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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
January 17, 2014



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.

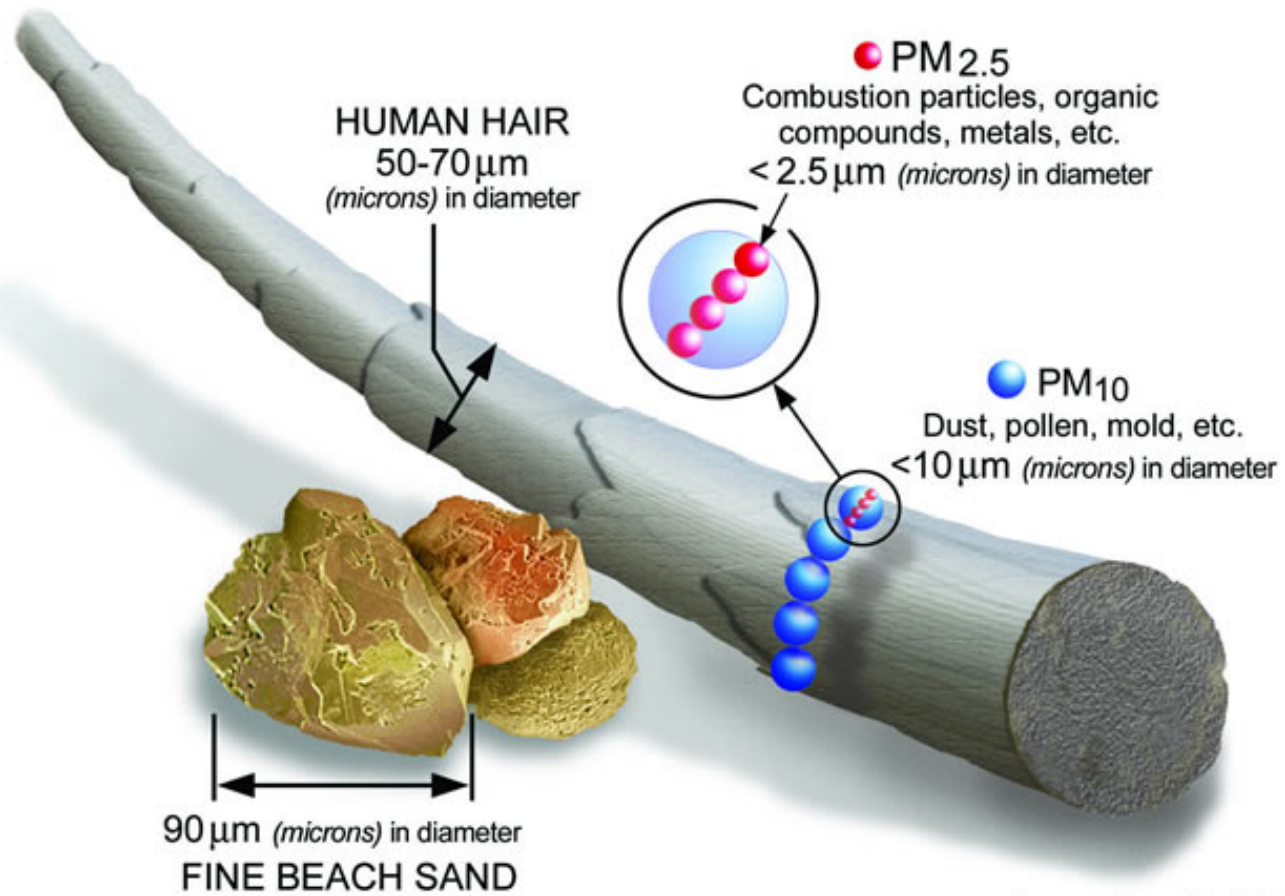
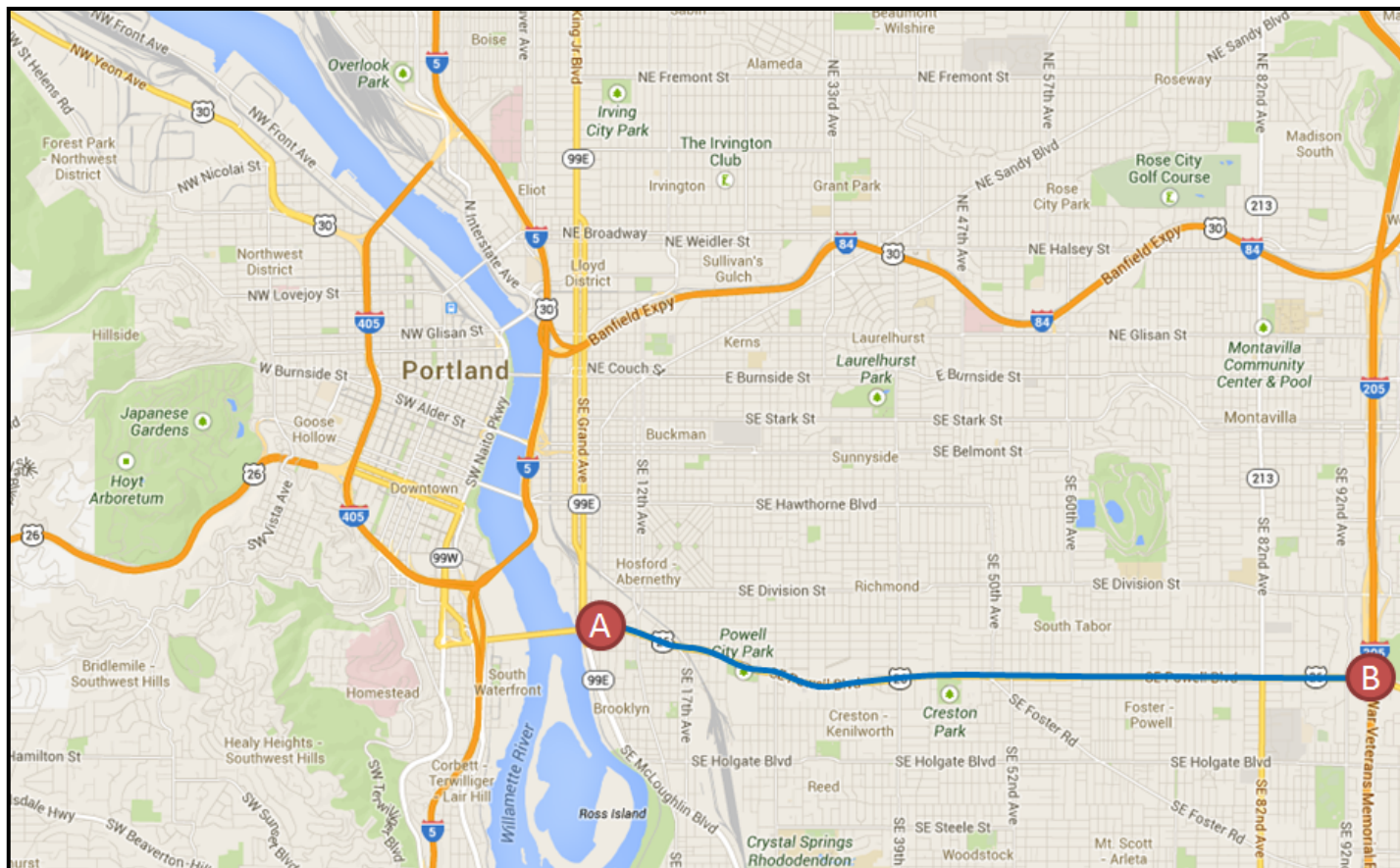


Image courtesy of the U.S. EPA

STUDY AREA – SE Powell Boulevard

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



OBJECTIVES

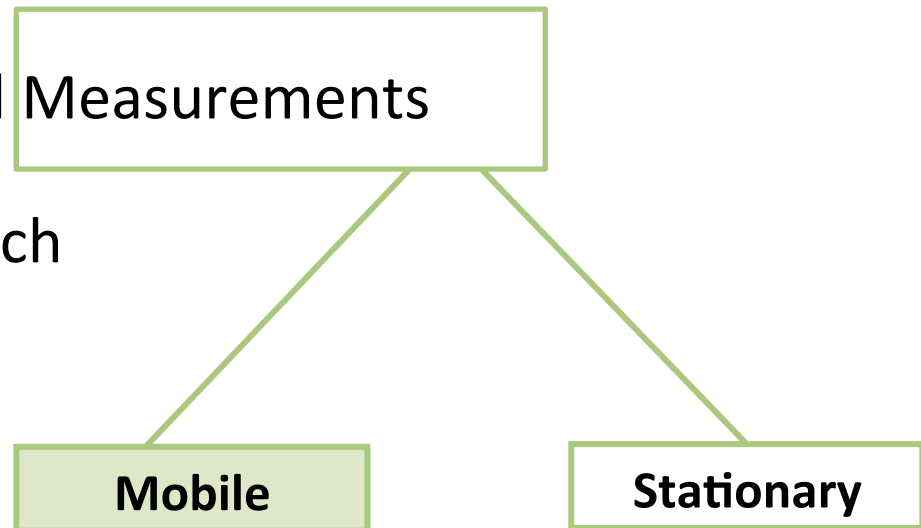
- Develop an efficient method to identify hot spot locations
 - *Better understand which variables are most related to variability in pollutant levels*
 - *Better understand the variability of exposure levels along a corridor*
- Long-term: Better inform personal exposure models and health analyses

