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Identficaton and Characterization of Pollutant Hot Spots Integratng Probe Vehicle, Traffic and Land Use Data

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Identification and Characterization of Pollutant Hot Spots Integrating Probe Vehicle, Traffic and Land Use Data

By
Katherine E. Bell, P.E.
Miguel A Figliozzi, Ph.D.

FRIDAY SEMINAR
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OTREC
OREGON TRANSPORTATION RESEARCH AND EDUCATION CONSORTIUM
U.S. Department of Transportation
Research and Innovative Technology Administration

NITC NATIONAL INSTITUTE for TRANSPORTATION and COMMUNITIES
U.S. Department of Transportation
Research and Innovative Technology Administration

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OUTLINE

I. Introduction & Background

II. Available and Collected Data

III. Statistical Analysis

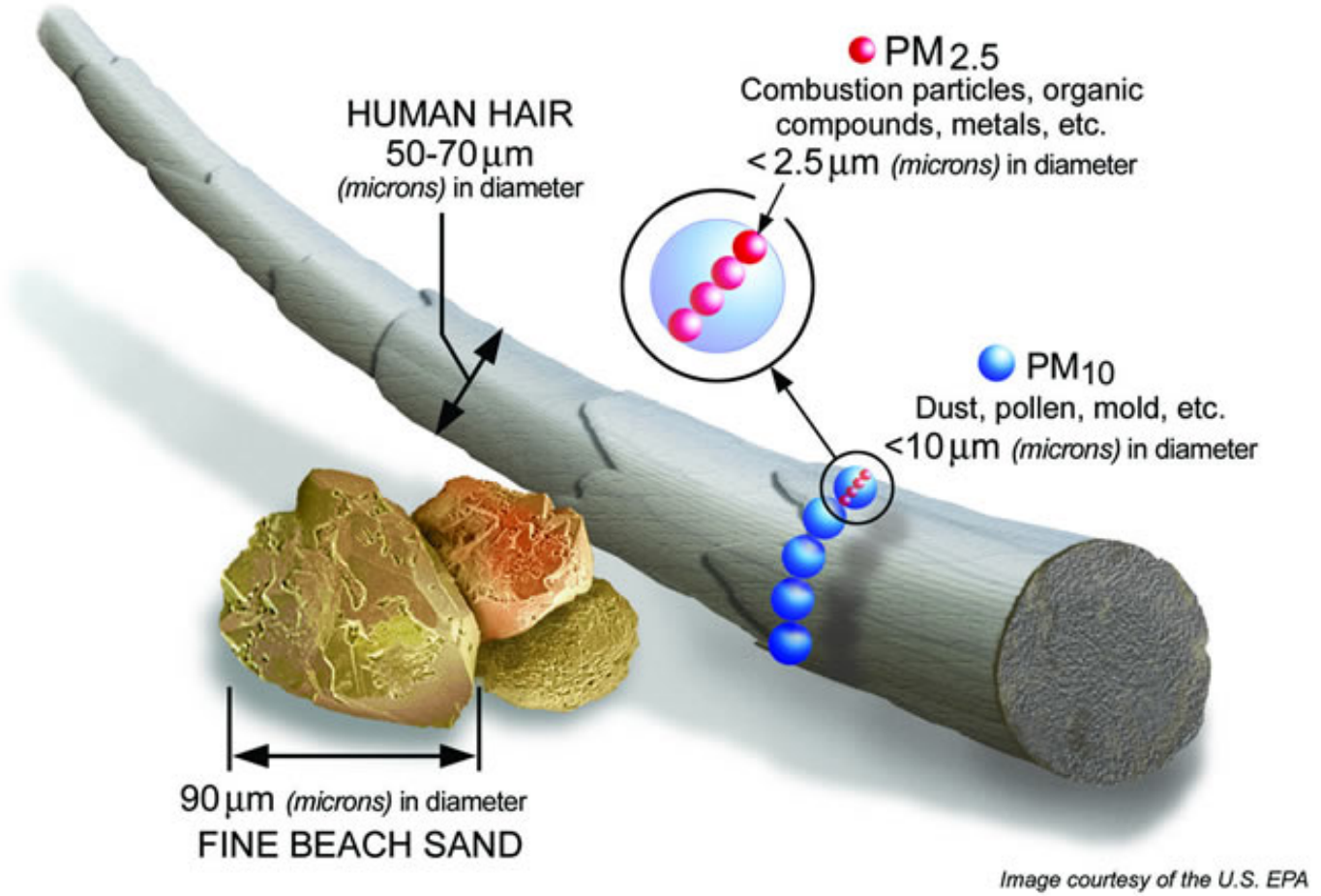
IV. Conclusions & Future Research

BACKGROUND

- Motor Vehicle Emissions – *CO2, CO, HC, NOX, MSATs*
- Fine Particulate Matter ($PM_{2.5}$) – *noncombustion & combustion*
  - *Carcinogenic*
  - *Heart problems*
  - *Respiratory problems*

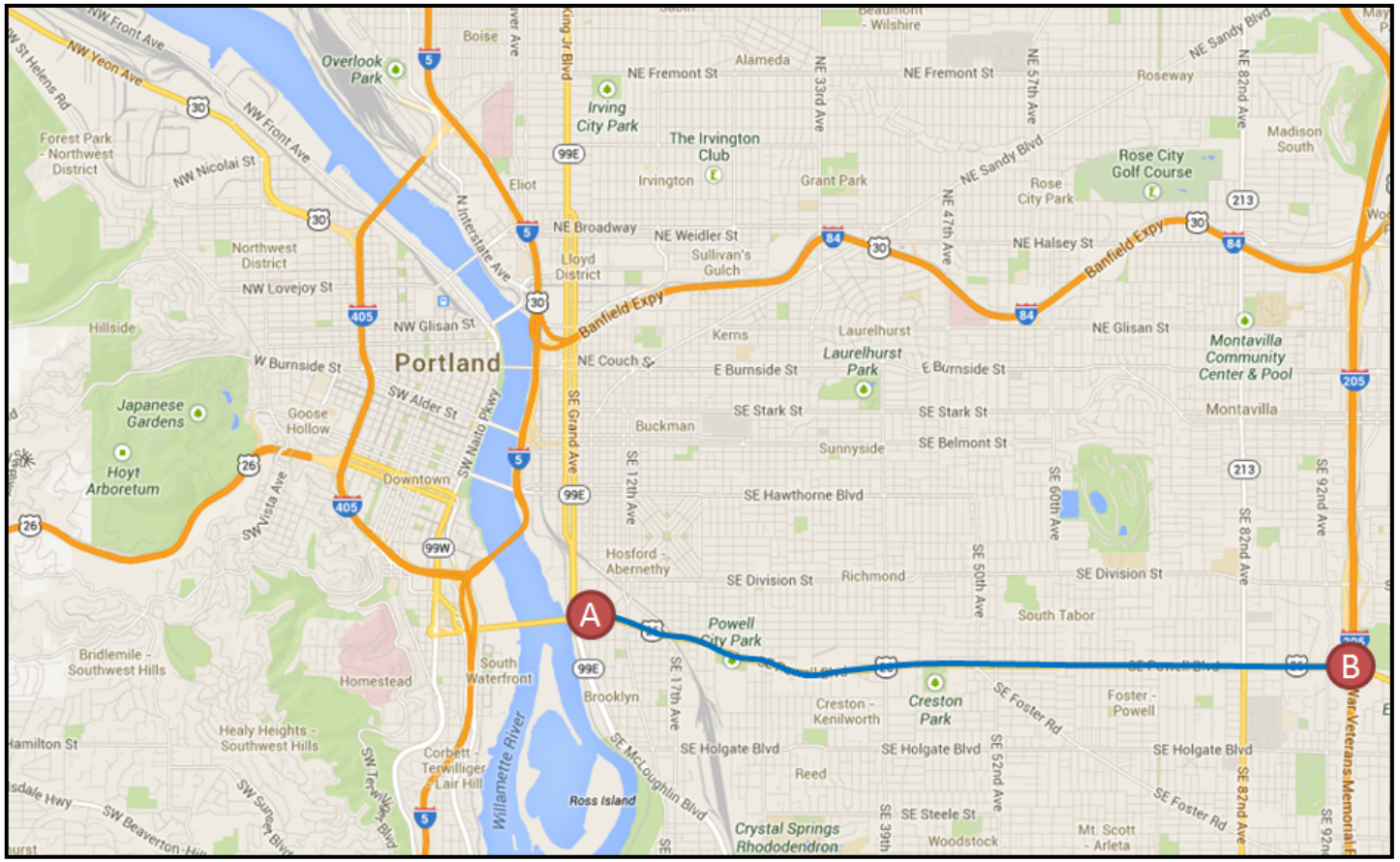
- Volatile Organic Compounds (VOC) – *ozone precursors, carcinogens*

- **HOT SPOT:** Subsection of corridor that consistently has an average pollutant concentration above the 85th percentile when compared to all other subsections on the corridor.


HUMAN HAIR
50-70 µm
(microns) in diameter
PM2.5
Combustion particles, organic compounds, metals, etc.
< 2.5 µm (microns) in diameter
PM10
Dust, pollen, mold, etc.
<10 µm (microns) in diameter
90 µm (microns) in diameter
FINE BEACH SAND
Image courtesy of the U.S. EPA

STUDY AREA – SE Powell Boulevard

- 4.6 miles – *SE 7th Ave to I-205*
- Multi-modal
- 2-lanes each direction
- Variety of land uses



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OBJECTIVES

- Develop an efficient method to identify hot spot locations
    - *Better understand which variables are most related to variability in pollutant levels*
    - *Better understand the variability of exposure levels along a corridor*
- Long-term: Better inform personal exposure models and health analyses

LITERATURE REVIEW

1) Air Quality Health and Environmental Concerns
2) Air Quality Modeling and Measurements
3) Powell Boulevard Research
4) Land Use Regression

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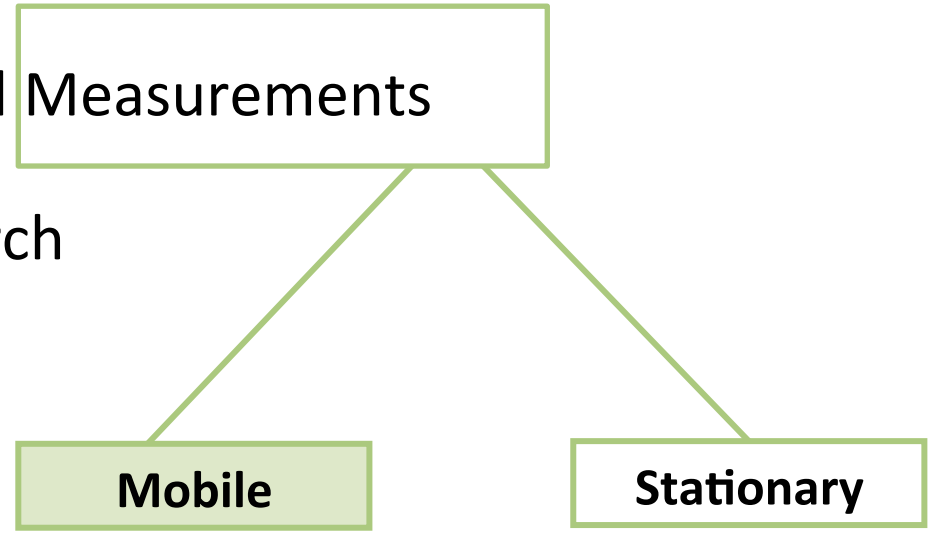

