

Trees as Green Infrastructure: *Urban heat, air quality, & residential energy*

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Acknowledgments

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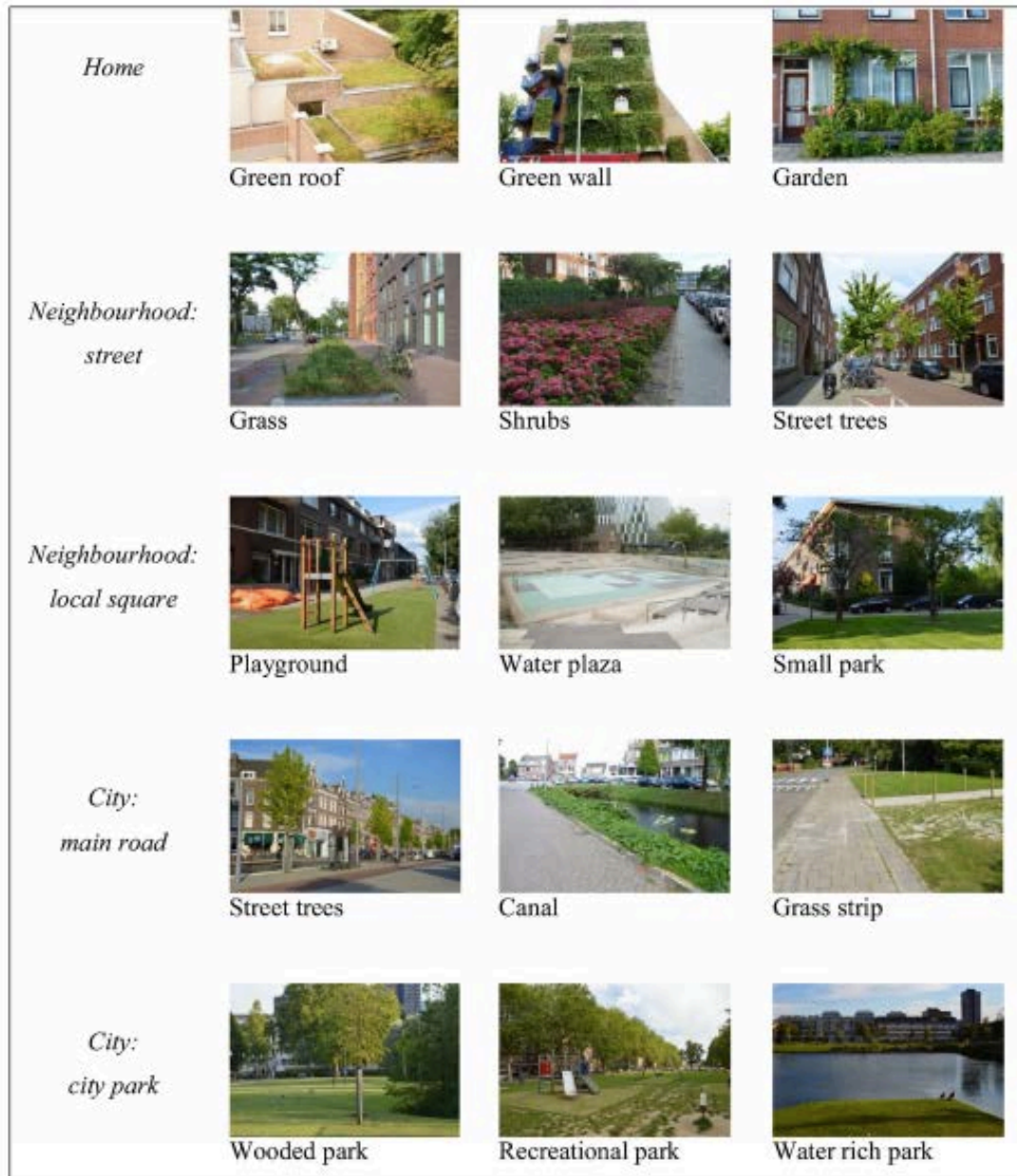
Meenakshi Rao, Air Quality Specialist, Oregon DEQ



Portland State
UNIVERSITY



What is Green Infrastructure?



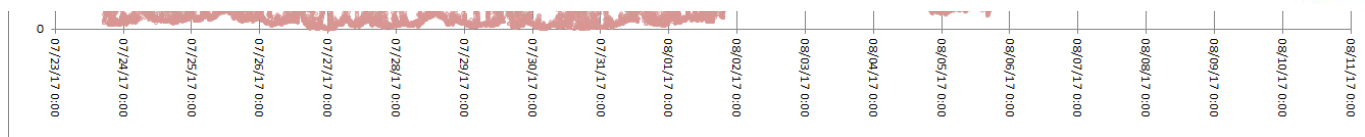
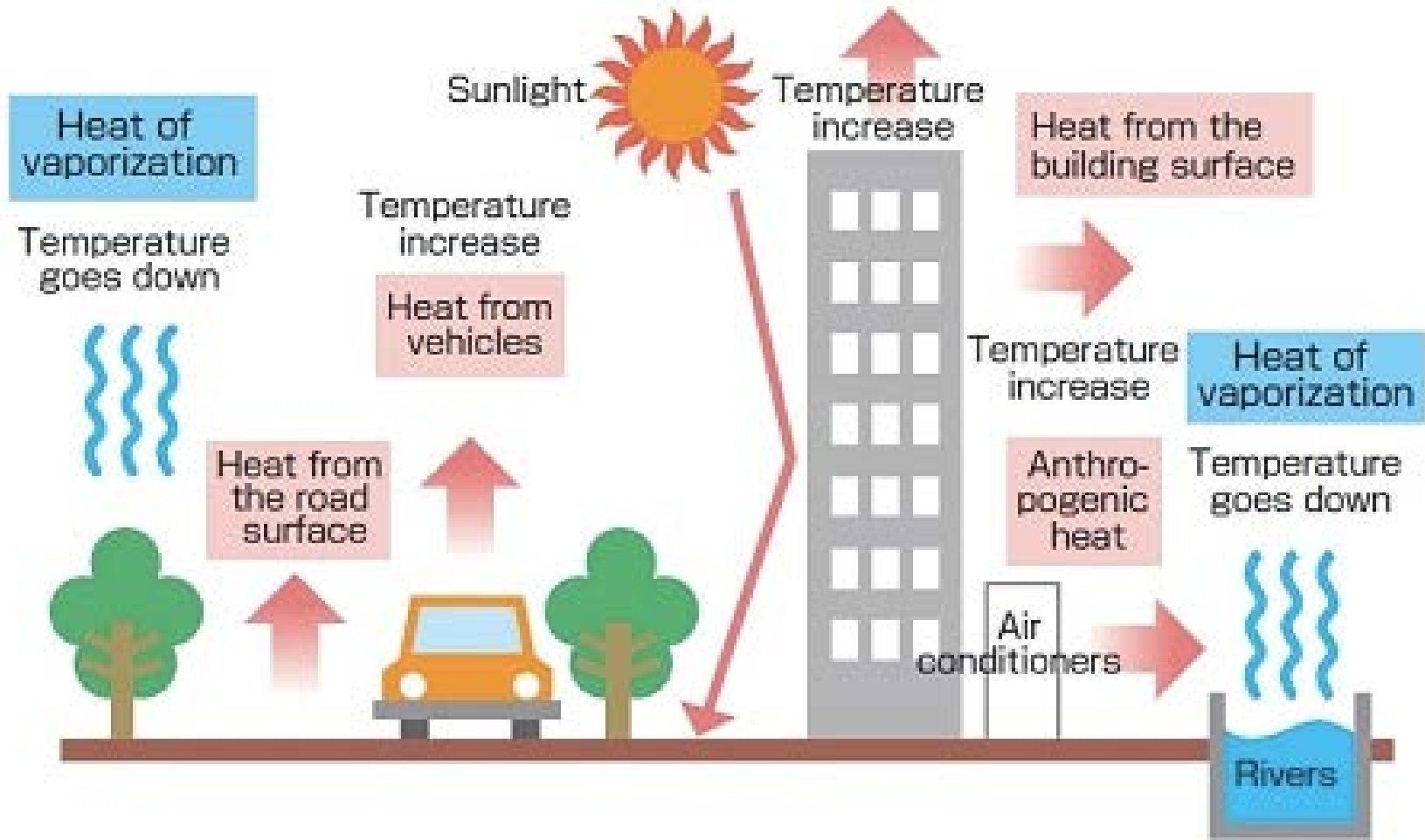
“It’s not what you look at that matters, it’s what you see...”