LITERATURE REVIEW

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

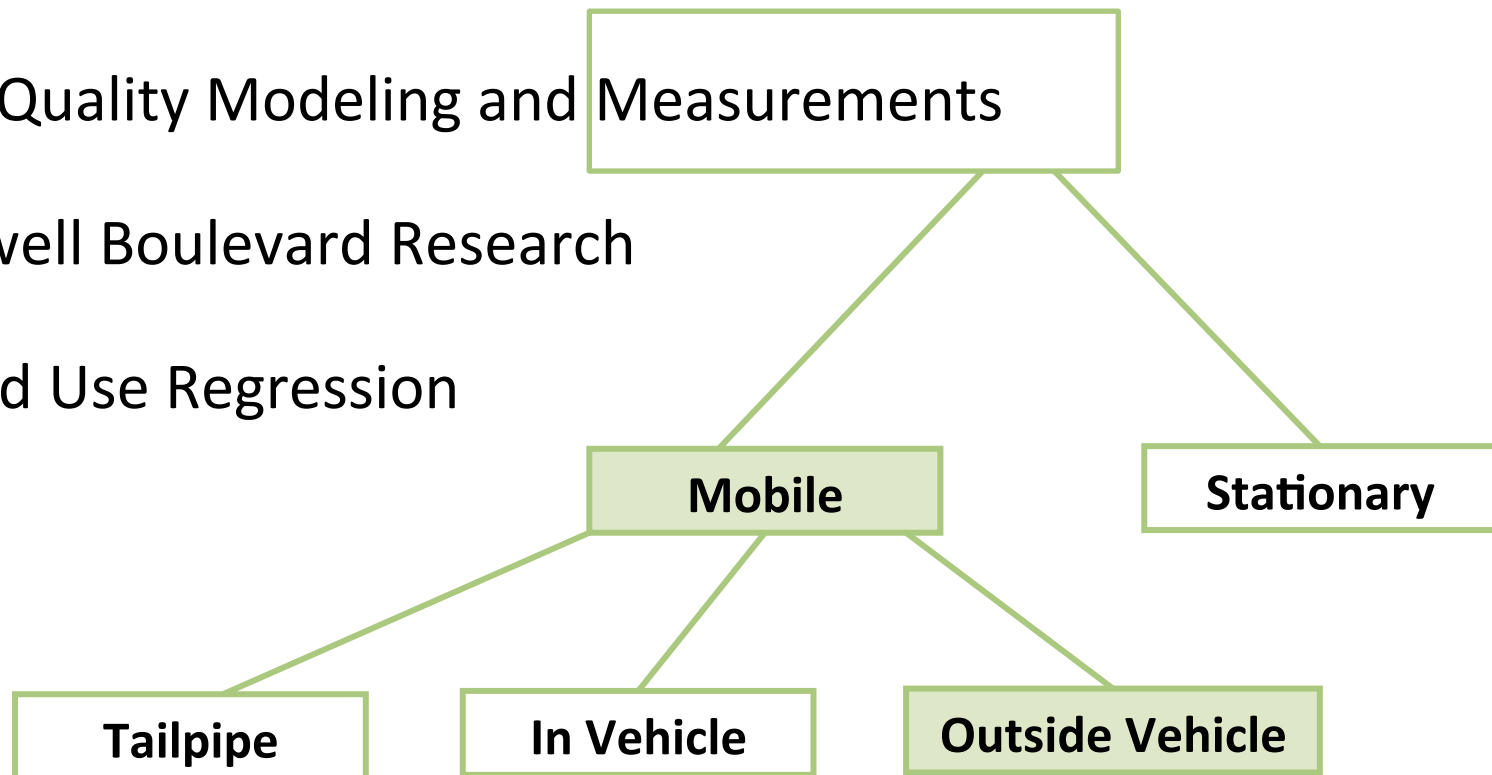
LITERATURE REVIEW

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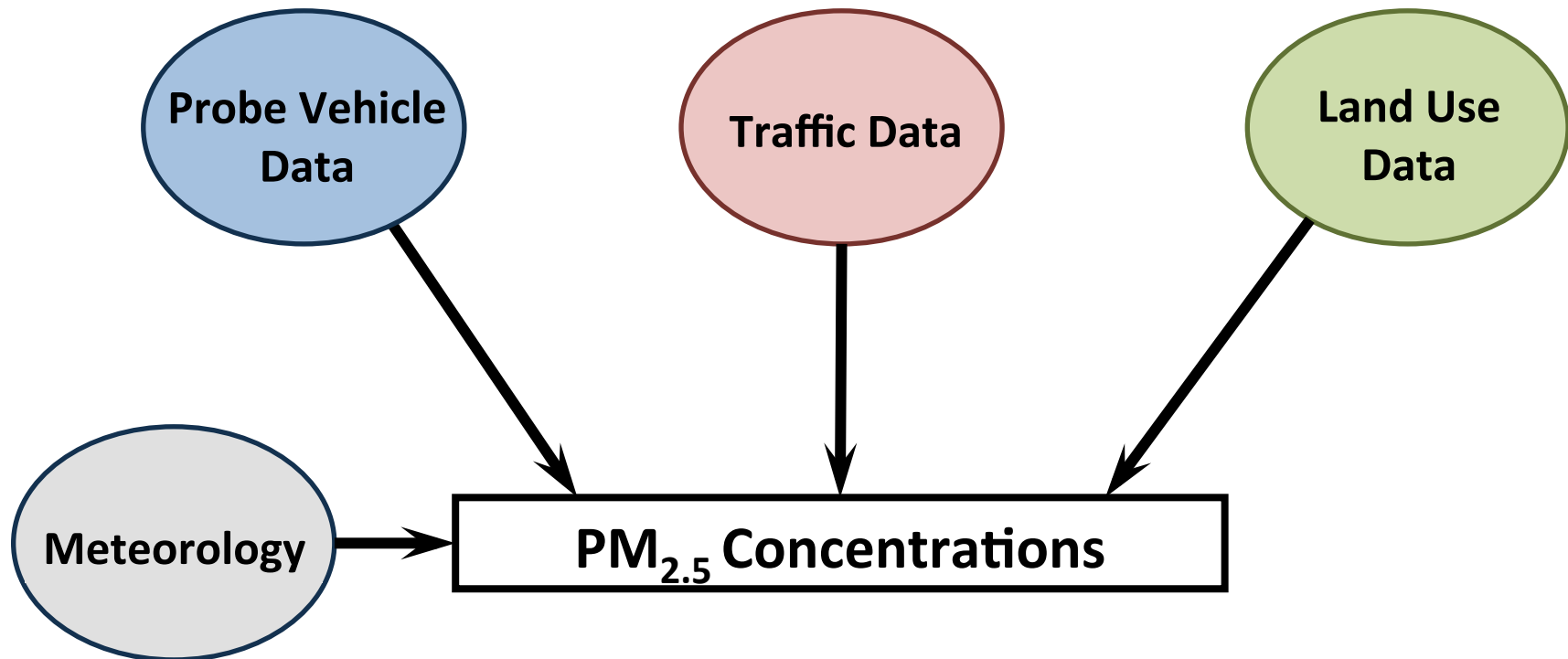


LITERATURE REVIEW

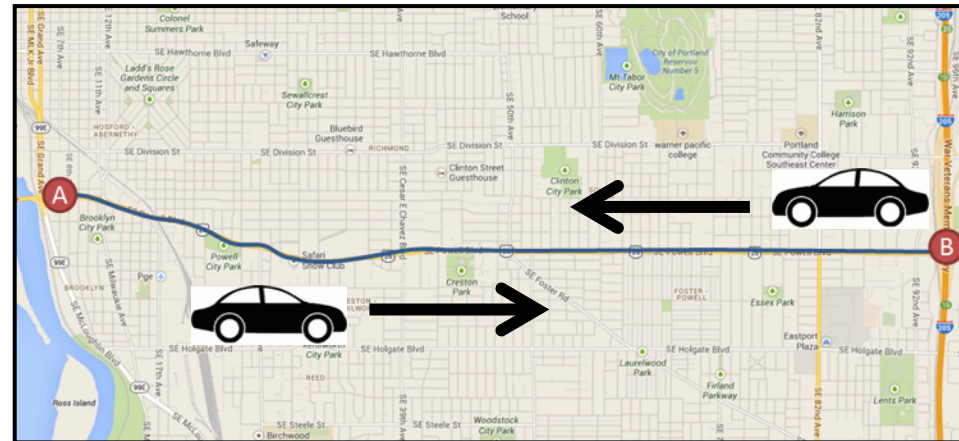
- 1) Air Quality Health and Environmental Concerns
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AVAILABLE & COLLECTED DATA

