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TRANSPORTATION RESEARCH BOARD

The Near-Road Pooled Fund Study

Monday, September 30, 2019
2:00-3:30 PM ET

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Providers Program. Credit earned on completion of this program will be reported to RCEP. A certificate of completion will be issued to participants that have registered and attended the entire session. As such, it does not include content that may be deemed or construed to be an approval or endorsement by RCEP.

RCEP

REGISTERED CONTINUING EDUCATION PROGRAM

Purpose

Provide an overview of the research done through the transportation pooled fund (TPF) to understand near-road air quality data, improve near-road air quality evaluations, implement effective mitigation, and more effectively respond to stakeholder information requests

Learning Objectives

At the end of this webinar, you will be able to:

- Identify common technical methods used to assess near-road air quality
- Describe the need to assess near-road air quality
- Summarize the efforts of the transportation pooled fund (TPF) study

National Assessment of Near-Road (NR) Air Quality: Requirements, Trends, and Analysis Insights

Work Sponsored by the Near-Road Air Quality Transportation Pooled Fund (TPF)

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For: U.S. Transportation Research Board (TRB) Webinar Series

Organized by the TRB Standing Committee on Transportation and Air Quality
Available via TRB's website:
http://www.trb.org/ElectronicSessions/RecordedSessions.aspx

Transportation Pooled Fund

- Five-year program
- Sponsors
  - Arizona DOT
  - Caltrans
  - Colorado DOT
  - FHWA
  - Ohio DOT
  - Texas DOT
  - Virginia DOT
  - Washington State DOT, lead agency
- Research – STI

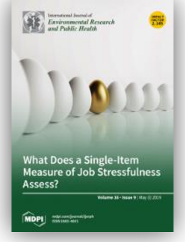
Objective: *"Improve the state of knowledge regarding, and the ability of state DOT staff to address, near-road air quality issues."*

Outline

1. Introduction: Pooled fund, motivation, EPA requirements
2. Data Overview: CO and NO_2 are not current problems; $PM_{2.5}$ is high at some sites
3. Near-Road $PM_{2.5}$: Increment varies across near-road (NR) sites
4. Trends: Starting to emerge, seem to be headed in right direction
5. Monitored Compared to Modeled: Disconnect between measured and modeled concentrations
6. Conclusions

Material Drawn From

(Partial List)

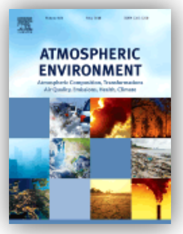


Brown et al., 2019: 2014-2016 data.

Conditions Leading to Elevated $PM_{2.5}$ at Near-Road Monitoring Sites: Case Studies in Denver and Indianapolis

Seagram et al., 2019: 2016 data.

National Assessment of Near-Road Air Quality in 2016: Multi-Year Pollutant Trends and Estimation of Near-Road $PM_{2.5}$ Increment

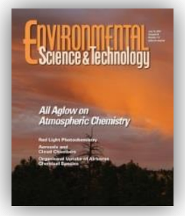


DeWinter et al., 2018: 2014 and 2015 data.

A National-Scale Review of Air Pollutant Concentrations Measured in the U.S. Near-Road Monitoring Network During 2014 and 2015

Reid et al., 2016: 2006-2035 modeled emissions.

Emissions Modeling with MOVES and EMFAC to Assess the Potential for a Transportation Project to Create Particulate Matter Hot Spots

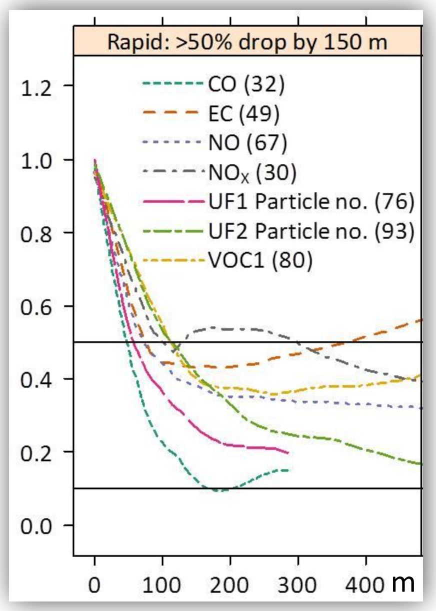


Karner, Eisinger, and Niemeier, 2010: 1978-2008 global data.

Near-Roadway Air Quality: Synthesizing the Findings from Real-World Data

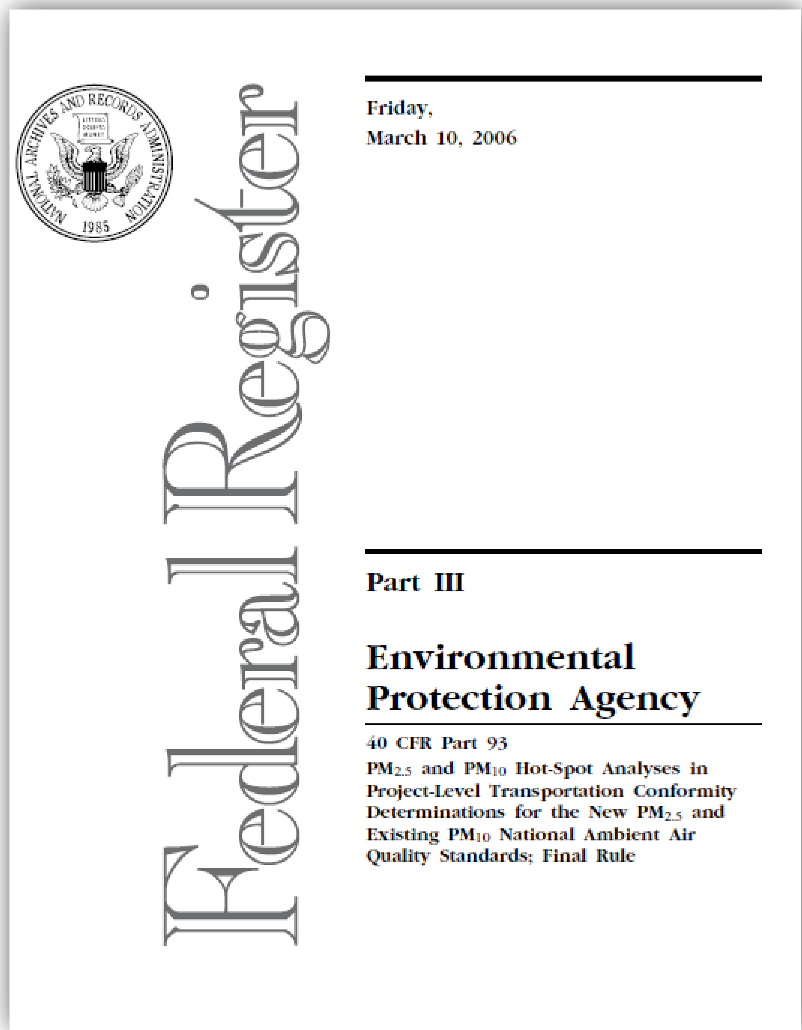
Motivation: NR Air Pollution

- CO, black carbon, NO_2, other pollutants are typically higher near major roadways
- HEI: traffic-related air pollution exposure linked to children's asthma (and other concerns)
- In 2010, EPA mandated air pollution monitoring near major roadways



Sources: Karner, Eisinger, and Niemeier (2010) *ES&T*, 44, 5334-5344; Health Effects Institute (2010); U.S. EPA NO_2 NAAQS, 40 CFR Parts 50 and 58

Motivation: Required NR Analyses



Federal Register

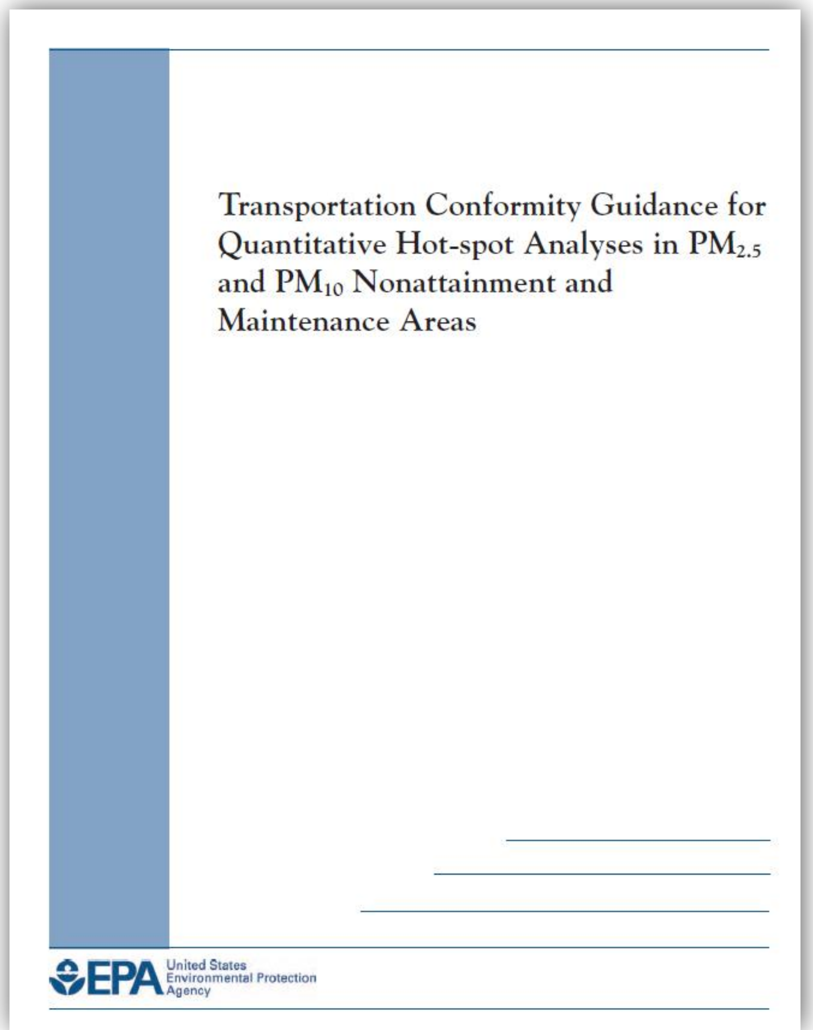
Friday,
March 10, 2006

Part III

Environmental Protection Agency

40 CFR Part 93

$PM_{2.5}$ and PM_{10} Hot-Spot Analyses in Project-Level Transportation Conformity Determinations for the New $PM_{2.5}$ and Existing PM_{10} National Ambient Air Quality Standards; Final Rule



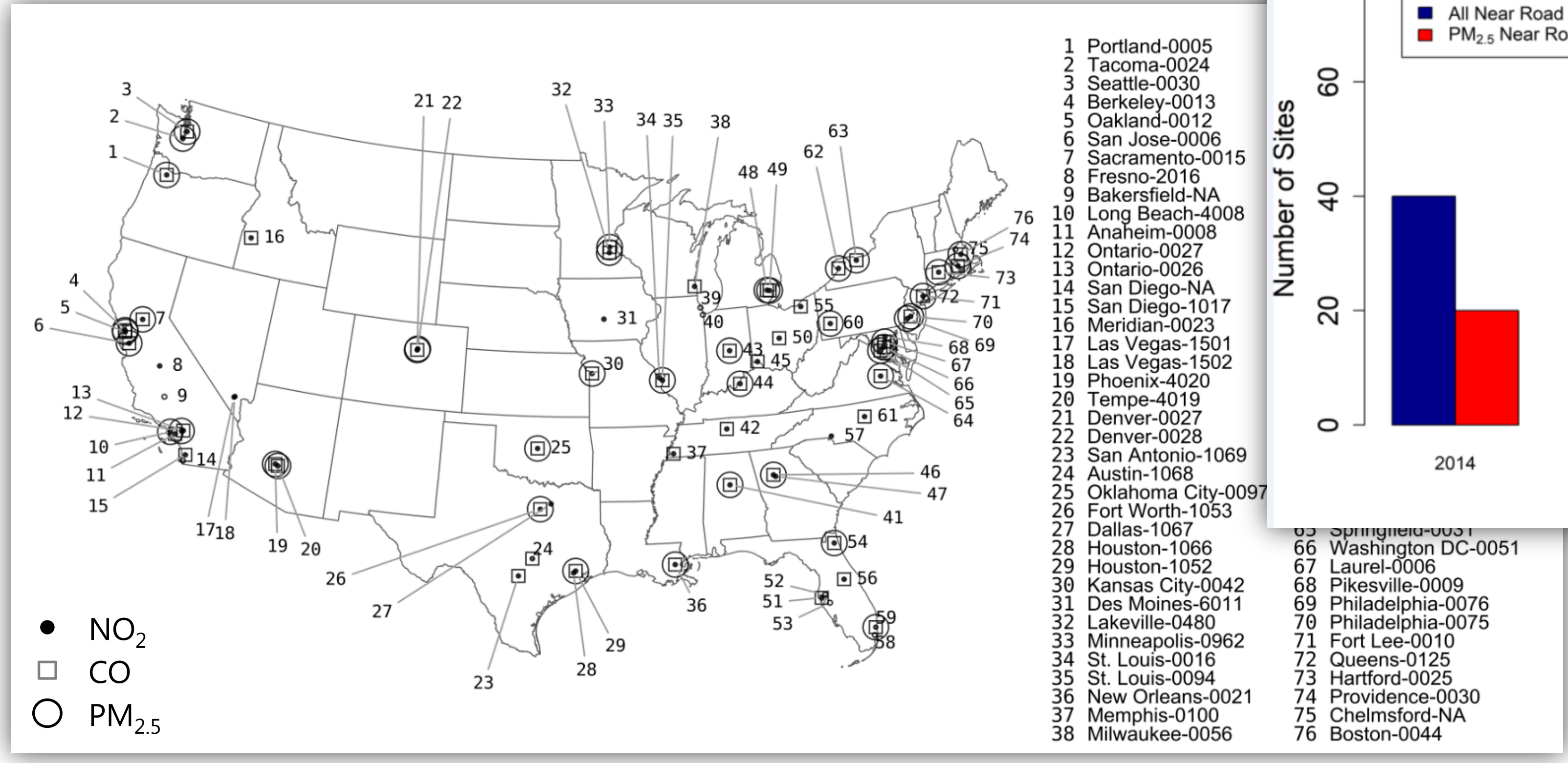
Transportation Conformity Guidance for Quantitative Hot-spot Analyses in $PM_{2.5}$ and PM_{10} Nonattainment and Maintenance Areas