-- HDT

Trees as Green Infrastructure

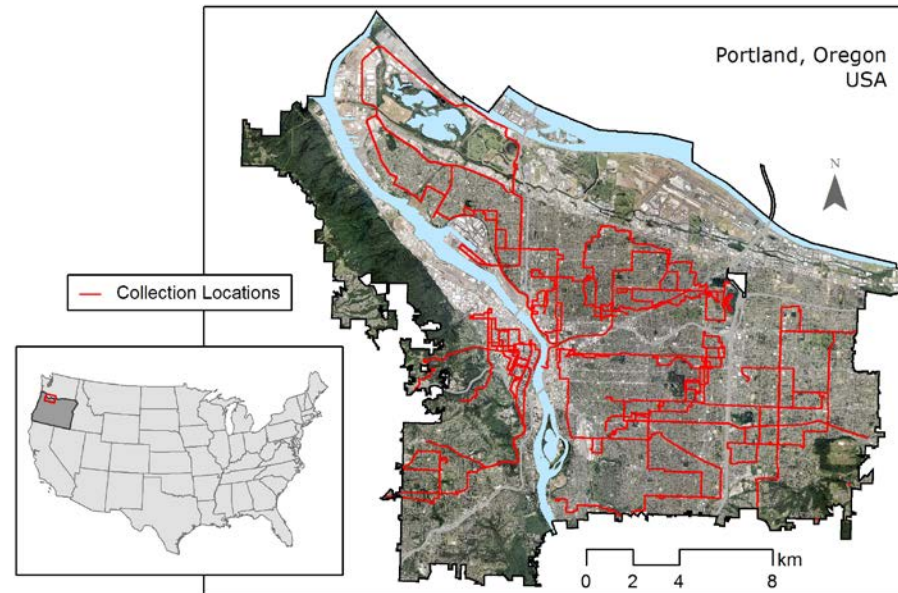
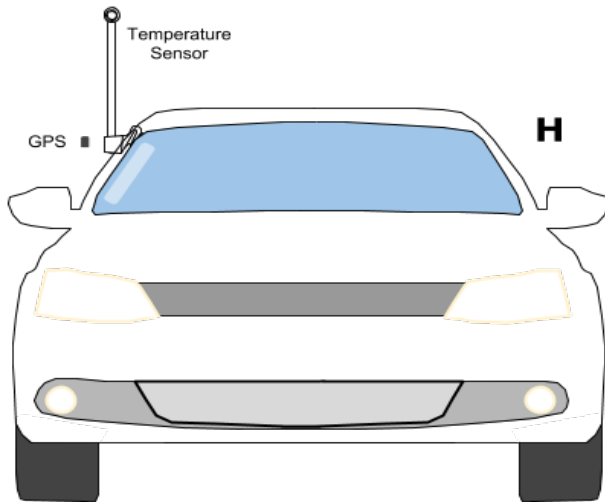
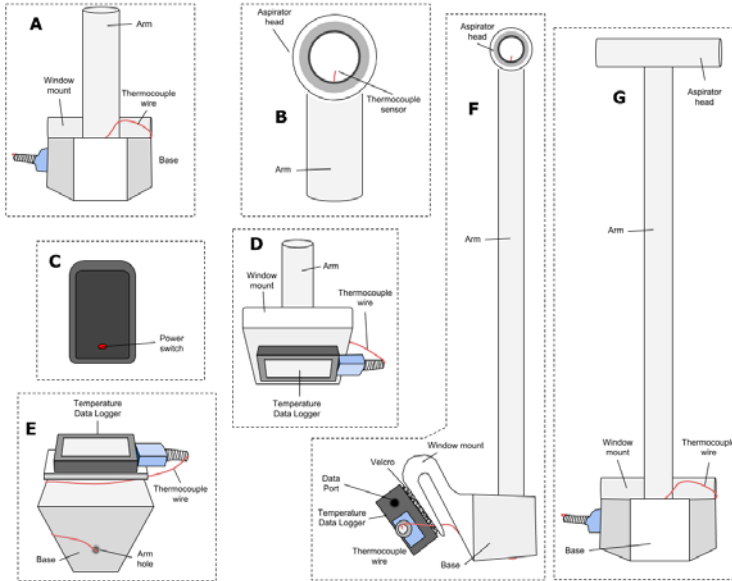
- For the Portland Metro Region, trees can....
 - ✓ Reduce temperatures for a development by 13⁰F (*urban heat*)
 - ✓ Reduce health care costs by over \$4.5M per year (*air quality*)
 - ✓ Reduce annual energy cost by over \$212/household (*energy use*)
 - ✓ Affect individual baby birth weight by over 60g (*human health*)