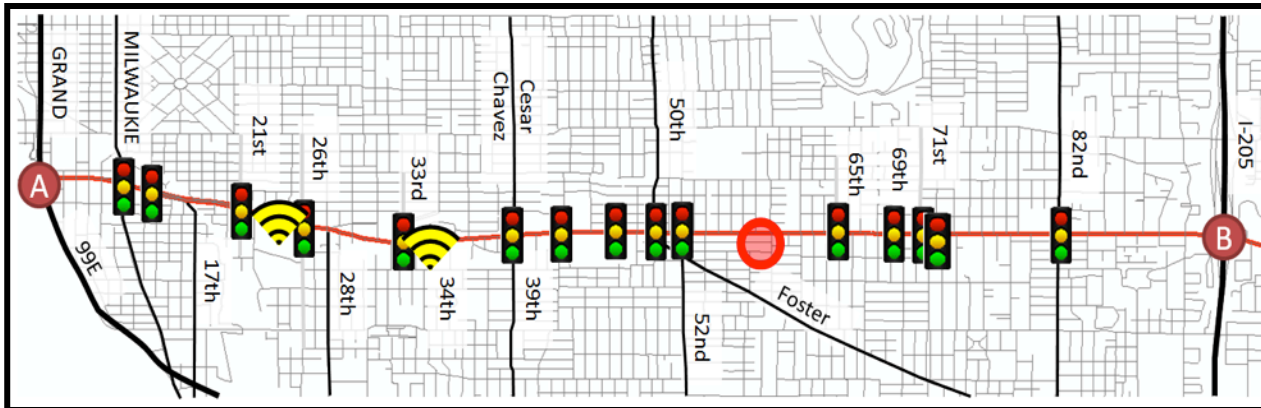







DATA COLLECTION



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

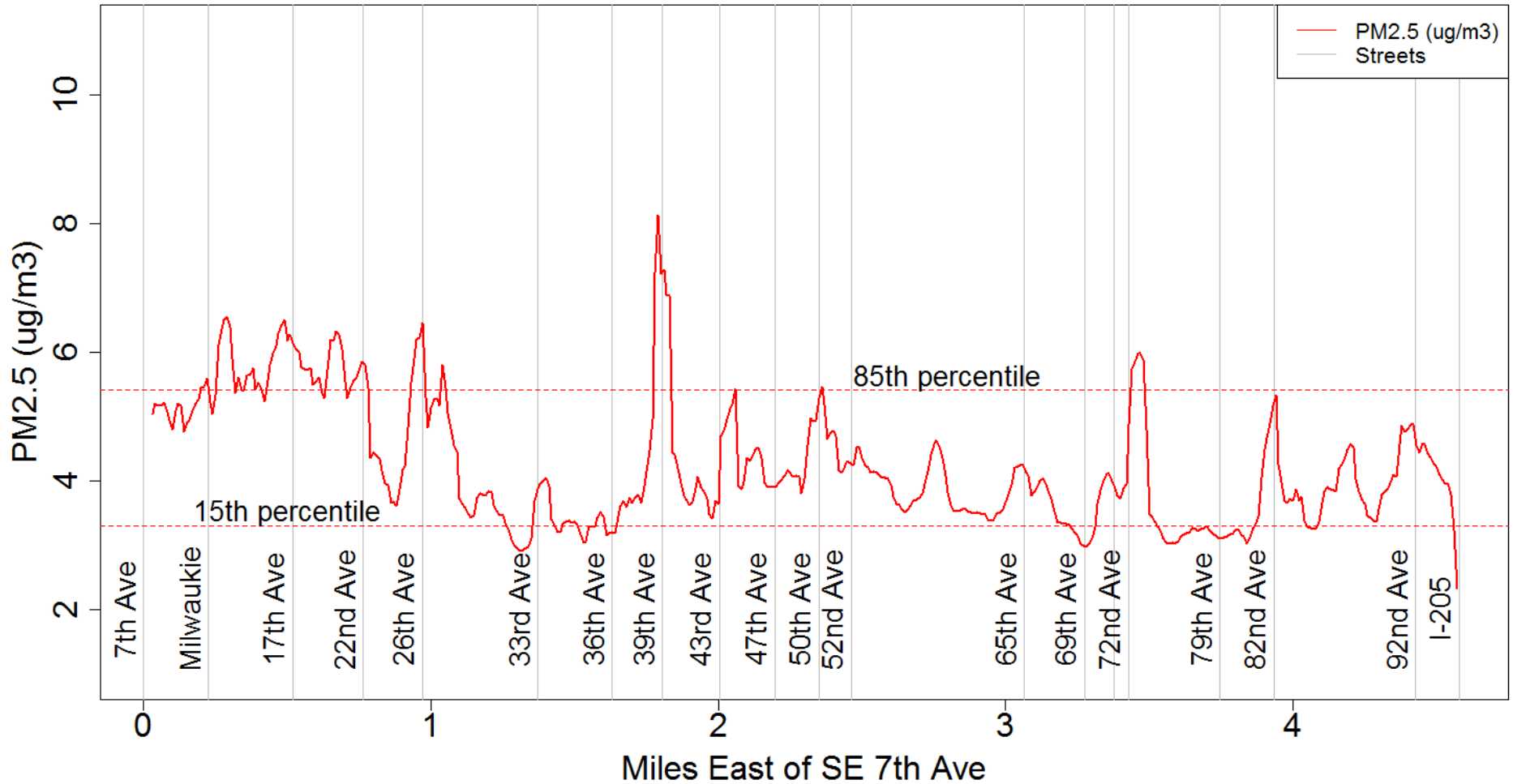
AVAILABLE DATA



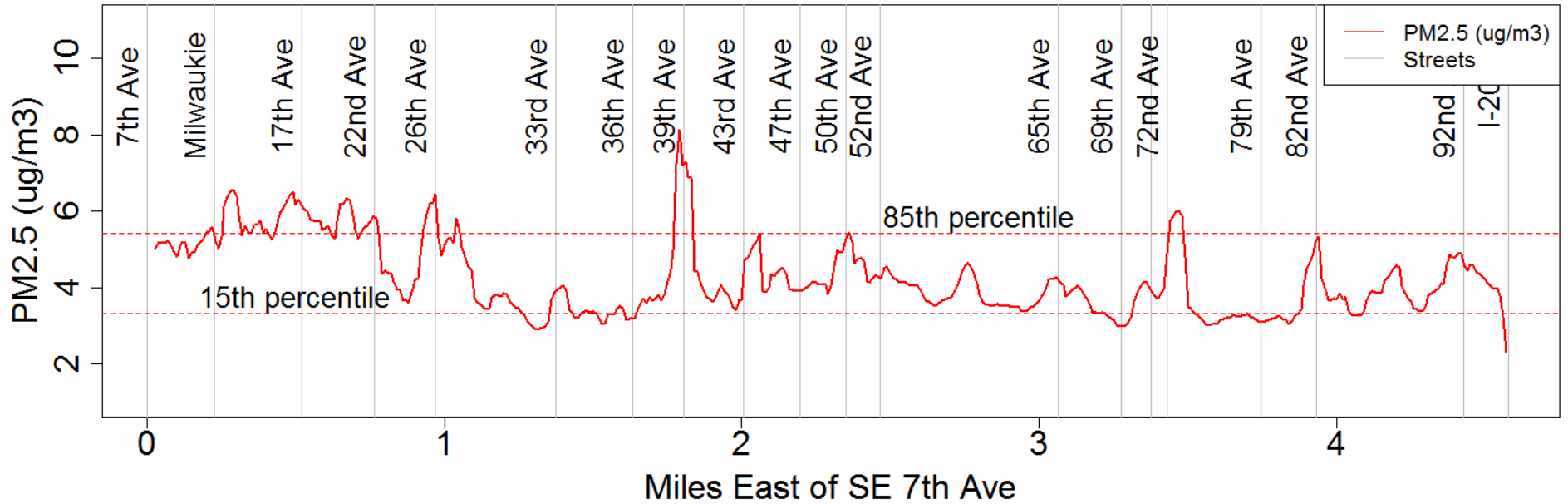
-  SCATS (Adaptive Traffic Signal) Data
-  Wavetronix SmartSensor HD Systems
-  Oregon DEQ Air Quality Monitoring Station
-  West End of Study Area
-  East End of Study Area

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

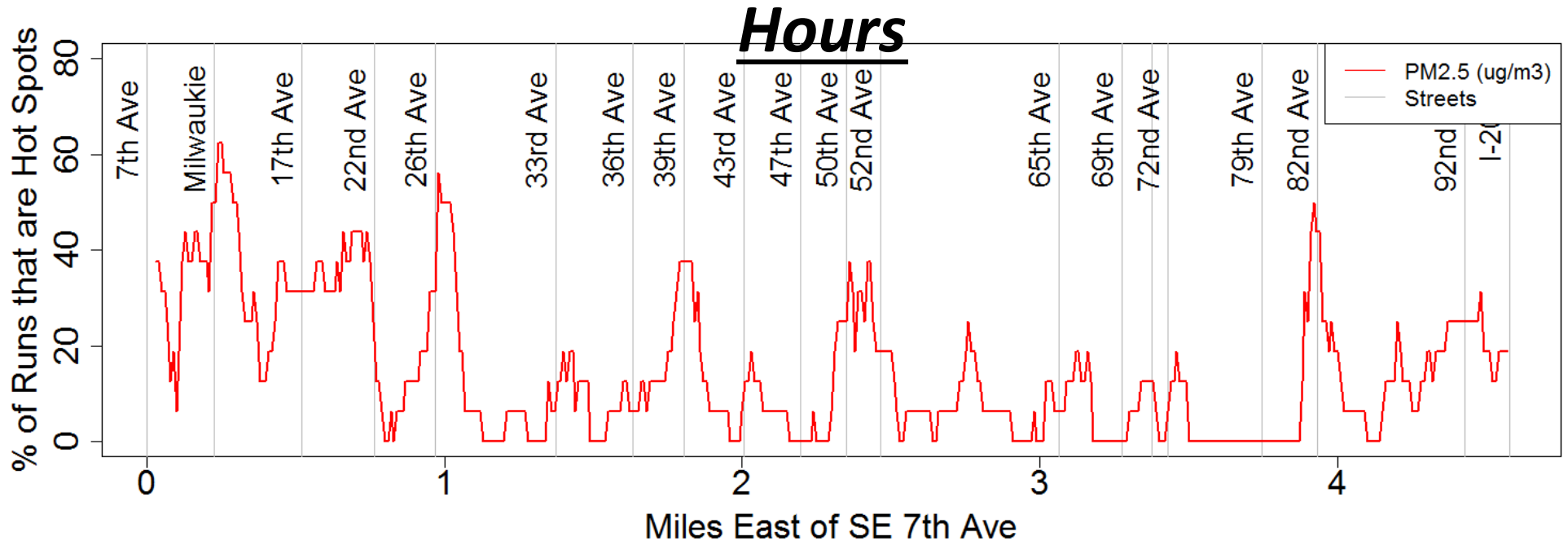
MOVING AVERAGE – All Study Hours



MOVING AVERAGE – All Study Hours



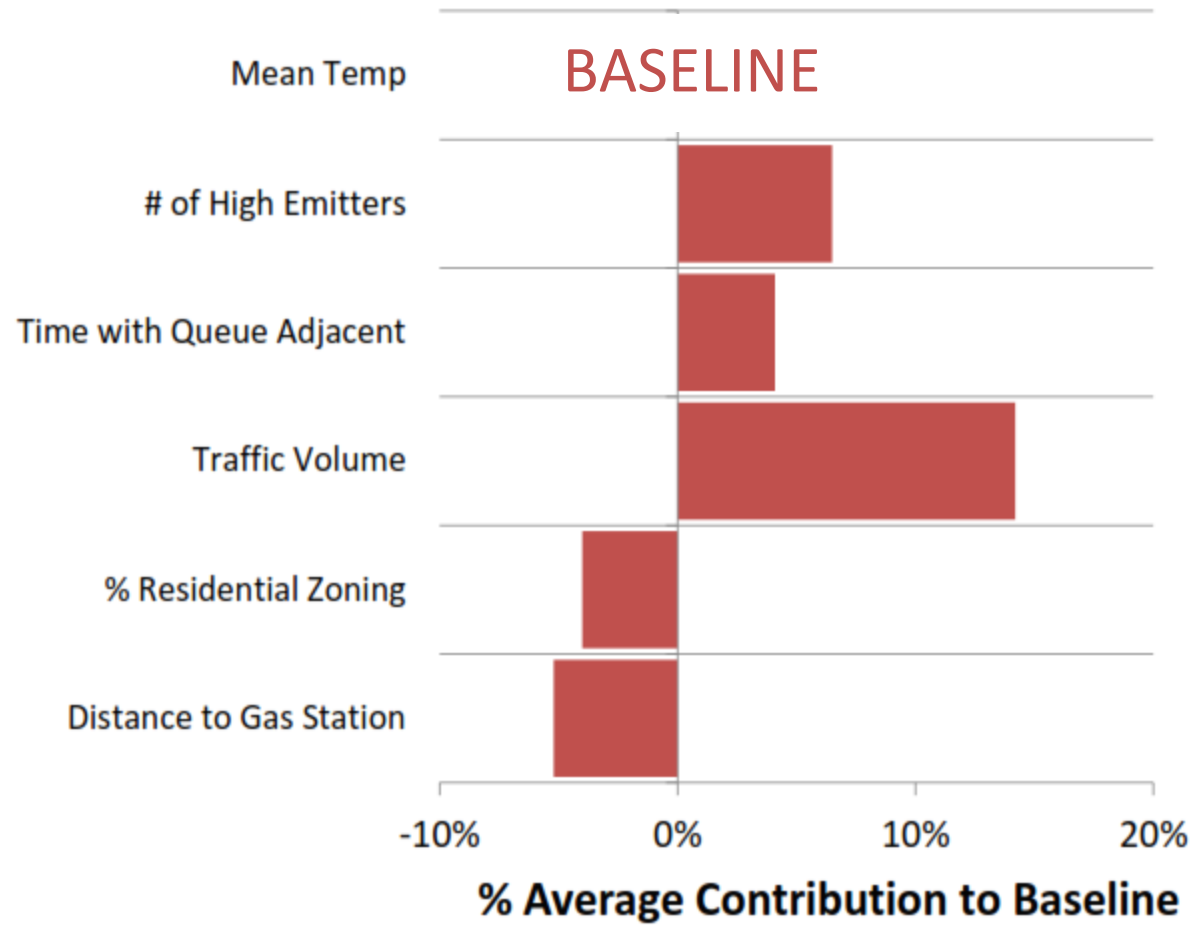
HOT SPOT FREQUENCY – All Study



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*

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)*

ACKNOWLEDGEMENTS

Oregon Transportation Research and Education Consortium (OTREC)
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Thesis Committee: Dr. Miguel Figliozzi, Dr. Robert Bertini and Dr.
Chris Monsere