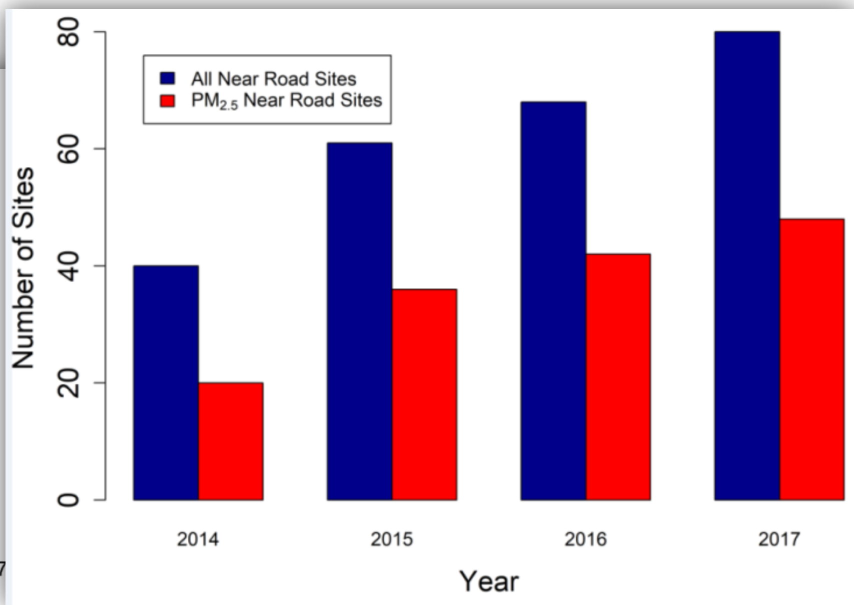
EPA United States Environmental Protection Agency

Federal mandates: near-road "hot-spot" analyses

- Carbon monoxide (CO)
- Particulate matter ($PM_{2.5}$ and PM_{10})

Motivation: EPA-Mandated NR Monitoring, 2014+



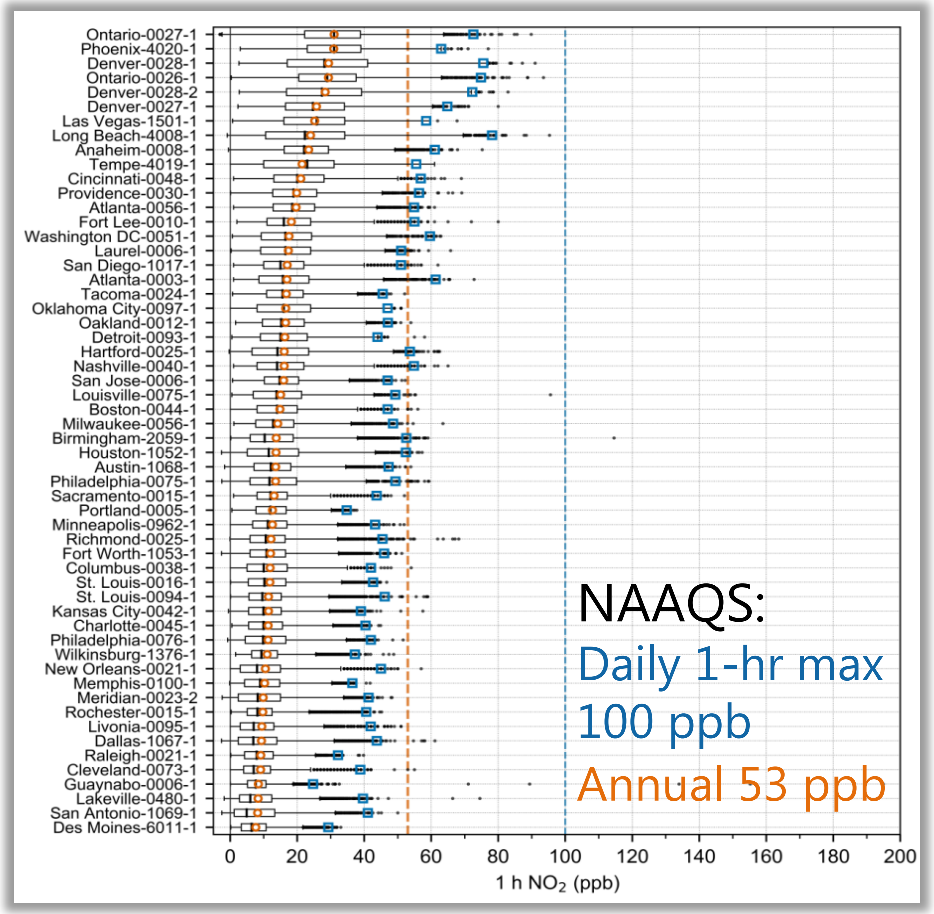


- NO_2 68 locations
- CO 53 locations
- $PM_{2.5}$ 42 locations

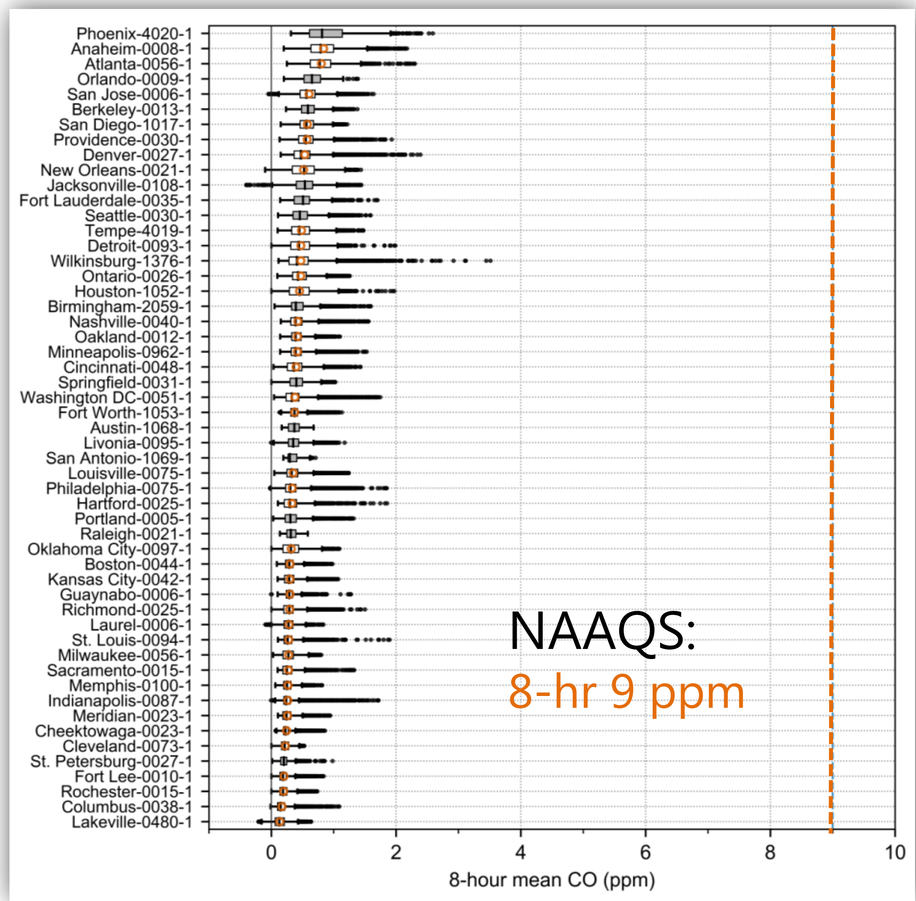
Site locations in 2016.
Source: Seagram et al., 2019,
Transportation Research Record

Multiple Years of Data Show NR CO and NO_2 Are Well Below NAAQS

2016 NO_2



2016 CO



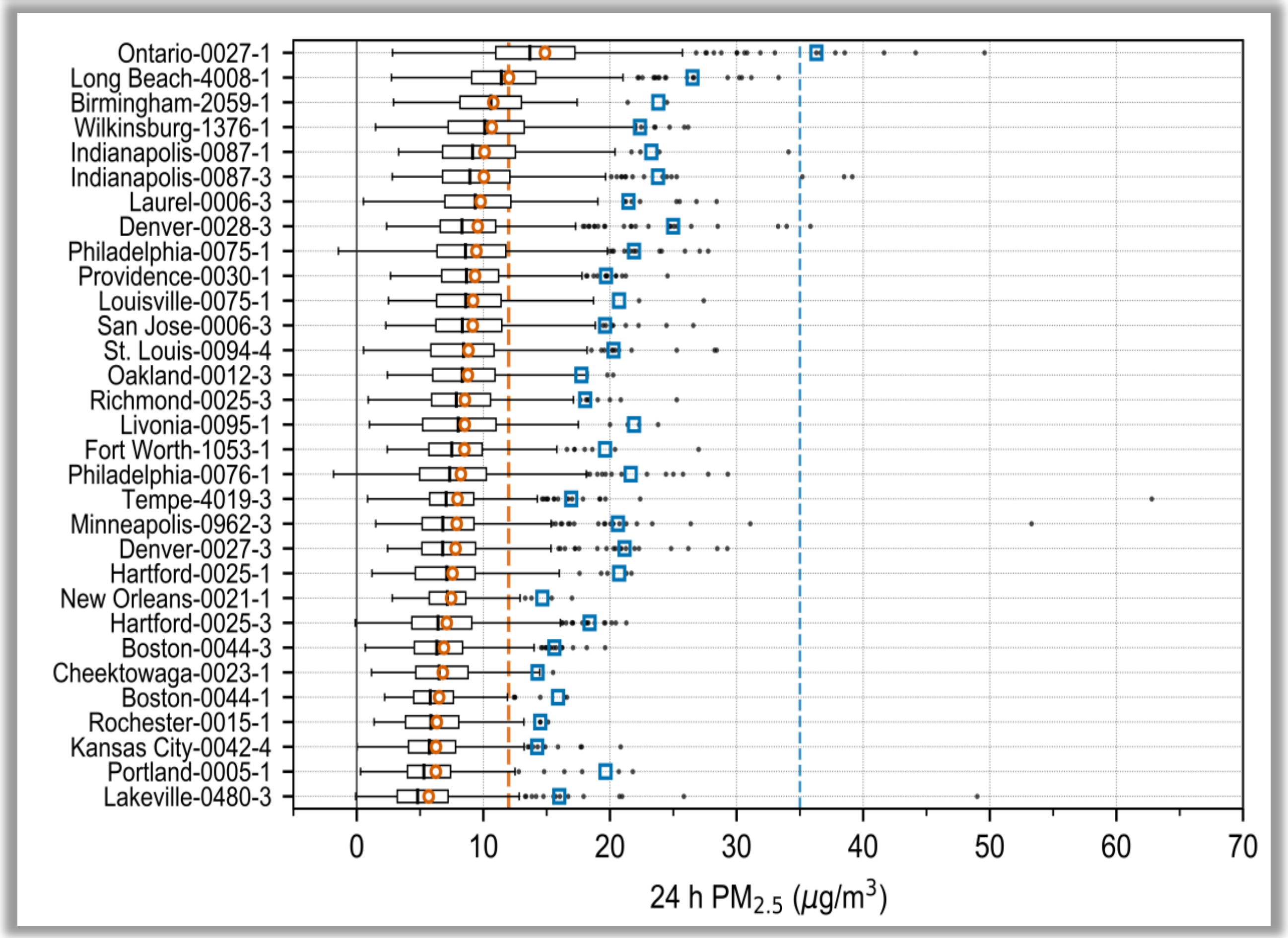
From Seagram et al., 2019, *Transportation Research Record*

These findings are for research purposes; do not use for determining attainment status.