Record Breaking Heat and Degraded Air Quality



Data Collection

Urban Heat

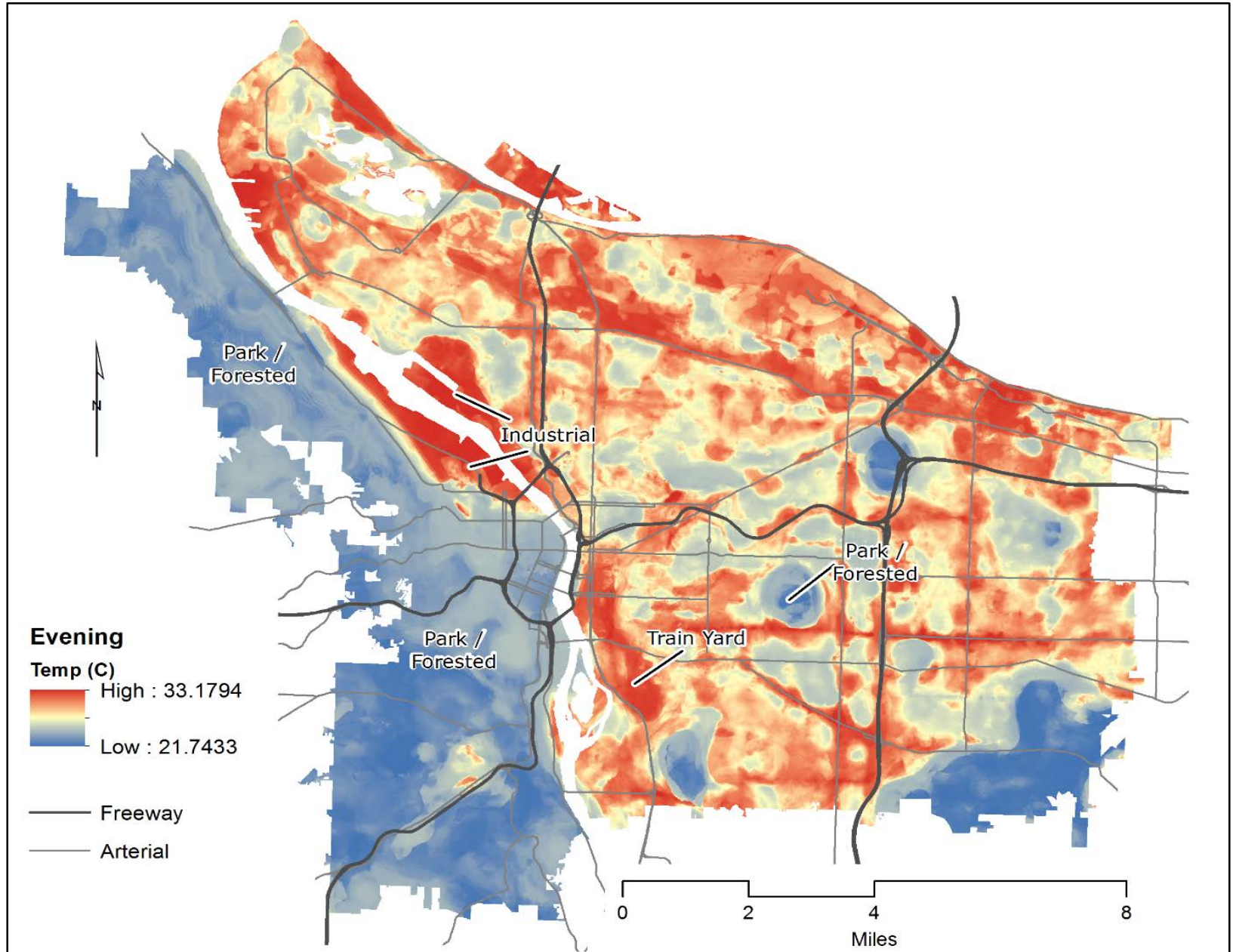


Cool Trees

- Six built environment factors helped to predict temperatures (one-meter resolution)
- From *most to least* important:
 - Percent Canopy: vegetation 3m or taller
 - Percent Vegetation: 3m or below
 - Biomass Density
 - Mean Building Height
 - Total Building Volume
 - Building Height Standard Deviation

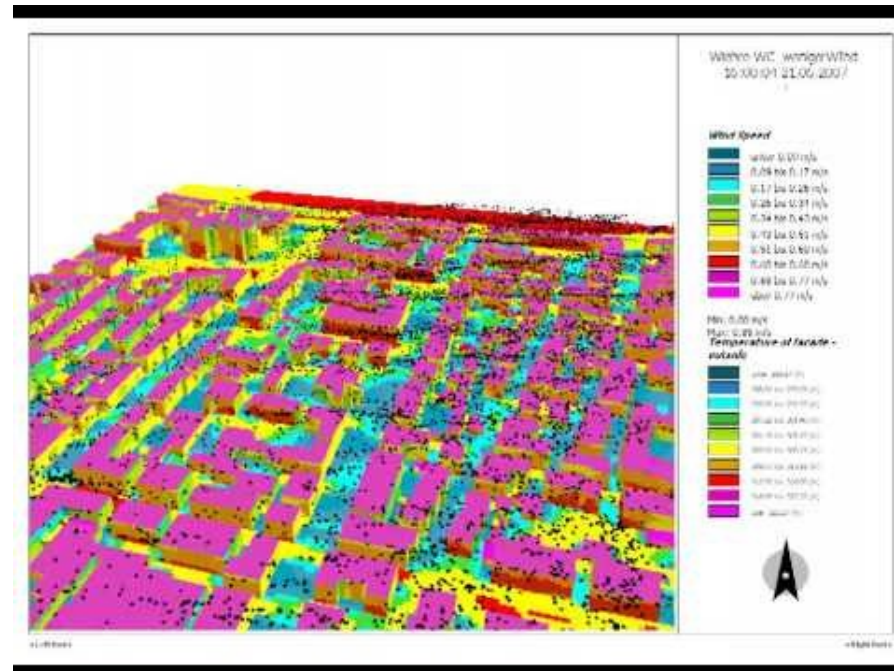
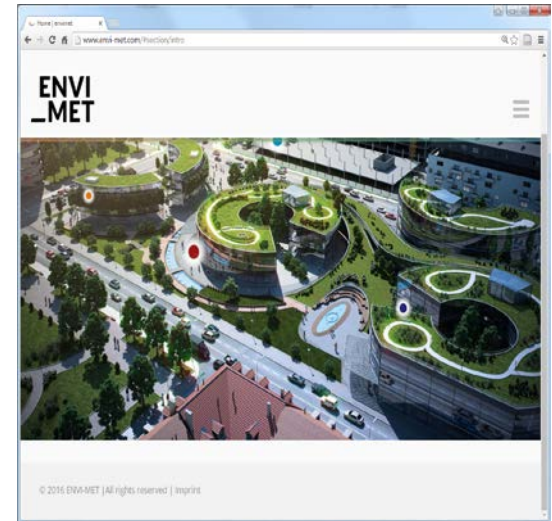
UHI Portland – Evening (7pm)

Urban Heat



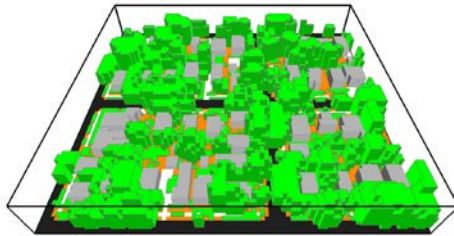
Predicting Temps

- ENVI-met 4 : High-resolution microclimate modelling system
 - A computational fluid dynamics model based several principles of
 - Fluid mechanics,
 - Thermodynamics, and
 - Atmospheric physics

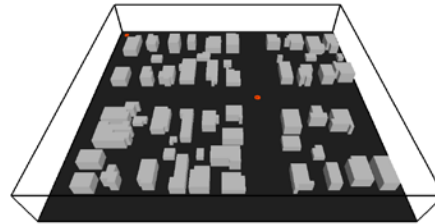


High Canopy Neighborhood

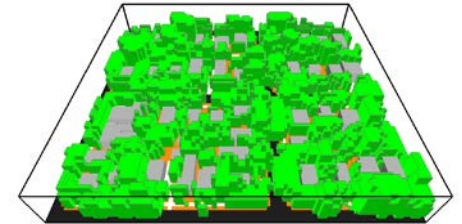
The role of trees in cooling the neighborhood



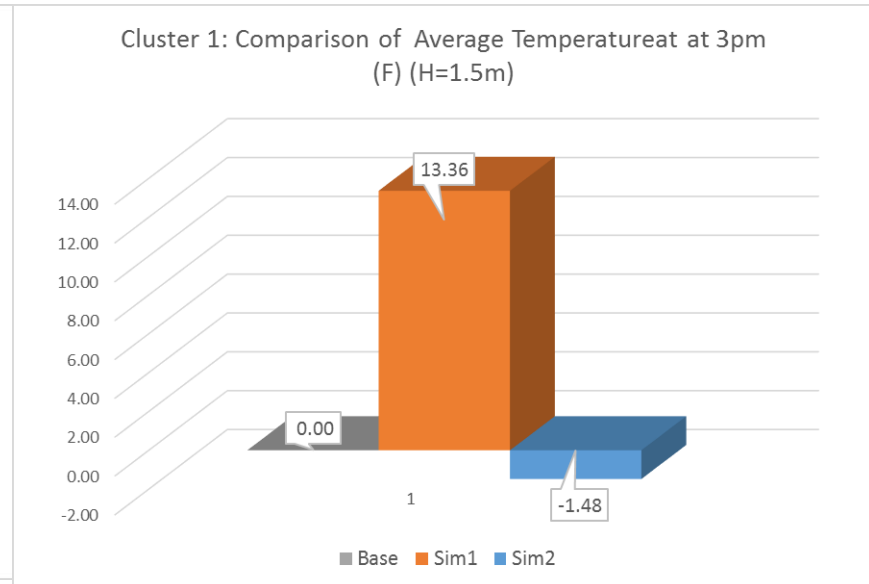
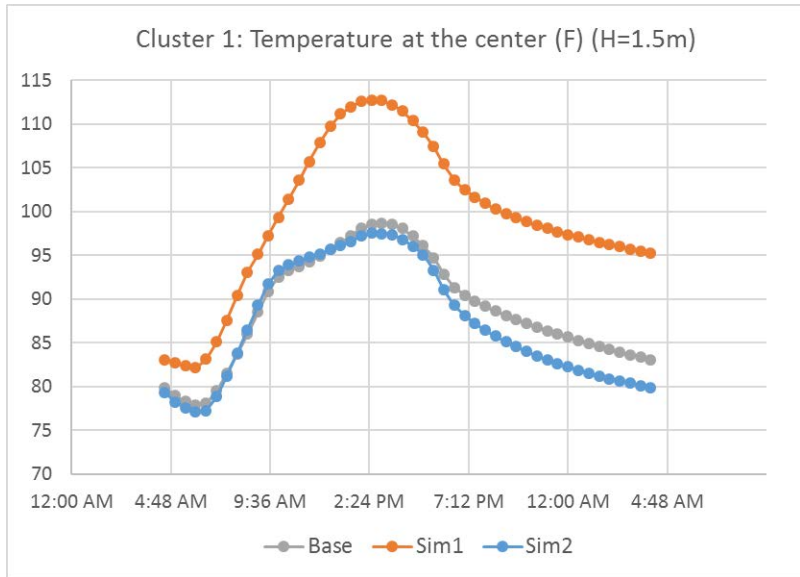
Base