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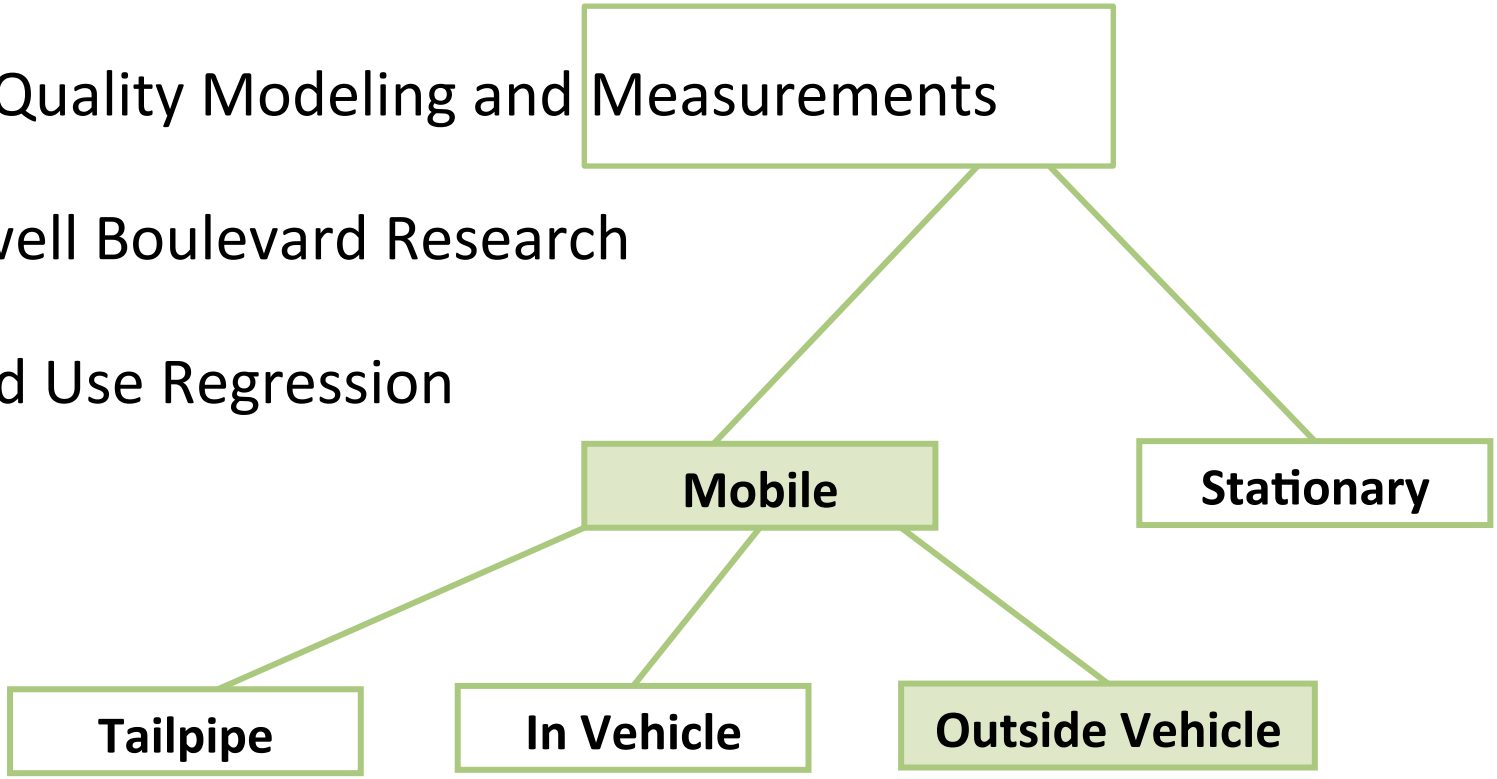
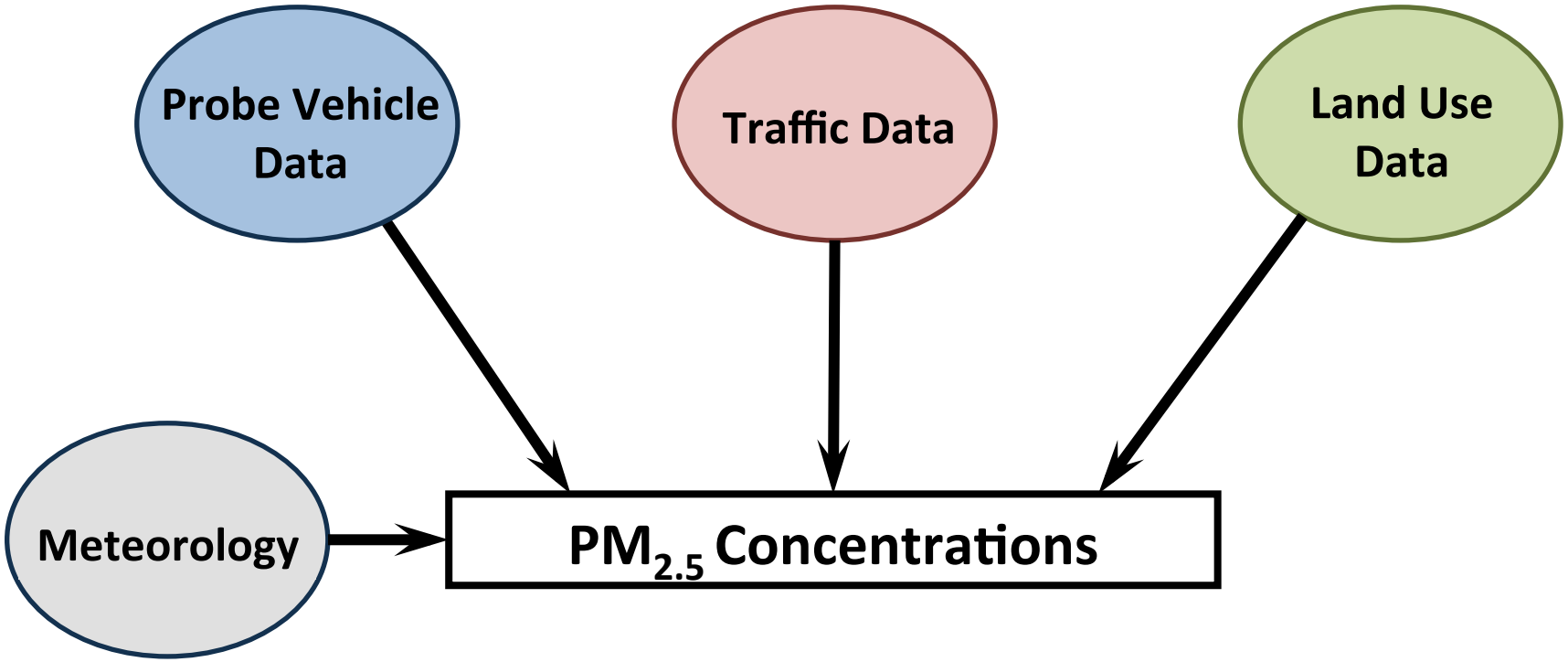


AVAILABLE & COLLECTED DATA



DATA COLLECTION

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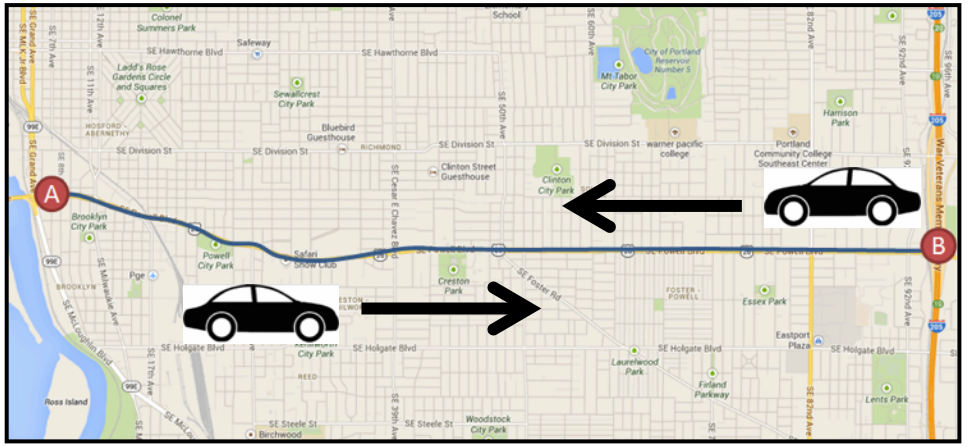
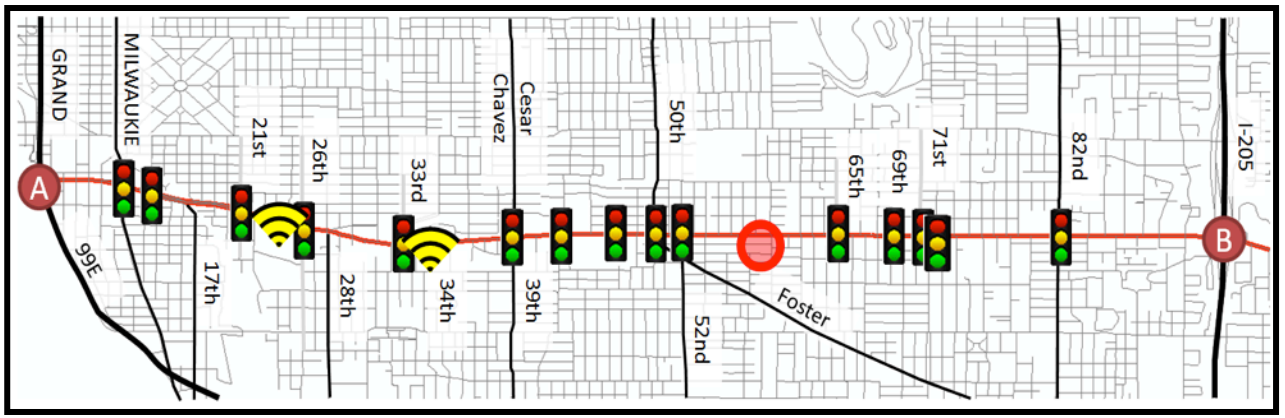
Probe Vehicle



Data Type	Equipment	Description	Measurement Frequency
GPS Data	iPhone 4 - "MyTracks" Application	*Location of probe vehicle*	1 second
Video Footage	4 CountingCars digital video cameras	*Front, Right, Left and Rear of Probe Vehicle*	Continuous
$PM_{2.5}$ ($\mu g/m^3$)	2 DustTrak DRX Aerosol Monitors (TSI Model 8533)	*Outside probe vehicle passenger windows, left and right*	1 second
VOC (ppb)	2 Ion-Science PhoCheck Tiger devices		1 second