2016 $PM_{2.5}$ – Most Sites Below NAAQS

24-hr: several sites > 35; *Ontario* *98th % > 35 µg/m³*

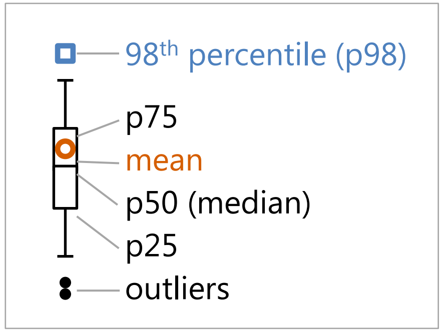
Annual: many sites near annual mean threshold, *Ontario, Long Beach above it*



NAAQS:

24-hr 35 µg/m³

Annual 12 µg/m³

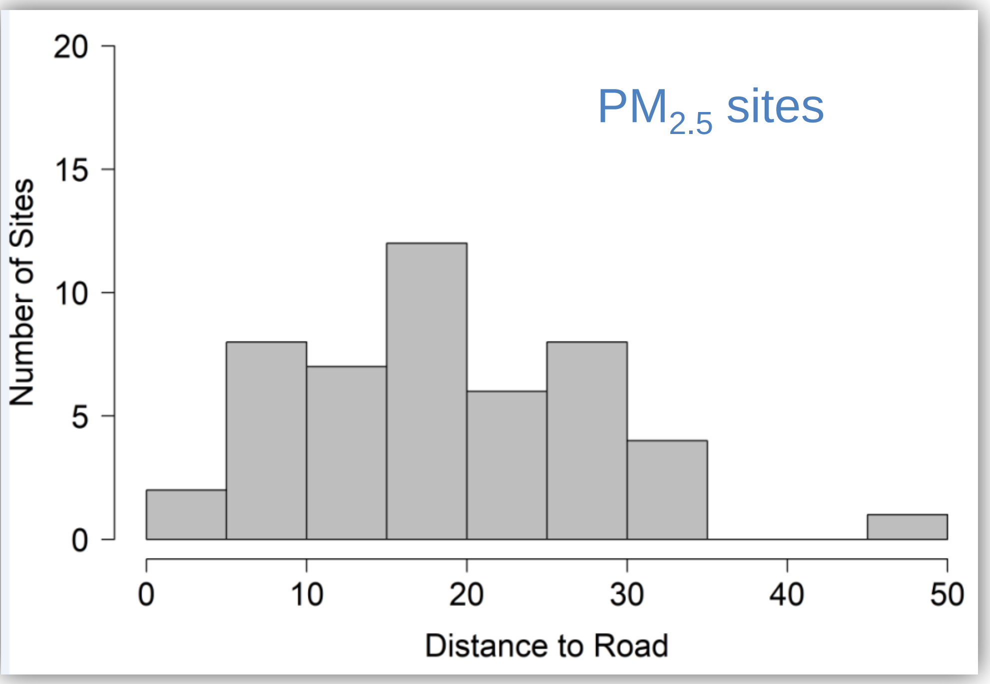


From Seagram et al., 2019, *Transportation Research Record*

These findings are for research purposes; do not use for determining attainment status.

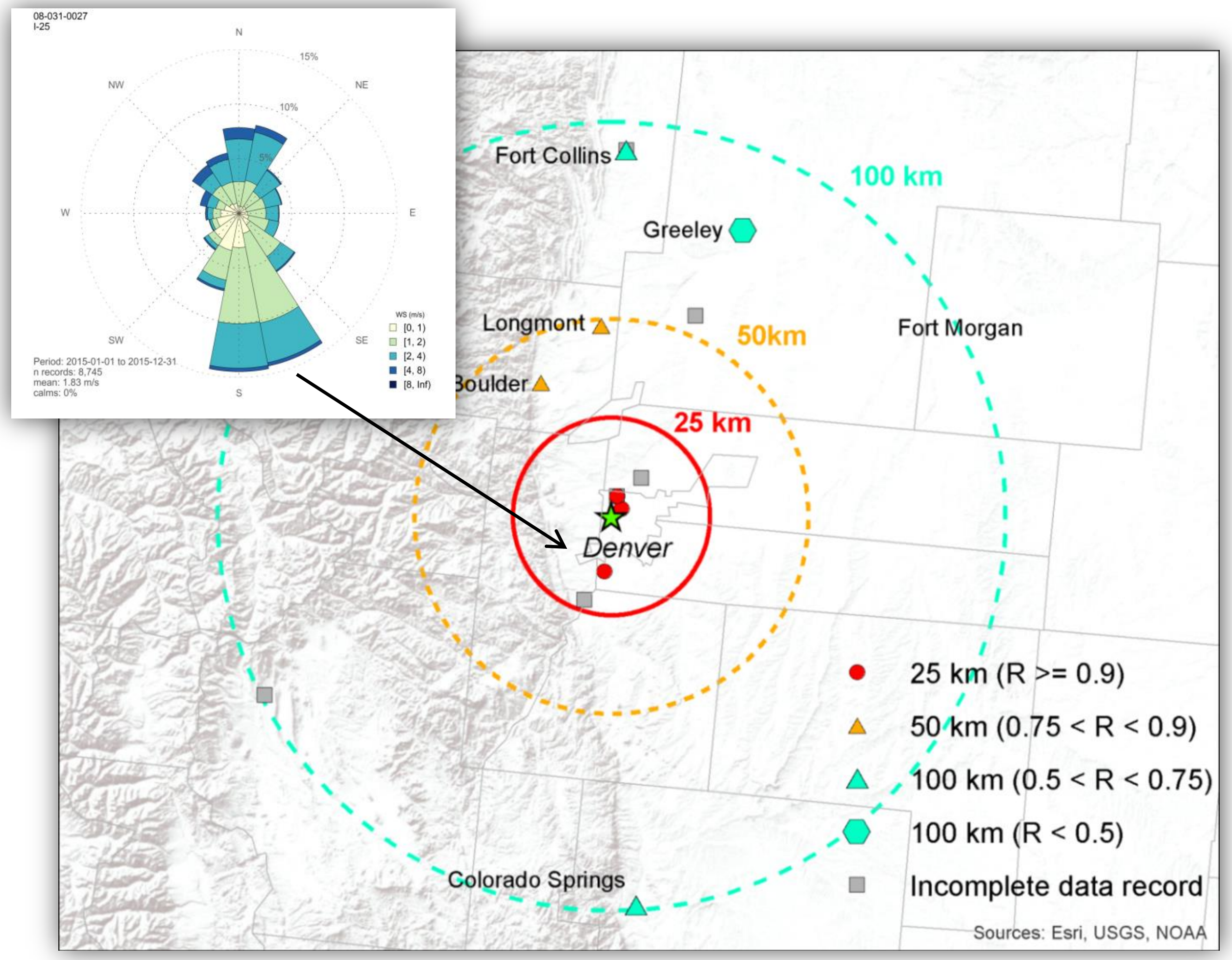
Factors to Weigh When Evaluating Increments (partial list)

- Distance to roadway
- Traffic volume
- Fleet mix (truck %)
- Meteorological conditions
- Background site selection



Near-road sites by distance to roadway (m); 2017 data

$PM_{2.5}$ Increment: National Summary



Background Site Selection:

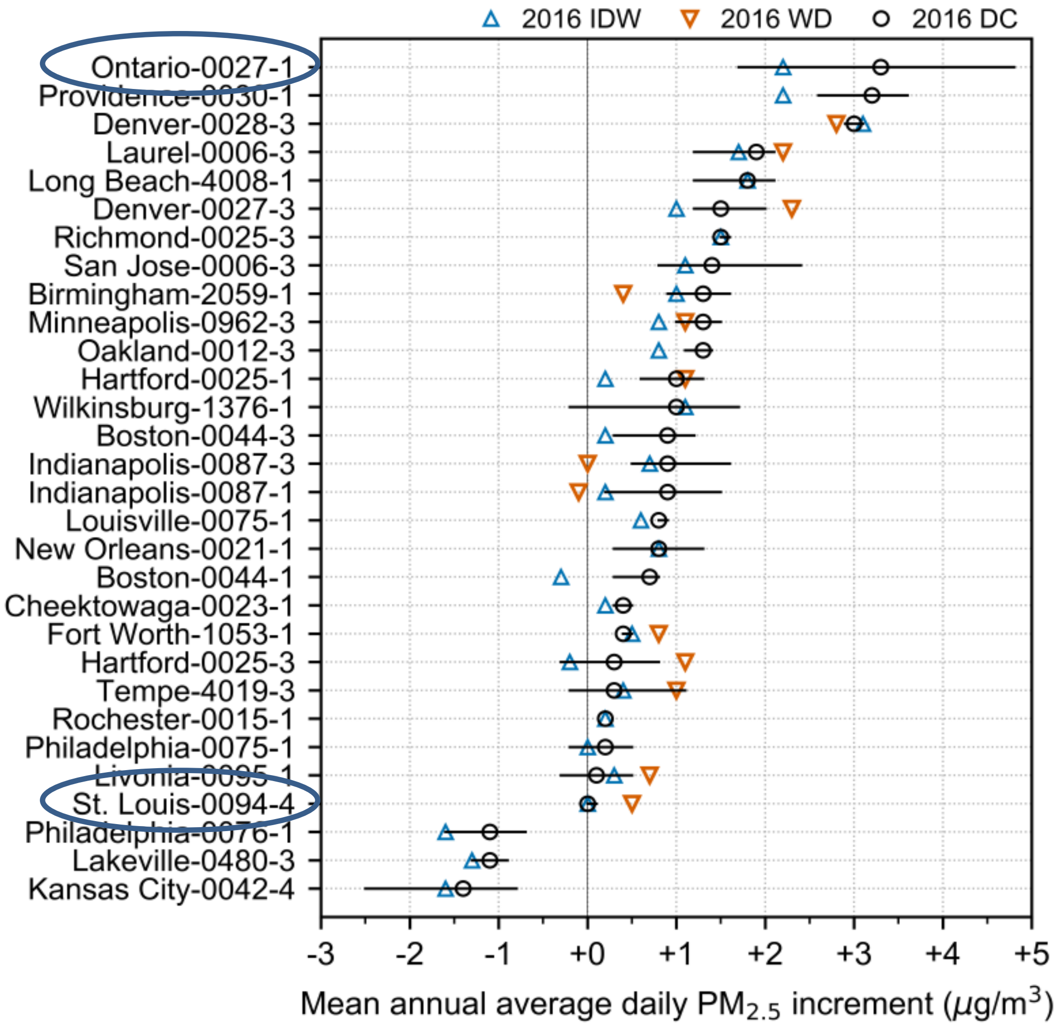
We Assessed Multiple Options/Analysis Approaches

2015 example results for Denver, distance/correlation (DC), in ug/m3

- 25/50/100 km: 3.0/3.1/3.9
- r^2 of 0.5/0.75/0.90: 3.0/3.1/2.8
- Ave. all six DC methods: increment = 3.2

(DeWinter et al., 2018, Table 2)

NR PM$_{2.5}$ Increment Results, 2016

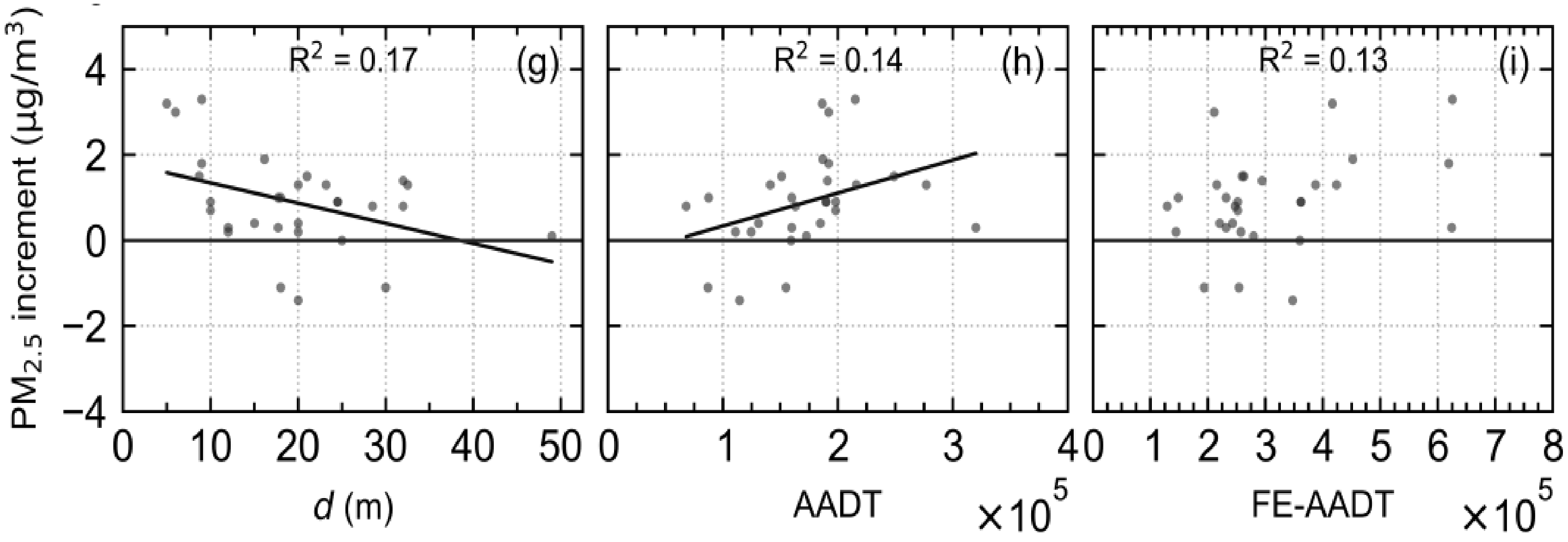


- Mean: 0.6 – 1.1 μg/m^3
- Most: 0.0 – 1.5 μg/m^3
- Increments vary widely among sites
- **Findings before consideration of confounding factors (next slides)**

Multiple methods used:
- Inverse distance weighting (IDW)
- Single upwind site (WD)
- Combination of nearby sites (Distance/Correlation, or DC)

(Seagram et al., 2019, Fig. 6)