Sim1

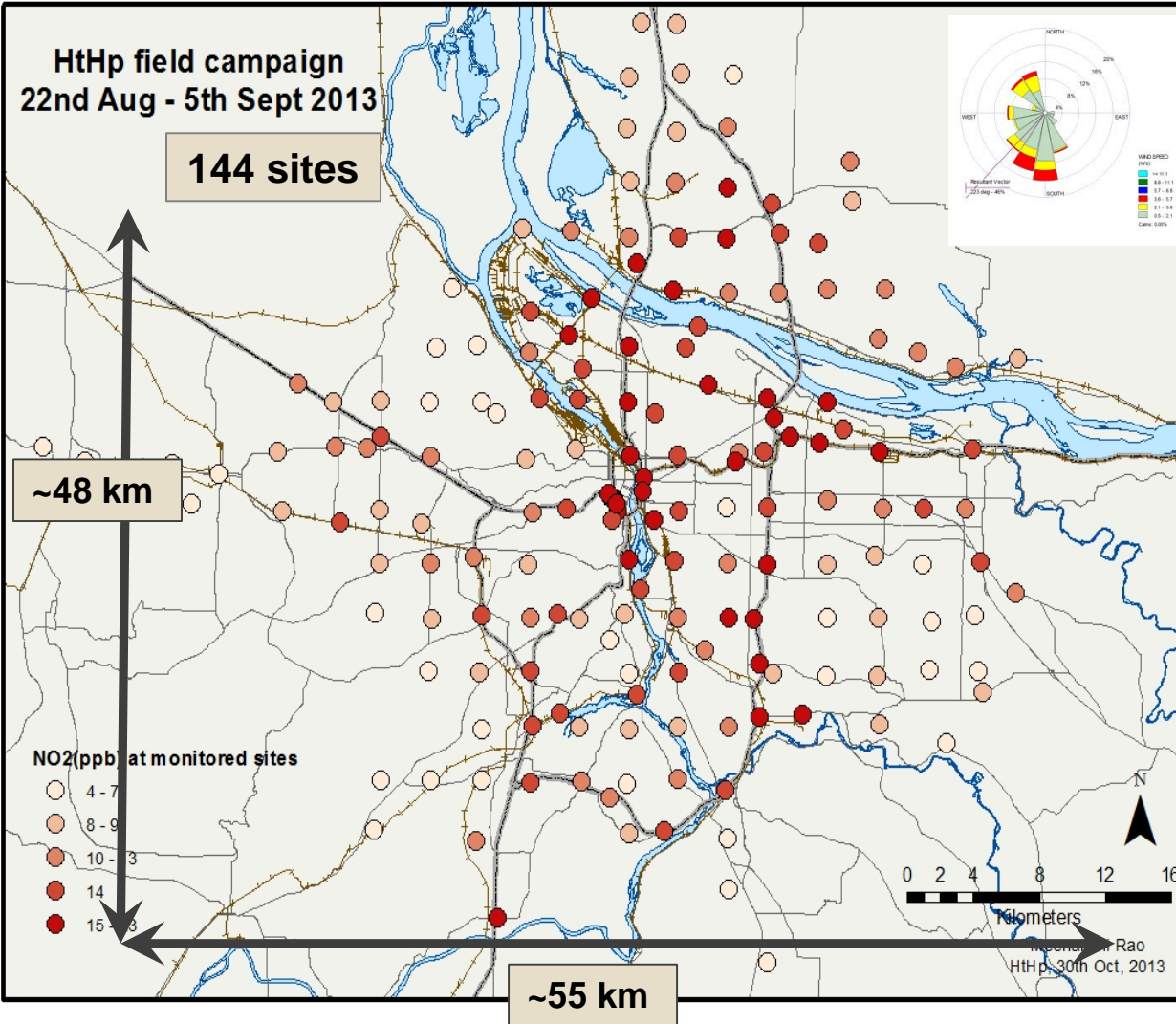
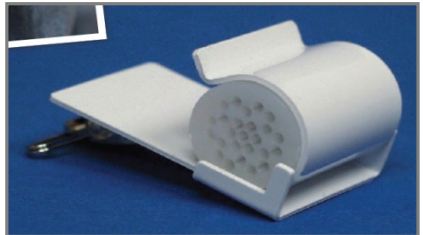
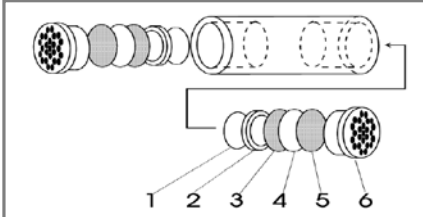


