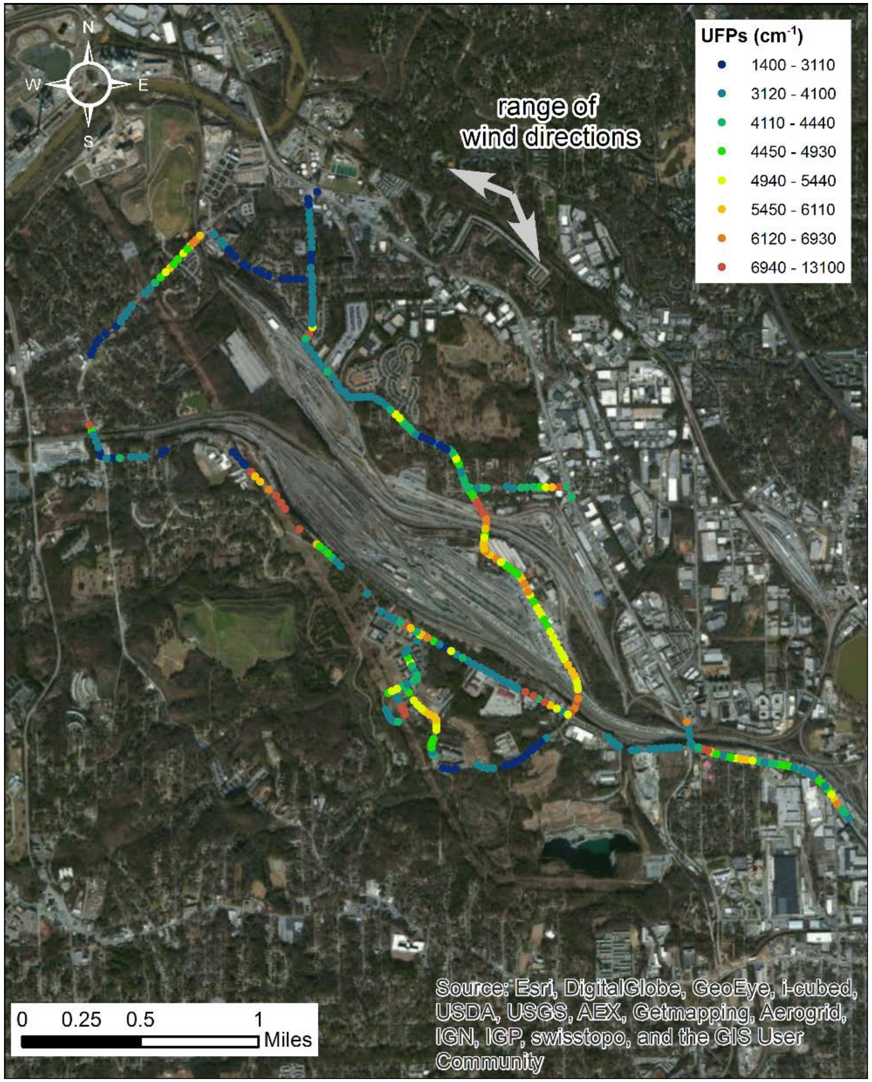
- Are there statistically significant differences in air pollutant concentrations downwind of the rail yard relative to upwind air?
- How do near-rail year air pollutant concentrations vary with wind direction, wind speed, time of day and week?
- How do the attributed emission species correlated with one another and what can be said about emission inventory estimates?

