Using air pollution sensors carried by cyclists and pedestrians to capture the spatio-temporal variability of air pollution in Toronto

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Objectives

ELSEVIER

Health & Place

Volume 34, July 2015, Pages 287–295

Spatial analysis of exposure to traffic-related air pollution at birth and childhood atopic asthma in Toronto, Ontario

K. Shankardass[a, b], M. Jerrett[c], S.D. D

Air pollution boosts heart attack risk

Public health significantly affected by air quality

CBC News Posted: Feb 15, 2012 12:18 PM ET | Last Updated: Feb 15, 2012 12:30 PM ET

Journal of Toxicology and Environmental Health, Part A: Current Issues

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/uteh20

The Association Between Chronic Exposure to Traffic-Related Air Pollution and Ischemic Heart Disease

Bernardo S. Beckerman [a] , Michael Jerrett [a] , Murray Finkelstein [b] , Pavlos Kanaroglou [c] , Jeffrey R. Brook [d] , M. Altaf Arain [c] , Malcolm R. Sears [e] , David Stieb [f] , John Balmes [a g] & Kenneth Chapman [h]

[a] School of Public Health , University of California Berkeley , Berkeley , California , USA

[b] Department of Family and Community Medicine , University of Toronto , Toronto , Canada

ELSEVIER

Environment Inte

Volume 74, January 2015,

Exposure to traffic-related air pollut… developing breast cancer among w… provinces: A case–control study

Perry Hystad[a], Paul J. Villeneuve[b], Mark S. Goldberg[c, d], Dan L… Kenneth Johnson[f], the Canadian Cancer Registries Epidemiology Re…

ELSEVIER

Environmental Research

Volume 115, May 2012, Pages 18–25

Neurobehavioral effects of exposure to traffic-relate… pollution and transportation noise in primary school… ☆☆

Elise van Kempen[a], Paul Fischer[a], Nicole Janssen[a], Danny Hou… Kamp[a], Stephen Stansfeld[b], Flemming Cassee[a]

ehp ENVIRONMENTAL HEALTH PERSPECTIVES

http://www.ehponline.org

Perinatal Exposure to Traffic-Related Air Pollution and Atopy at 1 Year of Age in a Multi-Center Canadian Birth Cohort Study

Hind Sbihi, Ryan W. Allen, Allan Becker, Jeffrey R. Brook, Piush Mandhane, James A. Scott, Malcolm R. Sears, Padmaja Subbarao, Tim K. Takaro, Stuart E. Turvey, and Michael Brauer

Motivation

- The development of air pollution surfaces is crucial for a better understanding of population exposure

- Live air pollution data can be used to investigate the effect of traffic management on air pollution hot spots (e.g. low emission zones)

- Mobile monitoring campaigns provide unparalleled coverage of an urban area

The rise of portable air pollution monitors coupled with GPS devices

Aeroqual sensor
(NO2 and O3)

DiscMini (UFP)

MicroAeth (BC)

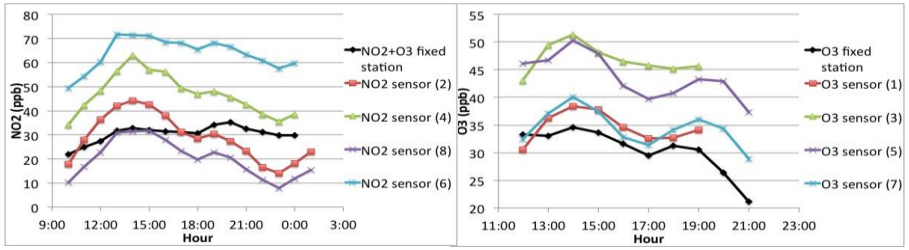
enables....