Sim2

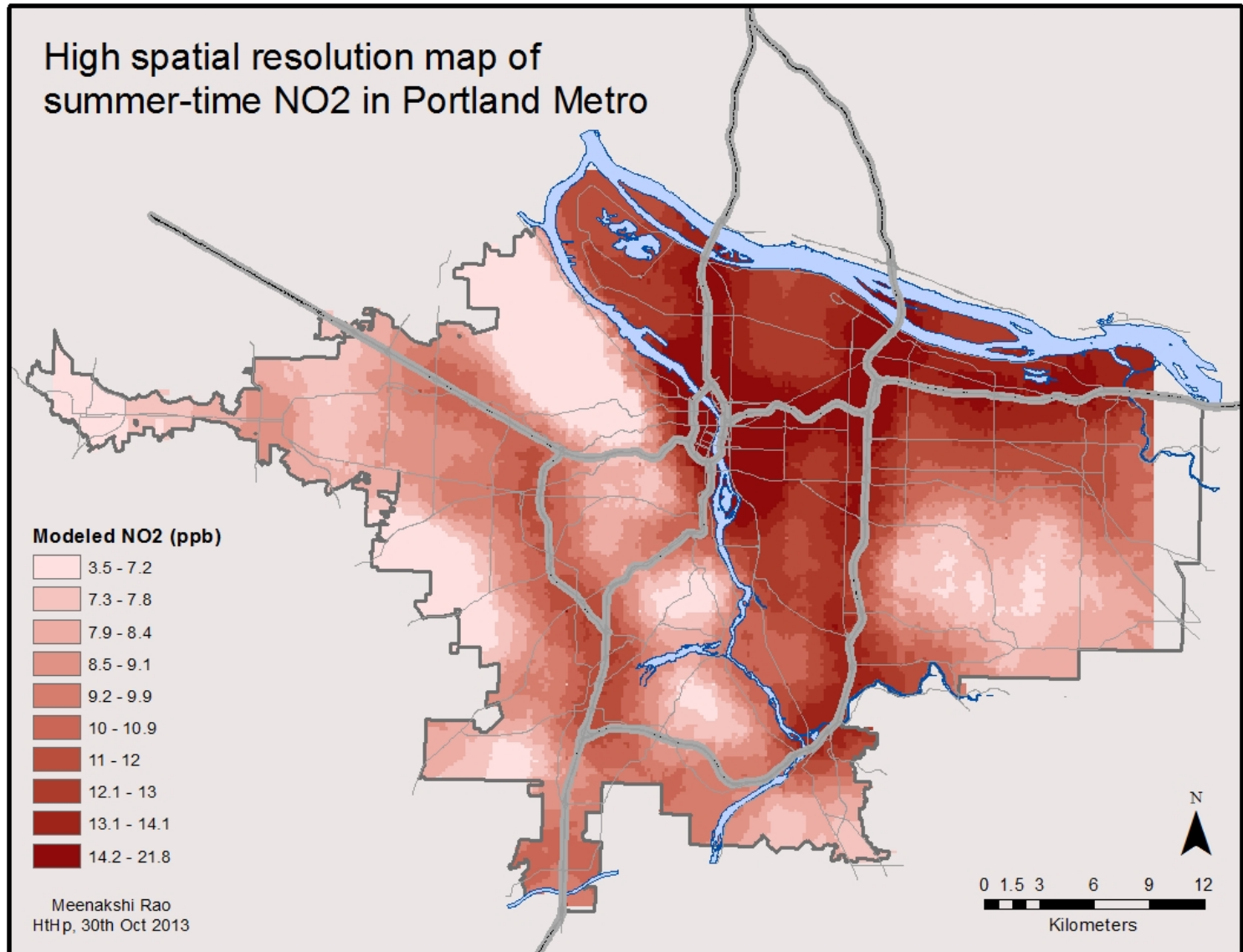


Data Collection

Air Quality



Mobile Air Pollutants



Built Environment and Air Quality

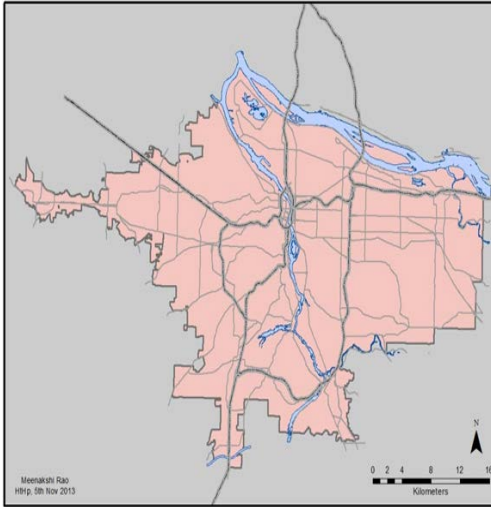
80% of the variation in air quality can be explained by six factors

Air Quality

	Air Pollutant
TRAFFIC VOLUME ON FREEWAYS within 1200m	19%
MAJOR ARTERIES within 500m	8%
ARTERIES within 350m	9%
POPULATION within 800m	10%
RAILROADS within 250m	4%
TREE COVER within 400m	-12%

Calculating Health Impacts

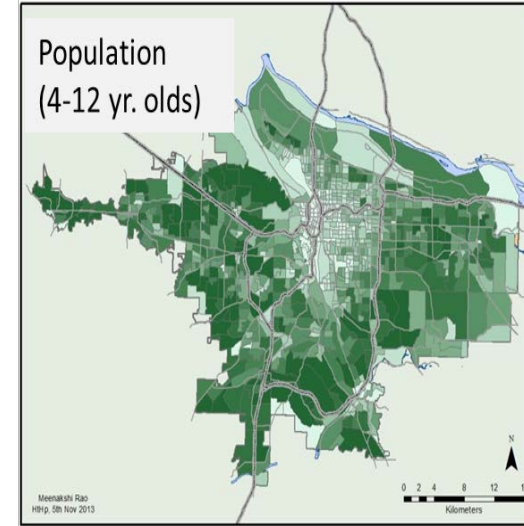
Air Quality



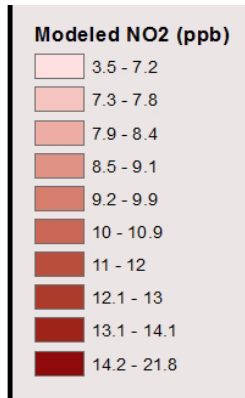
Regional Concentrations



Dose Response



Population 2013
(US Census Bureau)