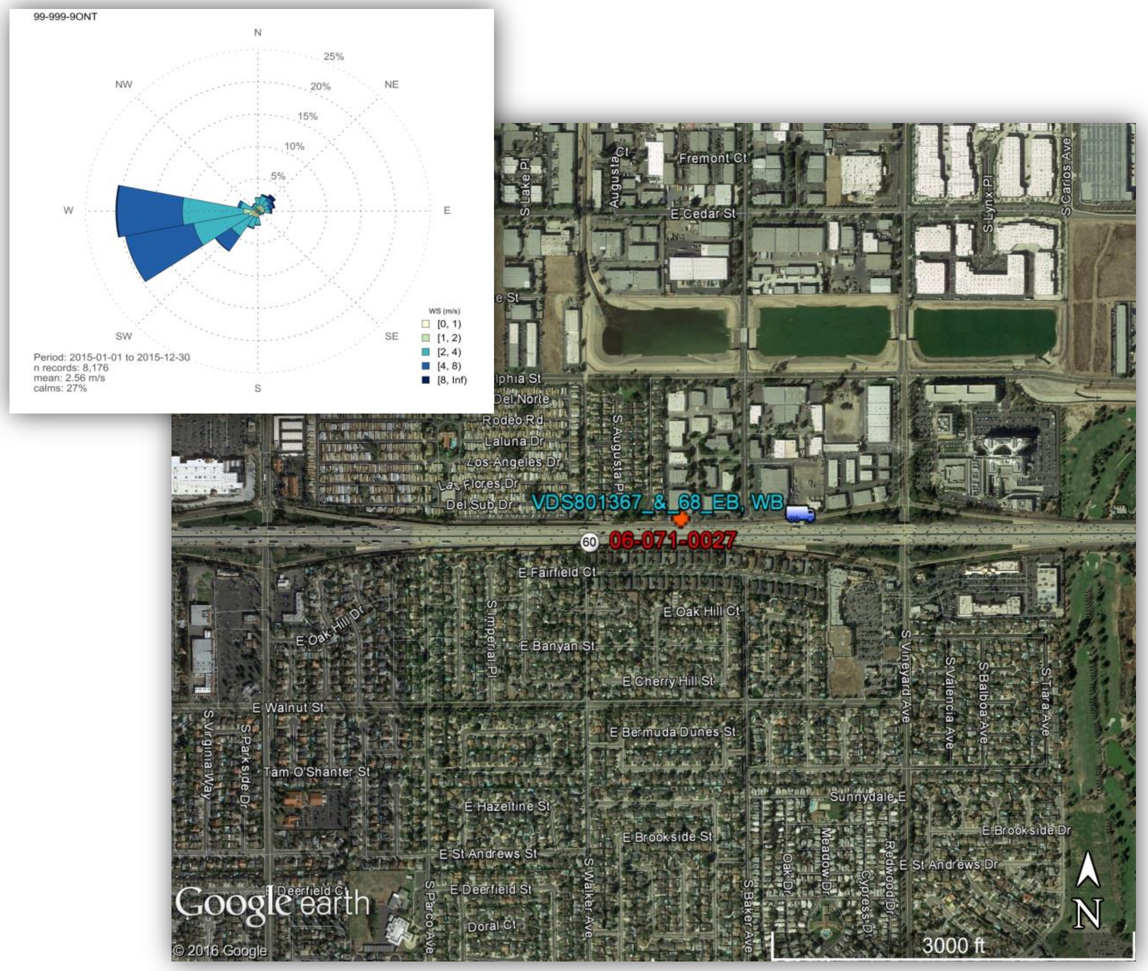
2016 $PM_{2.5}$ Increment Data:
Minimal Correlation vs. Distance or Traffic
Many Sites Have Confounding Factors (e.g., Ontario, St. Louis)



Lines show where relationships are significant, based on p-value ≤ 0.05

Source: Seagram et al., 2019, Fig. 7

Ontario (Southern California) State Route 60



Google Earth view

AADT: 215,000

FE-AADT: 625,736

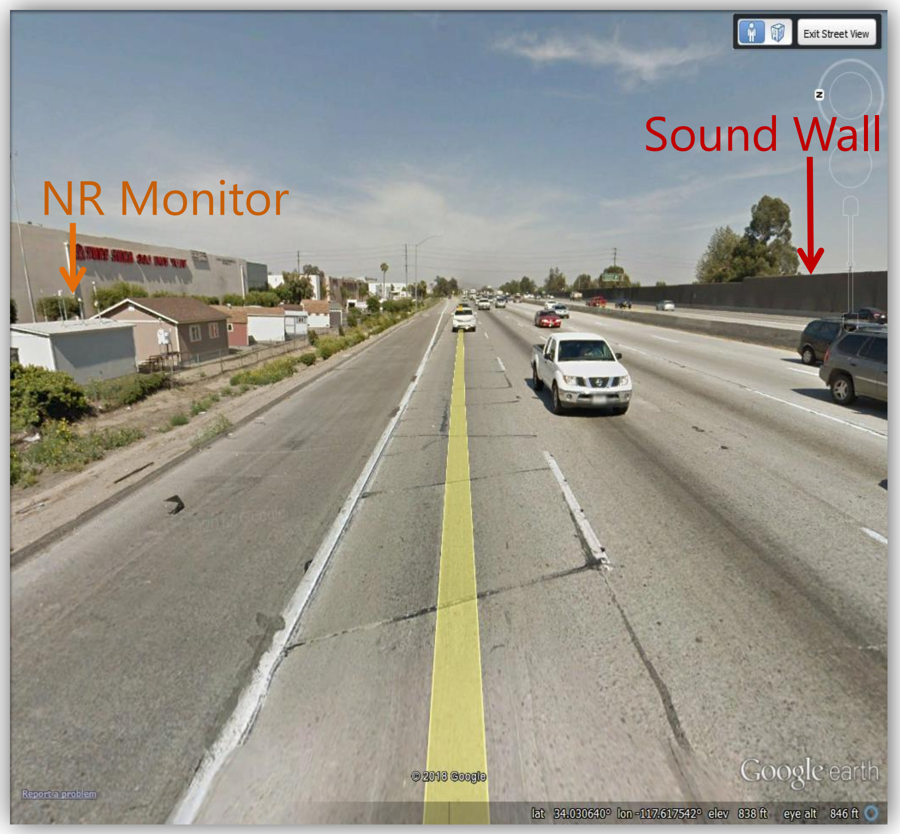
Estimated $PM_{2.5}$ increment:

~2.0 to 3.0 $\mu g/m^3$ (2016)

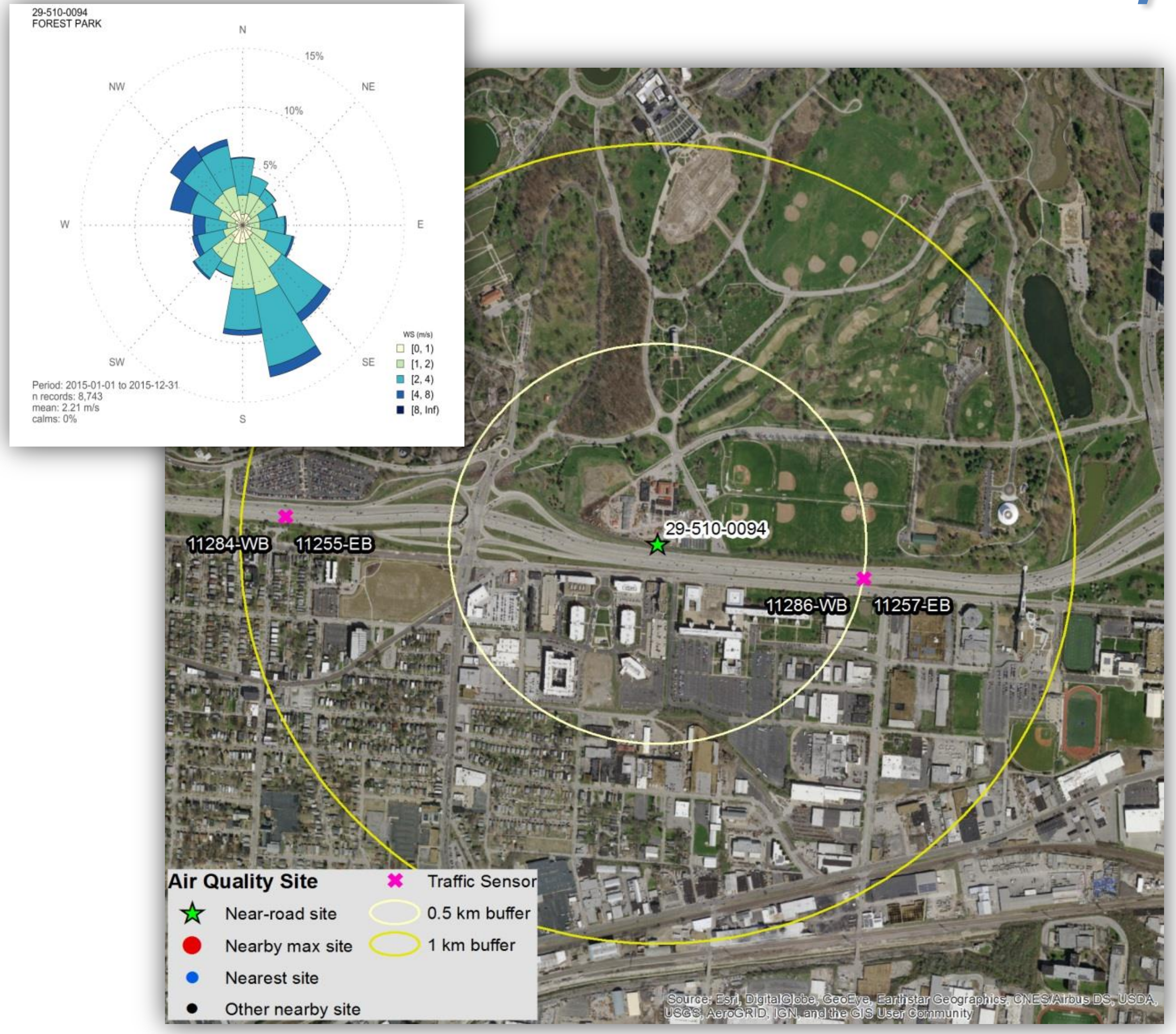
High Increment Illustration: Ontario, CA (SR-60)

Looking West

Looking East



St. Louis, I-64



Google Earth view

AADT: 159,326

FE-AADT: 360,077

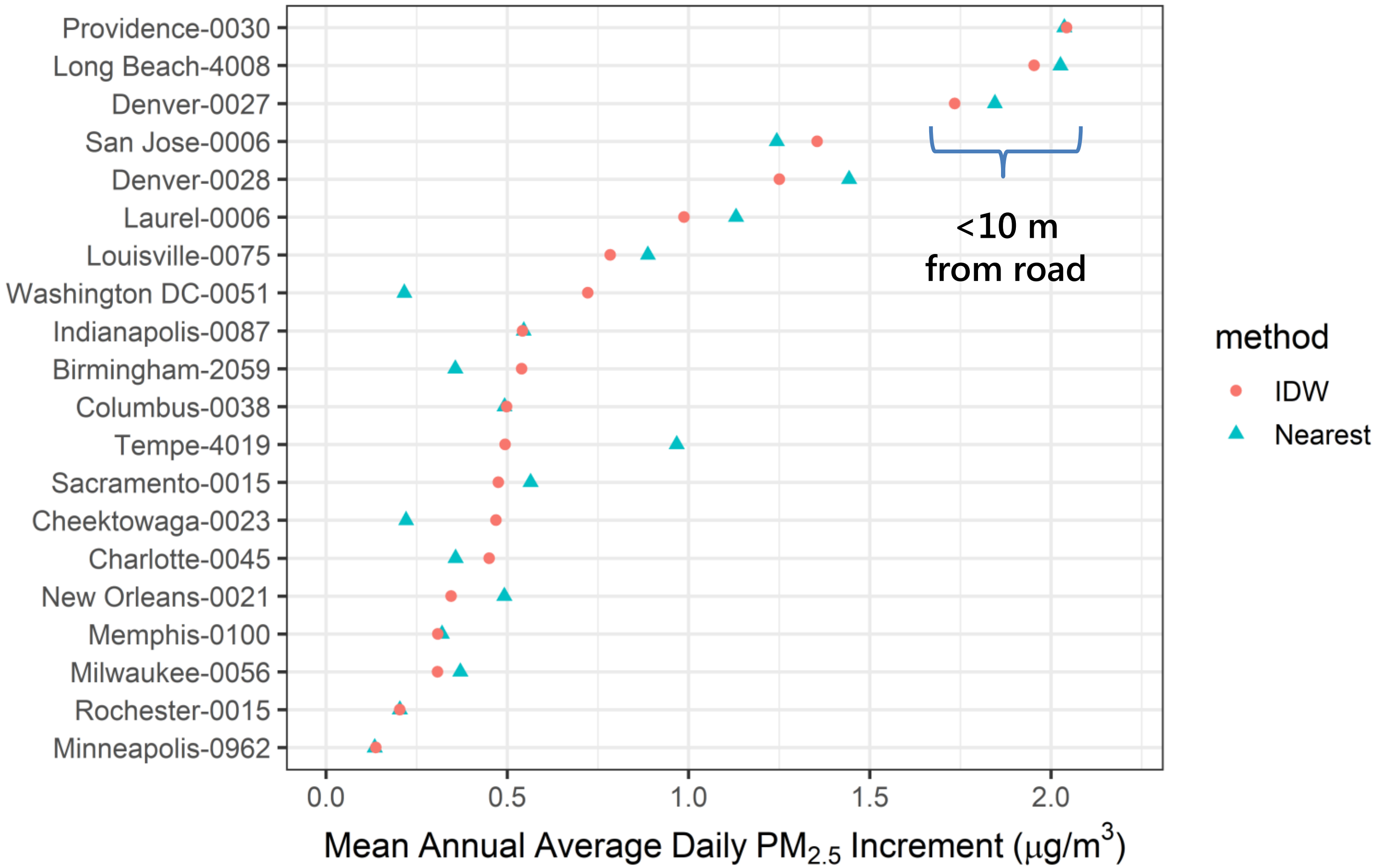
Estimated $PM_{2.5}$ increment:
~0.0 to 0.5 µg/m^3 (2016)