…mobile monitoring and panel studies

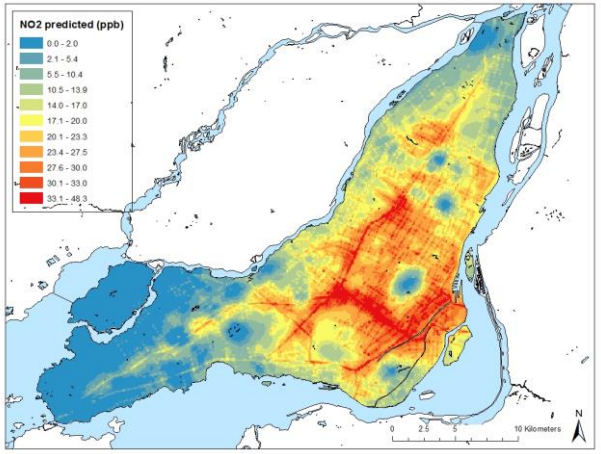
BUT….

Some hypotheses have not been tested and many questions regarding the role of air pollution sensors remain unanswered

- Sensors need calibration



- Is air pollution data collected in an ad-hoc way useful to capture the spatio-temporal variability of air pollution in an urban area?

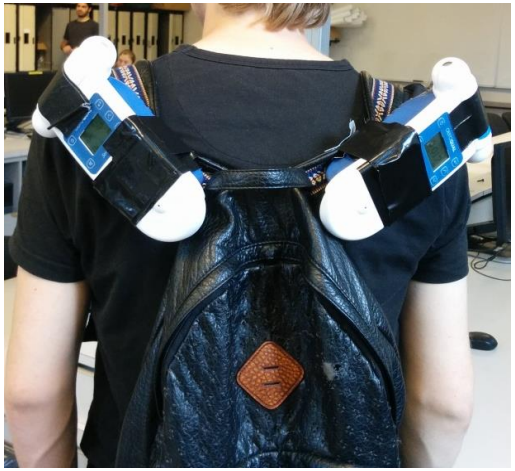


Comparing the performance of various data collection protocols

Fixed points

Cyclists