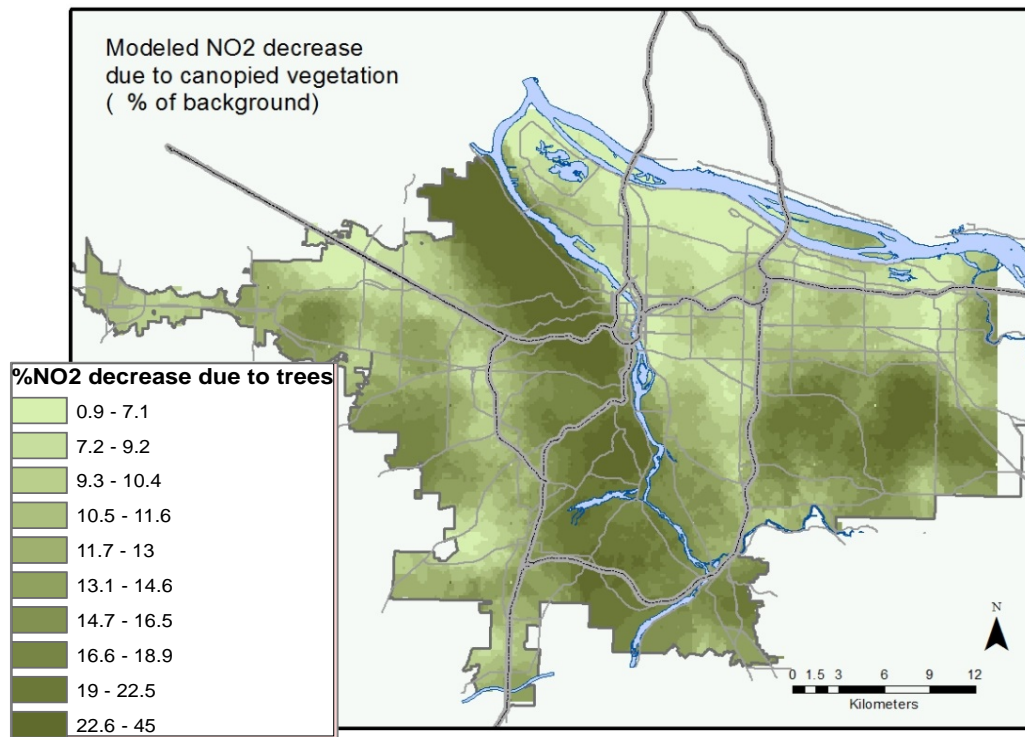


**Missed School Days
Emergency Room Visits
Hospitalizations
Lung Disease**

**Older Adults
Younger Adults
Lower Income
Minorities**

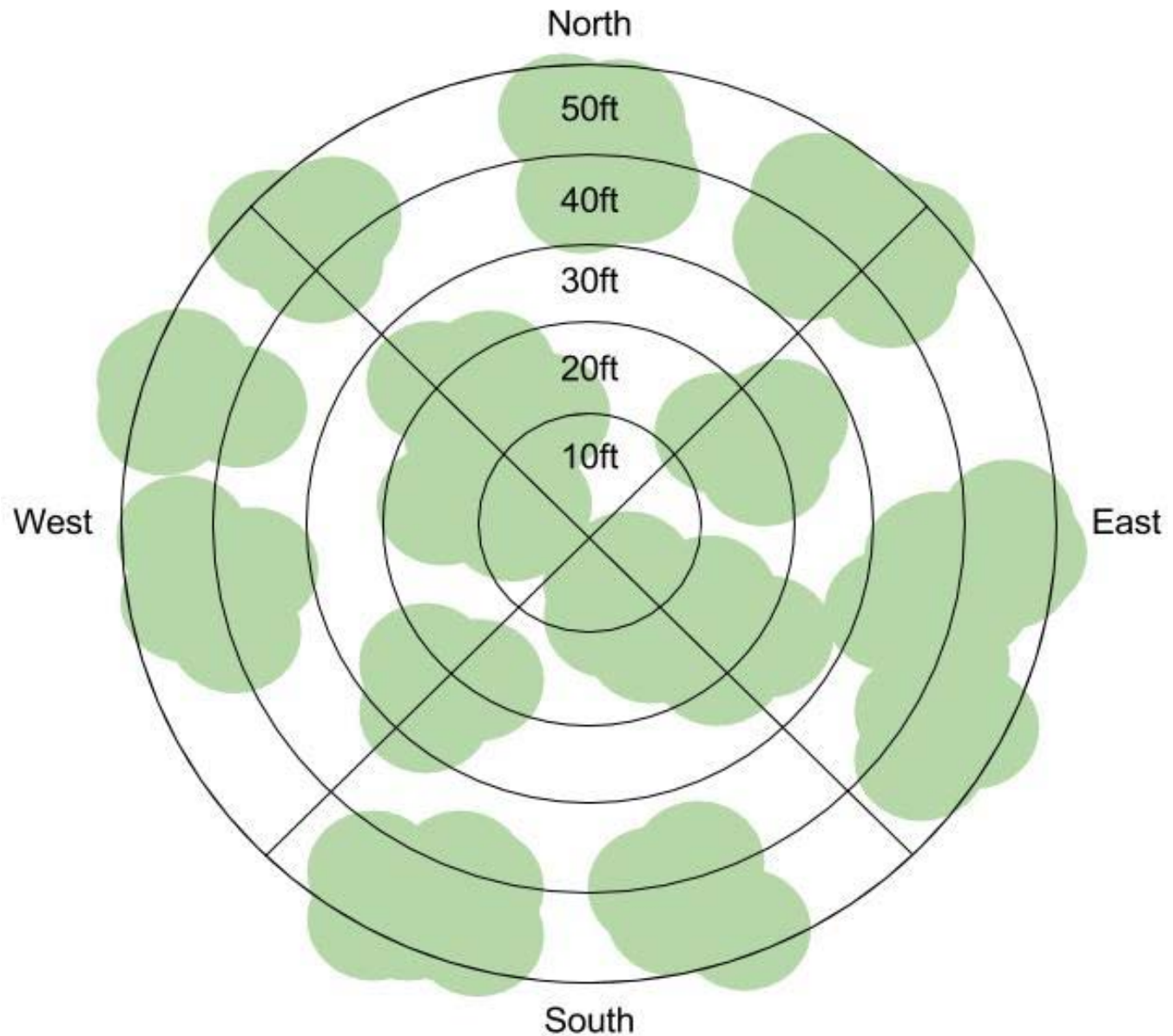
Health Value of Trees

Air Quality



Health Impact	Reduced Incidence due to Trees	Valuation of Benefit (in \$1,000,000)
Asthma Exacerbation, Missed school days (4-12 years)	6083	0.52
Asthma Exacerbation, One or More Symptoms (4-12 years)	17,663	2.76
Emergency Room Visits, Asthma (all ages)	46	0.01
HA, All Respiratory (65 and older)	49	0.92
HA, Chronic Lung Disease (less Asthma) (65 and older)	24	0.33
	Sum Value:	\$4.54

Data Collection



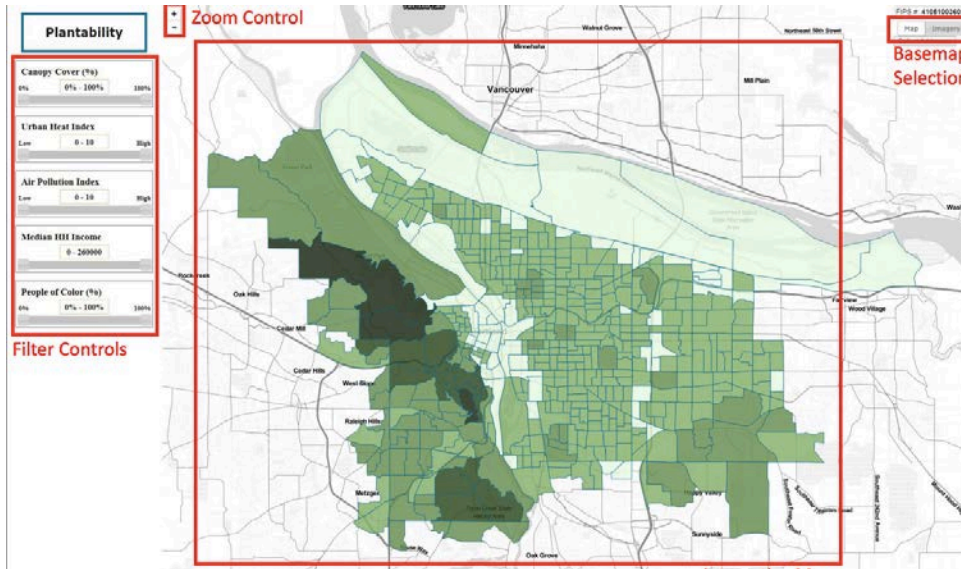
Residential Energy Use

Variable	Estimate	Std-Coeff.*	t Value
<i>(Intercept)</i>	1935.276	N/A	38.267
<i>Number of Electricity Meters (Count)</i>	1240.635	0.764925	645.72
<i>Building Value (USD)</i>	0.001969	0.171198	101.756
<i>Building Square Footage (ft²)</i>	0.172675	0.085094	52.945
<i>Parcel Area (acres)</i>	415.3556	0.072	56.969
<i>Building Age (Years Old)</i>	0.565482	0.026114	23.42
<i>Canopy Cover, N, 10ft</i>	61.91171	0.008682	6.028
<i>Land Value (USD)</i>	0.000129	0.006689	4.712
<i>Canopy Cover, S, 30ft</i>	-40.8586	-0.00572	-4.036
<i>Canopy Cover, W, 40ft</i>	-46.2597	-0.00648	-4.902
<i>Canopy Cover, E, 30ft</i>	-50.824	-0.00708	-4.978
<i>UHI, Morning (° C)</i>	-144.873	-0.05695	-48.512

Model Statistics: n = 61,710; Adjusted R² = 0.757; RMSE = 903; AIC = 3584596

*Standardized relative influence on the model

Community Engagement Effort



Finding locations to plant trees as a next step for engaging communities

Tree Cover (%)

0% 0 - 100 100%

Urban Heat Index

Low 0 - 10 High

Air Pollution Index

Low 0 - 10 High

Social

Right of Way

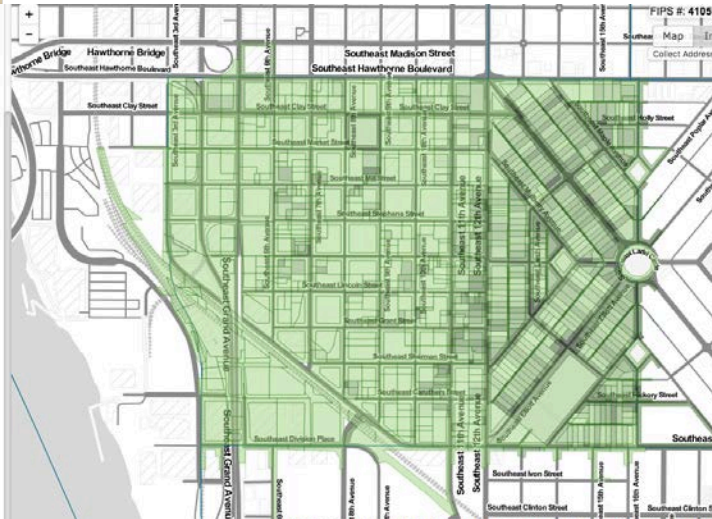
Public Either Private

Occupancy

Owner Either Renter

Land Use

SFR All MFR



Environmental

Tree Cover (%)