Alex Bigazzi, Adam Moore (PSU)



QUESTIONS



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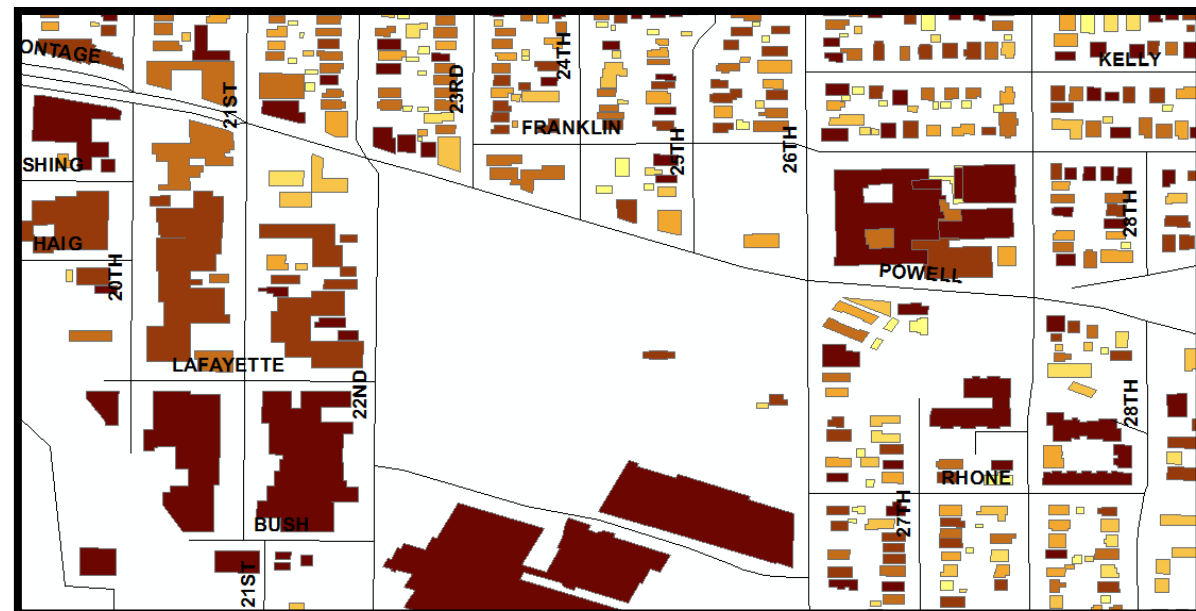
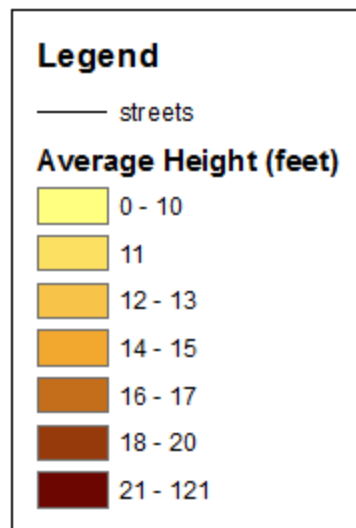
Related Masters Thesis will be available at <http://www.its.pdx.edu/publications.php>