Looking North

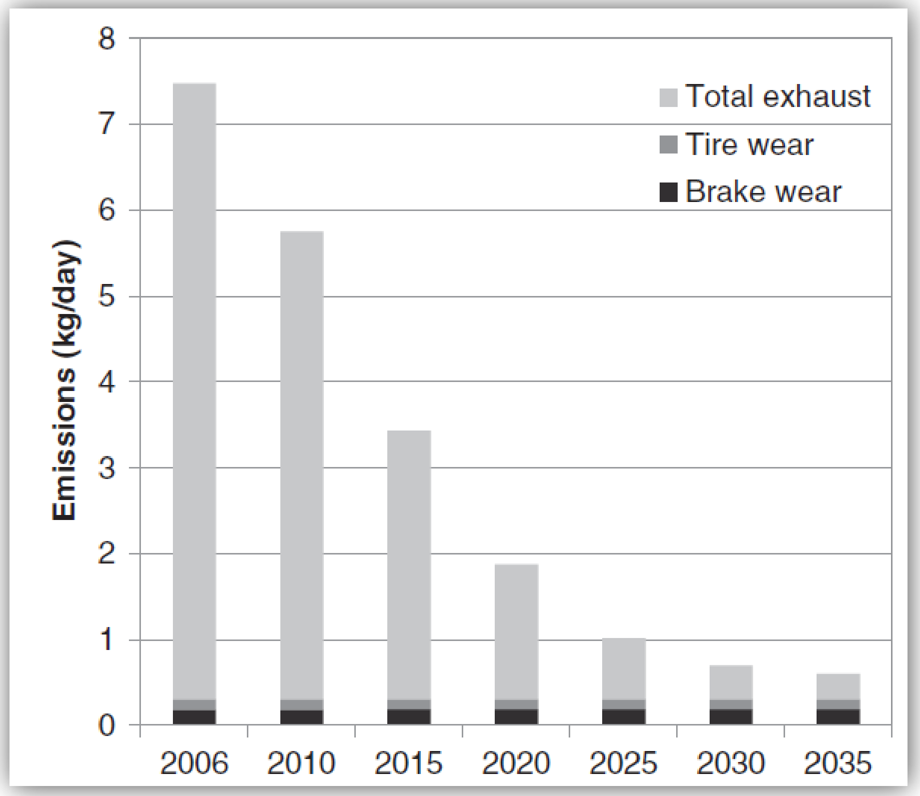
For scale of depressed roadway, note height of jogger

2017 $PM_{2.5}$ Increment Data:

Results After Removing Sites With Confounding Factors



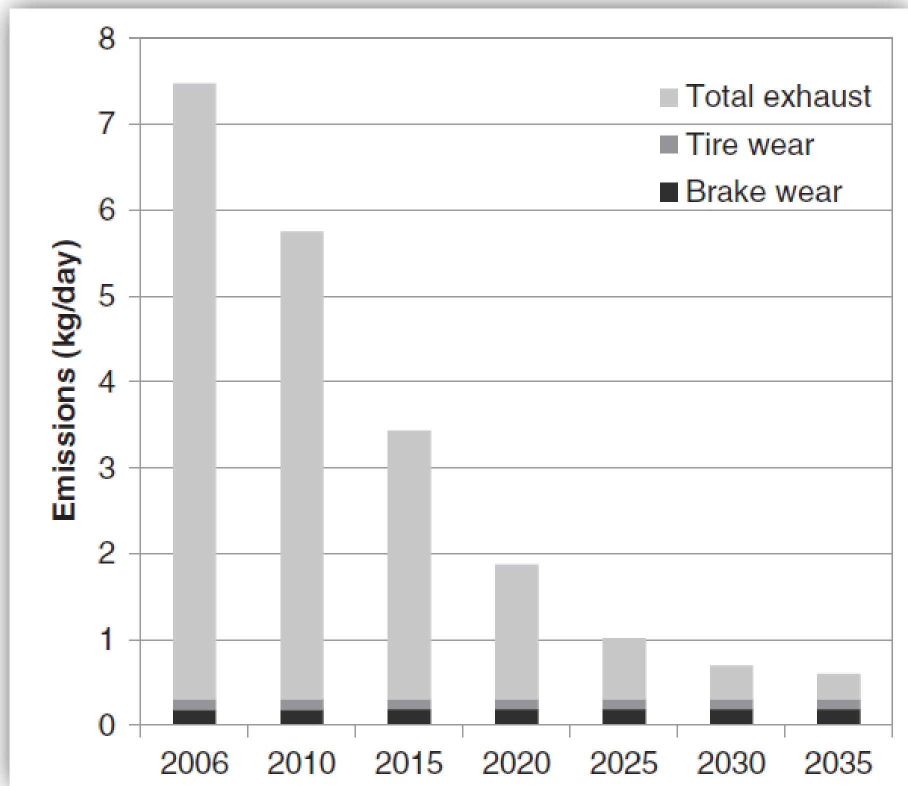
On-Road Emissions and NR $PM_{2.5}$ Generally Trending Down



$PM_{2.5}$ emissions, hypothetical freeway, 125,000 AADT, 8% of which are HDDVs (Reid et al., 2016, Fig. 3, MOVES data).

These findings are for research purposes and should not be used for determining attainment status.

On-Road Emissions and NR $PM_{2.5}$ Generally Trending Down



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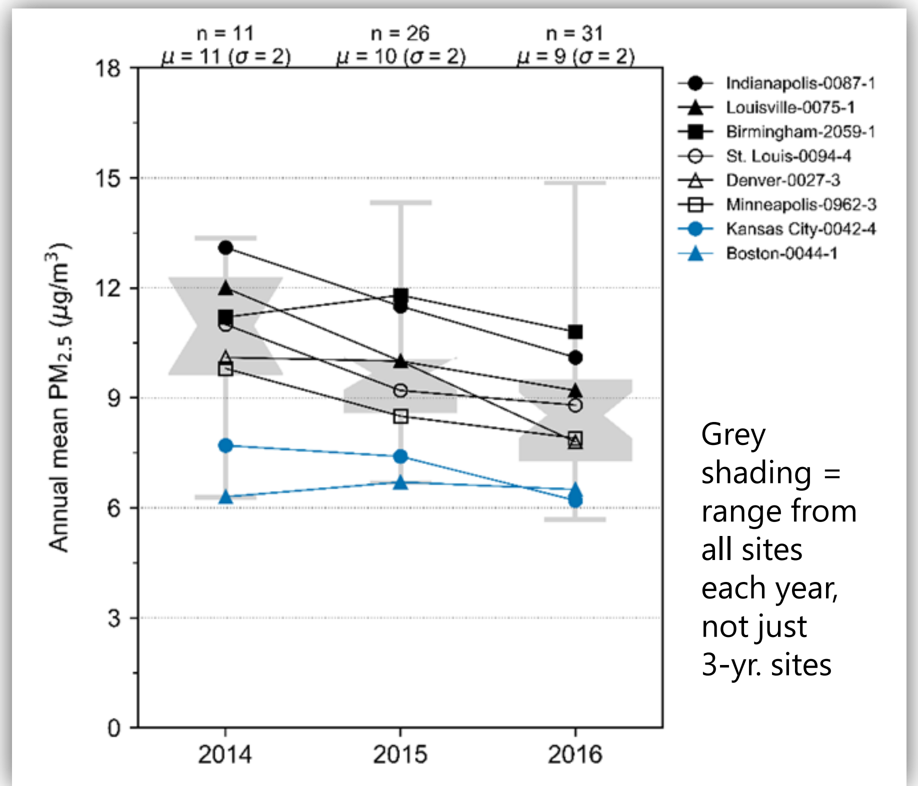


Grey shading = range from all sites each year, not just 3-yr. sites

Data for 8 areas; may not represent all sites.

$PM_{2.5}$ annual mean 24-hr concentrations, NR sites, areas with three years of data (Seagram et al., 2019, Fig. 5).

These findings are for research purposes and should not be used for determining attainment status.

Comparing Monitored and Modeled $PM_{2.5}$ Concentrations

Indianapolis (looking south)

Providence (looking north)

Monitored Compared to Modeled (Preliminary Findings)

Early Site Selection Work

Site	AQS ID	Site Name	Road Type	Hourly Traffic Volume	Hourly Traffic Speed	Hourly Vehicle Characterization	$PM_{2.5}$ Data	CO Data	Collocated Meteorological Data	Other Major Issues Identified[1]	Interest Site for 2015 Modeling?	Original 7 Sites from Table 1 of STI Site Selection Report
1	44-007-0030	Providence, RI (I-95) [0030]	I	x	x	x	H	x		x	yes	x
2	18-097-0087	Indianapolis, IN (I-70) [0087]	S	Dec	Dec	Dec	D3	x	x	x	?	
3	41-067-0005	Portland, OR (I-5) [0005]	S	x	x	x	D3	x	x	x	?	x
4	06-037-4008	Long Beach, CA (I-710) [4008]	S	Sep-Dec	Sep-Dec	Sep-Dec	D1			x	?	
3	06-071-0027	Ontario, CA (SR-60) [0027]	S	x	x	x	D1			x	?	x
5	29-510-0094	St. Louis, MO (I-64) [0094]	S	x	x	x	H	x	x	x	?	x
7	08-031-0027	Denver, CO (I-25) [0027]	S	x	x		H	x	x		no	x
8	25-025-0044	Boston, MA (I-93) [0044]	S	x	x	x	H	x		x	no	x
9	51-760-0025	Richmond, VA (I-95) [0025]	I	x	x		H	x		x	no	x
10	06-085-0006	San Jose, CA (US 101) [0006]	I	x	x	x	H	x		x	no	
11	06-001-0012	Oakland, CA (I-880) [0012]	S	Sep			H	x		x	no	
12	04-013-4019	Tempe, AZ (I-10) [4019]	I	x			H	x	x		no	
13	04-013-4020	Phoenix, AZ (I-10) [4020]	S	x			Q4	x	x		no	
14	39-061-0048	Cincinnati, OH (I-75) [0048]	S	Oct-Dec	Oct-Dec	Oct-Dec		x			no	
15	39-035-0073	Cleveland, OH (I-271) [0073]	S	x	x	x		x	x		no	
16	48-453-1068	Austin, TX (I-35) [1068]	S	x					x		no	
17	48-439-1053	Fort Worth, TX (I-20) [1053]	S	Jan-Mar	Jan-Mar		D3	x	x	x	no	
18	48-201-1052	Houston, TX (I-610) [1052]	S	Nov-Dec			D3	x	x		no	

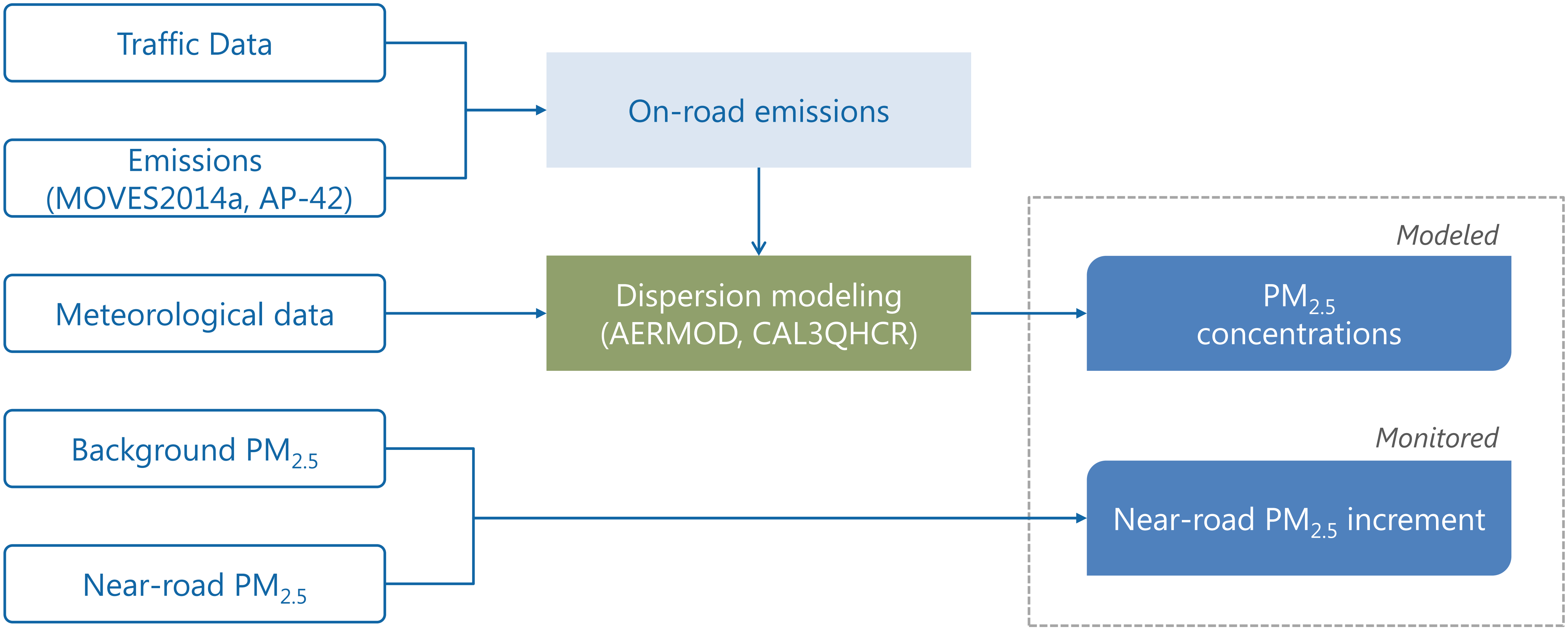
green cells designate potential issues for a site