0% 0 - 21 100%

Urban Heat Index

Low 7 - 10 High

Air Pollution Index

Low 6 - 10 High

Social

Right of Way

Public Either Private

Occupancy

Owner Either Renter

Land Use

SFR All MFR



Next Steps

- ◆ Integrate findings to describe the implication of trees on social, financial, and human health
- ◆ Develop online tools for decision-makers to evaluate impacts of tree loss/gain
- ◆ Identify policy levers for advancing expansion of green infrastructure
- ◆ Apply models and online tools to other cities





Contact:

Contact Vivek Shandas

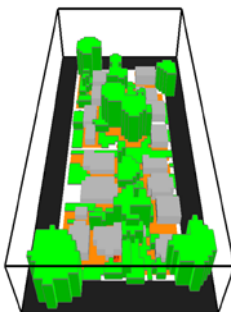
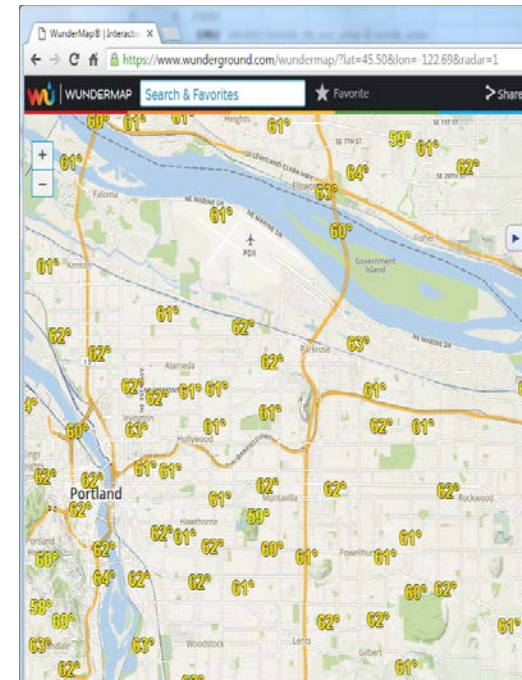
Email: vshandas@pdx.edu

Tel. 503-725-5222

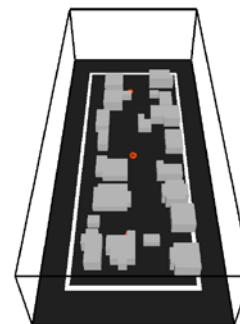
www.suprlab.org

Scenario Assessment

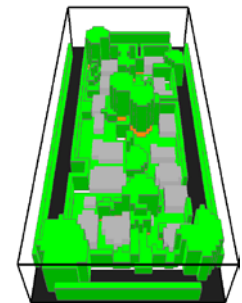
- Parameter calibration using Wunderground data
- Simulation date
 - August 18th 2016
- Scenarios
 - Base: Base model
 - Sim I: No greenspace
 - Sim2: Full greening



Base



Sim1



Sim2

Birth Weight and Gender

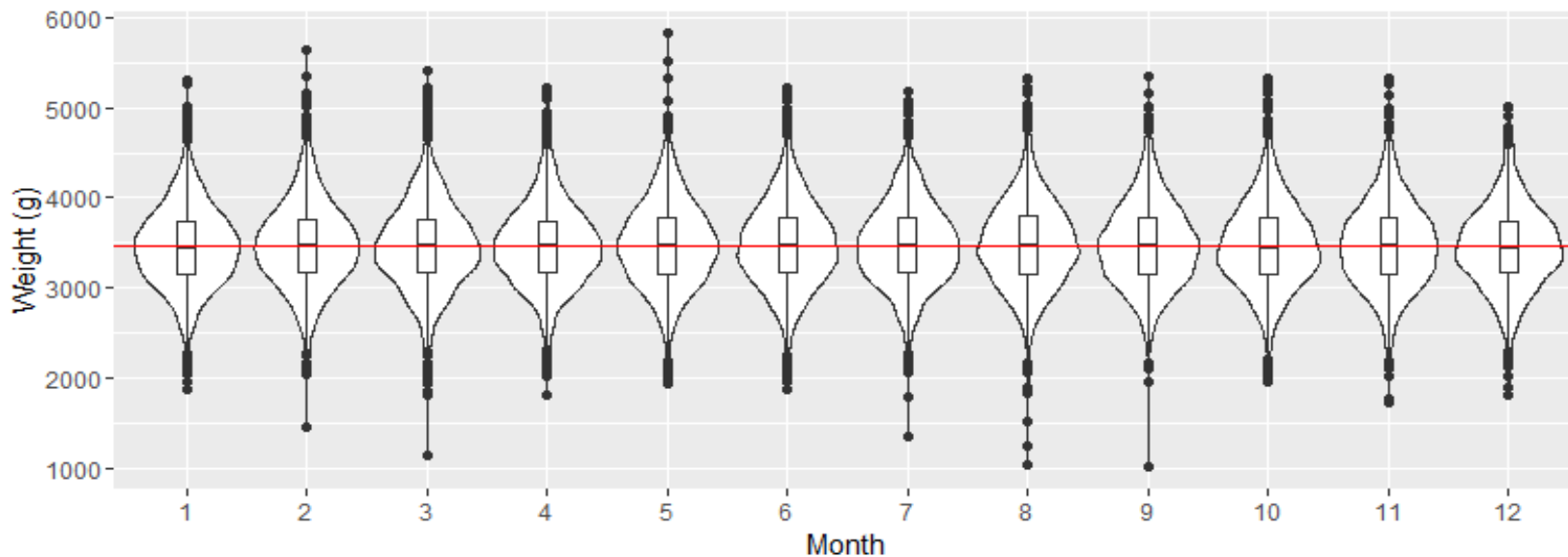
Live, singleton, full term, births to women in City of Portland between 2010-2014:

Year	BW (g)(females)	BW (g)(males)	BW (g) (all)	% female	% male	Total
2010	3412	3532	3472	49.9 %	50.1 %	7,571
2011	3402	3529	3467	48.9 %	51.1 %	7,553
2012	3416	3527	3474	48.1 %	51.9 %	7,646
2013	3400	3537	3470	48.7 %	51.3 %	7,487
2014	3397	3537	3468	49.4 %	50.6 %	6,981
Total full term births in City of Portland						37,238