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

Wind from the Southwest

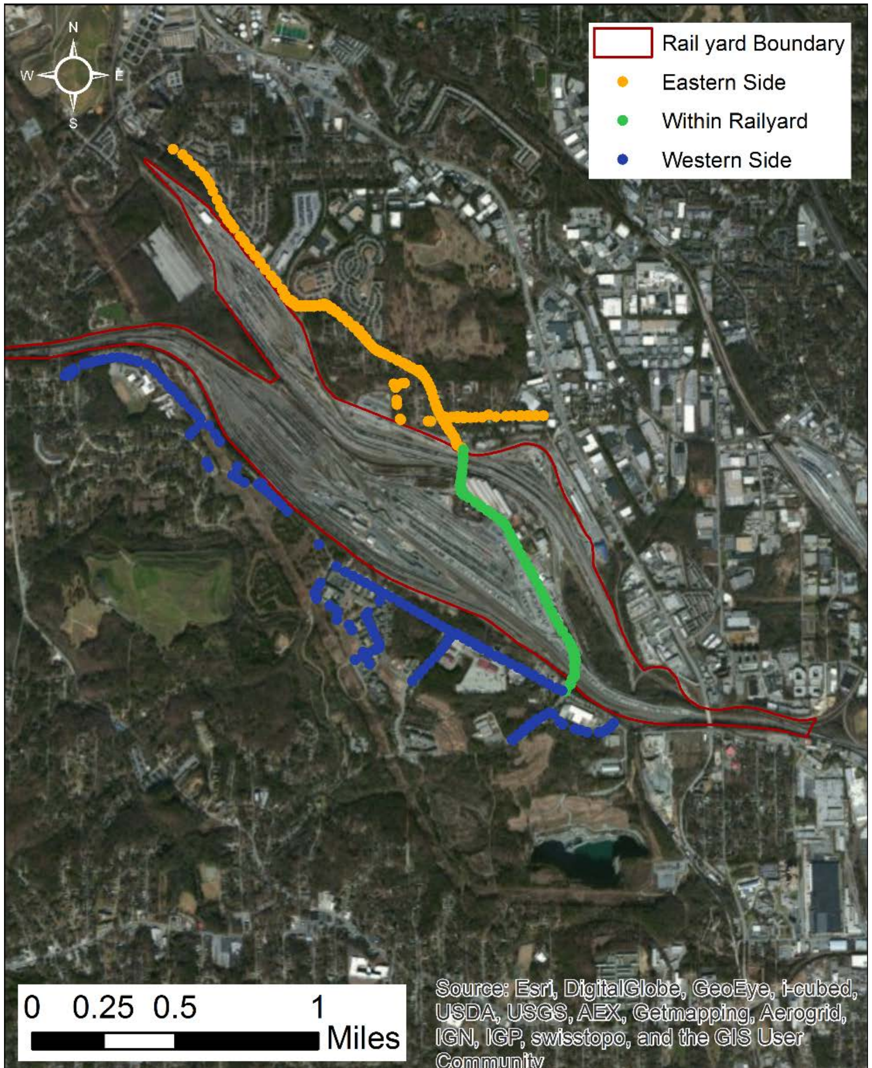


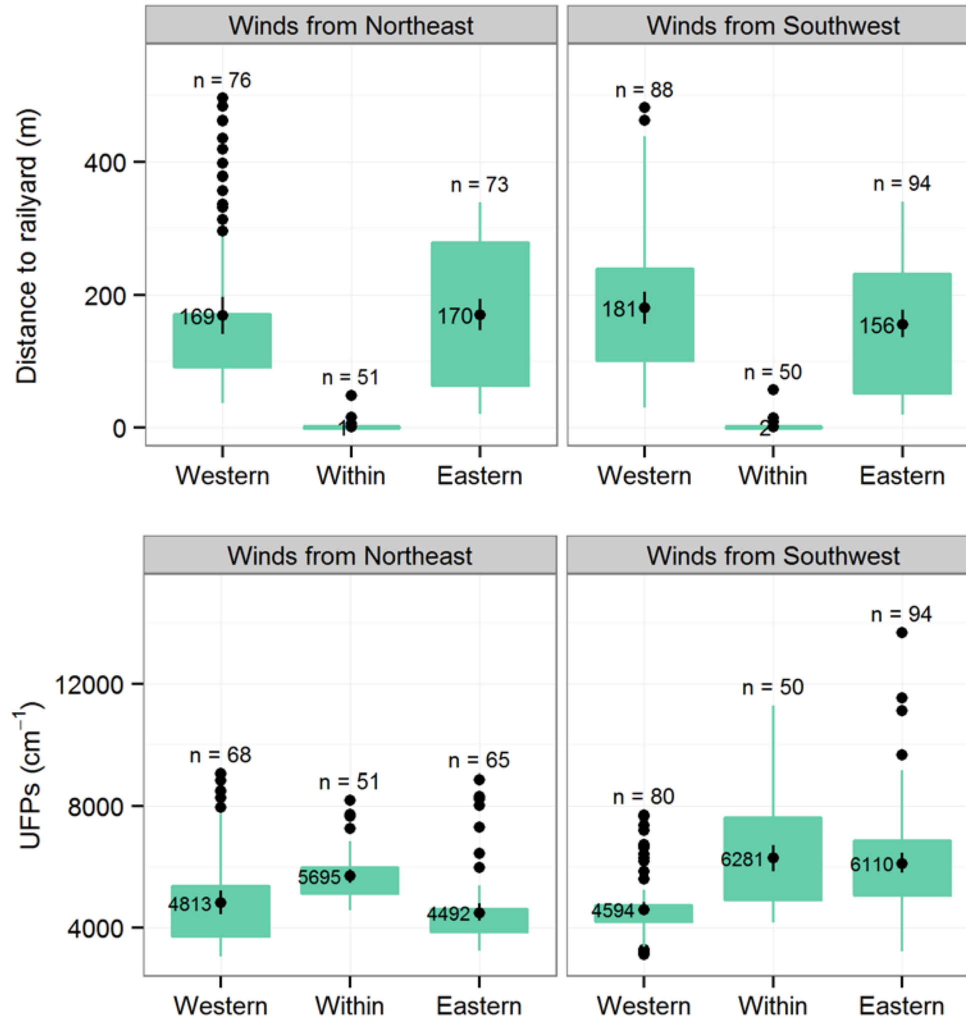
Wind from the Northeast



Upwind-Downwind Differences

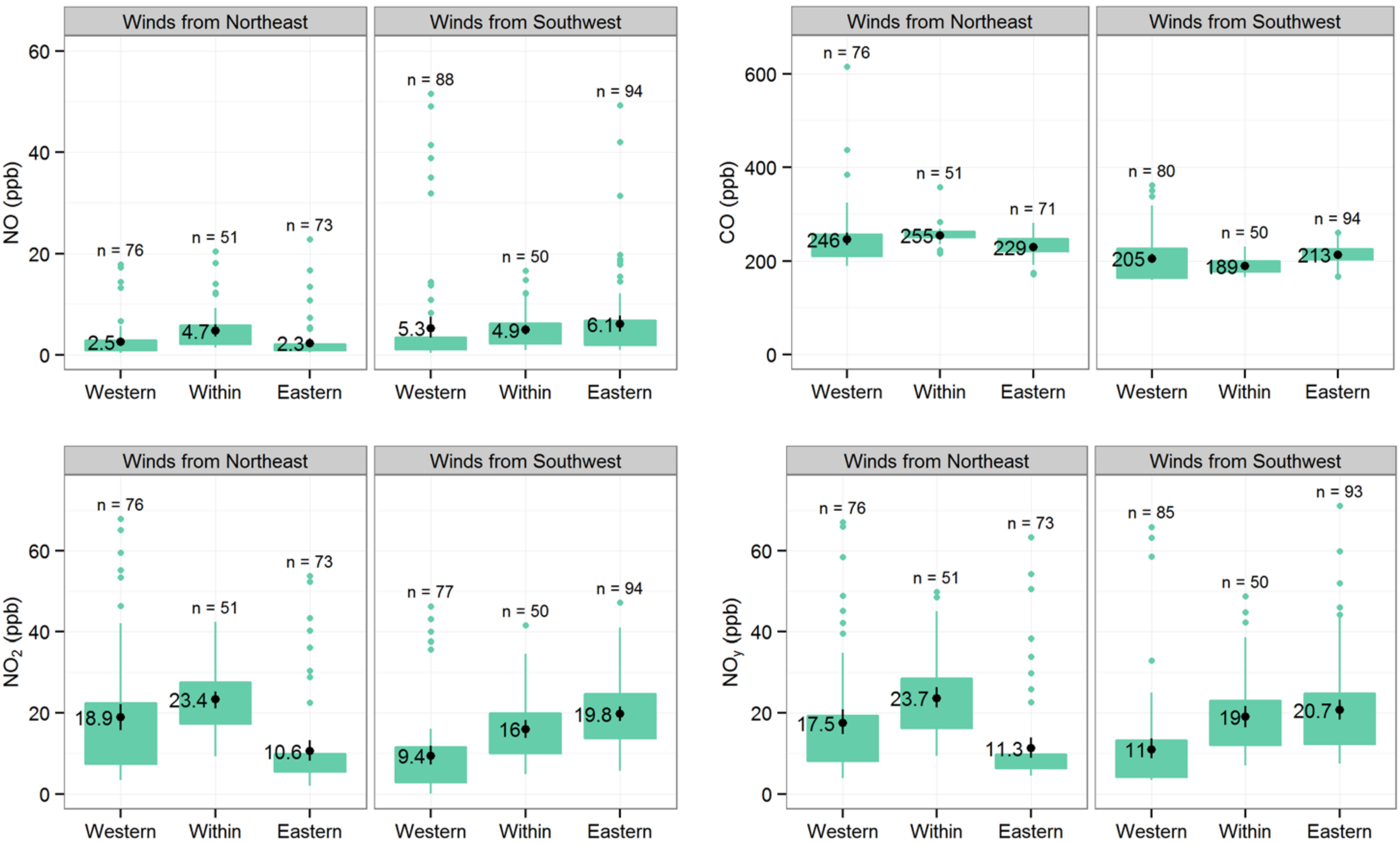
Median concentrations by 50 m segment and wind category