Data

- 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*

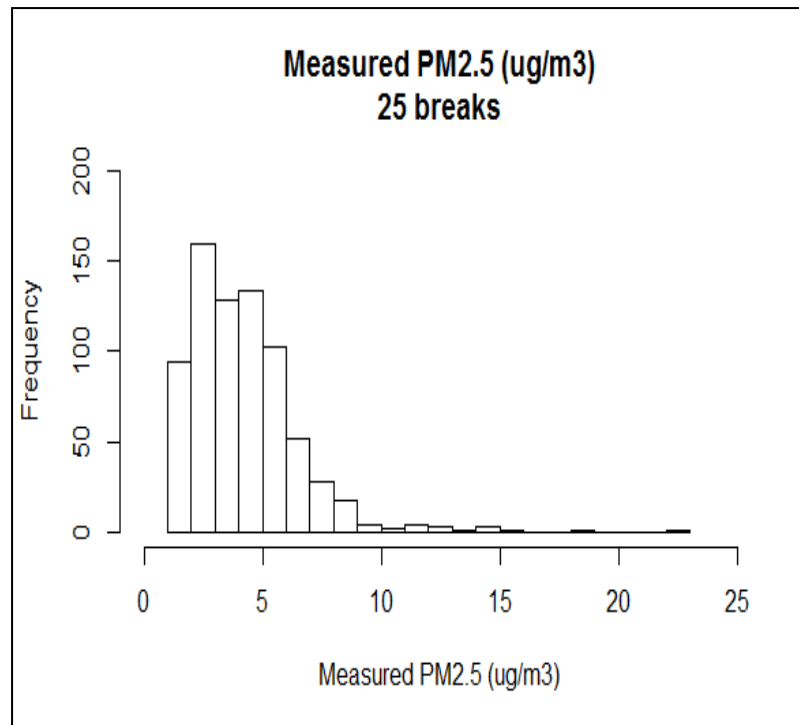
AVAILABLE DATA

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



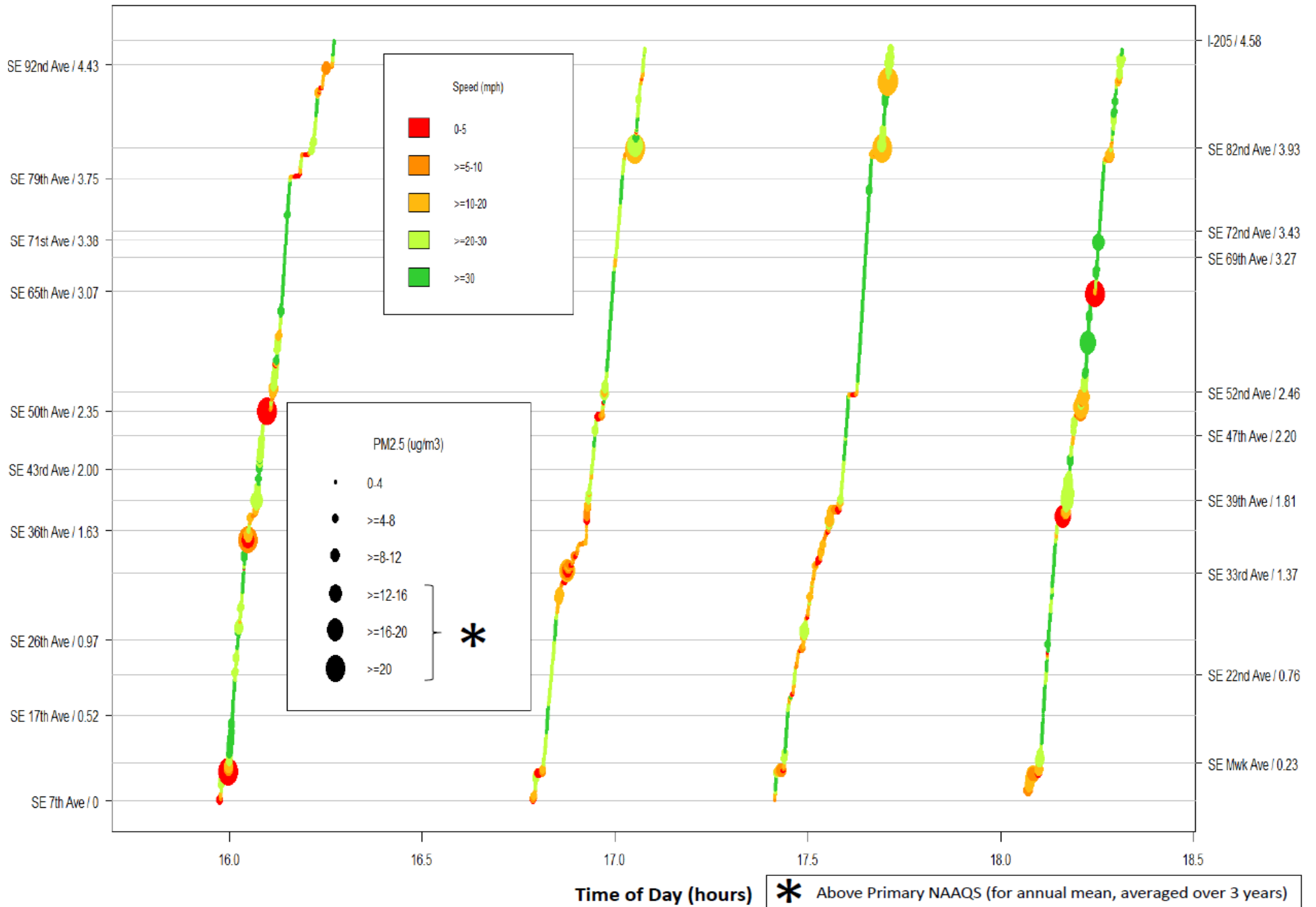
STATISTICAL ANALYSIS

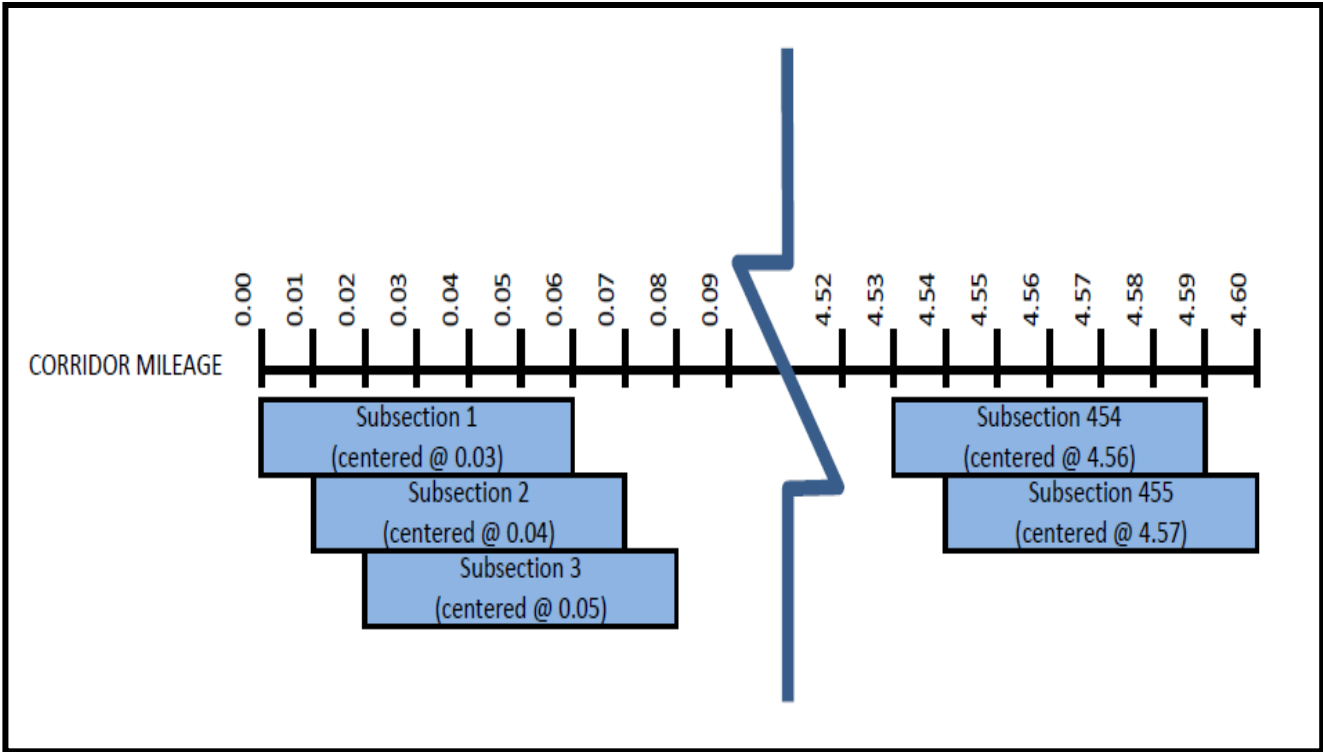
- 1) Mann-Whitney-Wilcoxon Test
- 2) Simple Regression Analysis
- 3) Multiple Regression Analysis

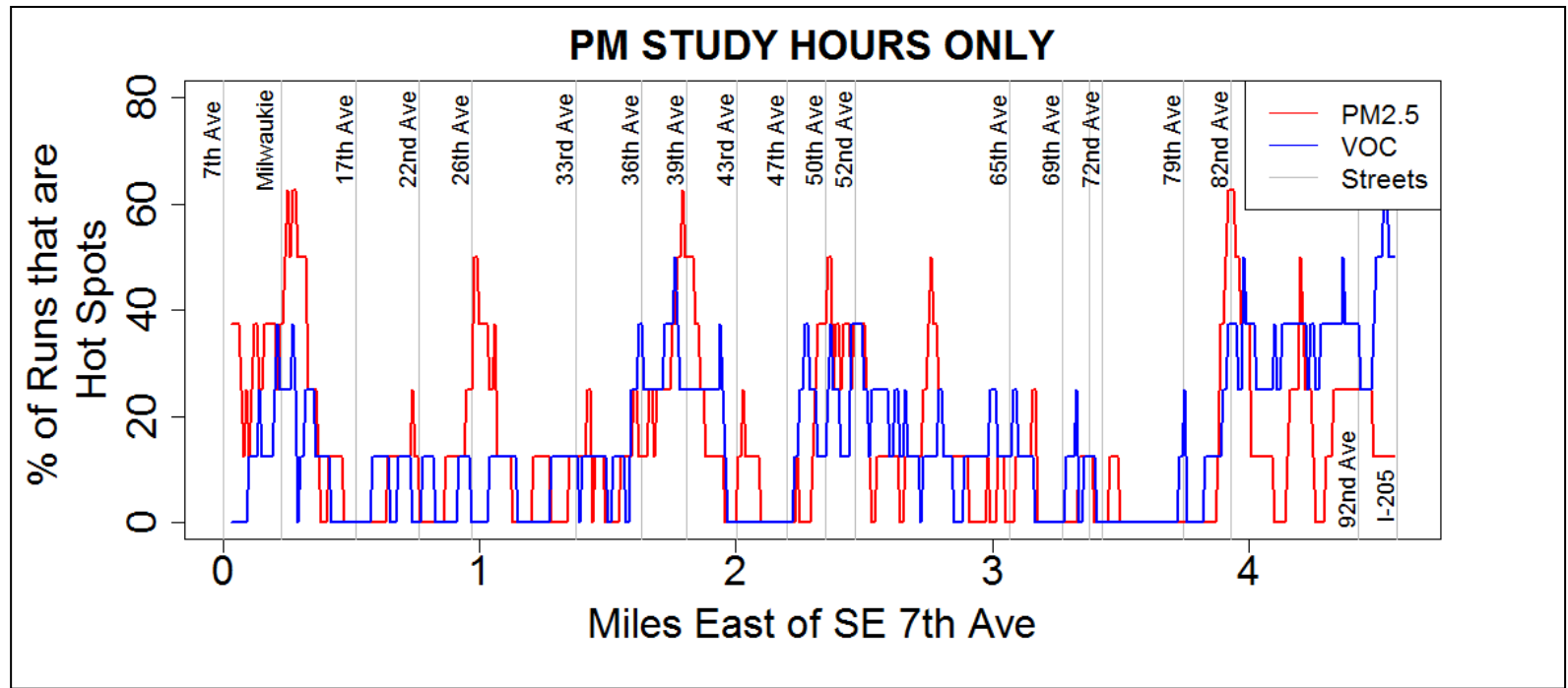
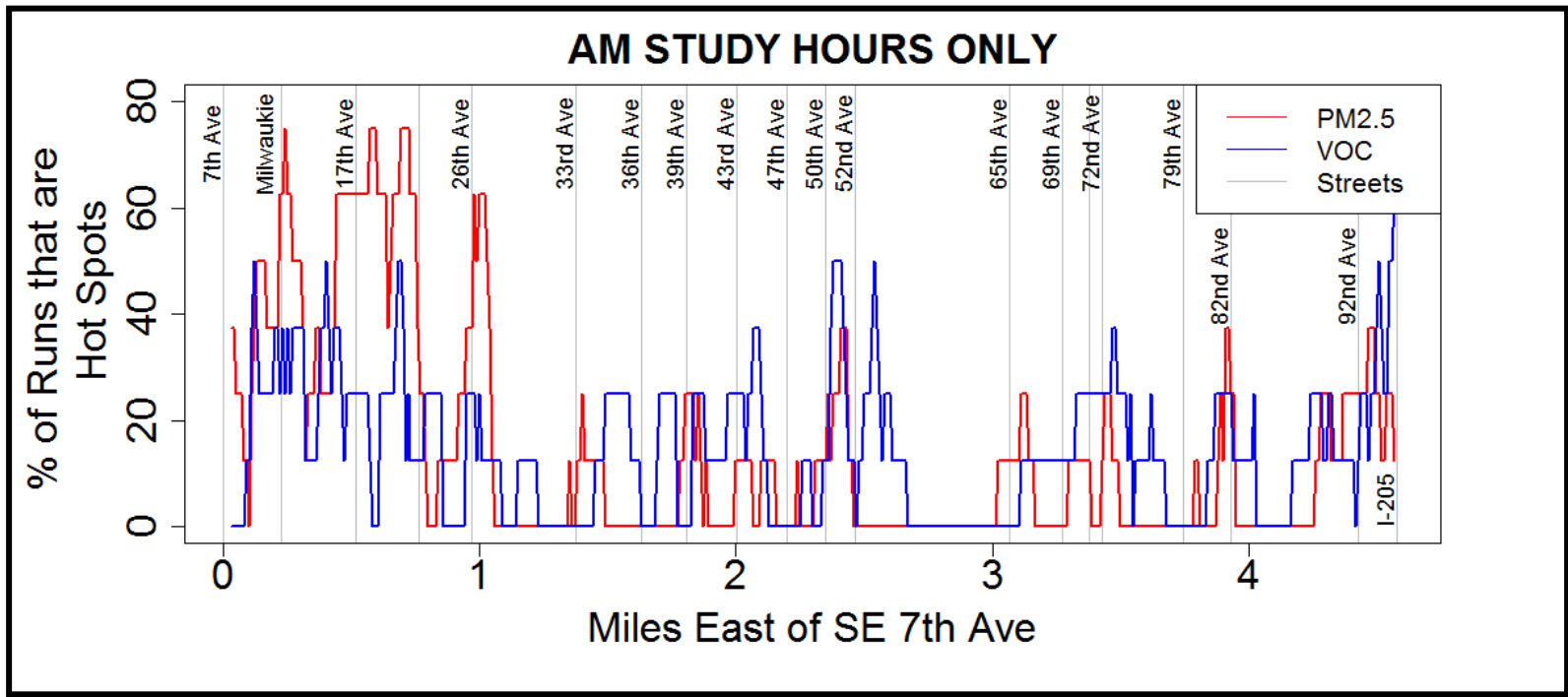