* Statistics are for births to mothers whose with accurately geocoded residences

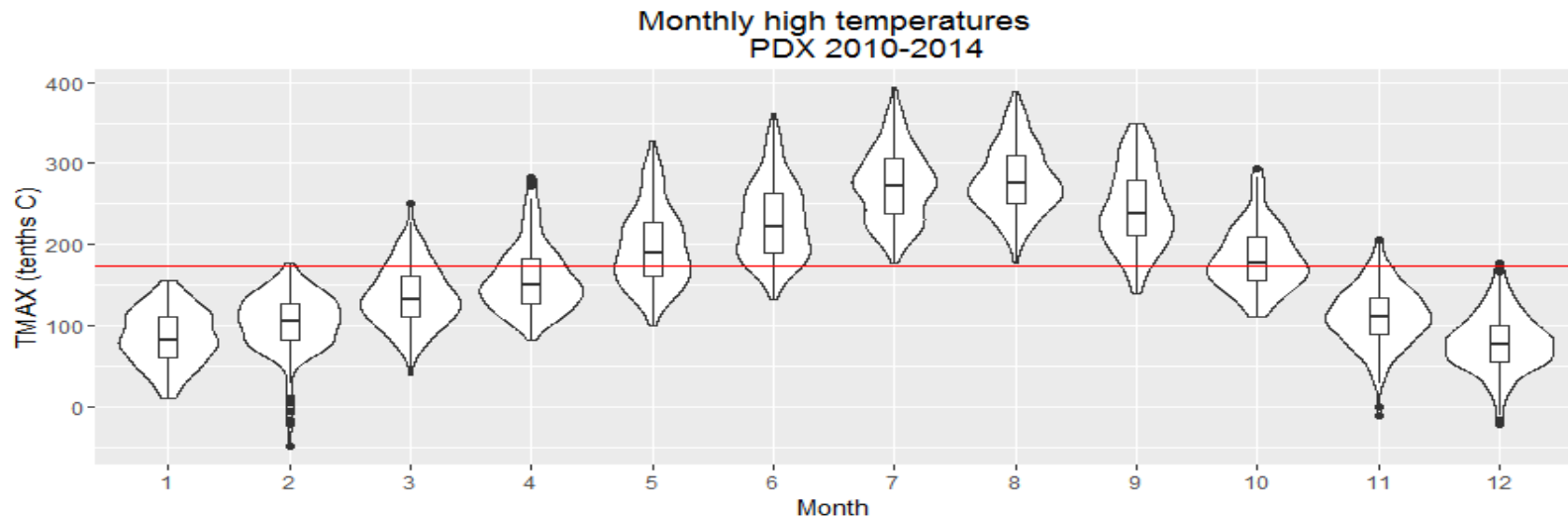
Monthly Births

Live, singleton, full-term birth weight
PDX 2010-2014



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean (g)	3459	3473	3460	3466	3481	3479	3478	3479	3479	3465	3467	3452
January Comparison	1.000	1.004	1.001	1.002	1.006	1.006	1.006	1.006	1.006	1.002	1.002	0.998
IQR (g)	588.5	590	585	567	633	612	596	643	624	618	624	572
January Comparison	1.00	1.00	0.99	0.96	1.08	1.04	1.01	1.09	1.06	1.05	1.06	0.97
Number	2,843	2,773	3,285	3,156	3,417	3,273	3,257	3,378	3,299	3,072	2,760	2,725
January Comparison	1.00	1.07	1.16	1.15	1.20	1.19	1.15	1.19	1.20	1.08	1.00	0.96

Average Monthly Temperatures



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average monthly high (Celsius)	8.6	10.3	13.7	15.9	19.7	23.0	27.3	27.9	24.5	18.3	11.1	7.9
Max monthly high (Celsius)	15.6	17.8	25.0	28.3	32.8	36.1	39.4	38.9	35.0	29.4	20.6	17.8
Average monthly low (Celsius)	2.2	3.1	4.4	6.1	9.4	12.3	14.5	15.3	12.9	9.1	4.4	2.5
Min monthly low (Celsius)	-5.0	-7.8	-2.2	-0.6	2.8	7.2	8.9	9.4	7.2	0.0	-7.8	-11.0

Results: Small for Gestational Age

Small for GA Odds Ratio	Odds Ratio	Range
Num days > 85F in pregnancy	1.002	0.998 – 1.007
Num days > 85F in first trimester	0.999	0.994 – 1.005
Num days > 85F in the second trimester	1.006	1.001 - 1.012
Num days > 85F in the third trimester	0.998	0.994 - 1.003

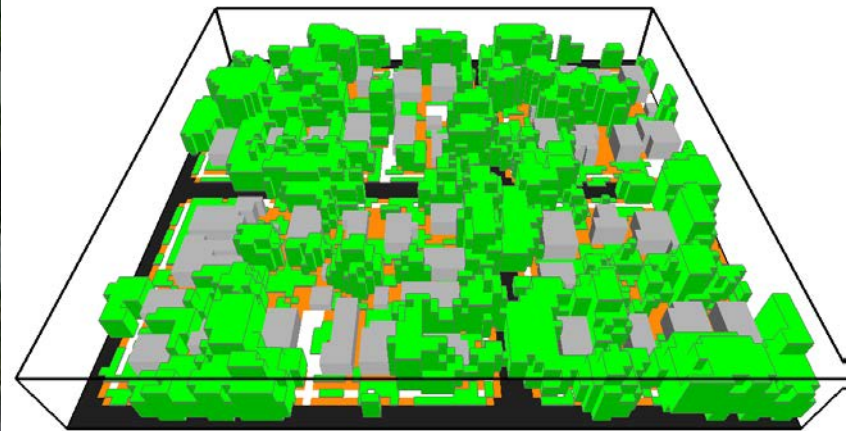
Results: Preterm Birth

Preterm Birth Odds Ratio	Odds ratio	Range
Num days > 85F in pregnancy	0.977	0.972 – 0.982
Num days > 85F in first trimester	0.998	0.991 – 1.004
Num days > 85F in the second trimester	1.012	1.005 – 1.019
Num days > 85F in the third trimester	0.957	0.950 – 0.964

Results: Weight at Full-Term

Weight at Full-Term Birth	Weight change g/day	Conf. Int.
Num days > 85F in pregnancy	0.3	-0.2 – 0.8
Num days > 85F in first trimester	-0.1	-0.7 – 0.5
Num days > 85F in the second trimester	-0.8	-1.5 – -0.2
Num days > 85F in the third trimester	1.0	0.5 – 1.6

High Canopy Neighborhood (HCN)

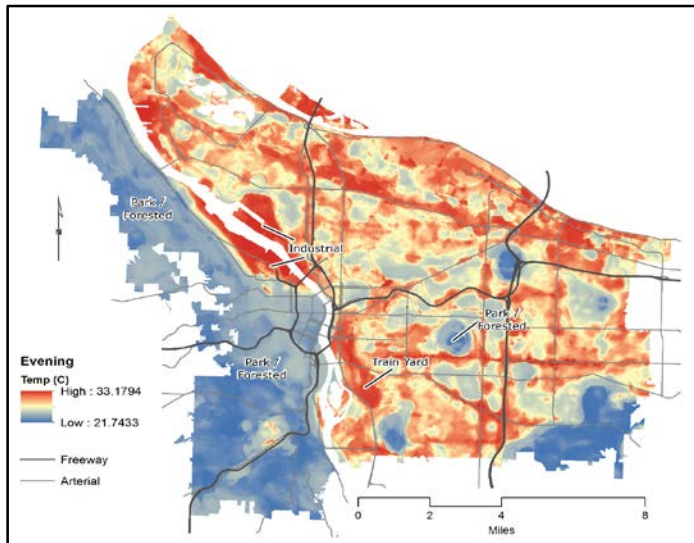


Birth Outcomes and Trees

- All births in the City of Portland 2010-2014
- Total of 161 variables related to baby & parents
- Geocoded 95,903 mother's residences
- Live, singleton, births (39,410)

Marital status	
Married	27,409
Not married	11,883
Unknown	118
Education	
No college	12,634
At least some college	26,558
Unknown	218
Prenatal care	
Yes	39,150
No	260
Unknown	0
Congenital anomalies	
Y	3,360
N	36,050
Unknown	0

Analysis Frame



Odds Ratio = 1

Translates to exposure does not affect odds of outcome

Odds Ratio > 1

Translates to exposure associated with higher odds of outcome

Odds Ratio < 1

Translates to exposure associated with lower odds of outcome

Birth Outcomes – by trimester

1. Small for Gestational Age (SGA)*
2. Pre-term: births < 37 weeks
3. Weight gain
4. Overall UHI impact on weight gain

*Oken et al (2003) SGA tables

Results: UHI and Birth Weight

Variable	Estimate	Std.	Error	t value	Pr(> t)
(Intercept)	4730.97	1001.04	4.726	2.81E-06	***
Baby's Sex Male	125.43	35.21	3.563	0.000394	***
No Pre-natal Care	-195.68	187.24	-1.045	0.296374	
Total Pregnancies	25.09	10.66	2.354	0.018885	*
Mother's Race (White/Non)	147.88	47.33	3.124	0.001861	**
No College (Y/N)	-54.98	40.06	-1.373	0.170342	
Mother Married (Y/N)	105.51	39.93	2.642	0.008441	**
Non-Congenital Birth Condition	98.68	64.04	1.541	0.123838	
Urban Heat within 50M of Mother's Residence	-53.61	32.54	-1.647	0.099969	*

We observed a 53g decrease in birth weight per degree (F) rise in UHI within 50m of mother's residence