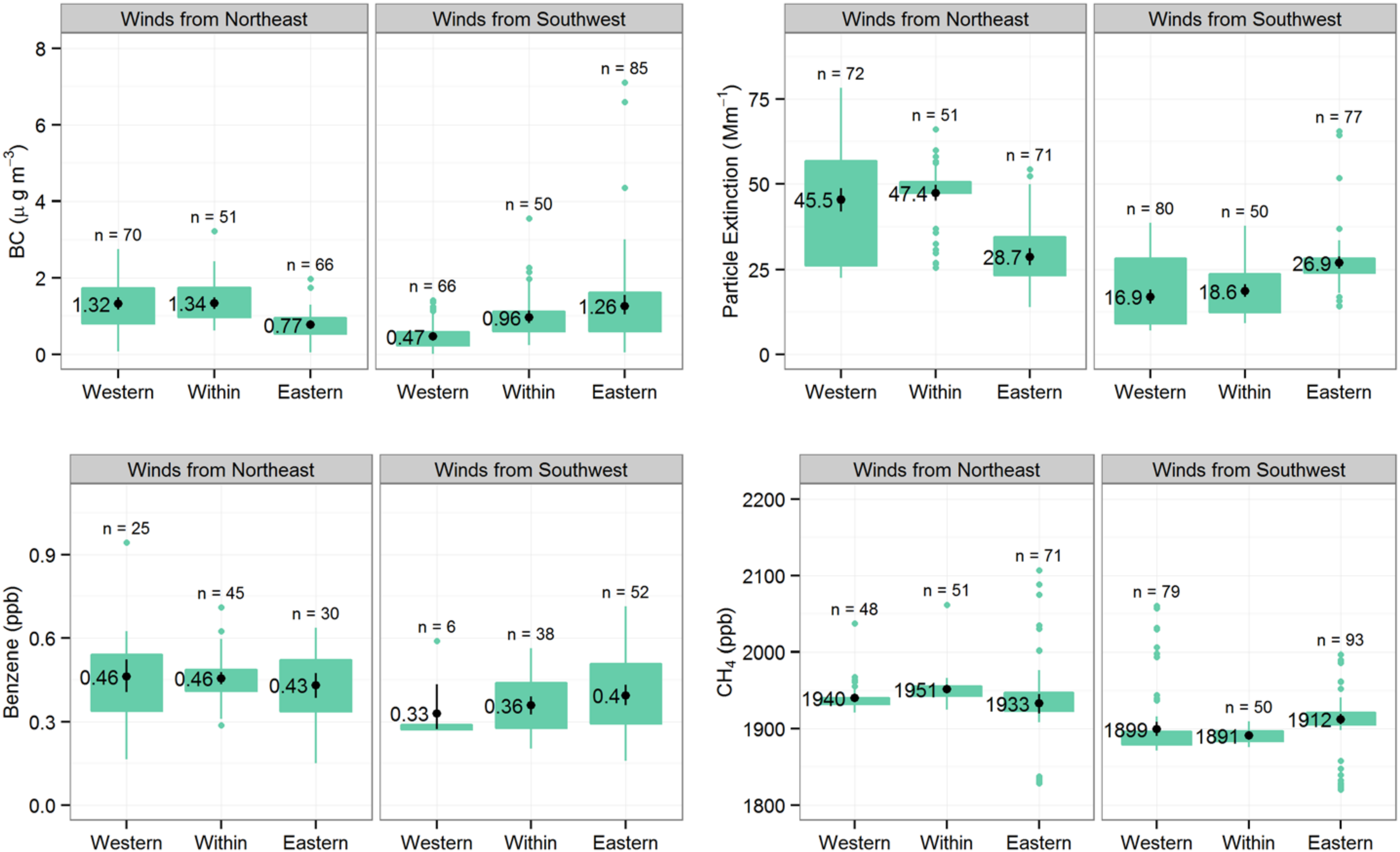


Points represent means and 95% CL

Upwind-Downwind Differences

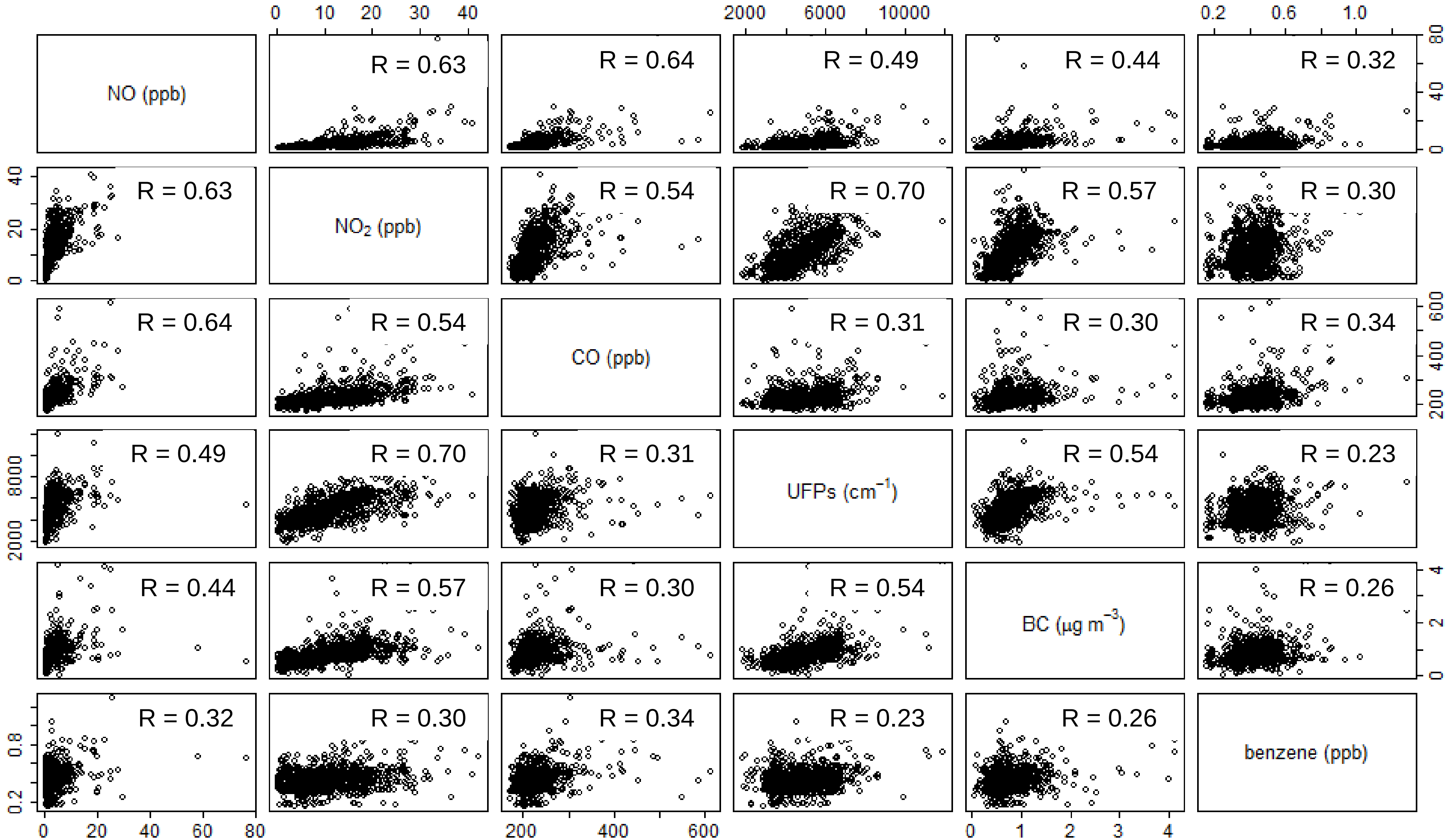


Upwind- Downwind Differences



Pollutant Correlations

50m medians all wind directions



Next steps

Upcoming presentation at AAAR

Paper in development

Ongoing collaboration with Georgia Tech and Aerodyne scientists on analyzing EPA mobile data and Georgia Tech stationary data

Computational Fluid Dynamics Modeling of a Simulated Rail Yard (CFD-RAIL)

CFD-RAIL: background

- Sensitivity study to explore these types of questions:
  - How do terrain features within a rail yard (containers, buildings) and surrounding the rail yard (boundary wall, neighborhoods) affect the transport of emissions?
  - Does the location of emissions within the rail yard matter for near-field air quality?
  - What is the effect of wind direction?

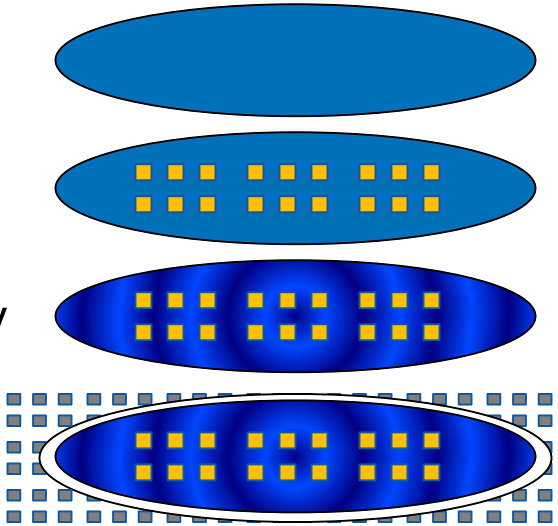
Approach:

- Idealized model with scale similar to Cicero yard, homogenous emissions

- Add within-yard structures – containers, buildings, cranes

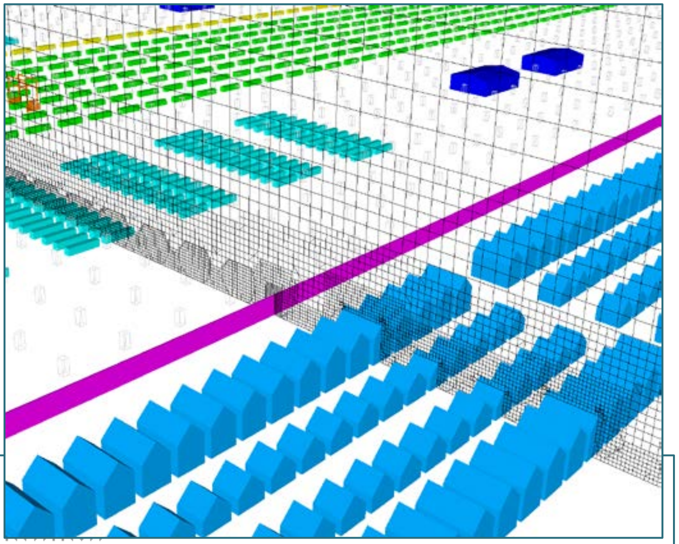
- Spatially weight the emissions, reflecting emissions inventory

- Add surrounding structures similar to Cicero environment – city blocks, noise barrier