Skewed
distribution

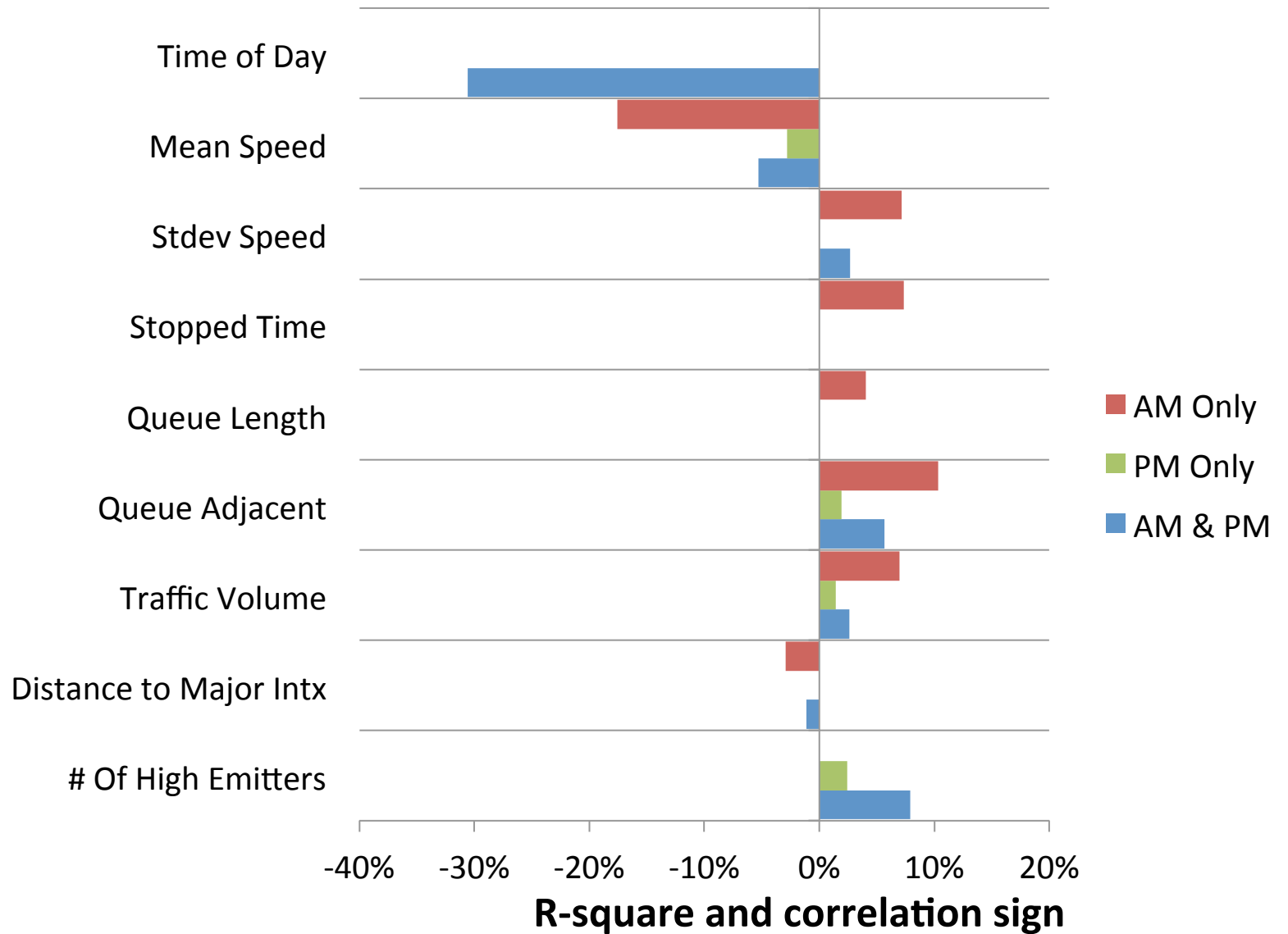
Time-Space-Air Quality Diagram







Simple Regression - Traffic



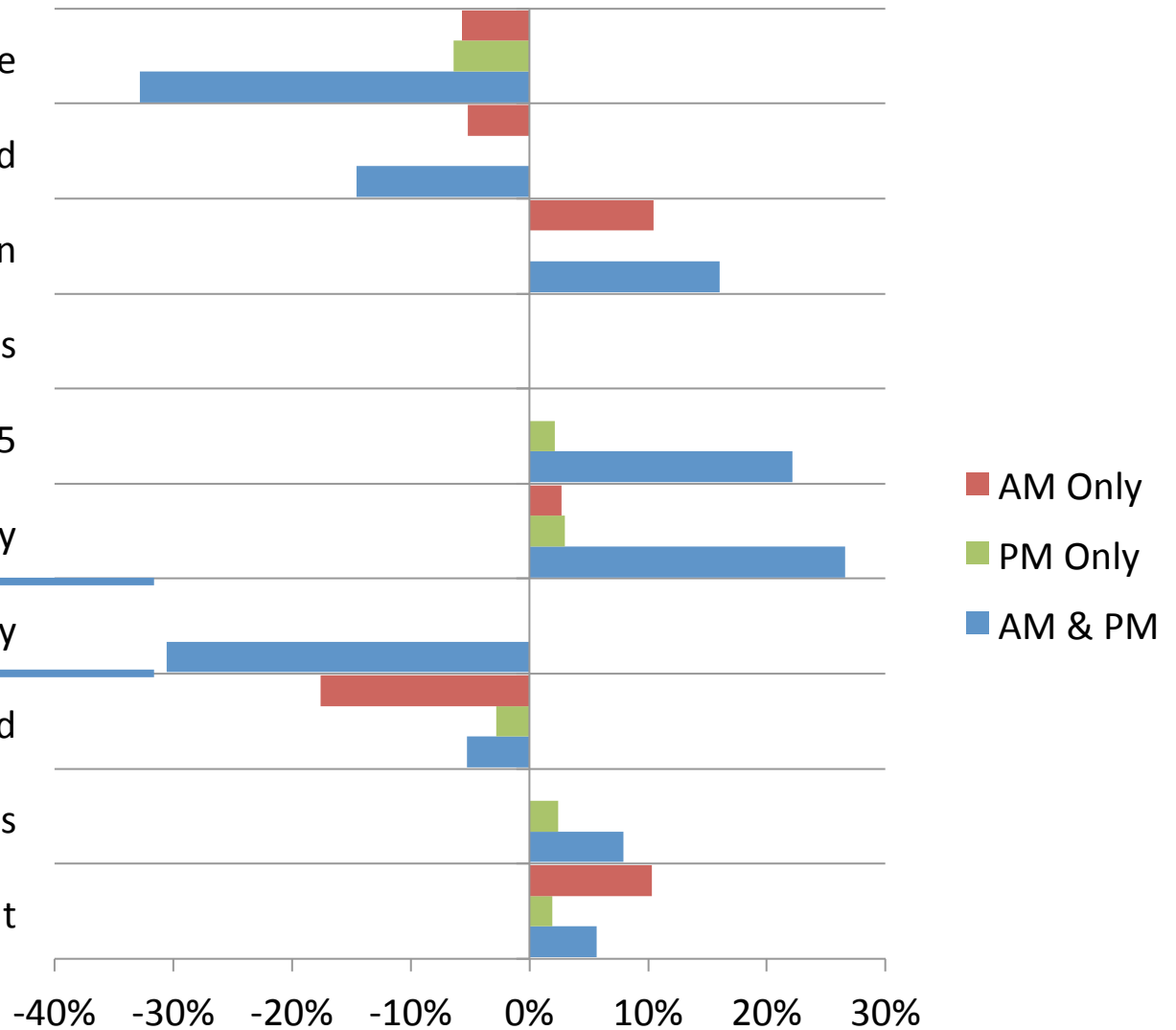
Simple Regression

Meteorology

Temperature
Wind Speed
Wind Direction Sin
Wind Direction Cos
Background PM2.5
Relative Humidity