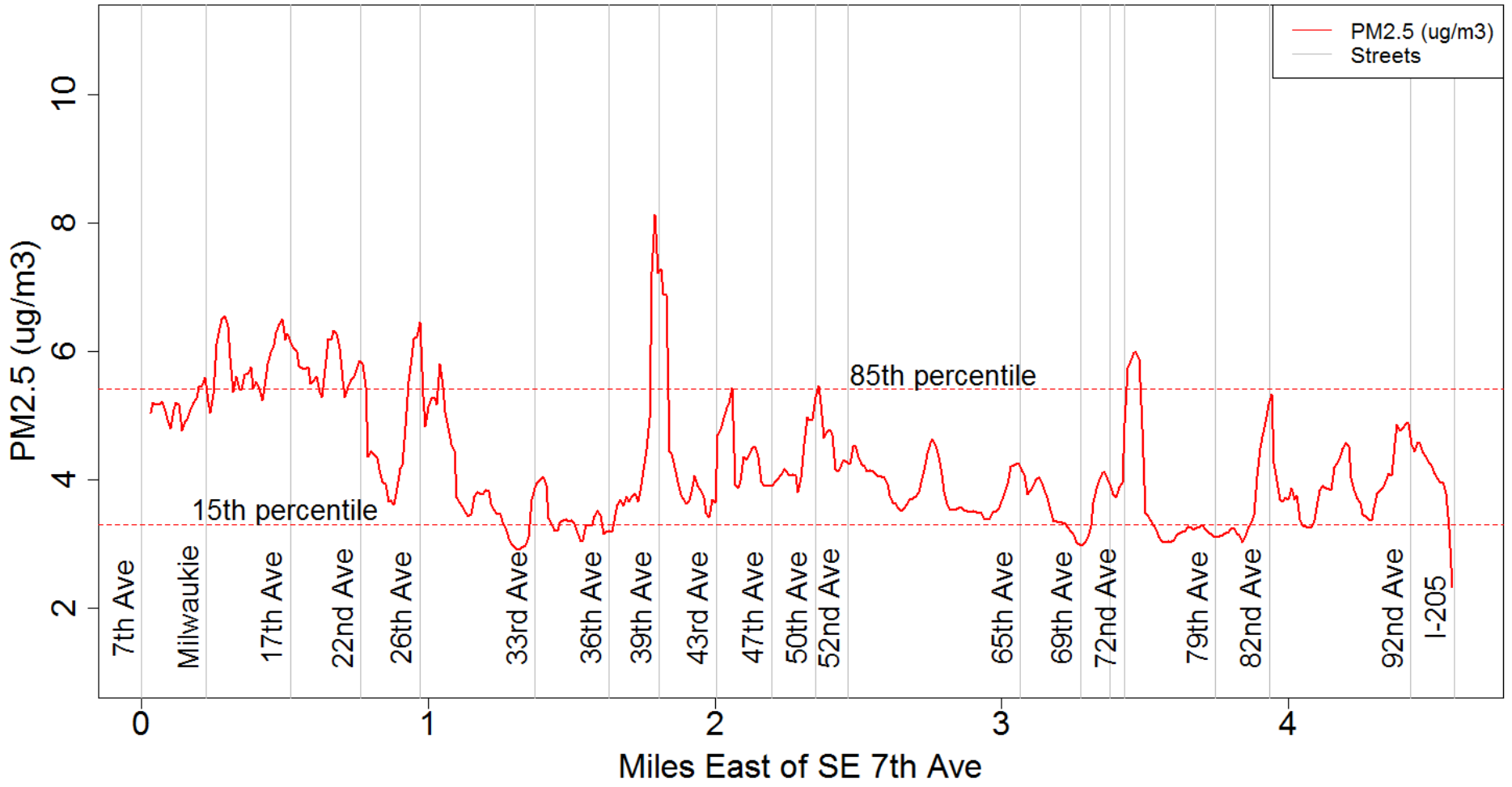
AVAILABLE DATA



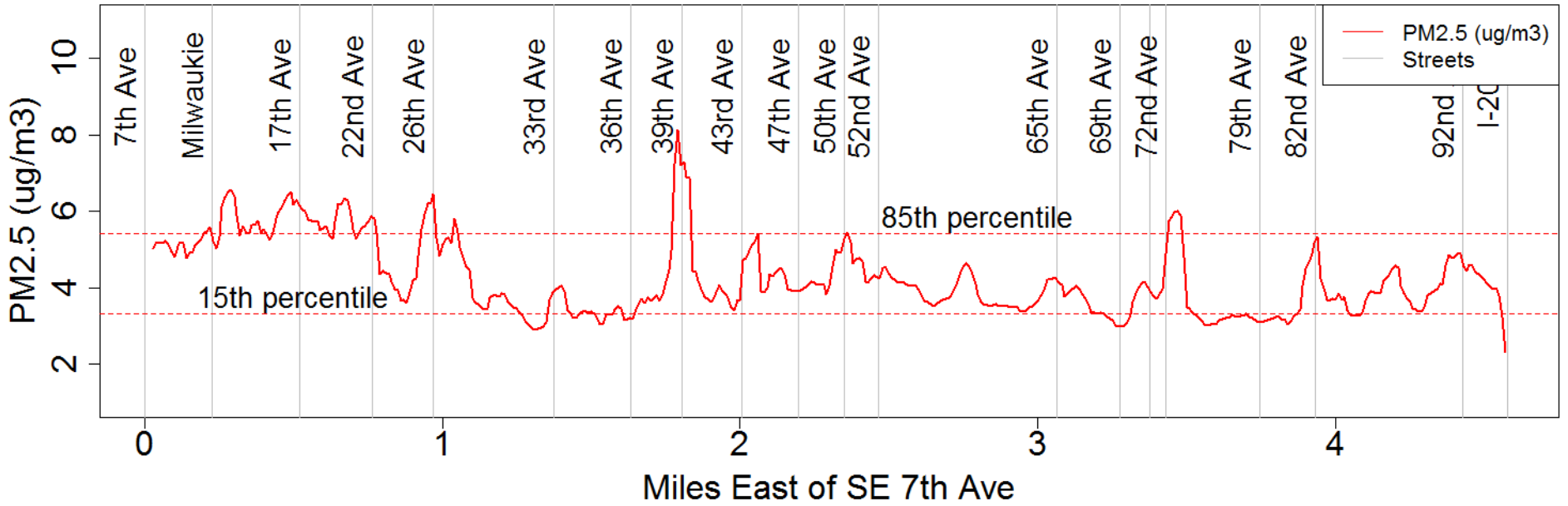
- SCATS (Adaptive Traffic Signal) Data
- Wavetronix SmartSensor HD Systems
- Oregon DEQ Air Quality Monitoring Station
- A: West End of Study Area
- B: East End of Study Area

Data Type	Data Source	Measurement Frequency
Meteorological	DEQ Station	5 minutes
Traffic	Wavetronix	10 seconds
	SCATS	15 minutes
Land Use	PortlandMaps	n/a
	Portland Metro RLIS*	n/a

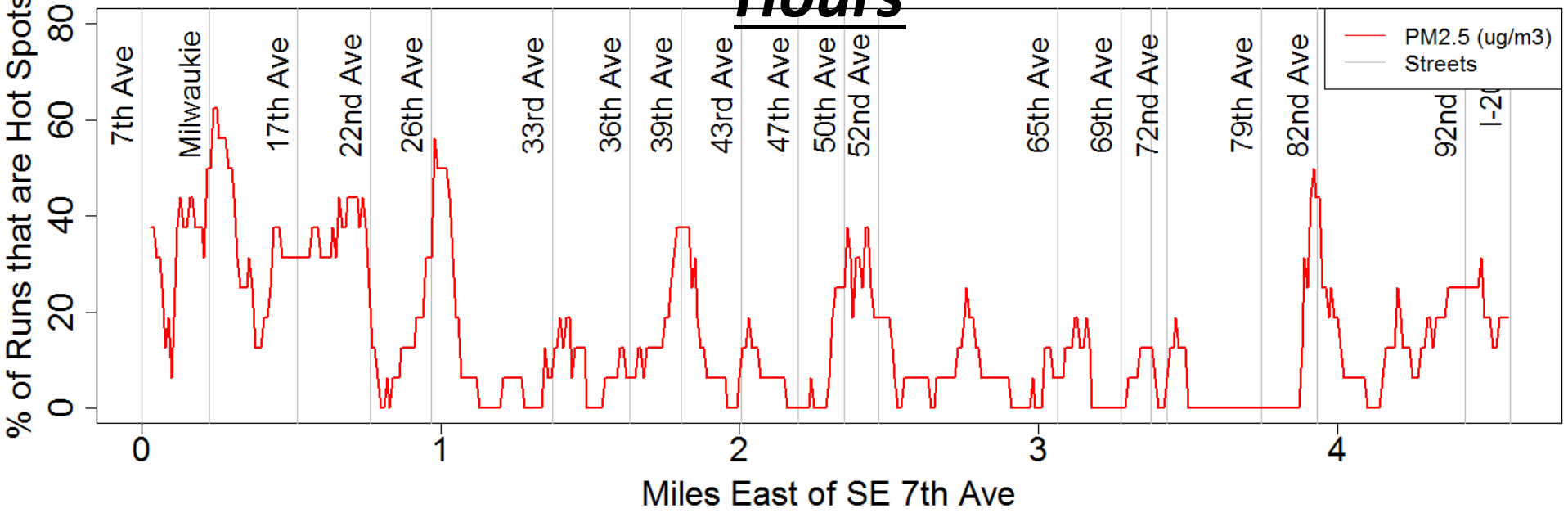
MOVING AVERAGE – *All Study Hours*



MOVING AVERAGE – *All Study Hours*

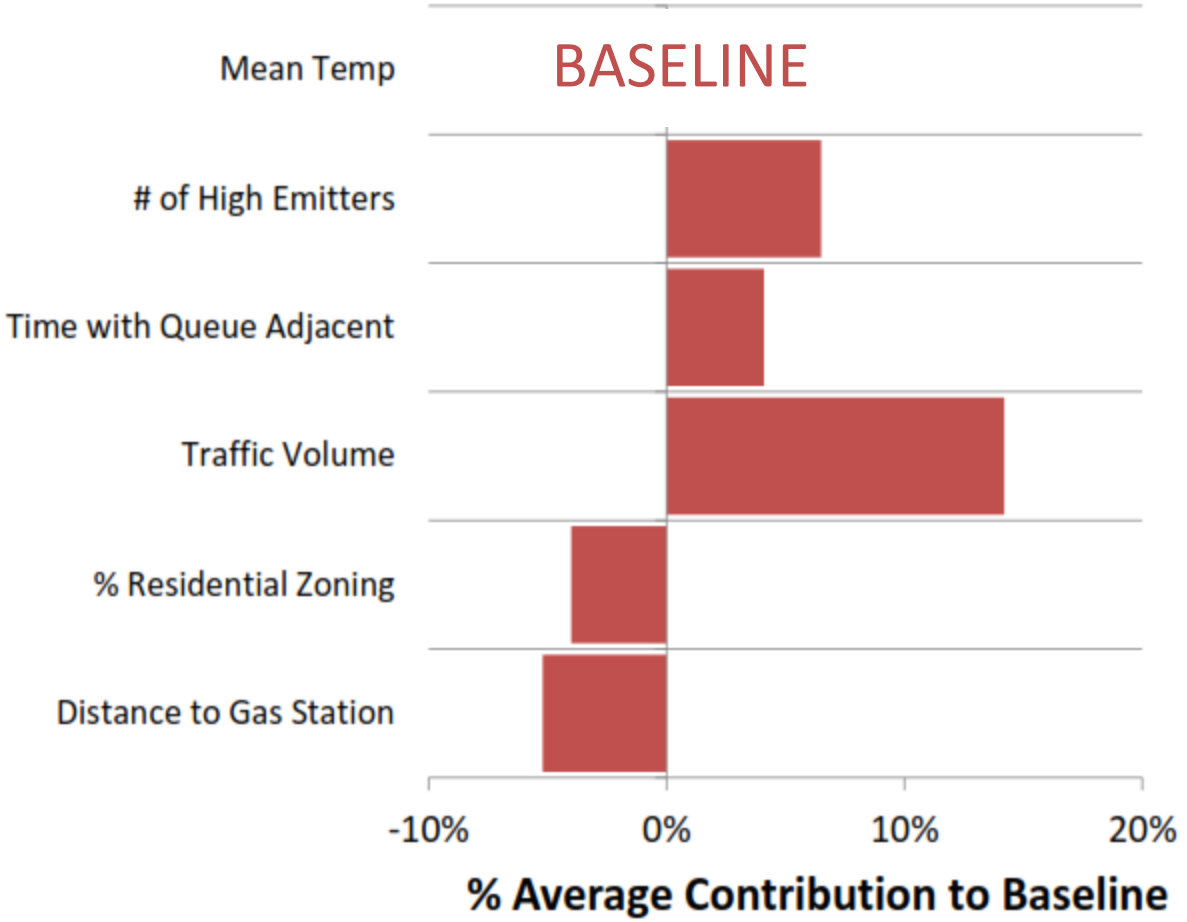


HOT SPOT FREQUENCY – *All Study Hours*



Multiple Regression – ALL DAY Data

- Linear Model: Adjusted R^2 = 36%
- Log-Linear Model: Adjusted R^2 = 52%



CONCLUSIONS

- **Hot Spot Identification**
  - *Consistency, magnitude and distance impacted*
  - *AM vs. PM: analyze together AND separately*
- **Statistical Analysis**

$PM_{2.5}$

- ***Strongest (+) Relationships**: Relative Humidity, Background $PM_{2.5}$ Concentrations, Presence of "High Emitters"*

$PM_{2.5}$

- ***Strongest (-) Relationships:** Temperature, Wind Speed, Traffic Speed*
- ***Land Use** variables also have statistically significant relationships with $PM_{2.5}$ concentrations*
- *Multiple Regression models can be adjusted depending on data available*

- **Mobile Outside Vehicle Measurements + Land Use Regression**
  - *Valuable tool to better understand relationships between hot spot locations and other variables*

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FUTURE RESEARCH

- **Cold Spots –** *study potential predictors*
- **VOC –** *perform regression analysis*
- **Predictors of Hot Spot Frequency**
- **Study "outliers"**
- **Other variables**
  - *Construction*
  - *Underpasses*
  - *Vehicle Classifications (more detailed)*

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Alex Bigazzi, Adam Moore (PSU)

QUESTIONS

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Related Masters Thesis will be available at http://www.its.pdx.edu/publications.php