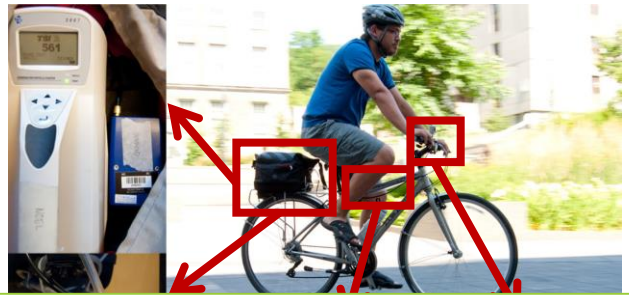
Pedestrians



Panel

- Fixed points

- Cyclists

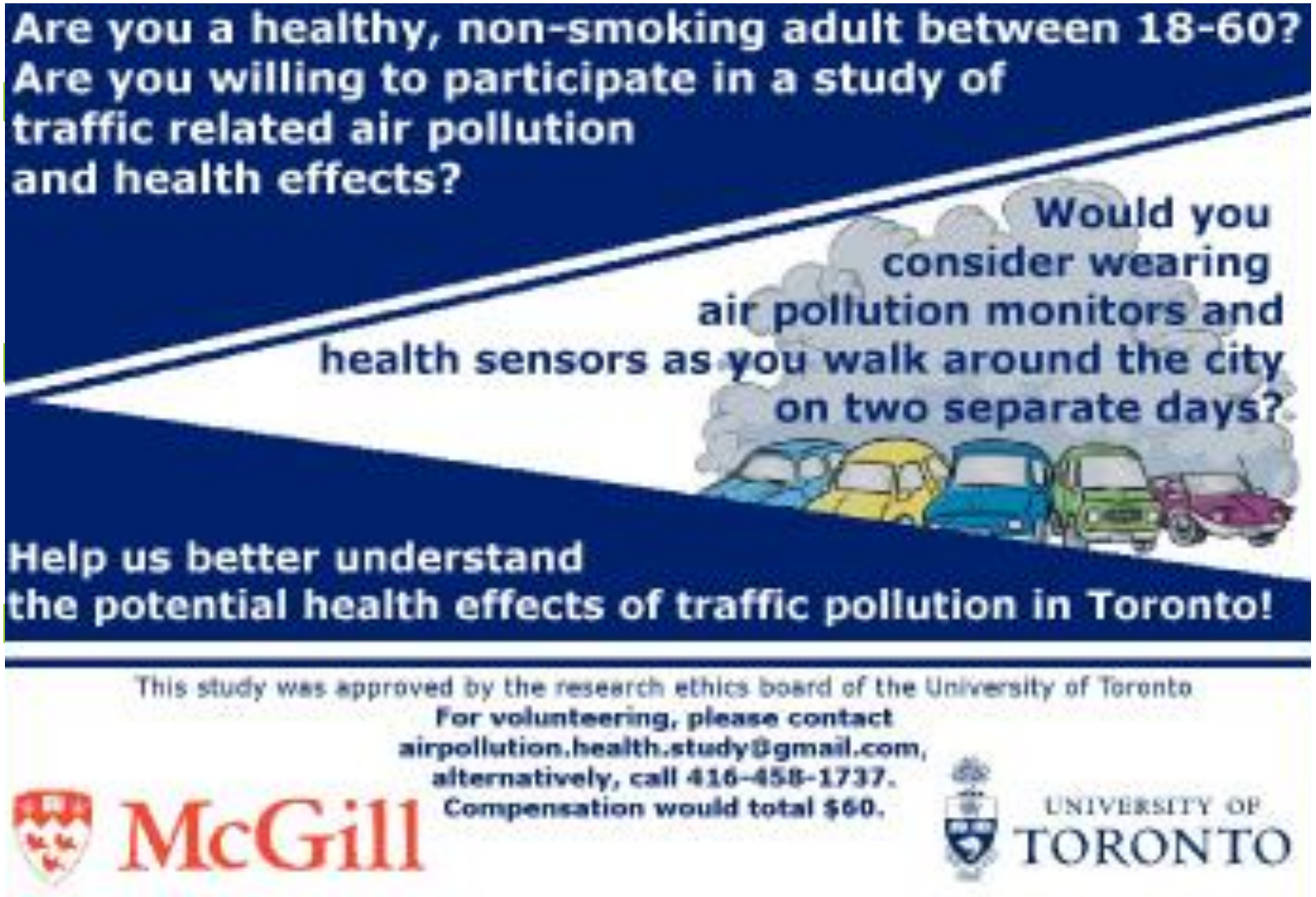


Four data collection protocols conducted in the same campaign

Panel study

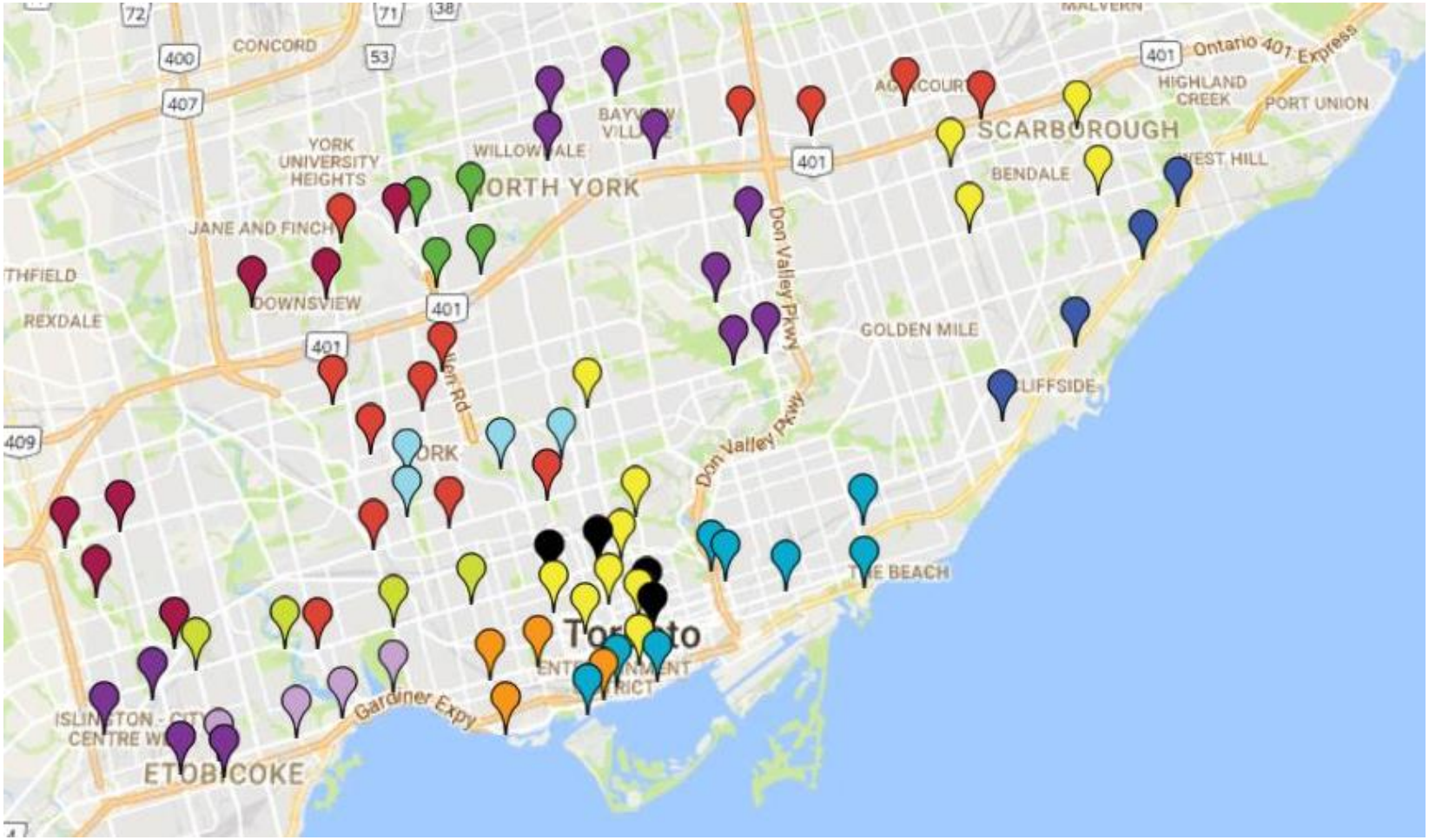
- Gold standard for measuring exposure
- Recruiting participants from the general population
- Personal exposure measured throughout the day, monitors are close to the body
- Physiological measures conducted to relate with acute health effects