orange cells designate critical issues for a site

red cells designate fatal flaws for a site

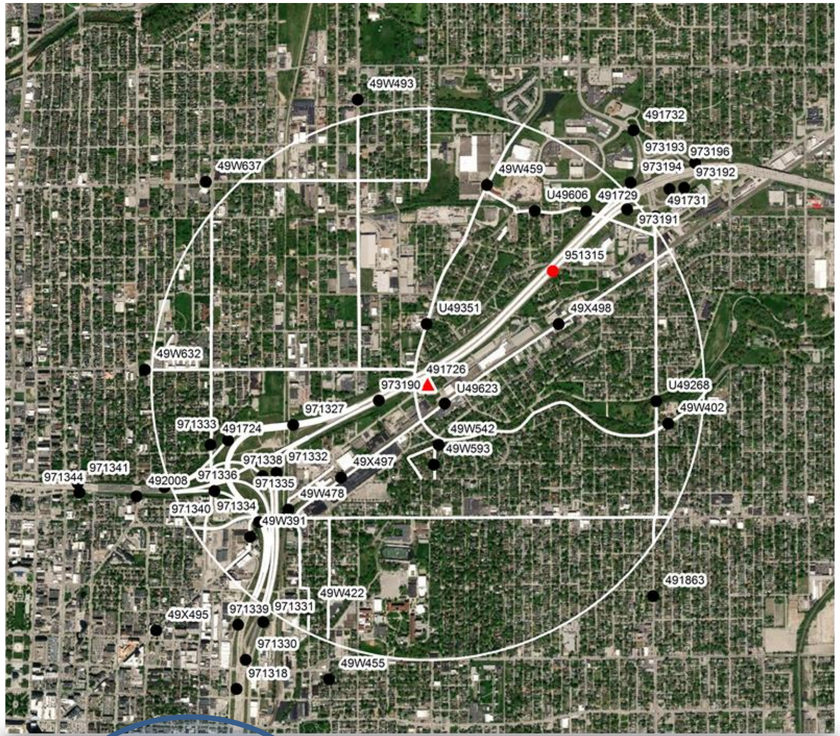
For Road Type, "S" indicates freeway segment, and "I" indicates proximity to freeway interchange

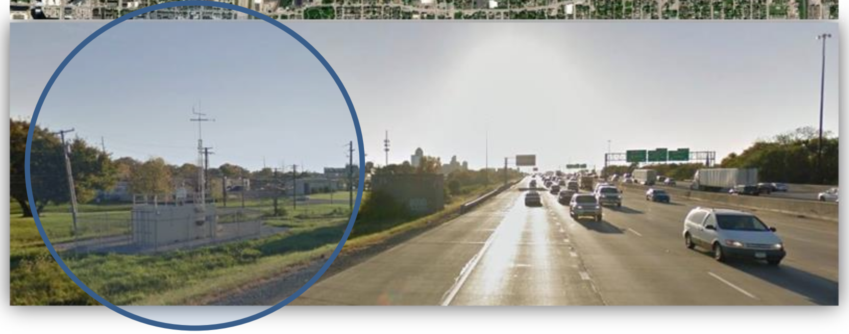
Technical Approach (The Modeling Chain)



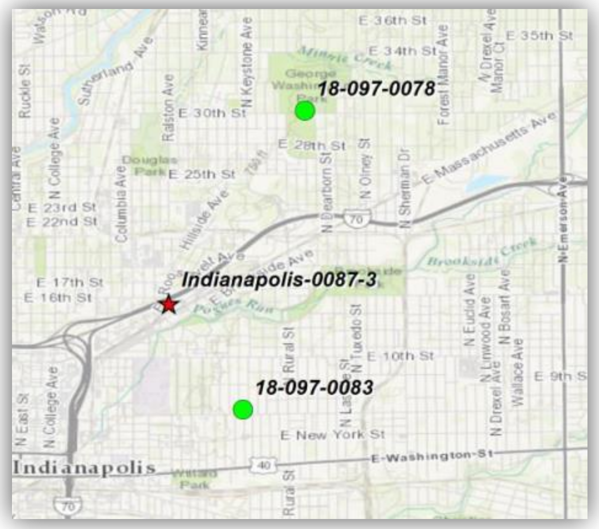
Model-to-Monitor Comparison

Indianapolis (2016)





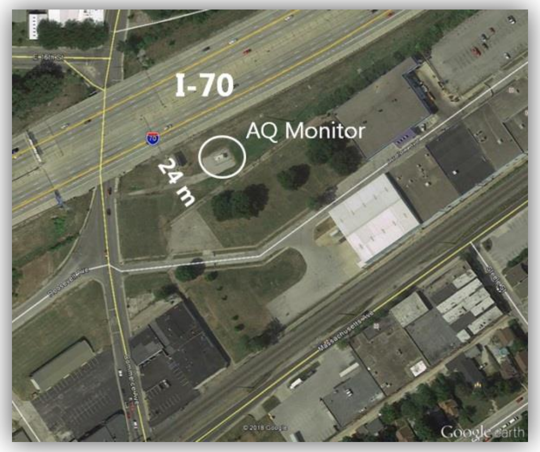
- NR site
- Links
- Permanent I-70 traffic monitor (951315)
- Temporary traffic monitor

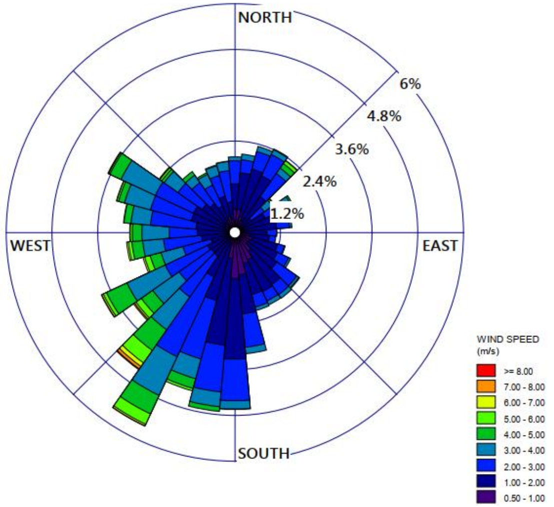


PM$_{2.5}$ Monitors

Near-road site (red star)

Background sites (green dots)





Indianapolis Traffic Data Summary

http://indot.ms2soft.com

Parameter	Description
Year of monitor data used	2016 for freeway links 2014-2016 for certain local roads (scaled to 2016)
Interstate monitors	1 permanent monitor (I-70, 0.9 from AQ monitor) 12 temporary monitors for I-70, I-65 (including ramps)
Arterial and local road monitors	36 temporary monitors for developing local roadway data
Speed data	Vehicle counts by speed bin (varying bins by monitor)
Class data	Vehicle counts by FHWA vehicle class

- Roadway links are mapped to monitors.
- Some links use data synthesized from multiple monitors.
- If speed or class information is missing, distributions are generated from local MOVES inputs and/or defaults.

Indianapolis Emissions Summary

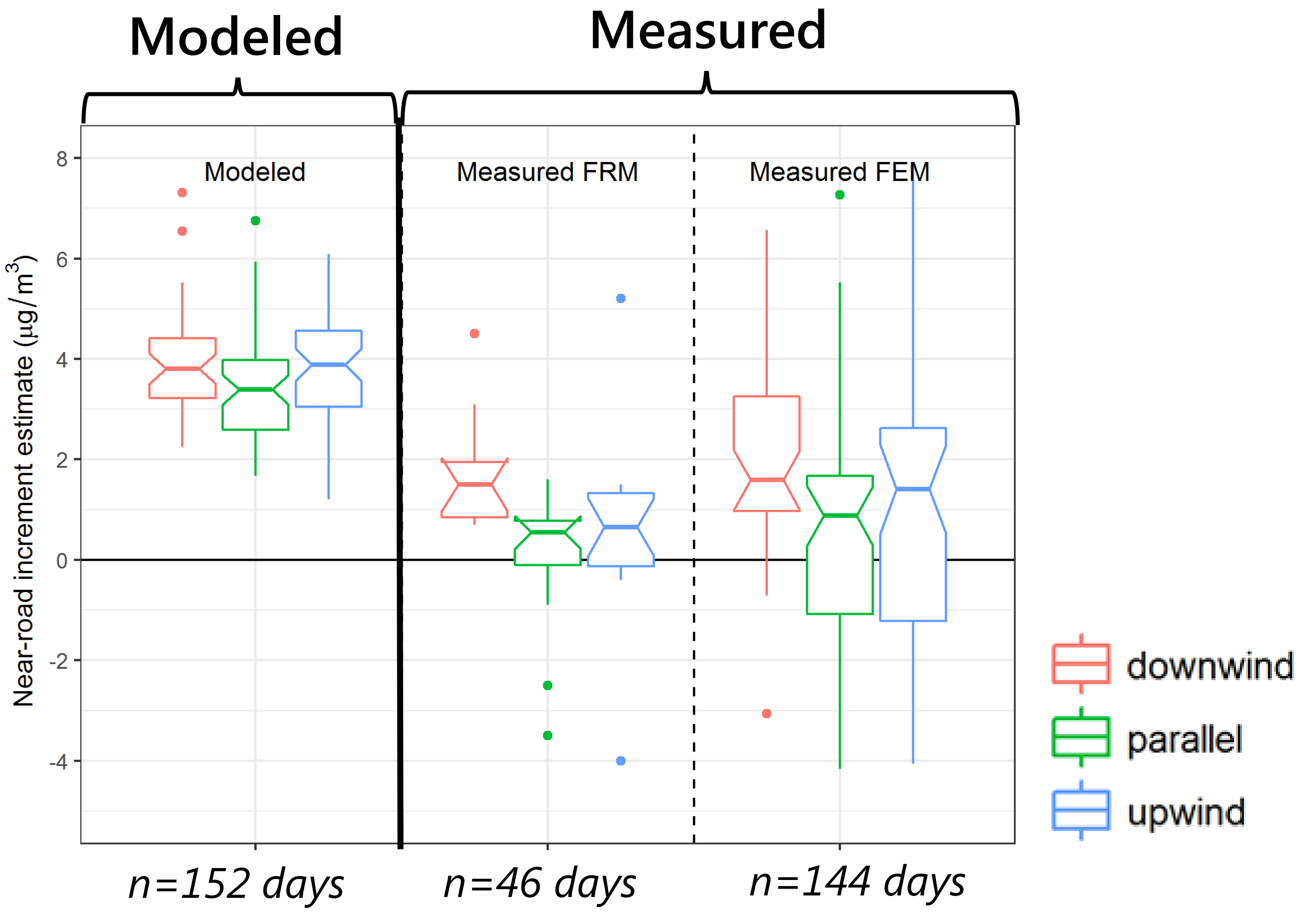
Includes entire modeling domain (20 miles of roads).

Process	Average Daily $PM_{2.5}$ Emissions (pounds/day)	% of Total
Road dust (AP-42)	37	53
Running exhaust	28	40
Brake wear	2	5
Tire wear	1	2
Total	**70**	**100**

Modeled fraction of non-exhaust $PM_{2.5}$ (60%) is high compared to recent near-road measurements in Toronto (Hwy. 401, ~400,000 AADT), where ~35% of traffic-related $PM_{2.5}$ was from non-exhaust components.

Source: Jeong et al., "Temporal and spatial variability of traffic-related PM2.5 sources: Comparison of exhaust and non-exhaust emissions." *Atmospheric Environment* 198 (2019) 55–69.