Traffic

Time of Day
Mean Speed
Of High Emitters
Queue Adjacent

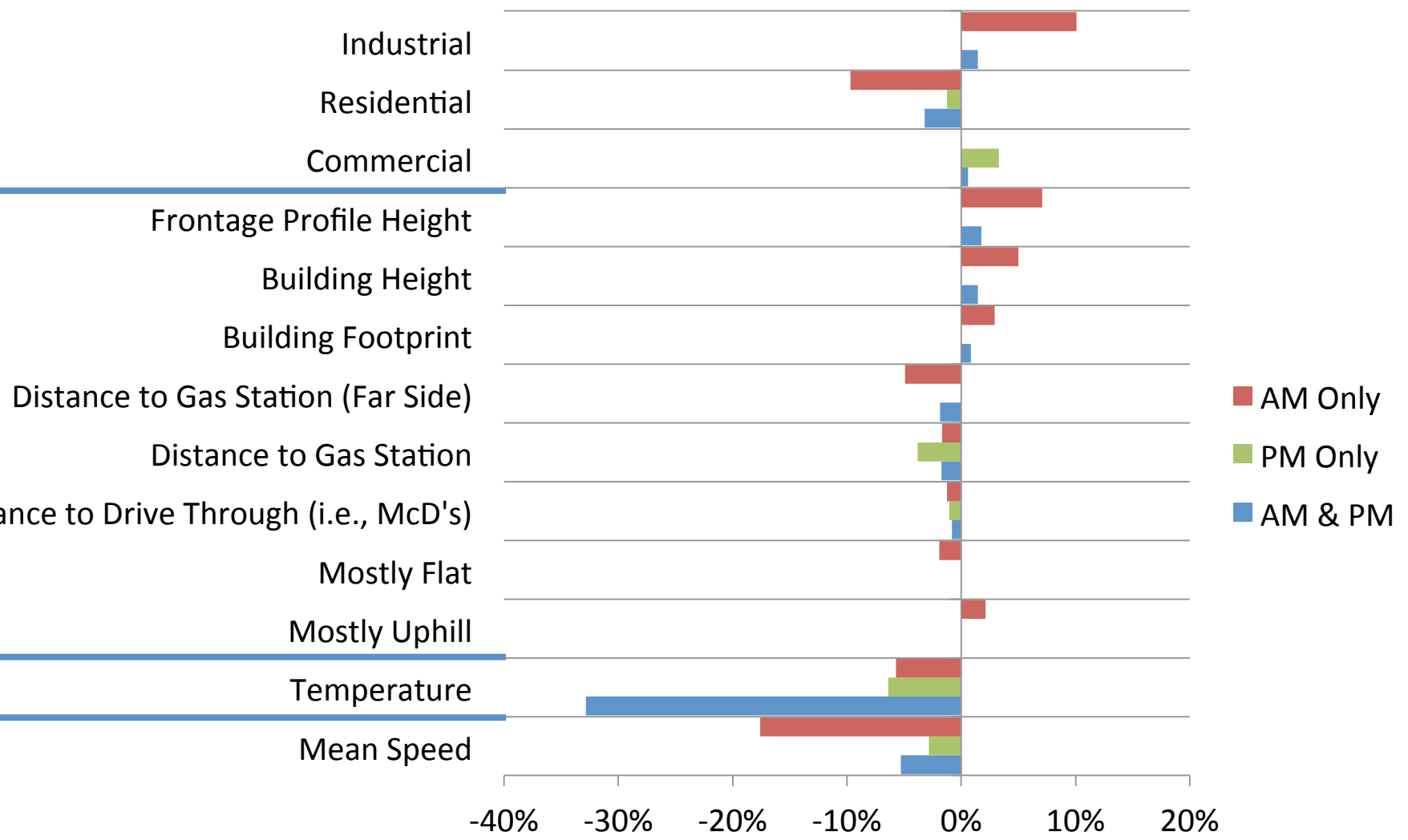


R-square and correlation sign

Simple Regression

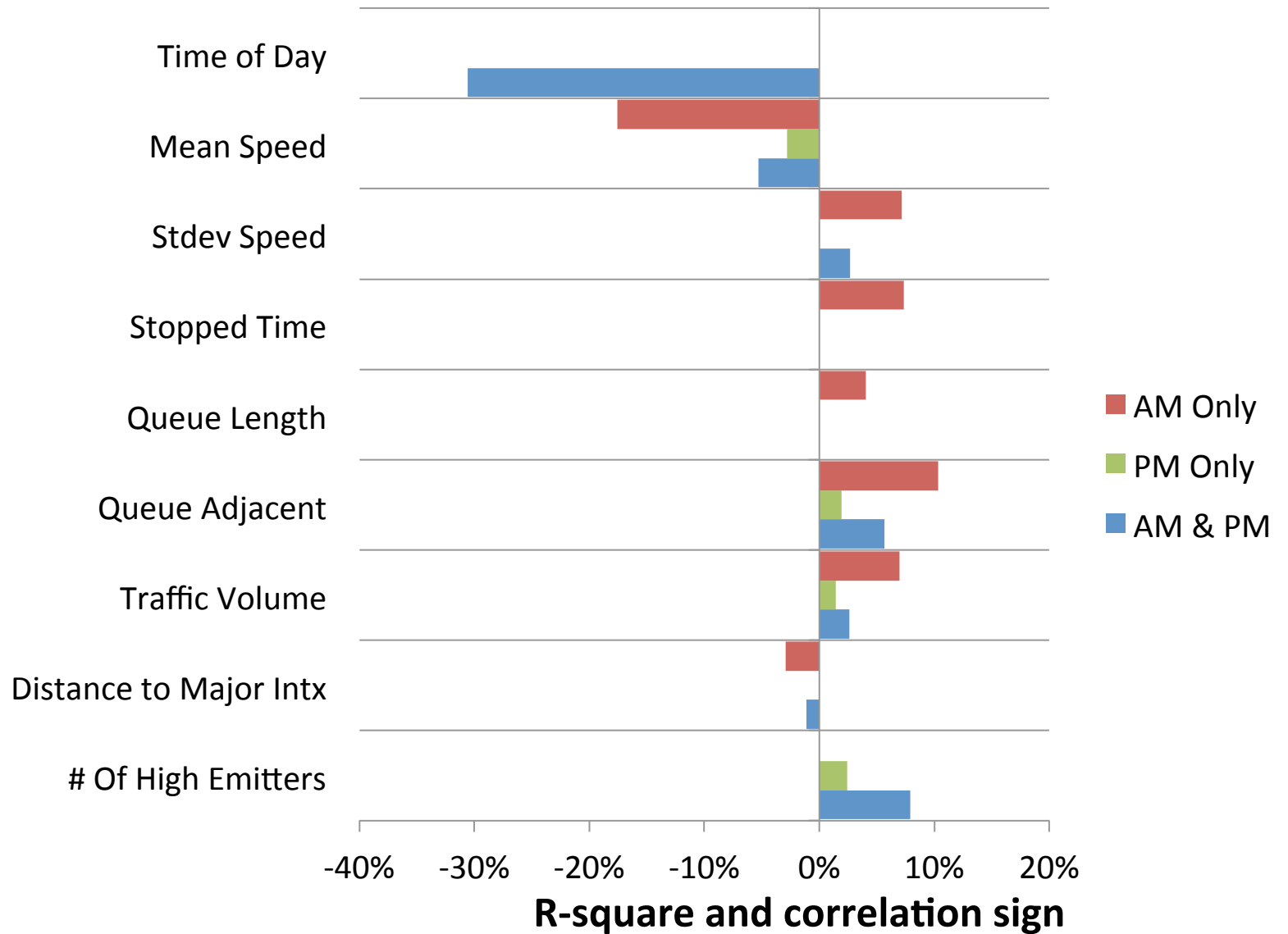
Zoning

Buildings



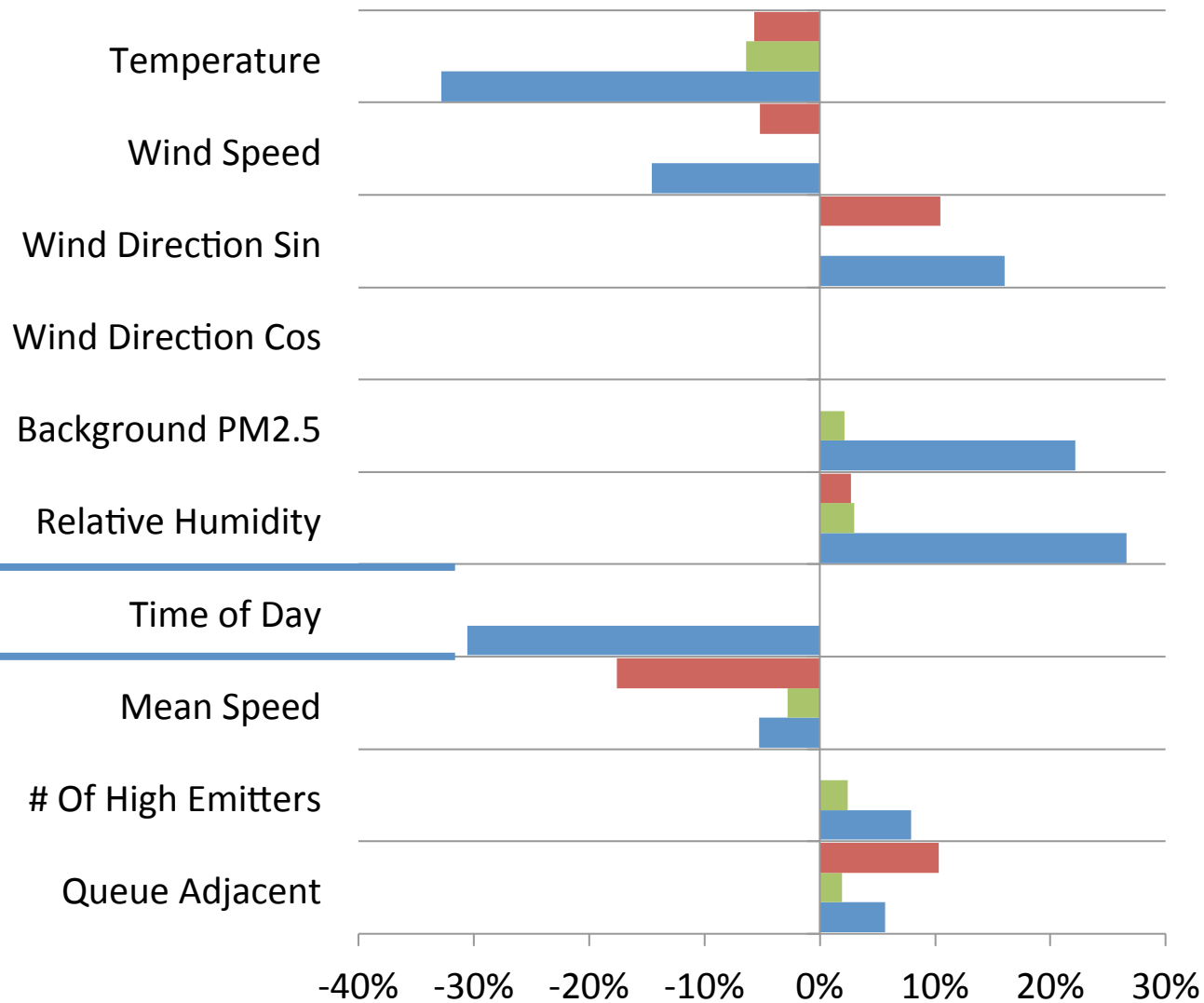
R-square and correlation sign

Simple Regression - Traffic



Simple Regression

Meteorology

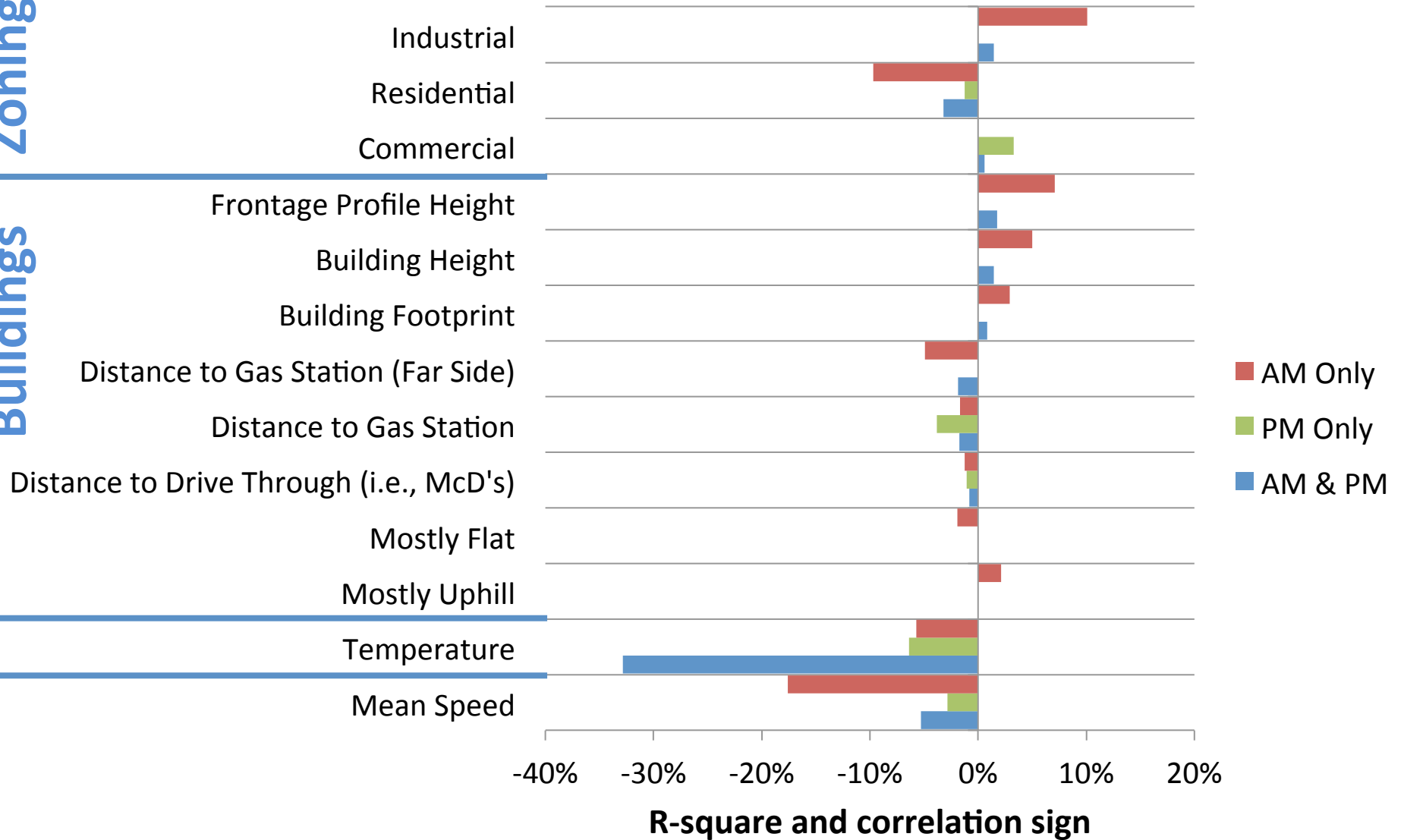


R-square and correlation sign

Simple Regression

Zoning

Buildings



Multiple Regression - % Contribution to Baseline

All Day Model - Example

Baseline

+7.2%

$$Y = 18.14 - 0.21(\text{Temperature}) + 2.00[\sin(\text{Wind Direction})] \\ + 0.22(\text{\#of high emitters}) + 1.41(\text{Time w queue adjacent}) \\ - 0.01(\text{\% Residential zoning}) - 0.12(\text{Distance to gas station})$$