Panel study

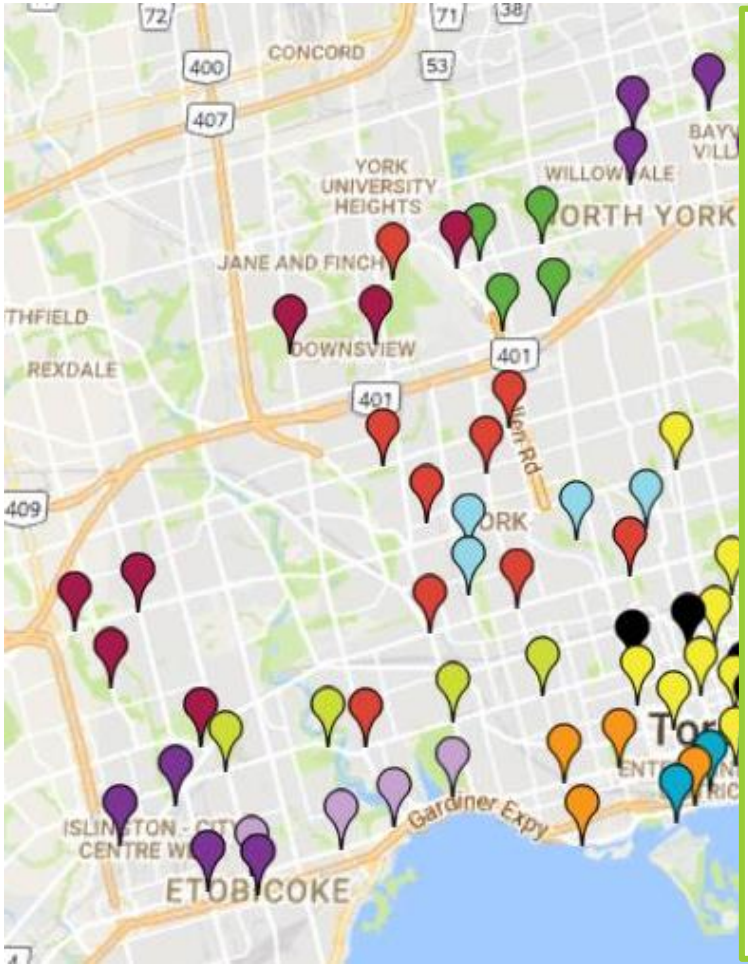

Are you a healthy, non-smoking adult between 18-60?
Are you willing to participate in a study of
traffic related air pollution
and health effects?
Would you
consider wearing
air pollution monitors and
health sensors as you walk around the city
on two separate days?
Help us better understand
the potential health effects of traffic pollution in Toronto!
This study was approved by the research ethics board of the University of Toronto
For volunteering, please contact
airpollution.health.study@gmail.com,
alternatively, call 416-458-1737.
Compensation would total $60.
McGill
UNIVERSITY OF
TORONTO

- Participants arrive at the study site, undergo baseline health measures, and go about their day, then come back at the end of the day
- Can we predict their exposures without having to conduct personal measurements?
- What is the error associated with potential mis-classification of exposure?