Modeled (AERMOD) 24-hr $PM_{2.5}$ Results Compared to Monitored Values (Indianapolis)

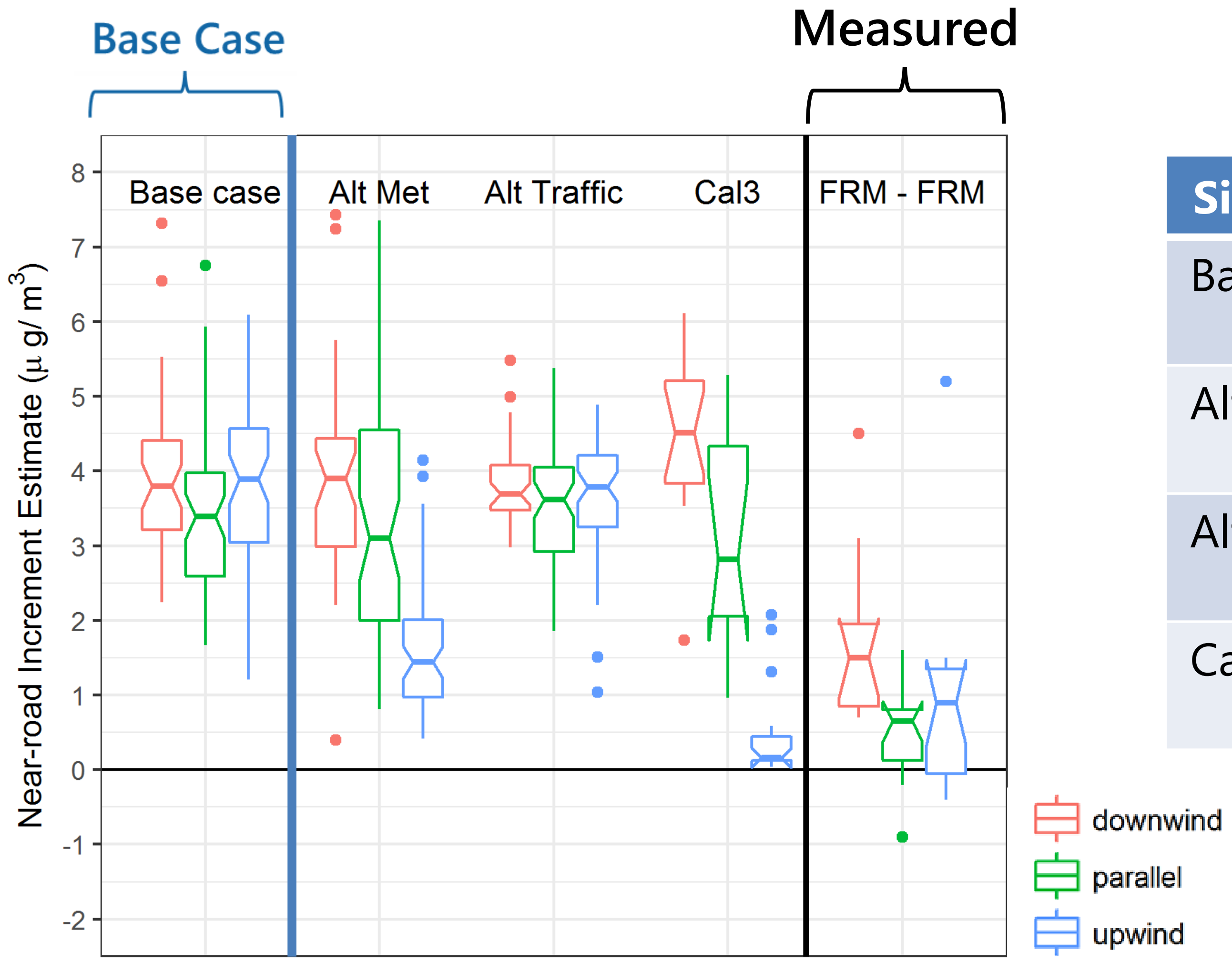


Modeled results are:

- Much higher (by factor of 3-4) than the monitored near-road increment
- Not as sensitive to wind direction compared to the measured increments

More details available from TRB talk: Craig et al., 2019

Indianapolis Model Sensitivity Comparisons

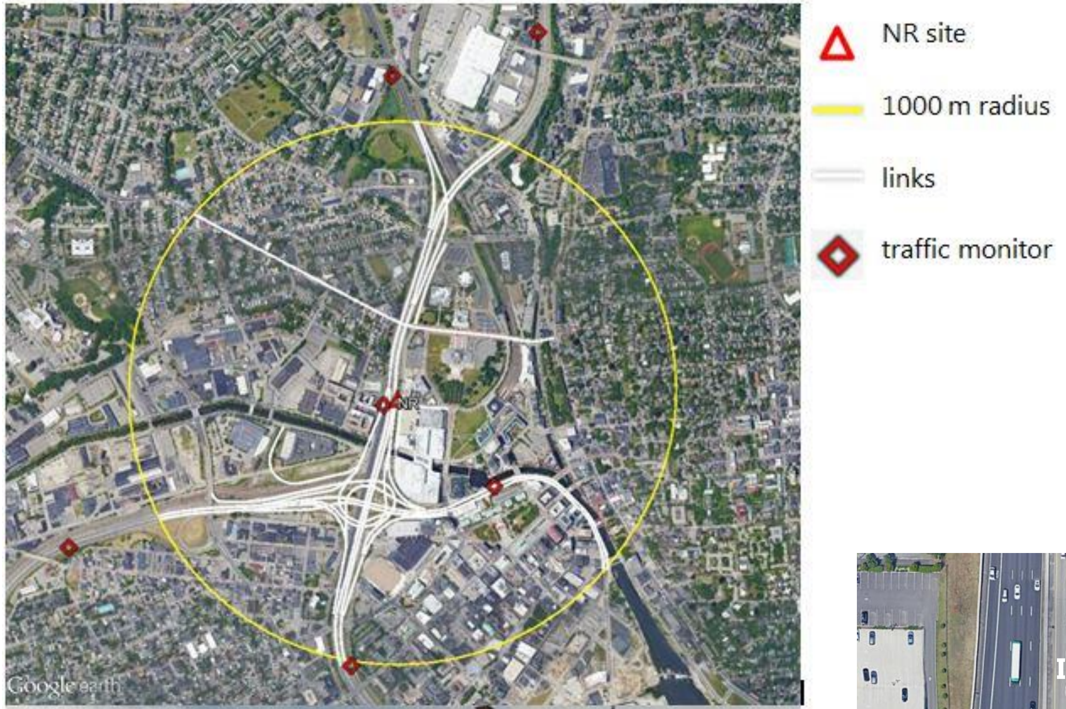


n=152 days for AERMOD cases; n=40 days for CAL3QHCR case

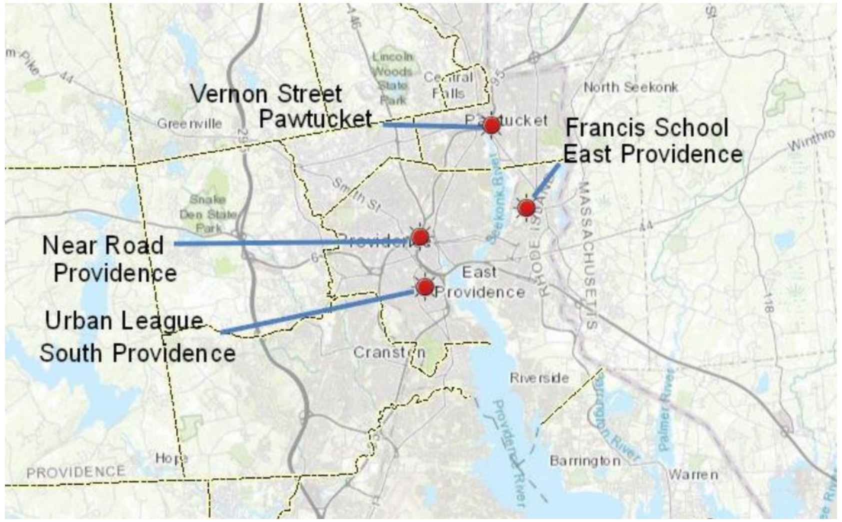
Simulation	Description
Base Case	AERMOD with hourly traffic and near-road meteorology
Alt Met	AERMOD with airport meteorology
Alt Traffic	AERMOD with time-aggregated traffic data
Cal3	CAL3QHCR with hourly traffic and near-road meteorology

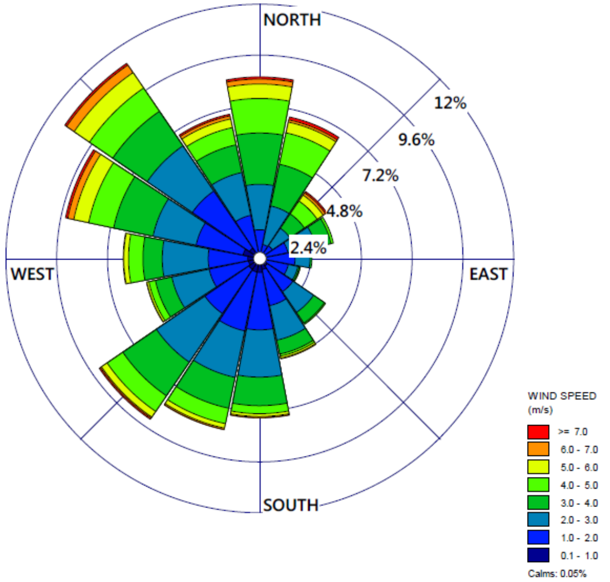
More details available from TRB talk: Craig et al., 2019

Providence (2015-2016)

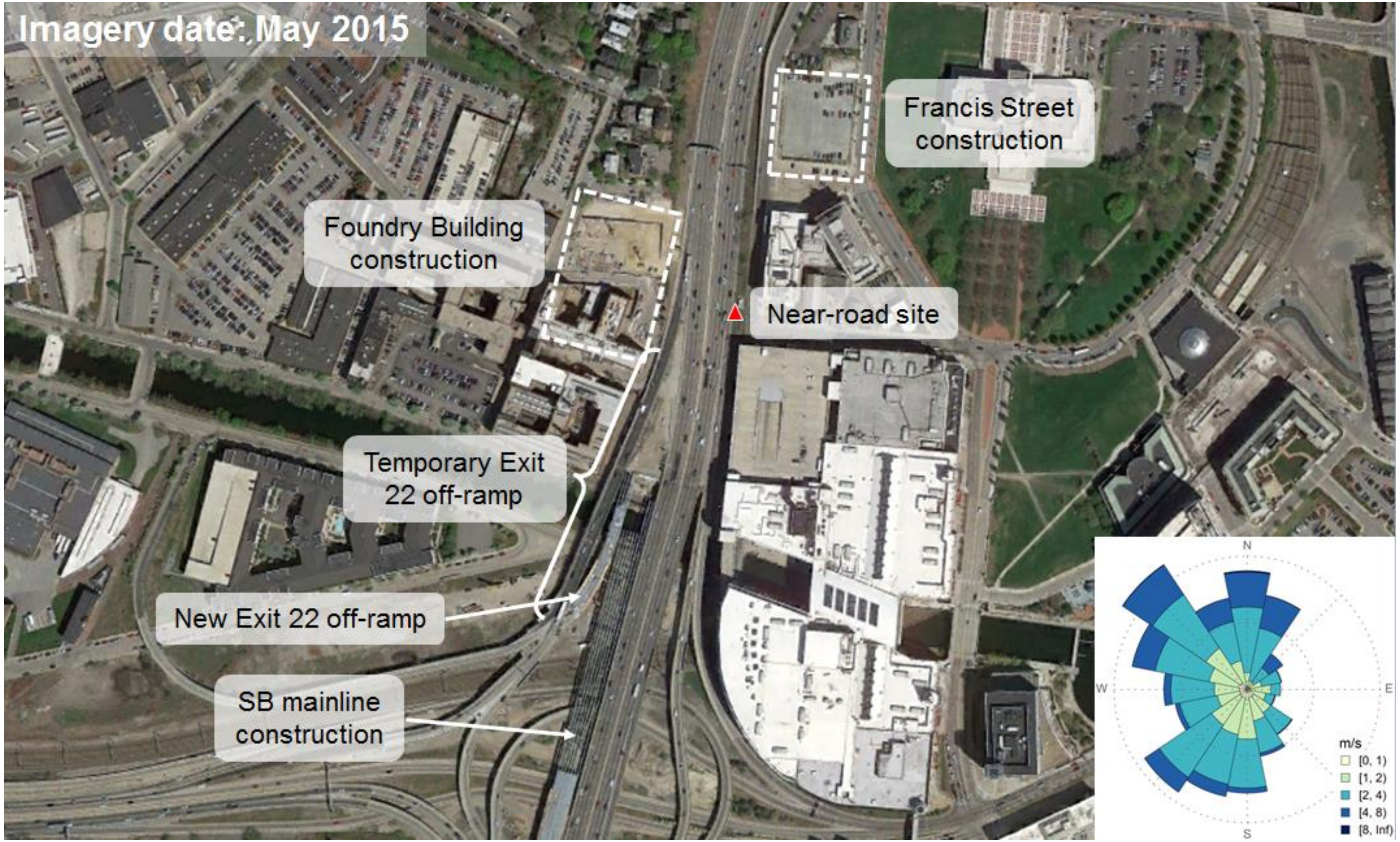


PM$_{2.5}$ Monitors





Providence 2015 Activities, Events (a Complicated Story)