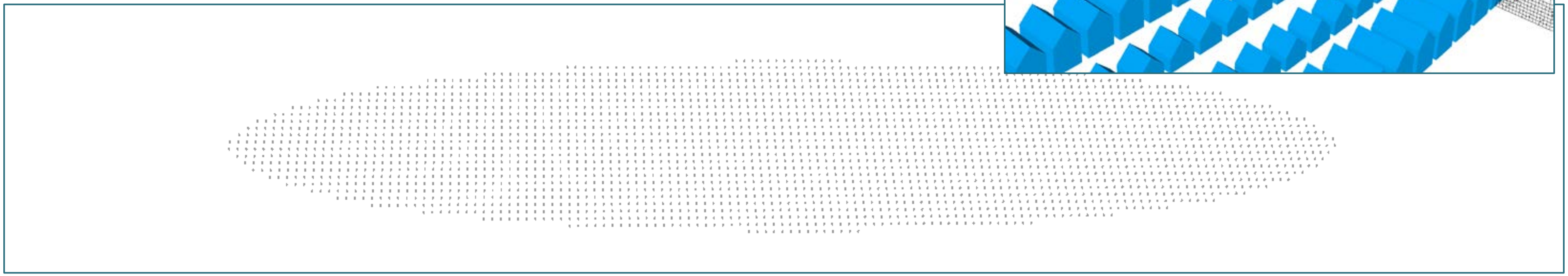


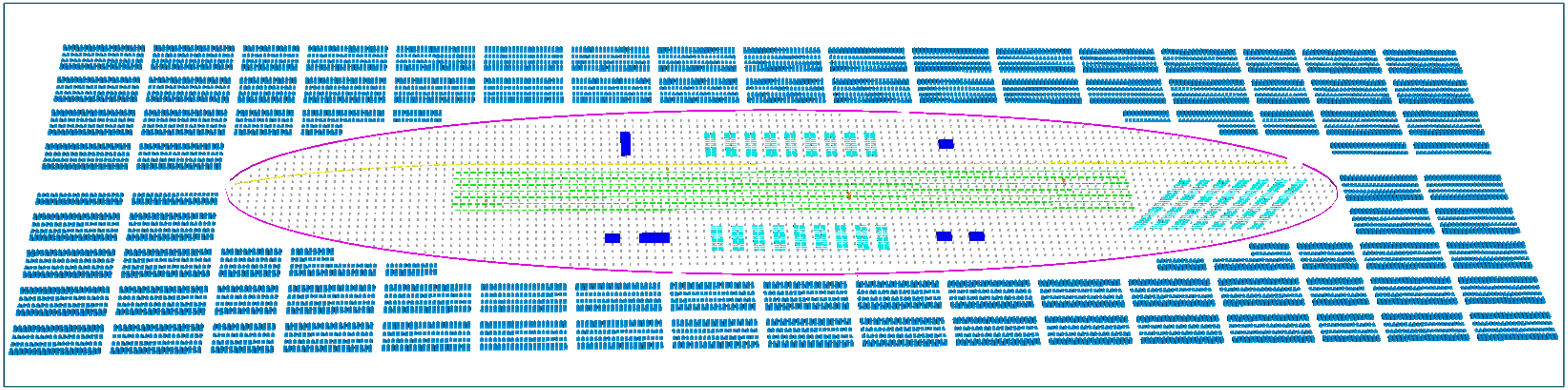
Vary wind direction, different combinations of above

CFD-RAIL: model set-up



CFD model: Ranging from simple homogenous emissions over designated area to weighted emissions with complex terrain.





CFD-RAIL: model set-up

Scenario	Spatially weighted emissions (E)	Rail yard structures (Y)	Surrounding boundary wall (W)	Surrounding houses (N)
Base (B)				
B-E	●			
B-Y		●		
B-EY	●	●		
B-EYW	●	●	●	
B-YW		●	●	
B-EYN	●	●		●
B-EYWN	●	●	●	●

CFD-RAIL: model set-up

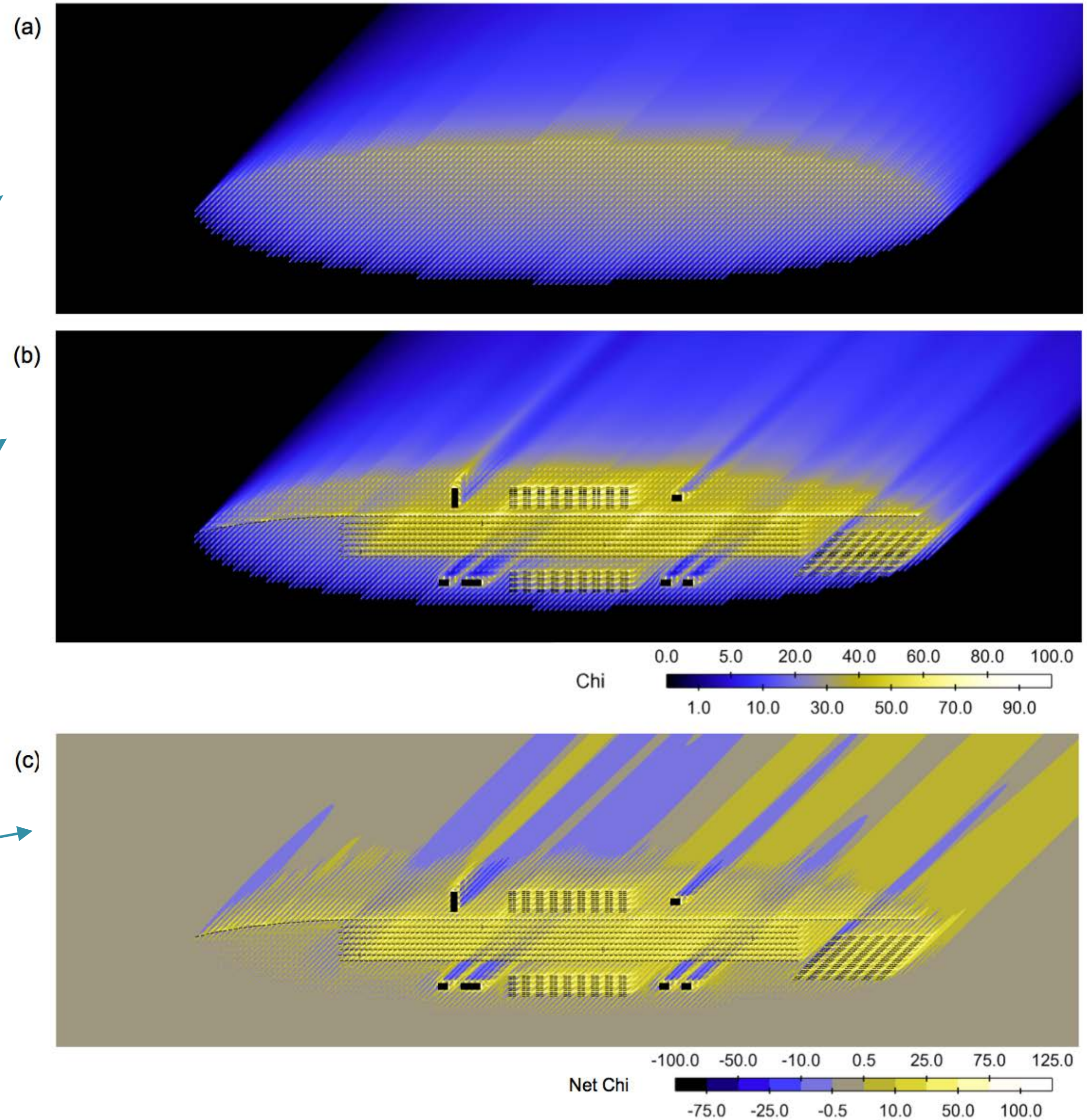
Evaluating sensitivity of progressively adding new terrain features:

Base: Homogenous emissions, no obstructions to air flow

With structures: Homogenous emissions, buildings and containers in yard

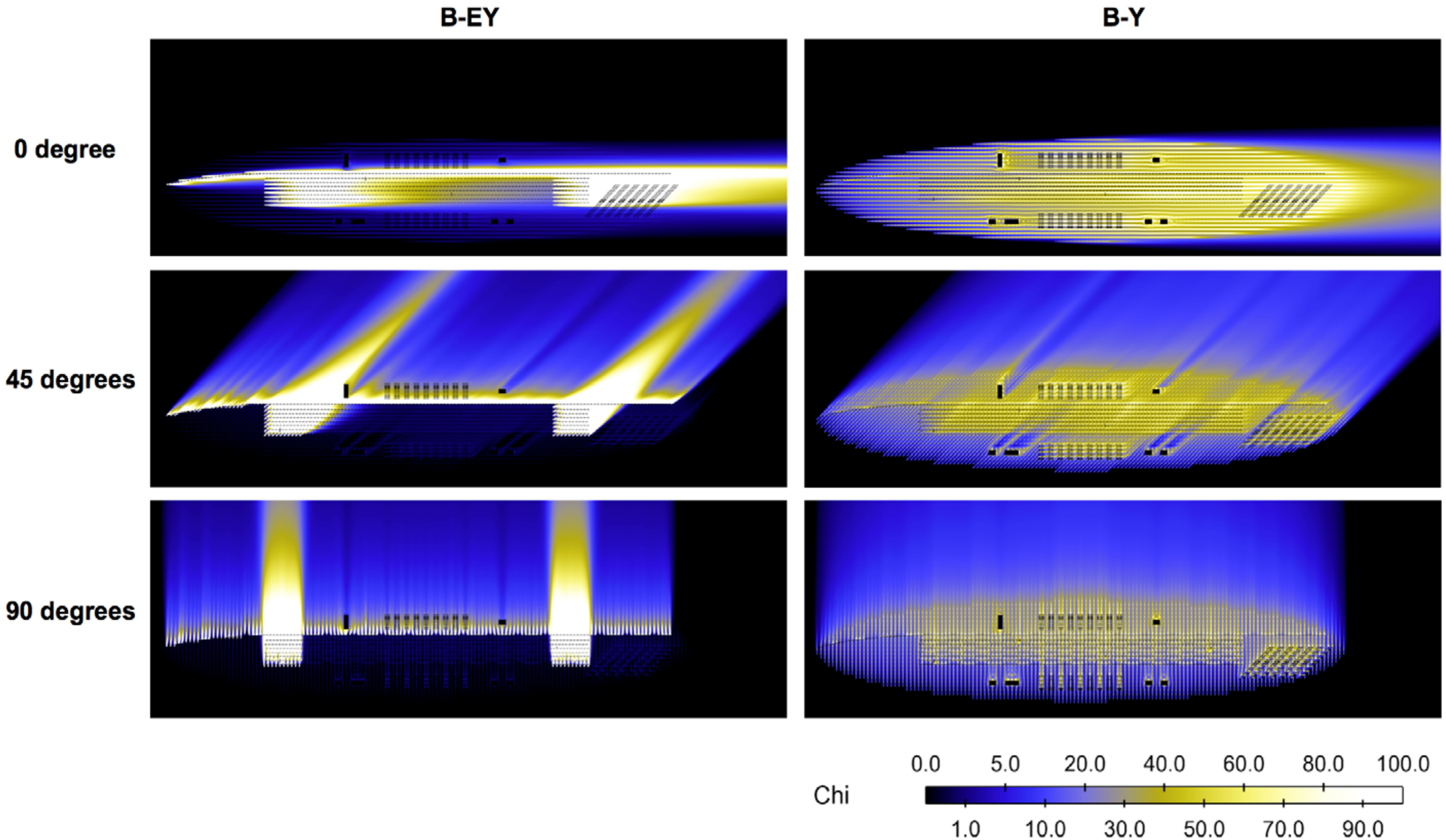
Subtraction of “with structures” minus “base”

Chi: normalized concentration of an inert pollutant



CFD-RAIL: model set-up

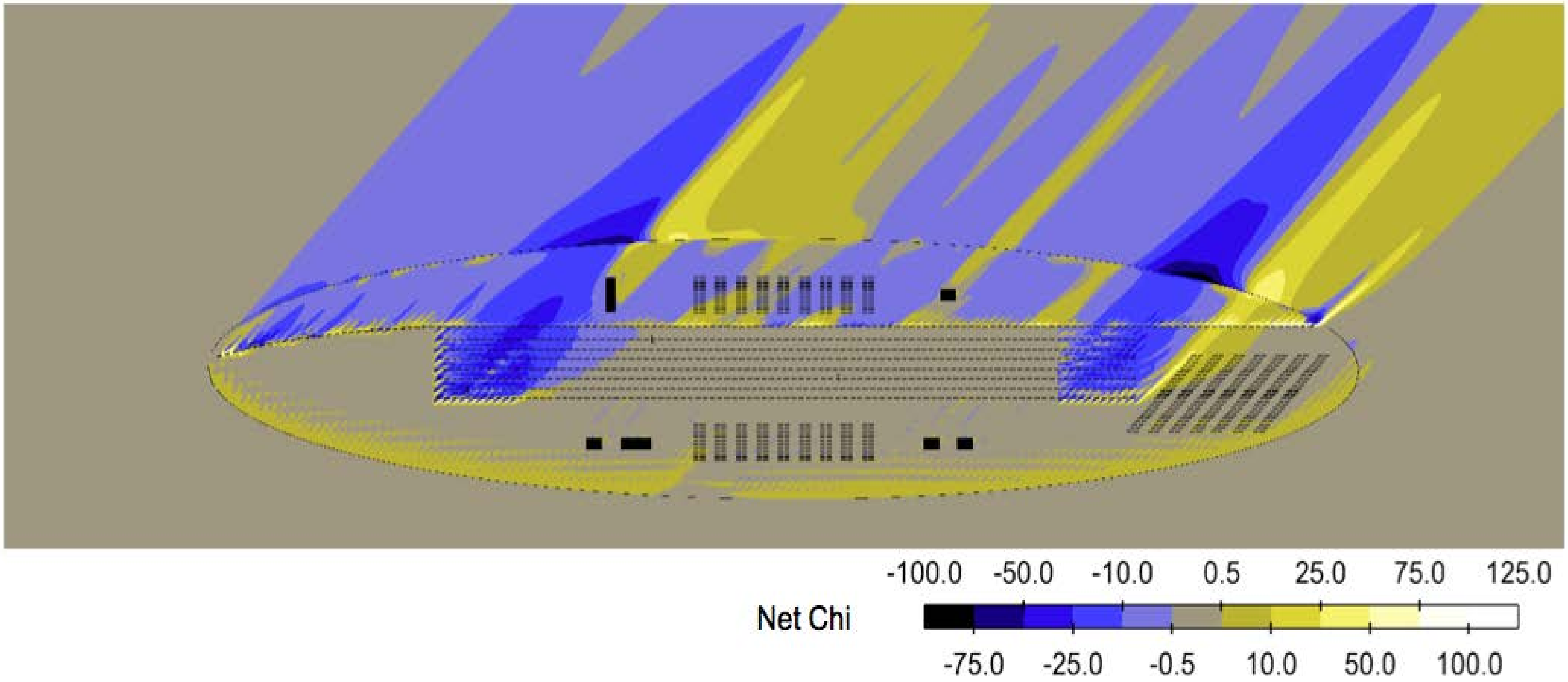
Effect of wind direction:



CFD-RAIL: model set-up

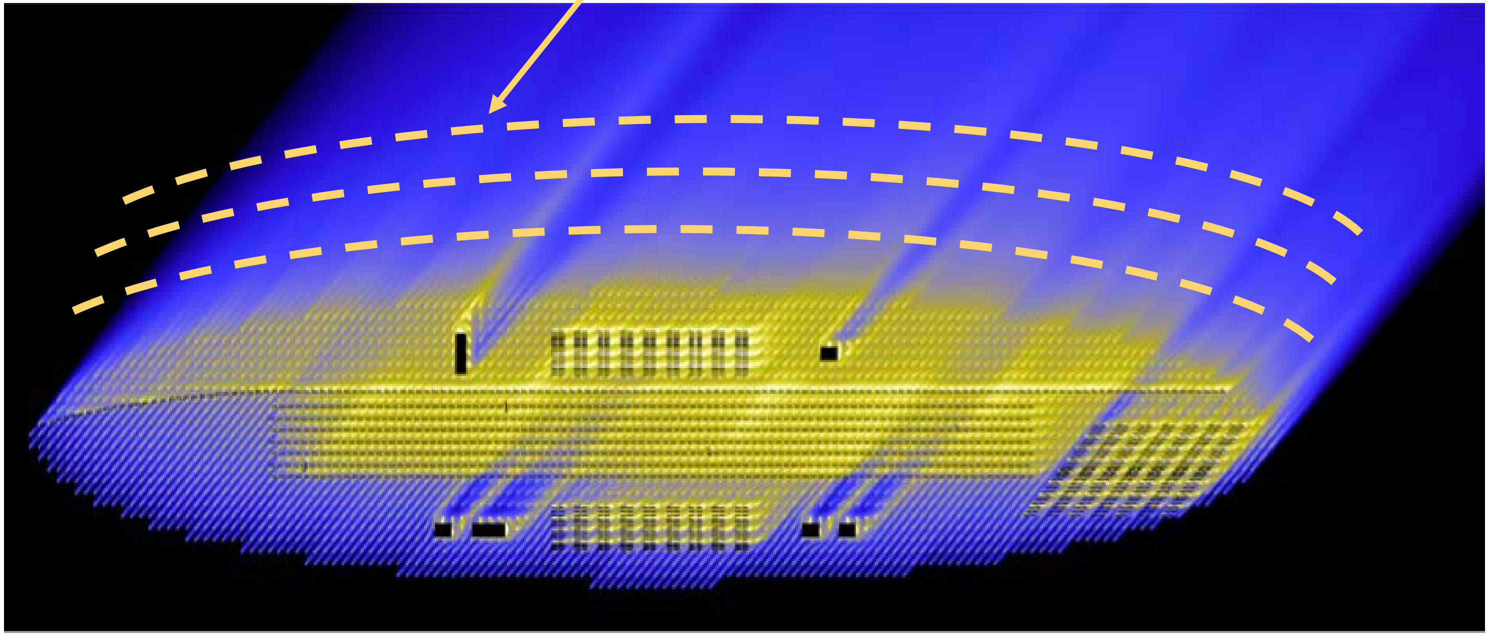
Effect of adding boundary wall:

NetChi = Scenario with wall minus scenario without wall



CFD-RAIL: overall results

For 45 degree wind case: Isolated data for a set height and distance away from rail yard boundary (e.g., Z = 1.5 m, distance from yard boundary = 25 m) – calculate mean and standard deviation



CFD-RAIL: overall results

	D = 25 m		D = 50 m		D = 100 m		D = 200 m		D = 400 m	
Case	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
B	28.02	8.99	23.99	8.15	18.47	7.63	12.24	6.66	6.88	5.11
B-E	26.65	24.58	23.39	22.49	18.56	19.25	12.63	14.70	7.16	9.70
B-Y	29.06	8.78	24.40	8.48	18.56	7.99	12.38	6.96	7.04	5.35
B-EY	29.39	27.40	25.28	24.55	19.70	20.73	13.29	15.76	7.51	10.35
B-EYW	20.46	17.87	20.20	17.56	16.39	15.69	11.35	12.17	6.74	8.44
B-YW	21.42	9.34	20.34	8.27	15.73	7.47	10.72	6.38	6.38	5.01
B-EYN	25.36	23.53	23.28	22.36	17.13	17.19	12.21	13.82	7.15	8.92
B-EYWN	19.11	16.51	18.32	17.21	15.05	14.84	11.36	12.61	6.87	8.45

Max mean and max standard deviation concentrations for scenario with weighted emissions and buildings/containers within yard

CFD-RAIL: overall results

	D = 25 m		D = 50 m		D = 100 m		D = 200 m		D = 400 m	
Case	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
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Addition of neighborhood structures (“N”) surrounding yard leads to ~14% reduction in mean at 25 m and lower standard deviation

CFD-RAIL: overall results

	D = 25 m		D = 50 m		D = 100 m		D = 200 m		D = 400 m	
Case	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
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B-EYWN	19.11	16.51	18.32	17.21	15.05	14.84	11.36	12.61	6.87	8.45

Lowest concentrations observed with addition of 6 m boundary wall - ~35% reduction in mean at 25 m and also lower standard deviation

Next steps

Paper in development summarizing results of the model simulations

CFD rail yard scenario models archived and available for future use

Summary

Field study findings:

- Both Atlanta and Cicero rail yards appear to have detectable local elevation in local air pollution for indicators of diesel exhaust
- Absolute concentration increases for downwind areas are moderate (e.g., 0.6 ug/m3 increase in BC); however can constitute a significant fraction of the total
- Inverse modeling approach successful in revealing source areas contributing to pollution levels – future development recommended to further quantify source contributions

Model study findings:

- Significant spatial variability expected in local air pollution measured at a fixed distance from a rail yard (e.g., 25 m)
- Heterogenous emissions in yard likely contribute to hot spot areas that vary with wind direction
- Addition of boundary wall may lead to reduction of local air pollution contribution from rail yard emissions

For more information

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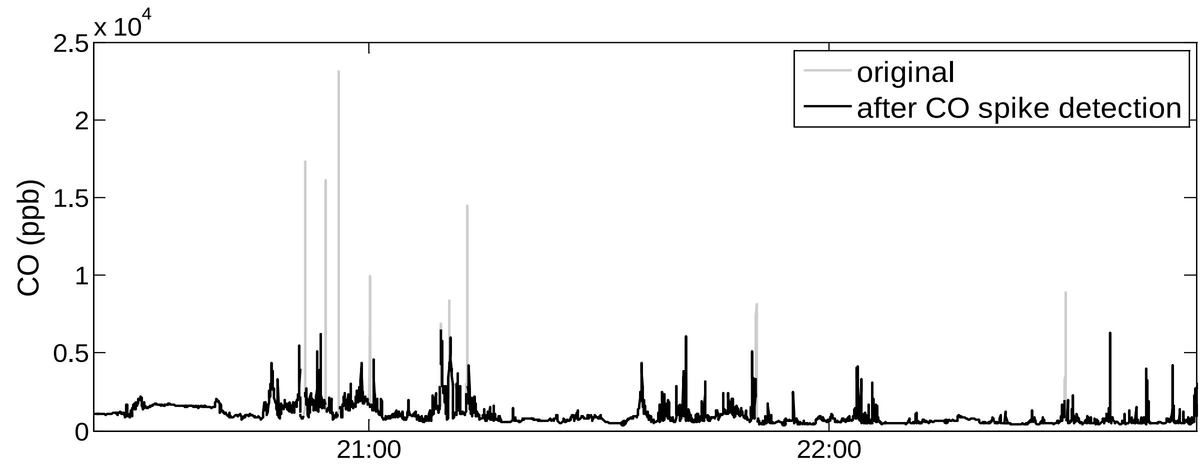
Appendix

CIRYS – mobile monitoring results

Raw data from instruments → Time-align GPS & air pollution data → Apply ONA smoothing procedure for BC data *Hagler et al., 2011* → Apply side road traffic exhaust filter (5-second moving coefficient of variation for CO) → Data from specific zones of interest are extracted, distance referenced to rail yard → Evaluation of downwind areas (50 m) relative to urban background



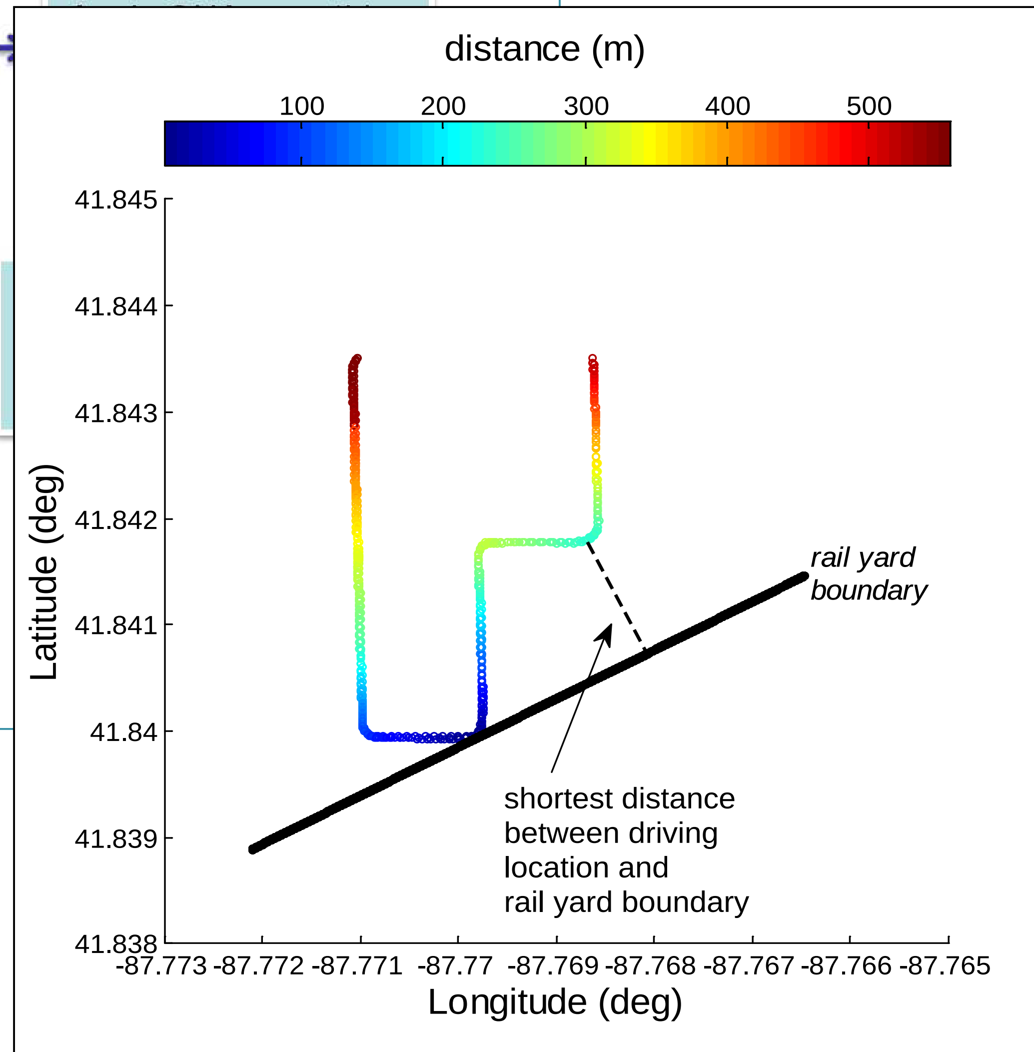
CIRYS – mobile monitoring results

Raw data from instruments

Time-align GPS & air pollution data

Data from specific zones of interest are extracted, distance referenced to rail yard

Evaluation of downwind areas (50 m) relative to urban background



CIRYS – mobile monitoring results

Raw data from instruments → Time-align GPS & air pollution data → Apply ONA smoothing procedure for BC data *Hagler et al., 2011*

↓

Apply side road traffic exhaust filter (5-second moving coefficient of variation for CO) → Data from specific zones of interest are extracted, distance referenced to rail yard

↓

Evaluation of downwind areas (50 m) relative to urban background