Fixed points



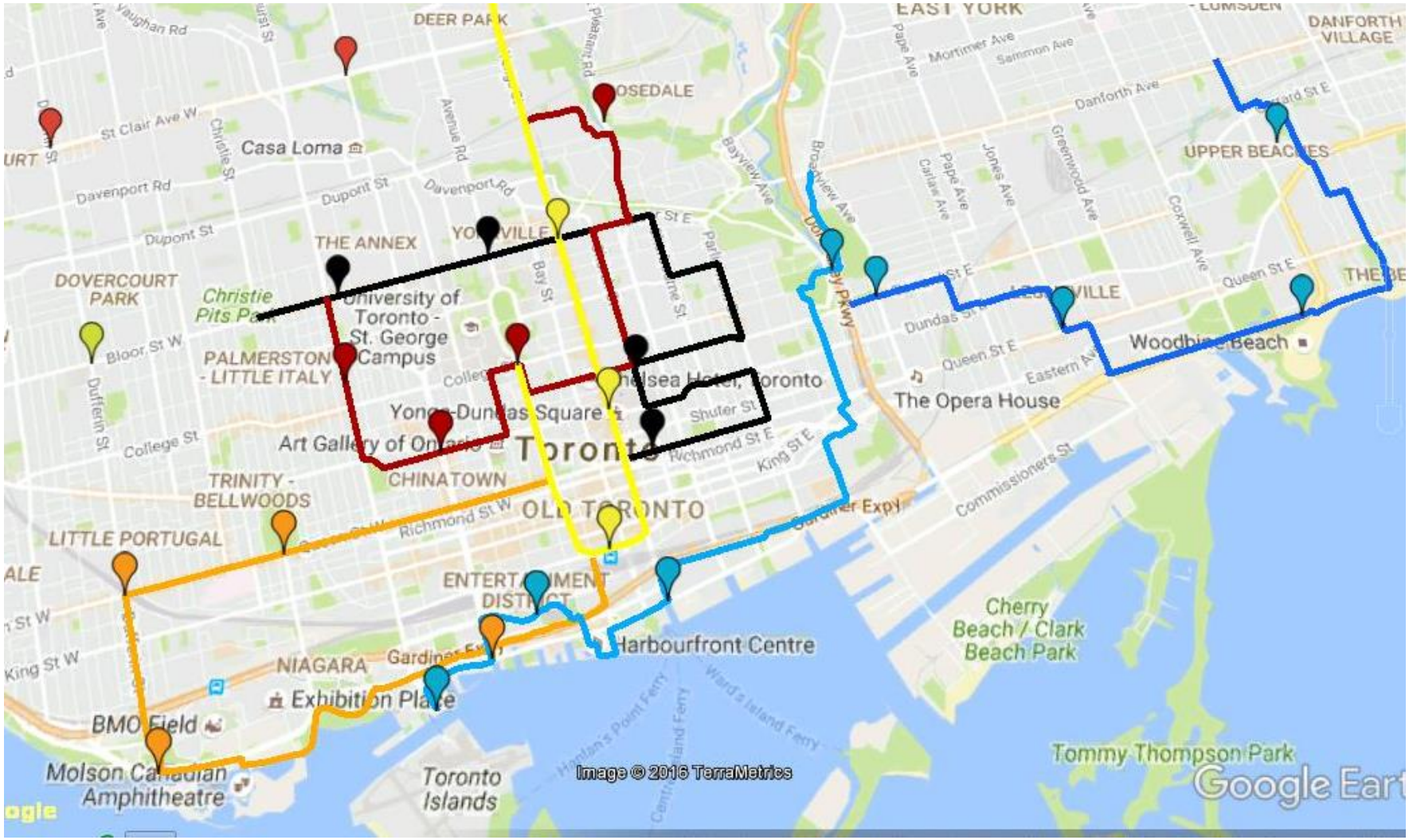
Fixed points



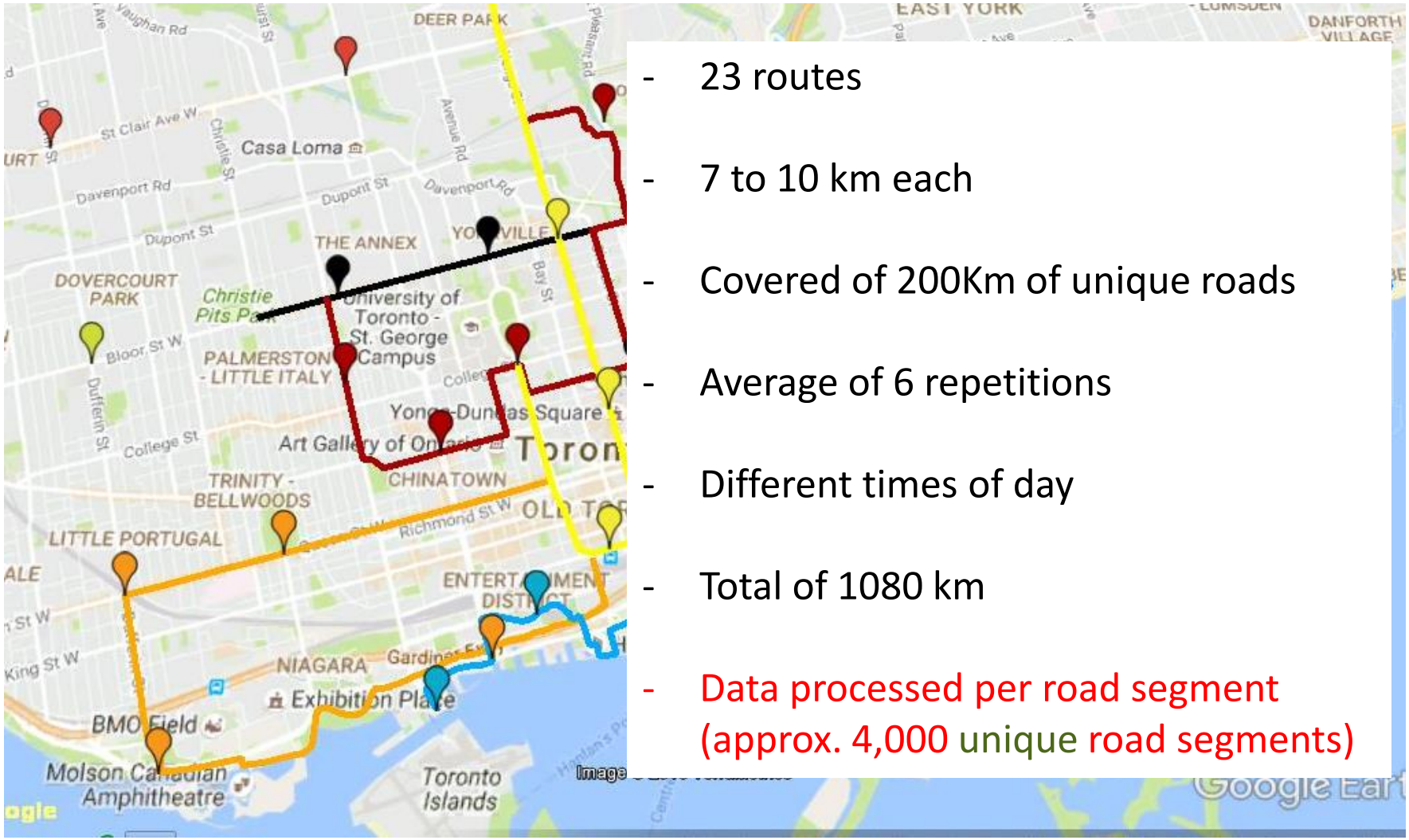
- 96 points
- Intersections and mid-block locations
- 6 visits per point, different times of day
- 20 minutes per visit
- Traffic counts (passenger car, passenger truck, light duty truck, transit bus, SHT, LHT, school bus, coach bus) and cyclists
- UFP, BC, noise