Providence $PM_{2.5}$ Emissions Summary

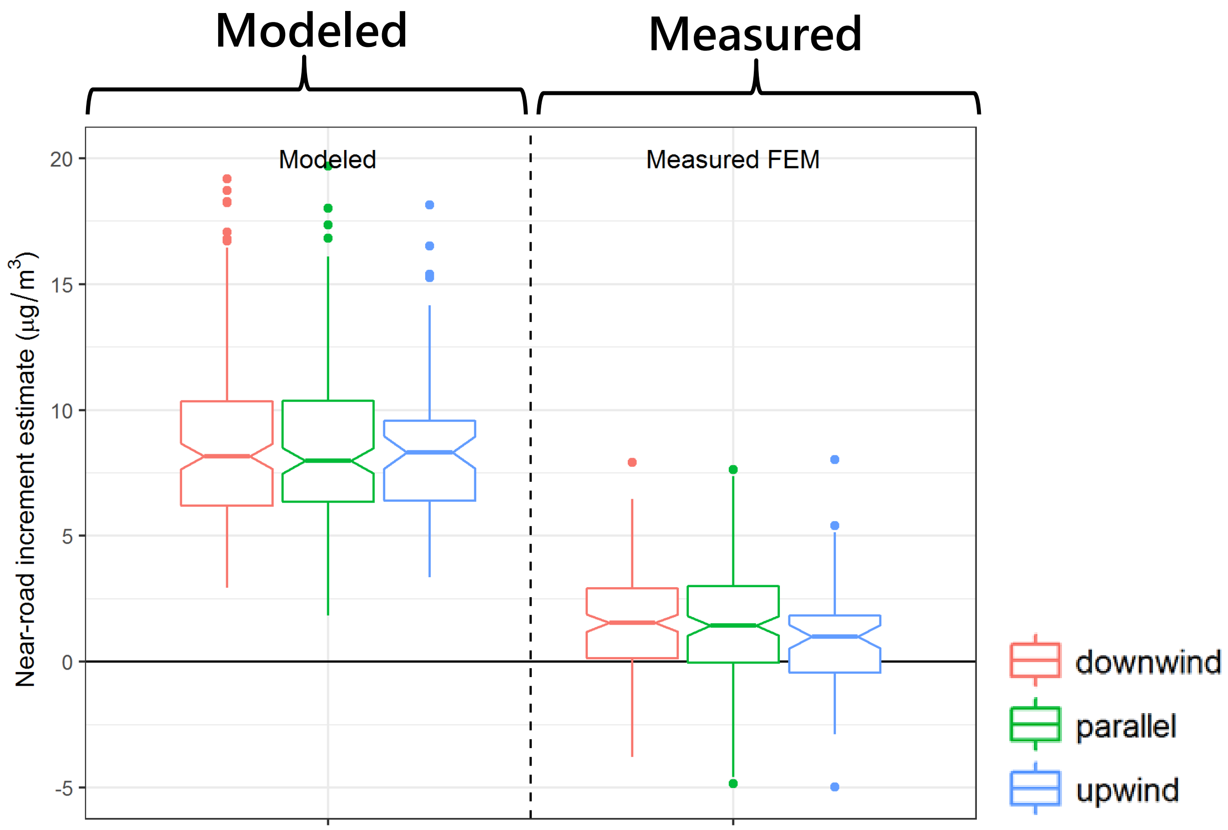
Includes entire modeling domain (9 miles of roads).

Process	Average Daily $PM_{2.5}$ Emissions (pounds/day)	% of Total
Road dust (AP-42)	24	44
Running exhaust	26	49
Brake wear	3	5
Tire wear	1	2
Total	**54**	**100**

Modeled fraction of non-exhaust $PM_{2.5}$ (51%) is high compared to recent near-road measurements in Toronto (Hwy. 401, ~400,000 AADT), where ~35% of traffic-related $PM_{2.5}$ was from non-exhaust components.

Source: Jeong et al., "Temporal and spatial variability of traffic-related PM2.5 sources: Comparison of exhaust and non-exhaust emissions." *Atmospheric Environment* 198 (2019) 55–69.

Modeled (AERMOD) 24-hr $PM_{2.5}$ Results Compared to Monitored Values (Providence)

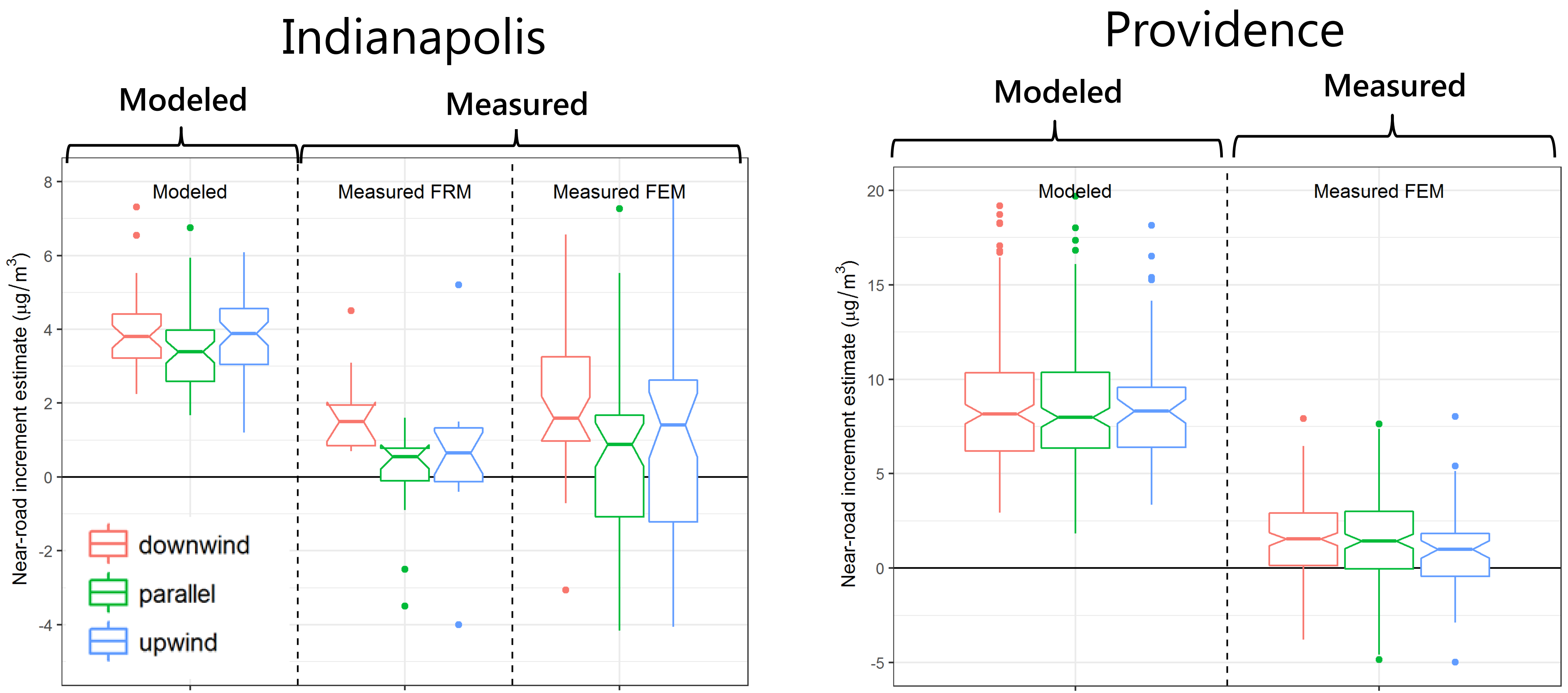


(n=382 days)

Modeled results are:

- Much higher (by factor of six) than the monitored near-road increment
- Not as sensitive to wind direction compared to the measured increments

Indianapolis vs. Providence Model Results



Near-Road $PM_{2.5}$ Modeling Synthesis

Parameter	Indianapolis (2016)	Providence[a] (2015/2016)	Riverside I-15 Conformity[b] (2035)
Measured Increment (µg/m^3)	0.9 ± 0.6	1.4 ± 0.2	--
AERMOD Average Increment (µg/m^3)	3.7	8.8	6.3
AERMOD Peak 24-hr Increment (µg/m^3)	7.3	22.0	16.3
AADT (% Heavy Duty Truck)	165,672 (14%)	223,036 (7%)	239,110 (17%)
FE-AADT	374,419	363,549	604,948
$PM_{2.5}$ emissions [lb/day/mile] (% road dust)	25.6 (51%)	30.3 (41%)	30.2 (44%)
Receptor distance to road	24.5 m	5.0 m	5.0 m

[a]Based on modeling for all 382 days
[b]http://www.scag.ca.gov/programs/TCWG%20Document%20Library/RIV071267/RIV071267QuanAnalysis.pdf

Uncertainty Context

- Modeling "chain" includes
  - Travel activity data
  - Emissions model (MOVES, AP-42)
  - Dispersion model (AERMOD, CAL3QHCR)
- Overall uncertainty (+200-500%) in the modeling chain in the Indianapolis and Providence analyses is large compared to approximate uncertainty associated with factors such as
  - Also (outside modeling chain) uncertainty in measured near-road increment (±20-70%)
  - "Intrinsic" dispersion model uncertainty (±50%)
- Next slide explores these issues further

Uncertainty Context

Component	Discussion
Travel Data	1. Volume, speed, and fleet mix are well characterized in this study
Emissions Modeling	2. *Modeled fraction of non-exhaust $PM_{2.5}$ emissions (51-60%) is high compared to recent near-road measurement studies* 3. Road dust (AP-42): Highly uncertain, ~50% of modeled emissions 4. Tire/brake wear (MOVES): Uncertain, but 7% of modeled emissions 5. Exhaust (MOVES): Uncertain; EPA has identified over-prediction of PM exhaust for light and heavy-duty vehicles*
Dispersion Modeling	6. Largest AERMOD biases associated with upwind conditions 7. Overall bias at Indianapolis was reduced when using CAL3QHCR or when using airport meteorology (however, airport data was not as representative as the local meteorological data used in the base case)
Overall Uncertainty	**Likely dominated by emissions and dispersion modeling components**

*Based on EPA MOVES Model Review Work Group documents; e.g., "Updates to MOVES Heavy Duty Running Exhaust Rates: Diesel, Gasoline, and Natural Gas," G.S. Sandhu, D. Sonntag, April 10, 2019; "Light Duty PM Emission Rates Update," M. Aldridge, March 1, 2017. See: https://www.epa.gov/moves/moves-model-review-work-group.

Insights from Model-Monitor Comparisons

1. Near-road modeling chain shows a high bias in $PM_{2.5}$ predictions compared to measured near-road increments. This finding was consistent in both the Indianapolis and Providence analyses.
2. Overall uncertainty in the modeling chain is likely dominated by uncertainties in the emissions and dispersion modeling components.
3. Modeled fraction of non-exhaust $PM_{2.5}$ emissions (51-60%) is high compared to recent near-road measurement studies.
4. AERMOD results with local meteorology are less sensitive to wind direction compared to measured near-road increments, or compared to CAL3QHCR results.
5. Time-aggregating travel activity data does not significantly impact model results.
6. Uncertainty in measured increments is small enough to support model-to-monitor comparison if enough days of data are considered.

Conclusions

1. CO and NO_2 both well below NAAQS thresholds; $PM_{2.5}$ is below NAAQS at most sites.
2. $PM_{2.5}$ increments vary widely, due to factors such as meteorology, traffic
   - Maximum <10 m from road is ~2.0 μg/m^3
   - Maximum >10 m from road is ~1.4 μg/m^3
3. The "modeling chain" over-predicted monitored concentrations
   - Modeled fraction of non-exhaust $PM_{2.5}$ emissions is high compared to recent near-road measurement studies.
   - Largest AERMOD biases associated with upwind conditions.

Research Needs

1. Further investigate near-road increments by refining understanding of what factors most influence NR $PM_{2.5}$ increments, especially given the weak statistical relationship between traffic conditions and measured increments.

2. Collect speciated $PM_{2.5}$ measurements to better characterize exhaust vs. non-exhaust contributions to near-road concentrations.

3. Complete additional analyses across different geographic settings, roadway types and configurations, and methodologies (e.g., tracer evaluations) to build a more complete picture of model vs. monitor comparisons.

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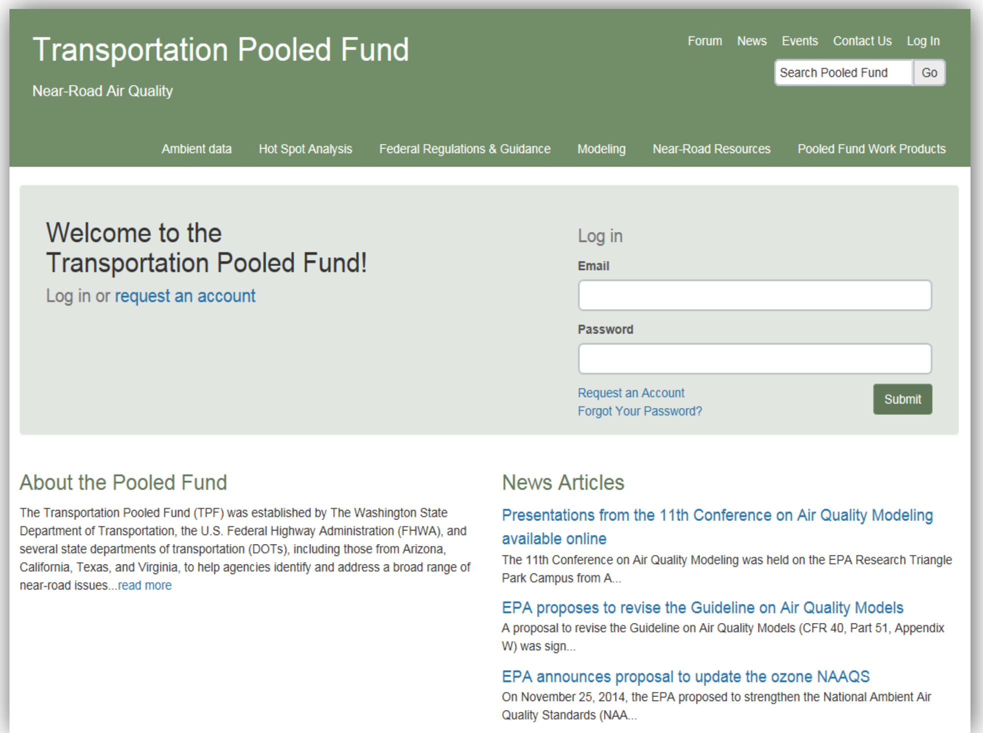

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