Data

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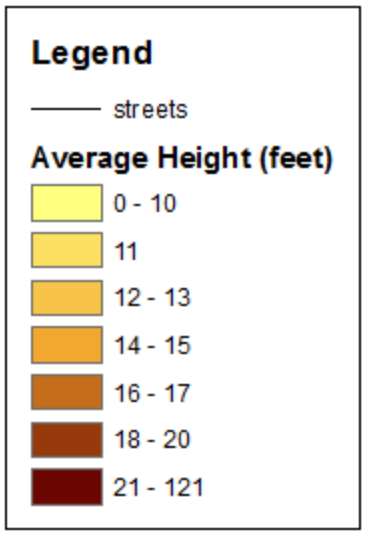
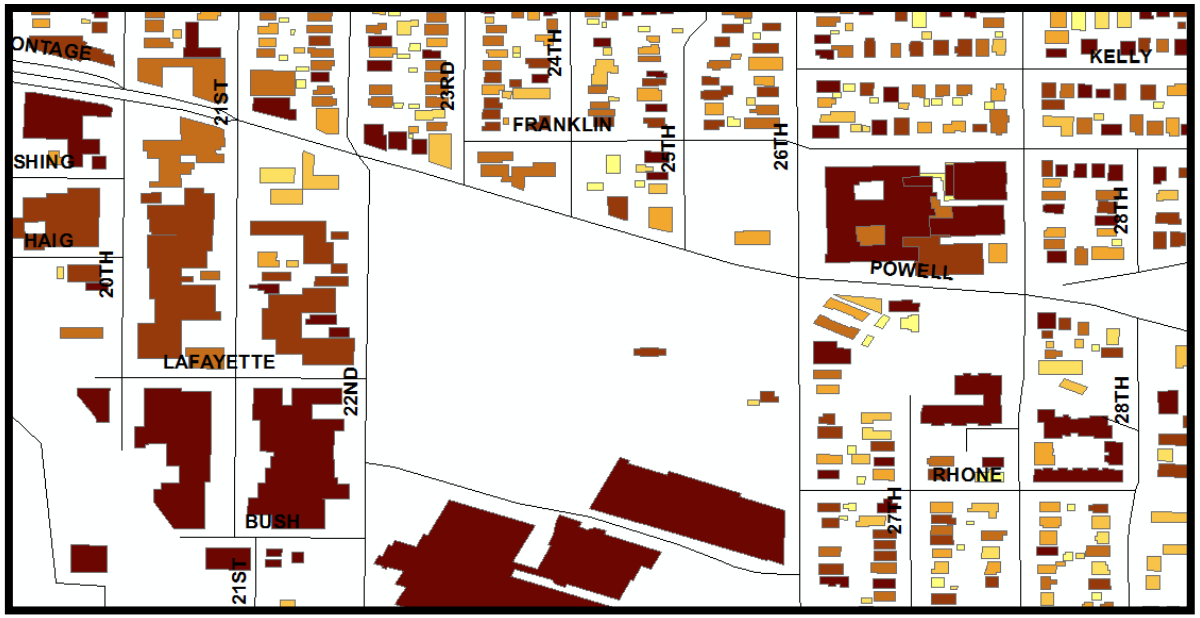
- Pollutant Concentration – *$PM_{2.5}$ and VOC*
- Probe Vehicle Behavior – *Location, Speed, Standard deviation of speed, Percent time accelerating, Stopped time*
- Traffic – *Queue length, Queue adjacent, Volume, Distance to major intersection, # of high emitters*
- Meteorological – *Wind Speed/Direction, Background $PM_{2.5}$, Relative humidity, Temperature*
- Zoning – *Commercial, Residential, Industrial, Open-space*
- Buildings & Businesses – *Drive-through business (i.e., McDonalds) Gas station, Building height, Building footprints*
- Elevation Changes – *Flat, Uphill, Downhill, High point, Low point*

AVAILABLE DATA

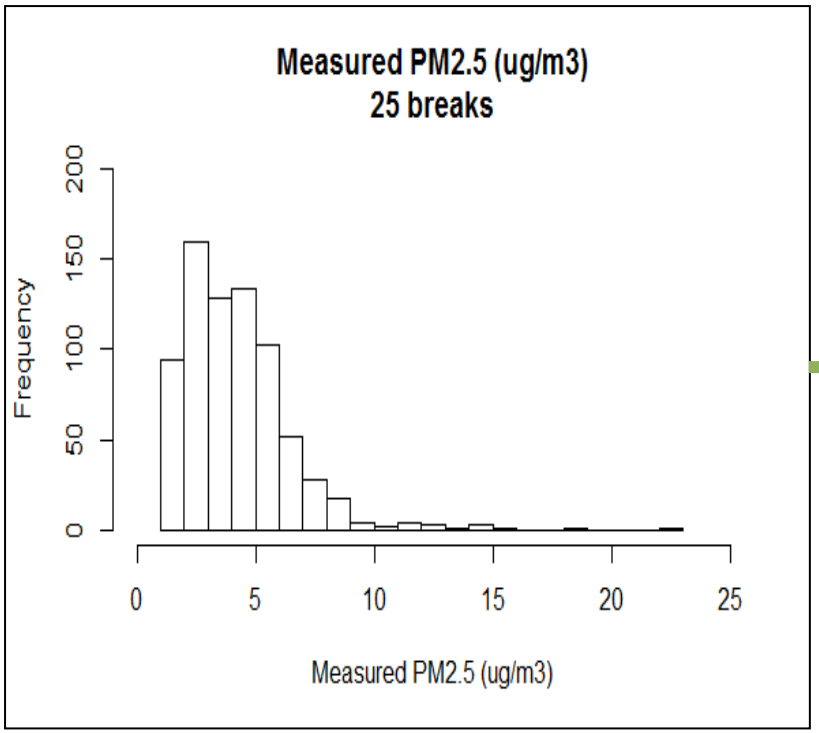
- **Traffic –** *Wavetronix & SCATS*
- **Land Use –** *PortlandMaps & RLIS*
- **Meteorological –** *DEQ Air Quality Monitoring Station*





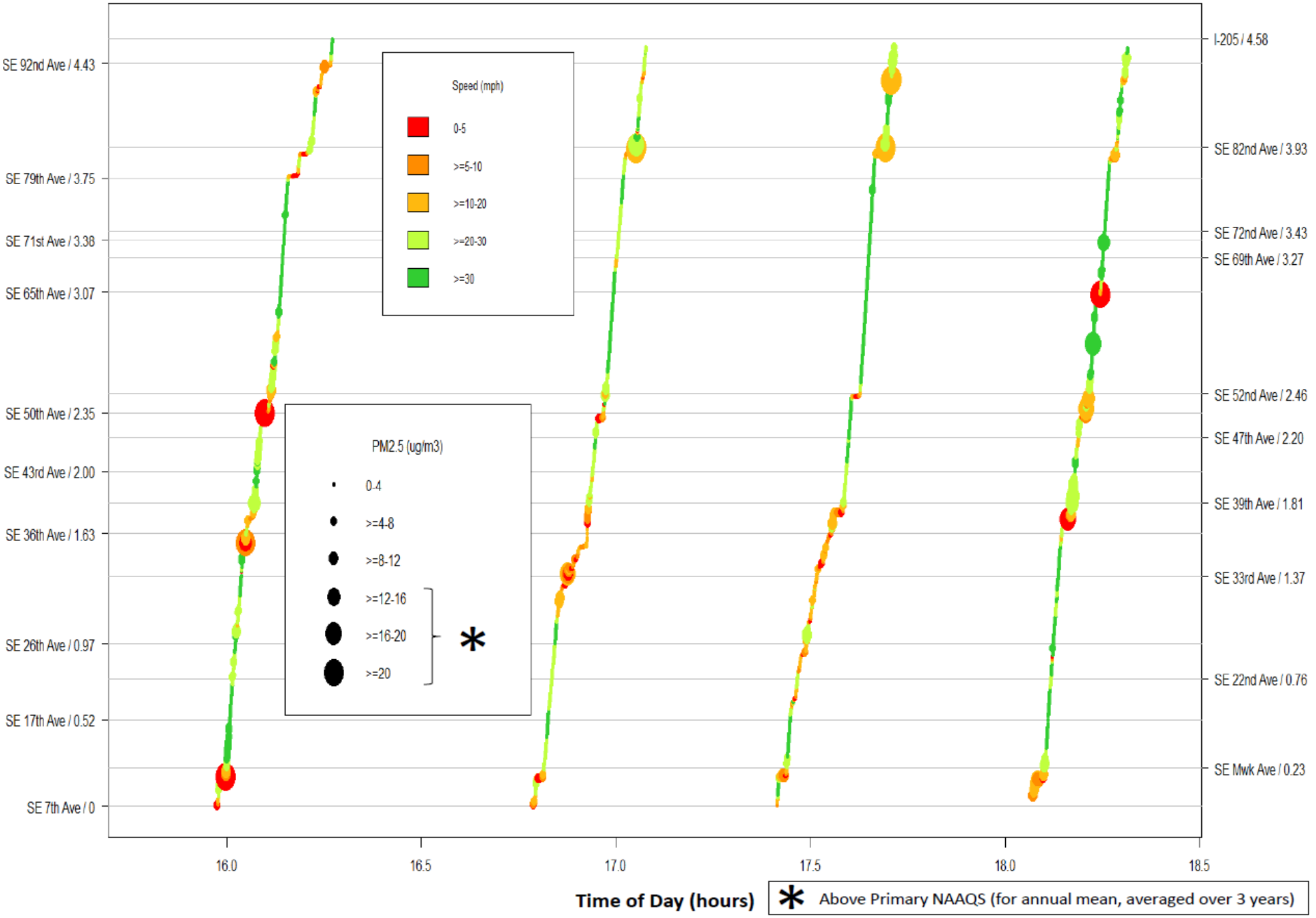
STATISTICAL ANALYSIS

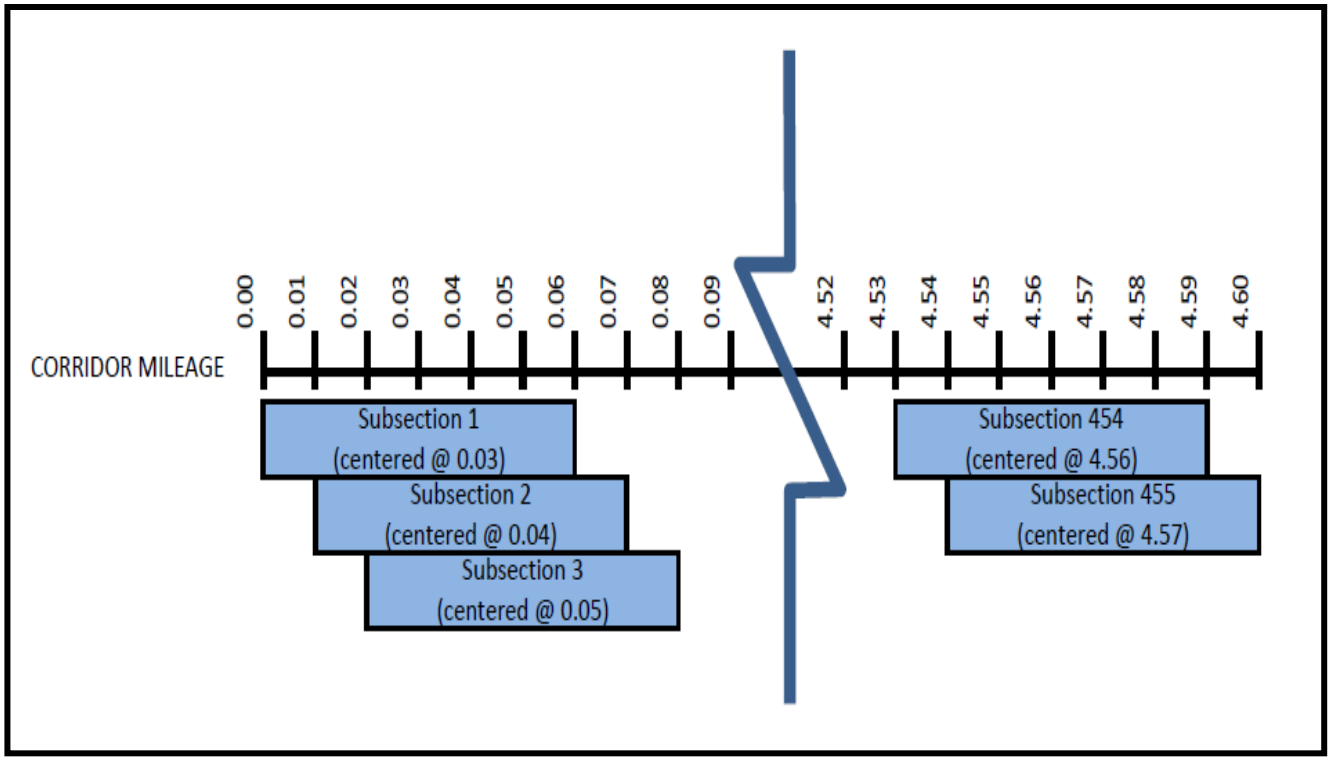
1) Mann-Whitney-Wilcoxon Test
2) Simple Regression Analysis
3) Multiple Regression Analysis