+6.5%

-4.6%

-3.1%

+3.5%

Multiple Regression

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

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

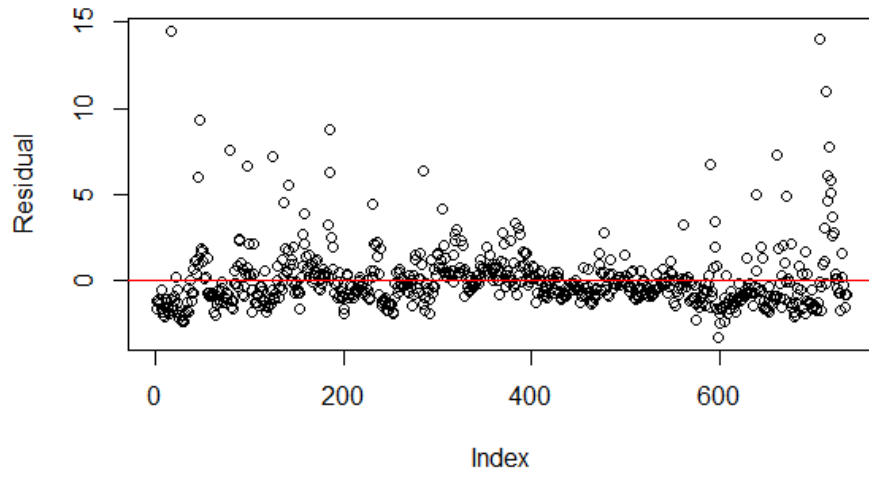
$$VIF_j = \frac{1}{1 - R_j^2}$$

- Correlations
- Log-linear Models

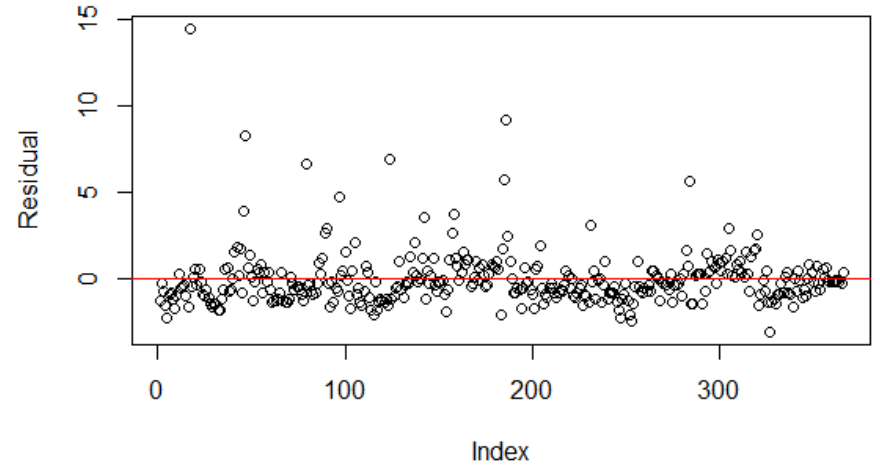
Correlations

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

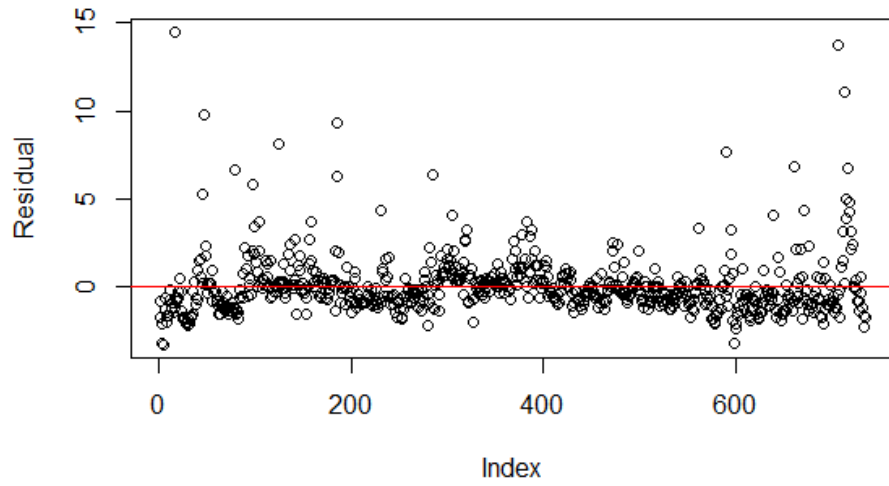
All Day



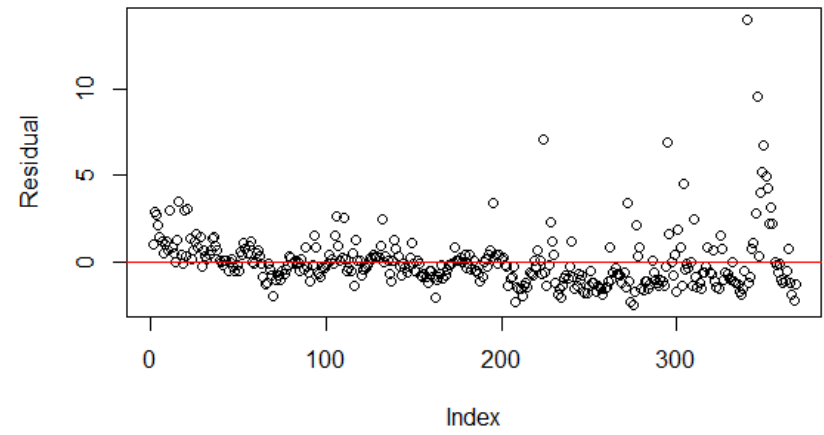
AM Only



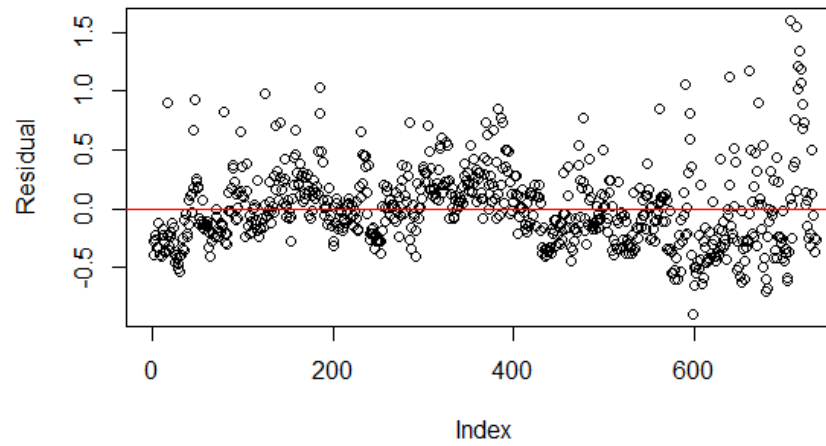
Split Day



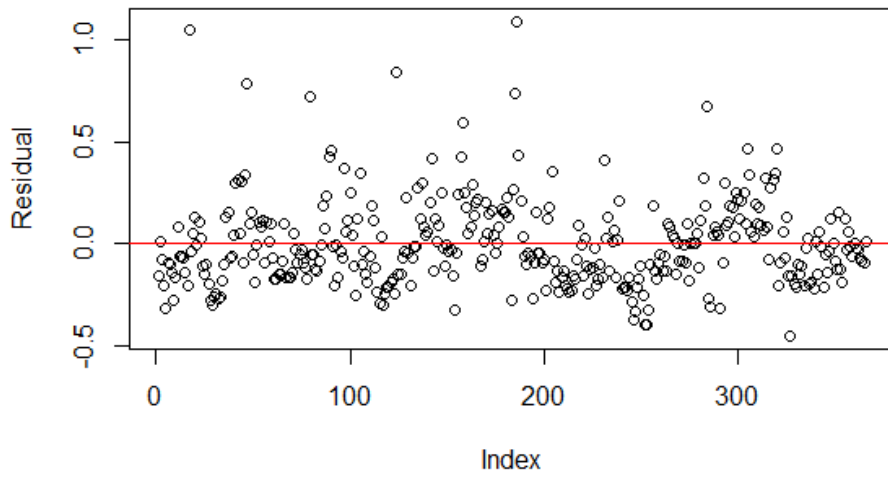
PM Only



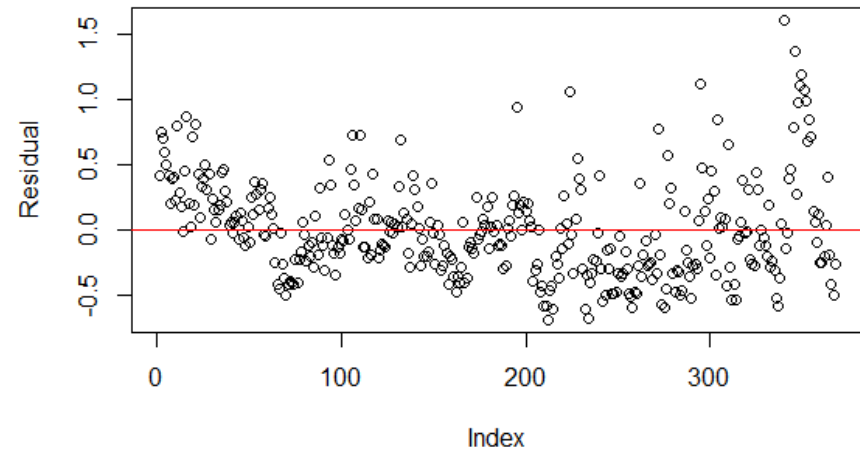
All Day, DV=log(y*1000)



AM Only, DV=log(y*1000)



PM Only, DV=log(y*1000)



Simple Regression

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%	