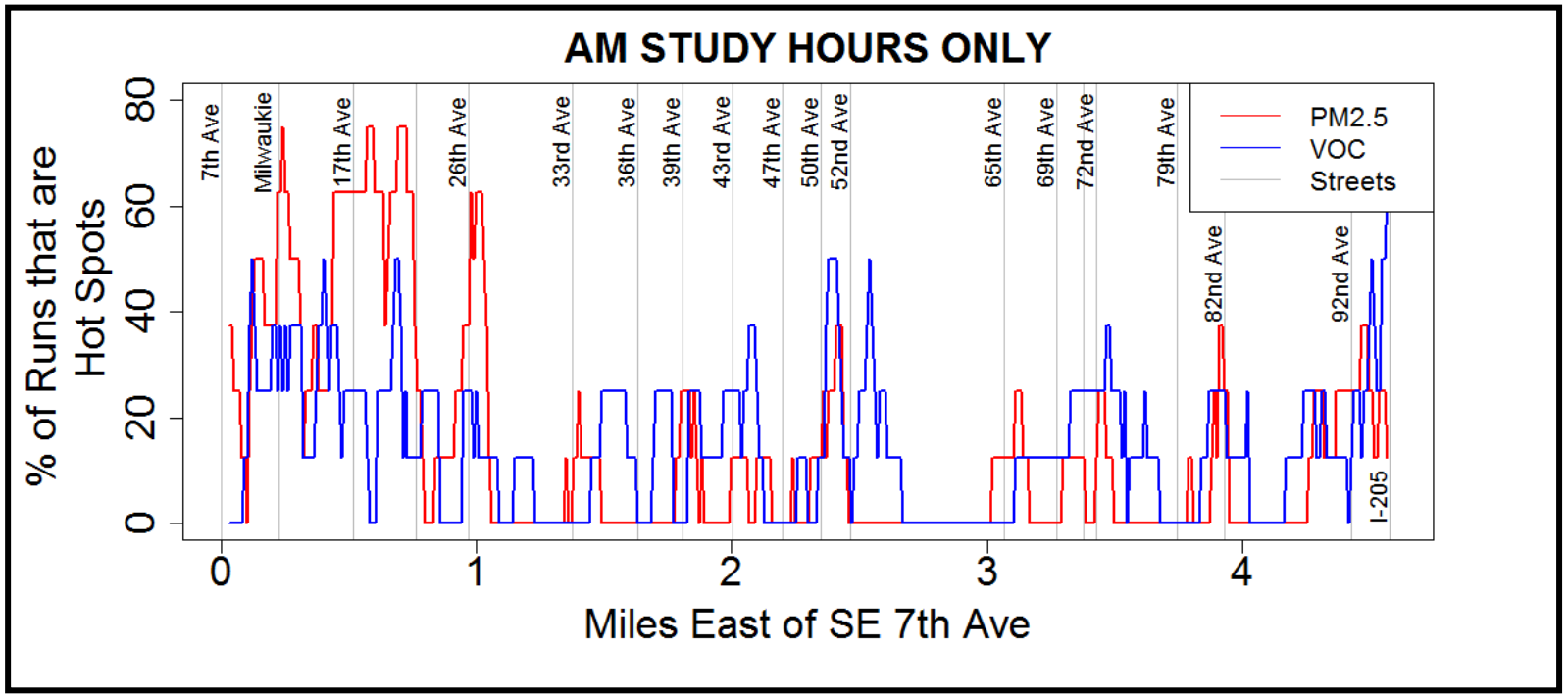


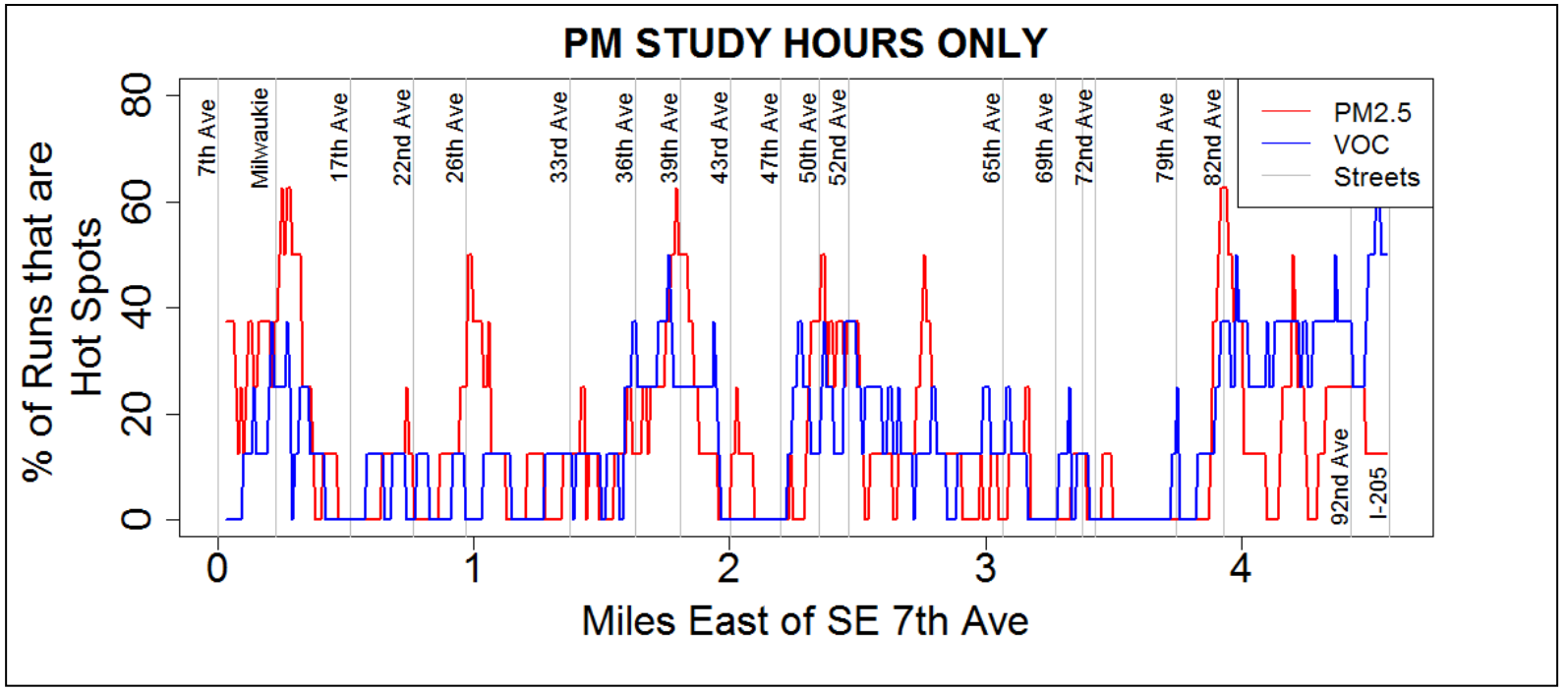
Skewed distribution

Time-Space-Air Quality Diagram




CORRIDOR MILEAGE
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
4.52
4.53
4.54
4.55
4.56
4.57
4.58
4.59
4.60
Subsection 1
(centered @ 0.03)
Subsection 2
(centered @ 0.04)
Subsection 3
(centered @ 0.05)
Subsection 454
(centered @ 4.56)
Subsection 455
(centered @ 4.57)


AM STUDY HOURS ONLY
% of Runs that are Hot Spots
0
20
40
60
80
7th Ave
Milwaukie
17th Ave
26th Ave
33rd Ave
36th Ave
39th Ave
43rd Ave
47th Ave
50th Ave
52nd Ave
65th Ave
69th Ave
72nd Ave
79th Ave
82nd Ave
92nd Ave
I-205
PM2.5
VOC
Streets
0
1
2
3
4
Miles East of SE 7th Ave


PM STUDY HOURS ONLY
% of Runs that are Hot Spots
0
20
40
60
80
7th Ave
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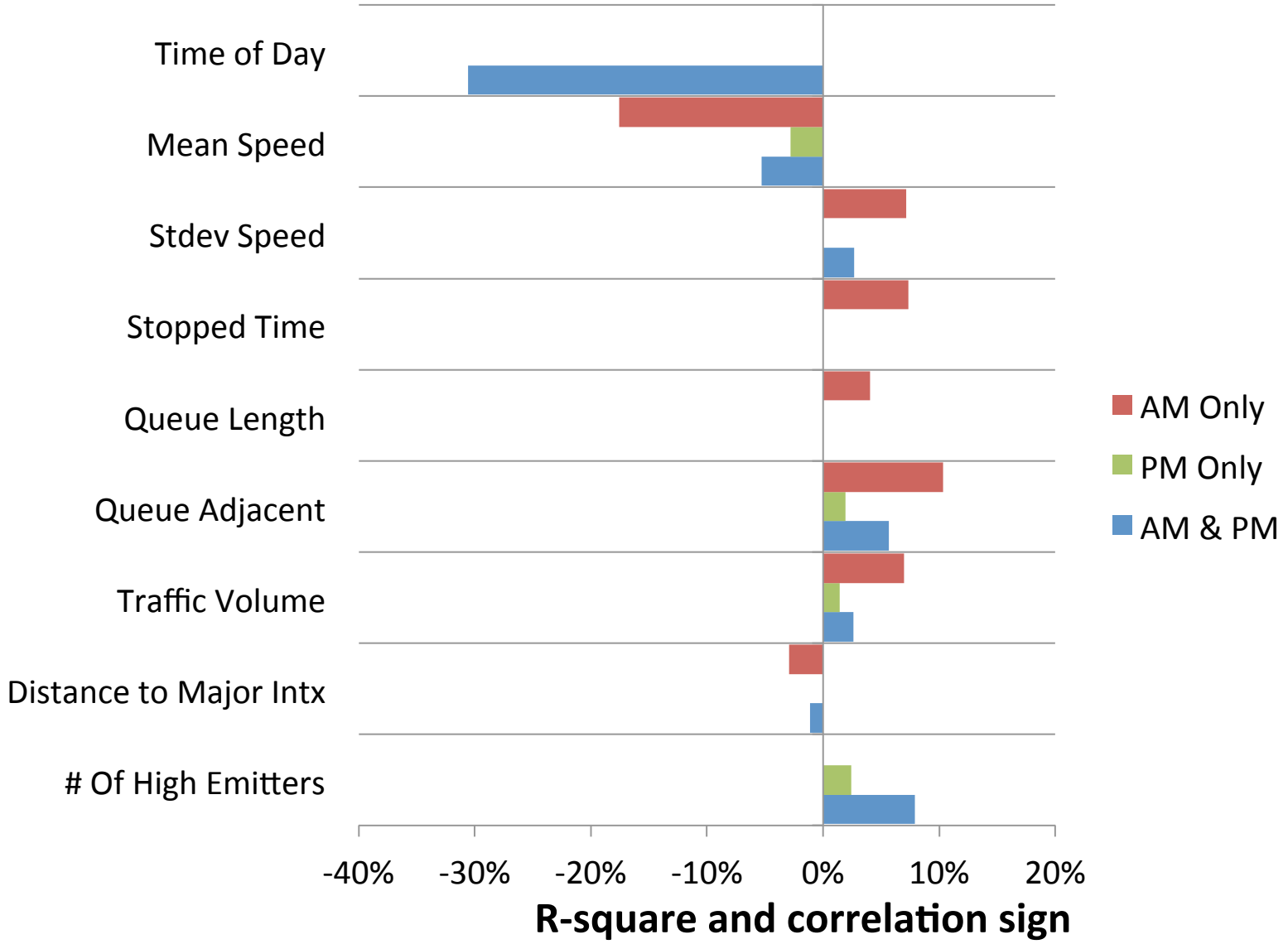
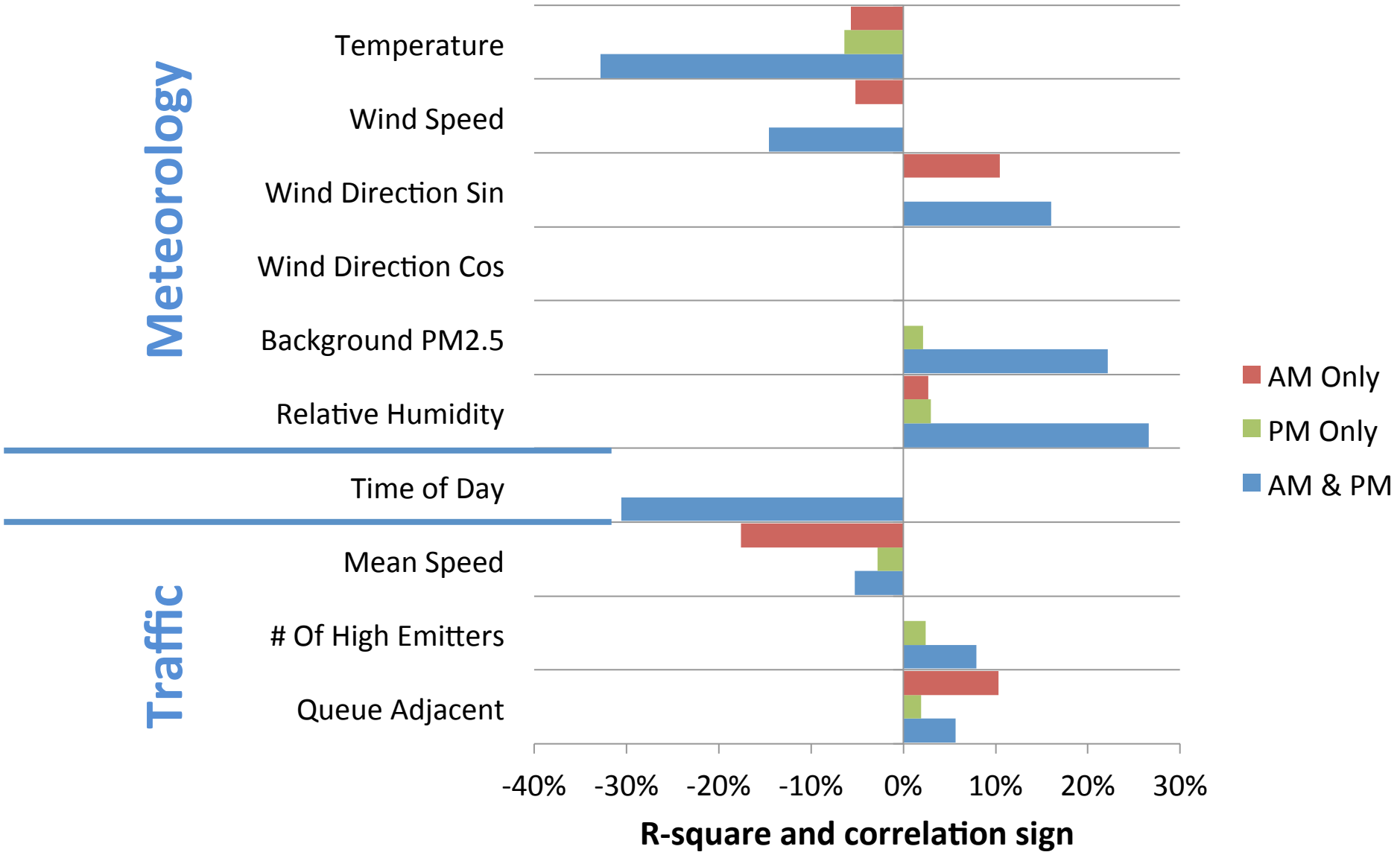
17th Ave
22nd Ave
26th Ave
33rd Ave
36th Ave
39th Ave
43rd Ave
47th Ave
50th Ave
52nd Ave
65th Ave
69th Ave
72nd Ave
79th Ave
82nd Ave
92nd Ave
I-205
PM2.5
VOC
Streets
0
1
2
3
4
Miles East of SE 7th Ave

Simple Regression - Traffic



Simple Regression



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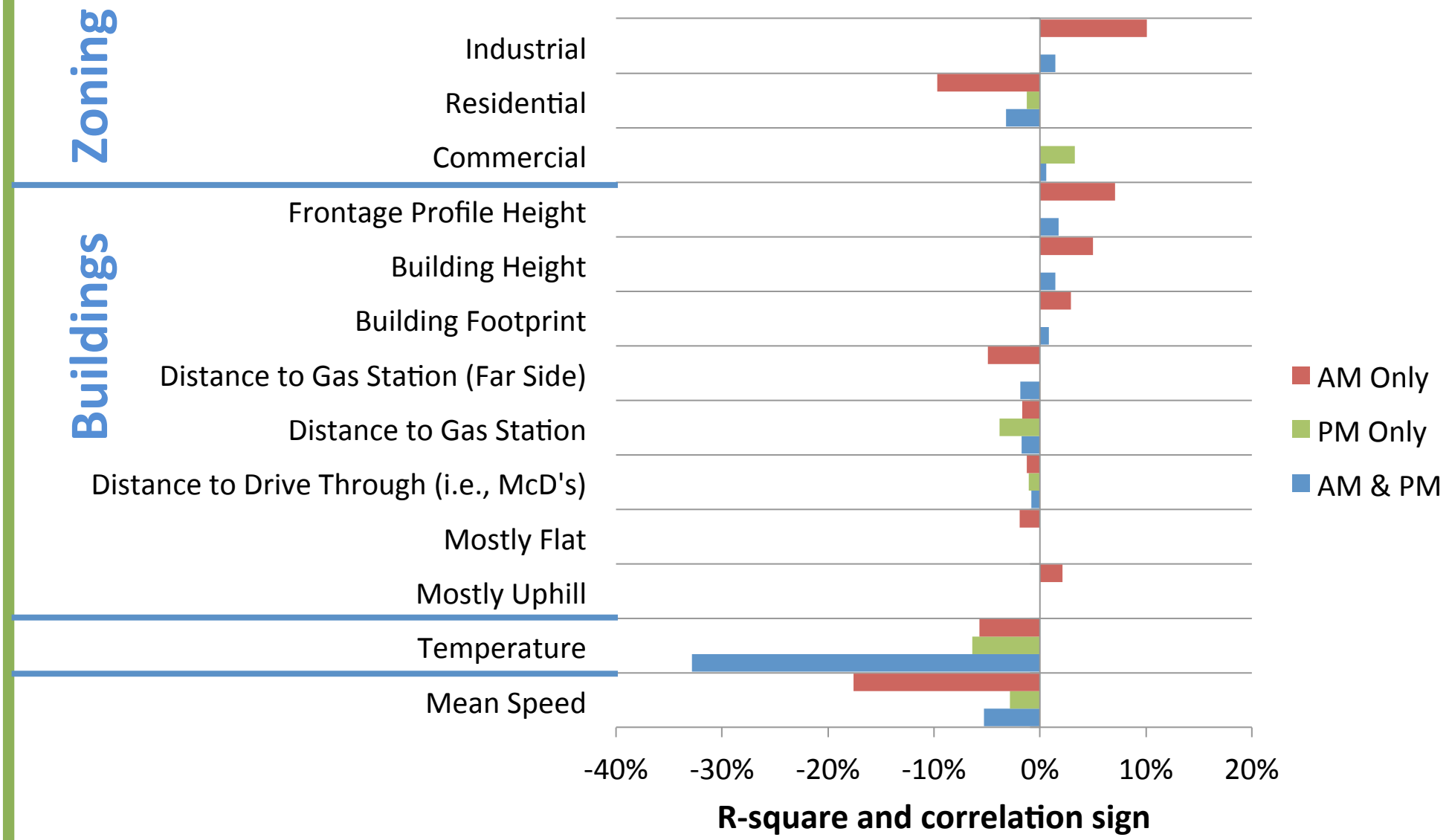
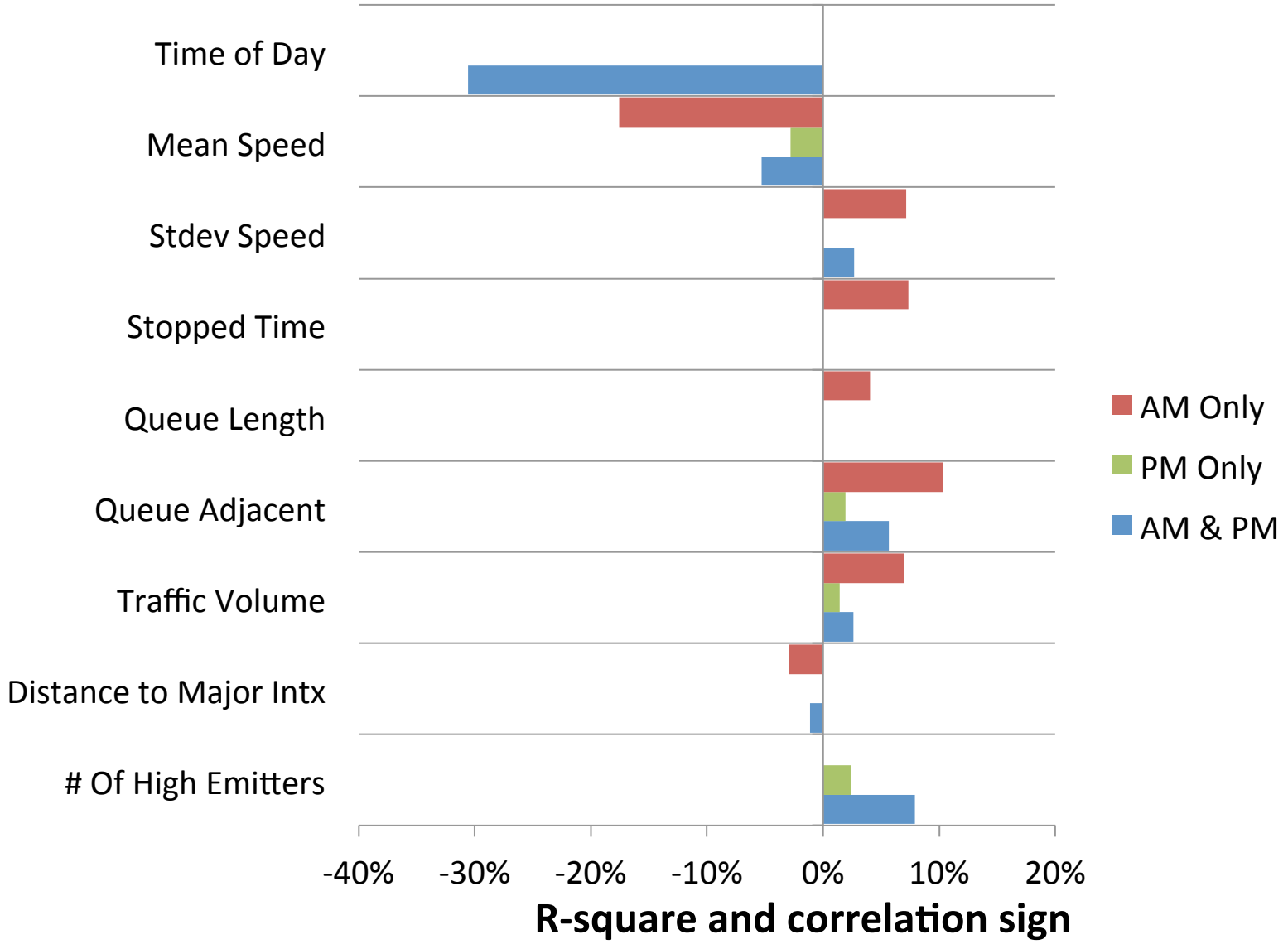
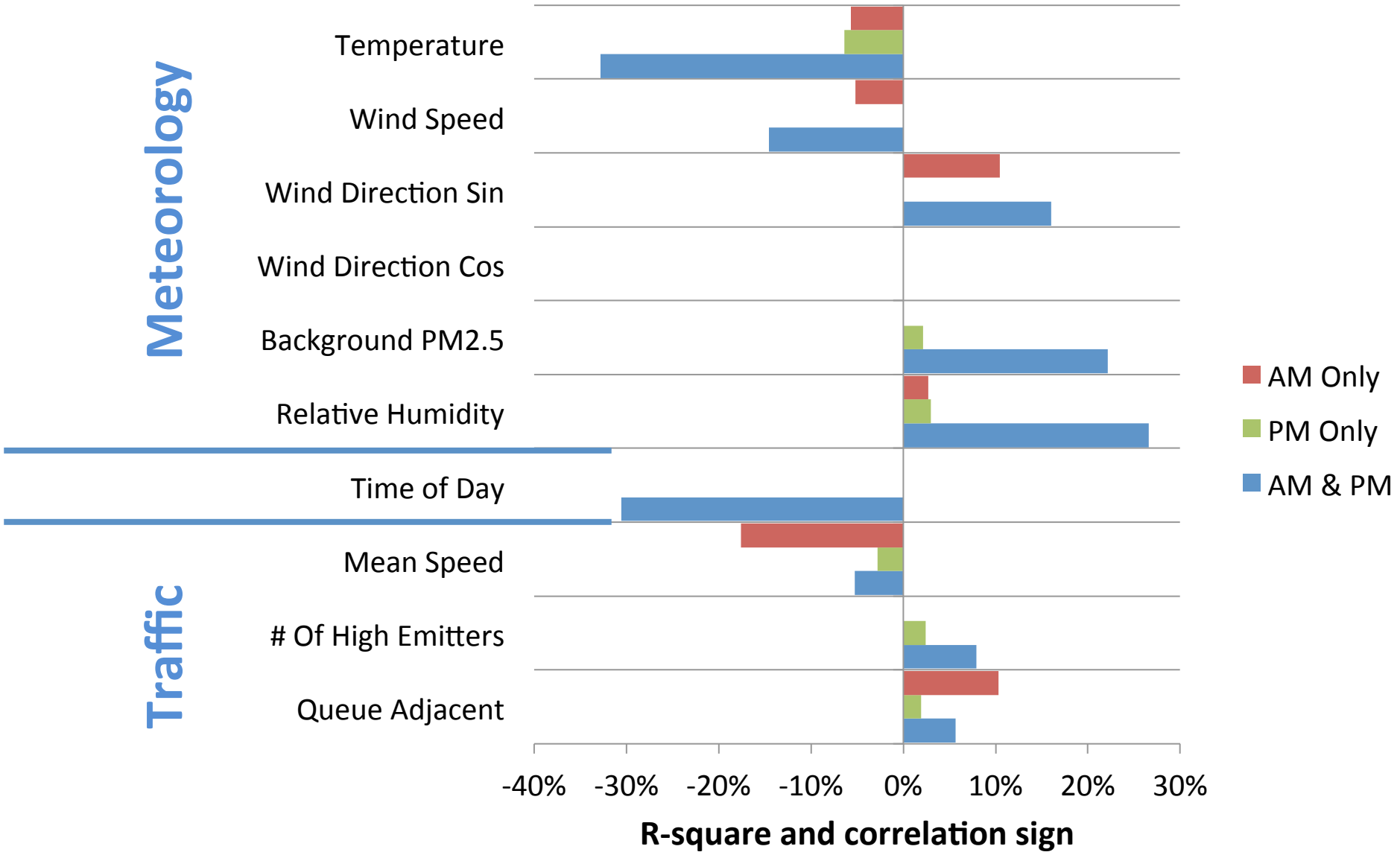


Simple Regression - Traffic



Simple Regression



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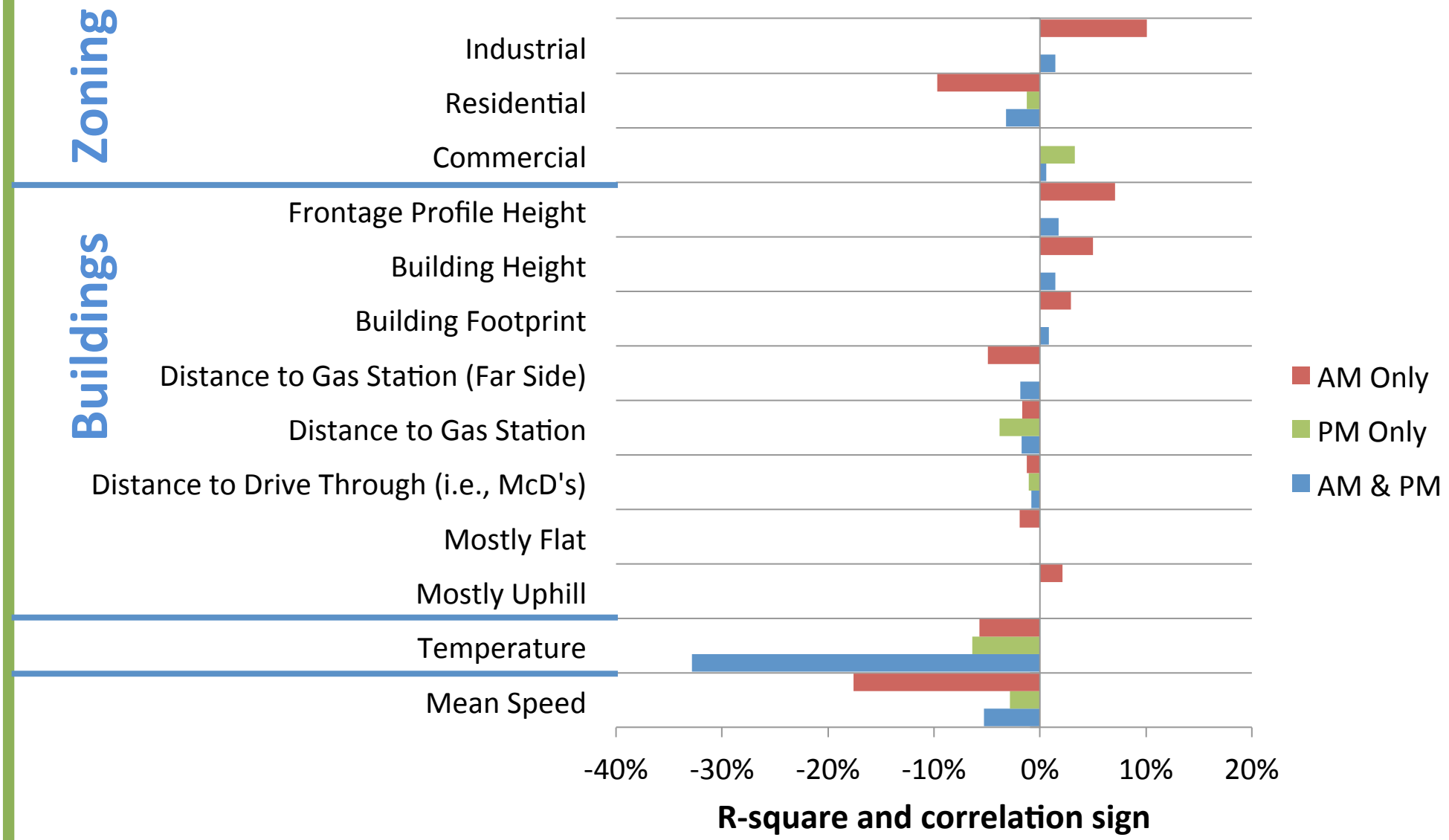

Multiple Regression - % Contribution to Baseline

All Day Model - Example

Baseline

+7.2%

$$Y = 18.14 - 0.21(Temperature) + 2.00[\sin(Wind\ Direction)]$$

+6.5%

$$+0.22(\#of\ high\ emitters) + 1.41(Time\ w\ queue\ adjacent)$$

$$- 0.01(\%\ Residential\ zoning) - 0.12(Distance\ to\ gas\ station)$$

+3.5%

-4.6%

-3.1%

Multiple Regression

$$Y_i = \beta_0 + \beta_1 X_{1i} + \ldots + \beta_k X_{ki} + \varepsilon$$

- R Step() function – *uses AIC criteria*
- p-value < 0.05
- Variance inflation factor (VIF) < 5

$$VIF_j = \frac{1}{1 - R^2{}_j}$$

- Correlations
- Log-linear Models

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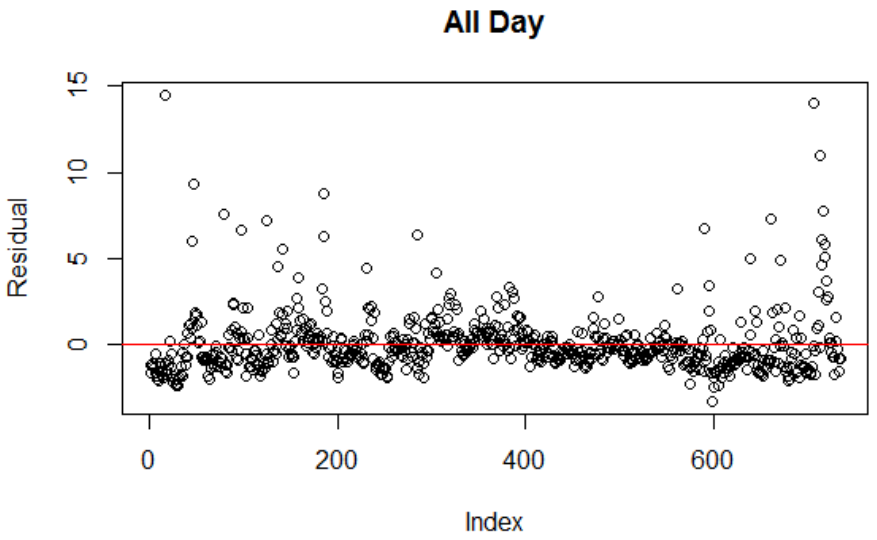
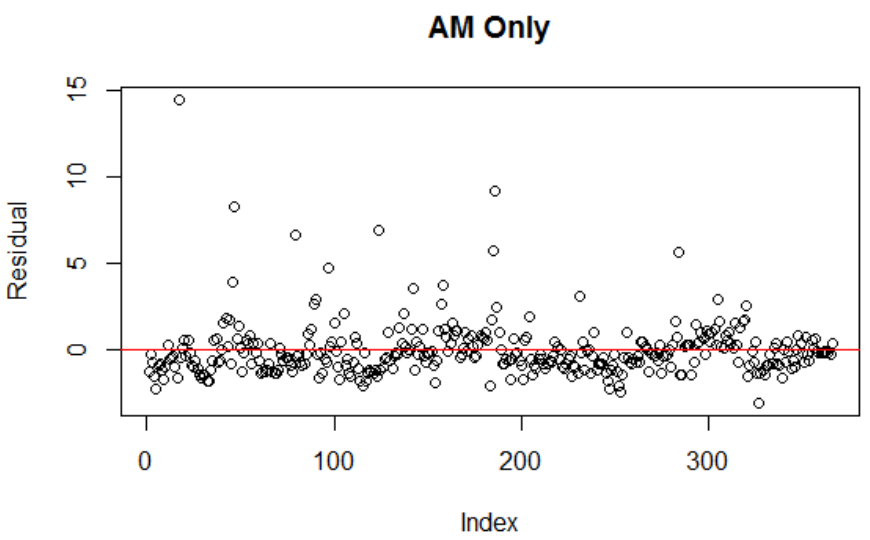
Correlations

R^2		**ResTotal**	**ResNear**	GasDistFar	H200AvgTotal	**ResFar**	GasDistAll	H200AvgNear	**IndTotal**	H200Total	**IndNear**	**IndFar**	H200Near	A200Total	DriveDistAll
3.22%	**ResTotal**	**1.00**													
2.28%	**ResNear**	**0.79**	**1.00**												
1.83%	GasDistFar	0.23	0.02	1.00											
1.74%	H200AvgTotal	0.26	0.20	0.30	1.00										
1.73%	**ResFar**	**0.79**	**0.24**	0.38	0.20	**1.00**									
1.70%	GasDistAll	0.28	0.22	0.15	0.04	0.22	1.00								
1.51%	H200AvgNear	0.19	0.20	0.12	0.73	0.10	0.03	1.00							
1.44%	**IndTotal**	**0.32**	**0.26**	0.25	0.37	**0.26**	0.16	0.27	**1.00**						
1.43%	H200Total	0.15	0.12	0.29	0.68	0.12	0.01	0.50	0.21	1.00					
1.10%	**IndNear**	**0.28**	**0.22**	0.22	0.32	**0.22**	0.14	0.14	**0.86**	0.18	**1.00**				
1.10%	**IndFar**	**0.27**	**0.22**	0.21	0.32	**0.22**	0.13	0.32	**0.85**	0.17	**0.46**	**1.00**			
0.88%	H200Near	0.03	0.03	0.16	0.51	0.07	0.04	0.62	0.12	0.72	0.10	0.11	1.00		
0.85%	A200Total	0.17	0.13	0.23	0.91	0.13	0.02	0.66	0.38	0.45	0.32	0.32	0.36	1.00	
0.78%	DriveDistAll	0.65	0.51	0.09	0.01	0.51	0.10	0.01	0.08	0.12	0.07	0.08	0.10	0.09	1.00
0.58%	**CommTotal**	**0.56**	**0.44**	0.04	0.21	0.44	0.15	0.15	**0.37**	0.28	**0.32**	**0.32**	0.19	0.18	0.56


All Day
Residual
Index
0
5
10
15
0
200
400
600


AM Only
Residual
Index
0
5
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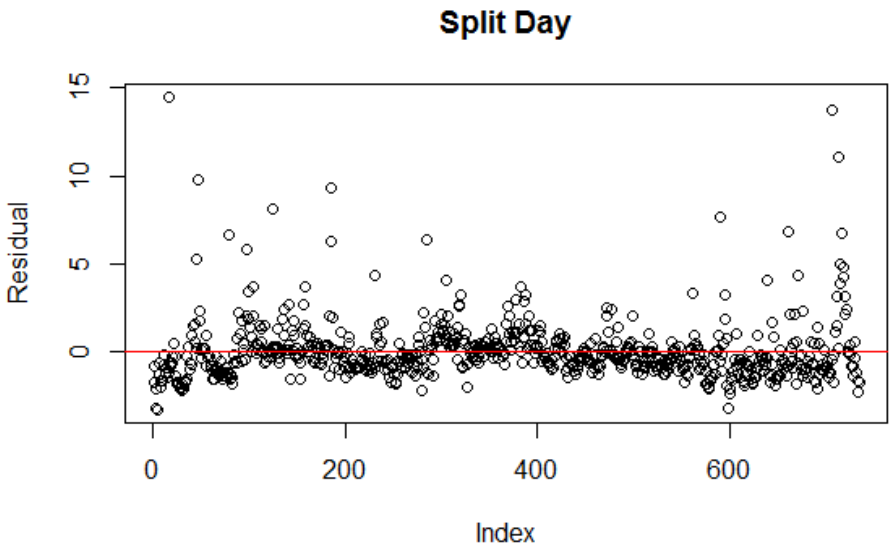
200
300


Split Day
Residual
Index
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200
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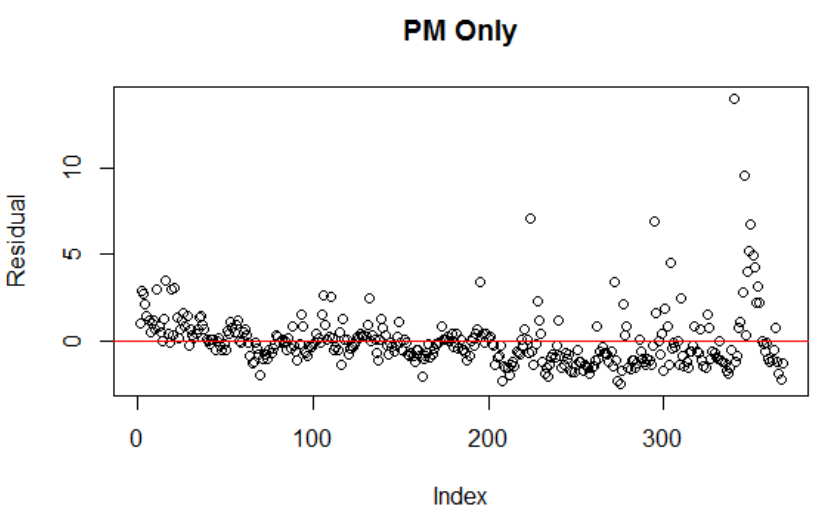
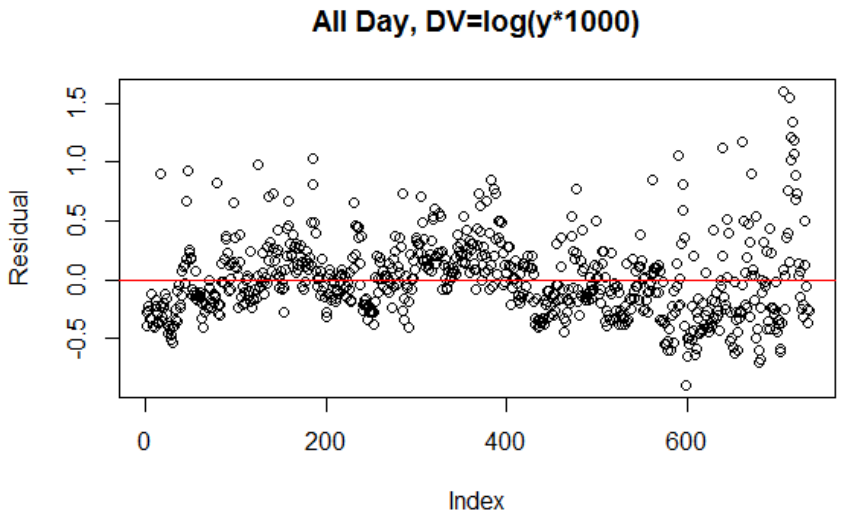
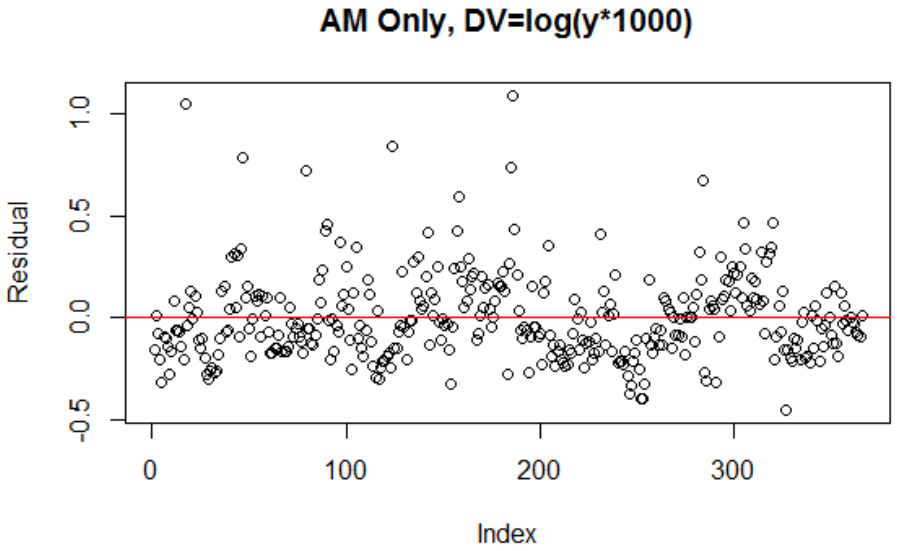
600


PM Only
Residual
Index
0
5
10
0
100
200
300


All Day, DV=log(y*1000)
Residual
-0.5
0.0
0.5
1.0
1.5
0
200
400
600
Index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Residual
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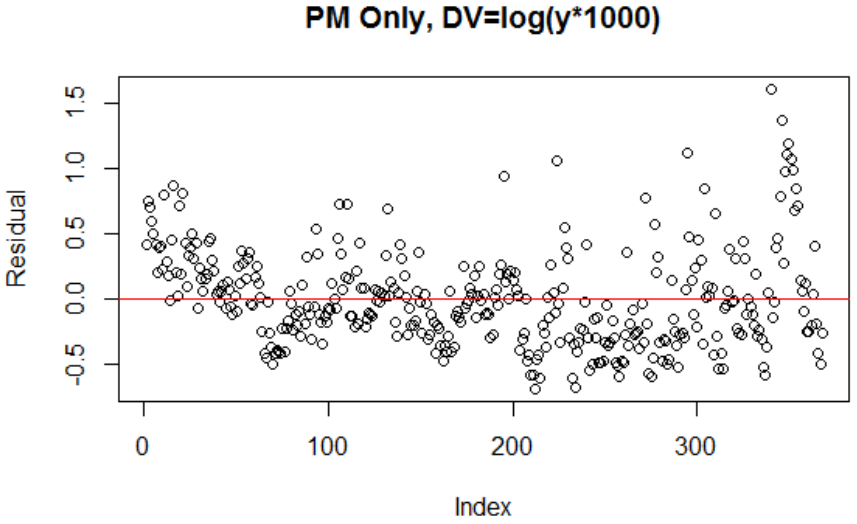
0.0
0.5
1.0
0
100
200
300
Index


PM Only, DV=log(y*1000)
Residual
-0.5
0.0
0.5
1.0
1.5
0
100
200
300
Index

Simple Regression

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Independent Variables		Dependent Variable: $PM_{2.5}$ Concentration (ug/m^3)								
		AM & PM			AM only			PM only		
		Change	p-value	R-sq	Change	Sig	R-sq	Change	Sig	R-sq
Time	TOD	-	0.0000	30.55%						
Probe Vehicle Behavior	MeanSpeed	-	0.0000	5.28%	-	0.0000	17.58%	-	0.0012	2.82%
	StdevSpeed	+	0.0000	2.68%	+	0.0000	7.14%			
	PercentAccel				-	0.0067	2.00%			
	StoppedTime				+	0.0000	7.32%			
Traffic	QueueLength				+	0.0001	4.04%			
	MeanQAdj	+	0.0000	5.66%	+	0.0000	10.34%	+	0.0074	1.95%
	Volume	+	0.0000	2.63%	+	0.0000	6.97%	+	0.0210	1.45%
	DistTo4Way	-	0.0043	1.11%	-	0.0010	2.94%			
	VolOverDist	+	0.0442	0.55%				+	0.0106	1.77%
	MeanEmitters	+	0.0000	7.90%				+	0.0028	2.41%
Meteorological	MeanWindSpeed	-	0.0000	14.56%	-	0.0000	5.20%			
	MeanWindDirSin	+	0.0000	16.01%	+	0.0000	10.44%			
	MeanWindDirCos									
	MeanBackPM2.5	+	0.0000	22.13%				+	0.0046	2.17%
	MeanRH	+	0.0000	26.62%	+	0.0017	2.68%	+	0.0009	2.95%
	MeanTemp	-	0.0000	32.83%	-	0.0000	5.70%	-	0.0000	6.40%

Independent Variables		Dependent Variable: $PM_{2.5}$ Concentration (ug/m^3)								
		AM & PM			AM only			PM only		
		Change	p-value	R-sq	Change	Sig	R-sq	Change	Sig	R-sq
Land Use - Zoning	CommNear				-			+	0.0008	3.05%
	ResNear	-	0.0000	2.28%	-	0.0000	5.88%	-	0.0279	1.32%
	IndNear	+	0.0045	1.10%	+	0.0000	9.02%			
	OpenNear									
	CommFar									
	ResFar	-	0.0003	1.73%	-	0.0000	6.10%			
	IndFar	+	0.0045	1.10%	+	0.0000	5.98%			
	OpenFar									
	CommTotal	+	0.0392	0.58%				+	0.0005	3.29%
	ResTotal	-	0.0003	3.22%	-	0.0000	9.67%	-	0.0340	1.22%
	IndTotal	+	0.0011	1.44%	+	0.0000	10.12%			
	OpenTotal									
Land Use - Buildings and Businesses	A200Near				+	0.0064	2.03%			
	H200Near	+	0.0111	0.88%	+	0.0079	1.93%			
	H200AvgNear	+	0.0009	1.51%	+	0.0000	5.51%			
	A200Far									
	H200Far									
	H200AvgFar				+	0.0029	2.41%			
	A200Total	+	0.0189	0.85%	+	0.0011	2.91%			
	H200Total	+	0.0012	1.43%	+	0.0000	5.00%			
	H200AvgTotal	+	0.0003	1.74%	+	0.0000	7.11%			
	DriveDistNear									
	GasDistNear									
	DriveDistFar				+	0.0491	1.06%			
	GasDistFar	-	0.0002	1.83%	-	0.0000	4.94%			
	DriveDistAll	-	0.0169	0.78%	-	0.0342	1.23%	-	0.0469	1.07%
	GasDistAll	-	0.0004	1.70%	-	0.0143	1.64%	-	0.0002	3.80%