Time block	Time
1	7 am to 11 am
2	11 am to 3 pm
3	3 pm to 7 pm

Pedestrian routes designed to overlap with fixed locations

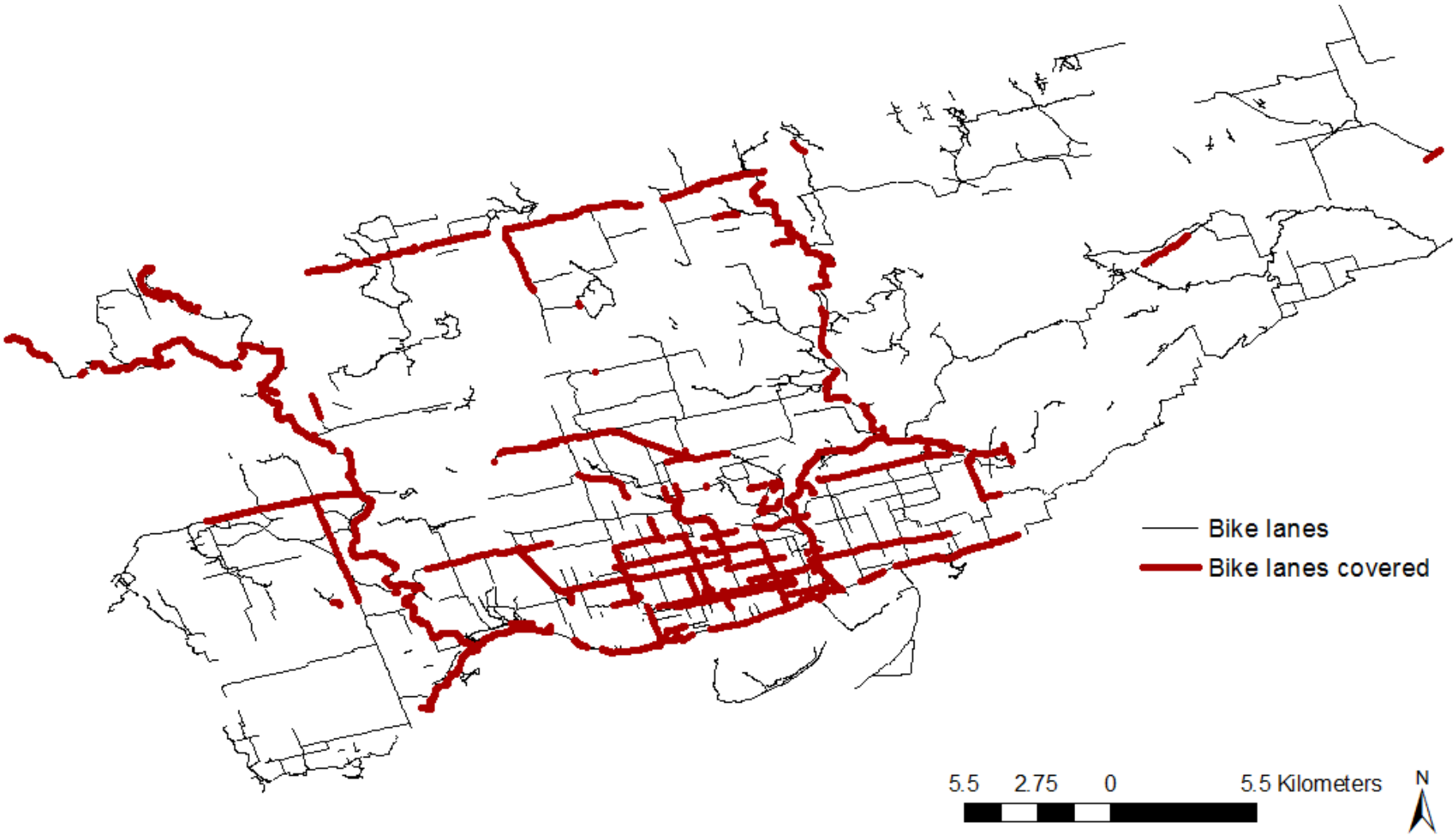


Pedestrian routes designed to overlap with fixed locations

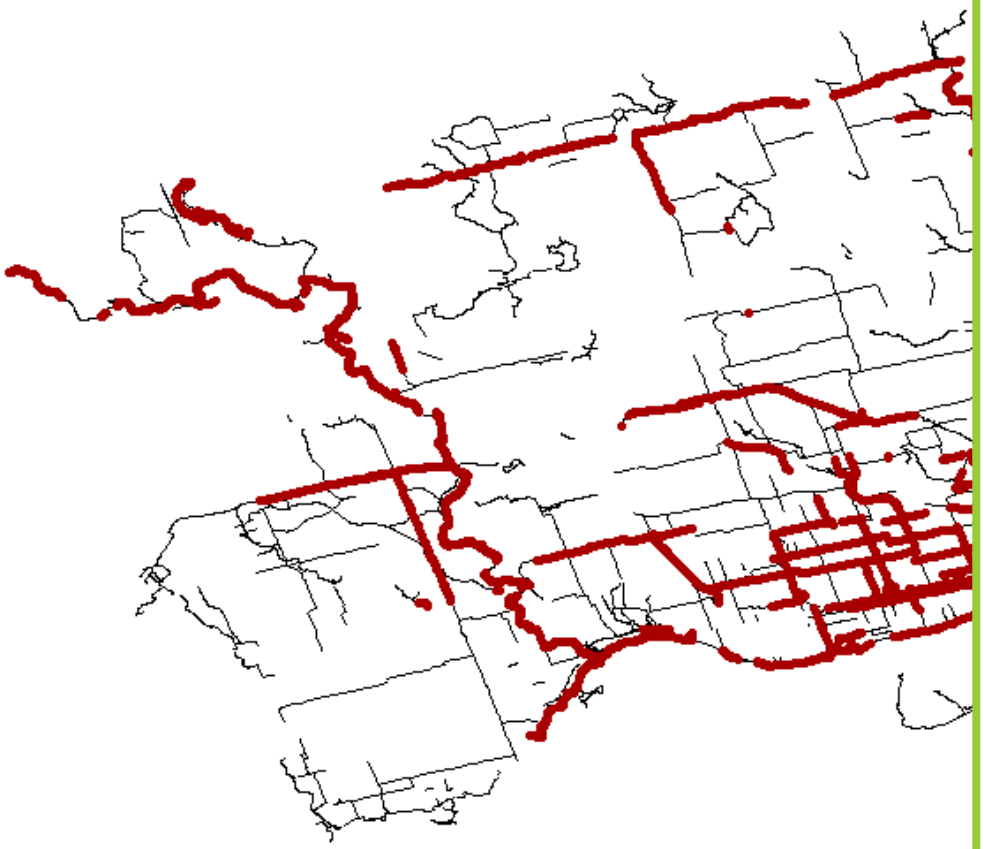


- 23 routes
- 7 to 10 km each
- Covered of 200Km of unique roads
- Average of 6 repetitions
- Different times of day
- Total of 1080 km
- Data processed per road segment (approx. 4,000 unique road segments)

Cycling routes



Cycling routes



- 10 routes, 24 to 31 km each
- 270 km covered in total
- Partial overlap with pedestrian routes
- Each route was repeated 6 to 8 times, at least once per time block
- Total of 1860 km
- Approx. 3,900 road segments

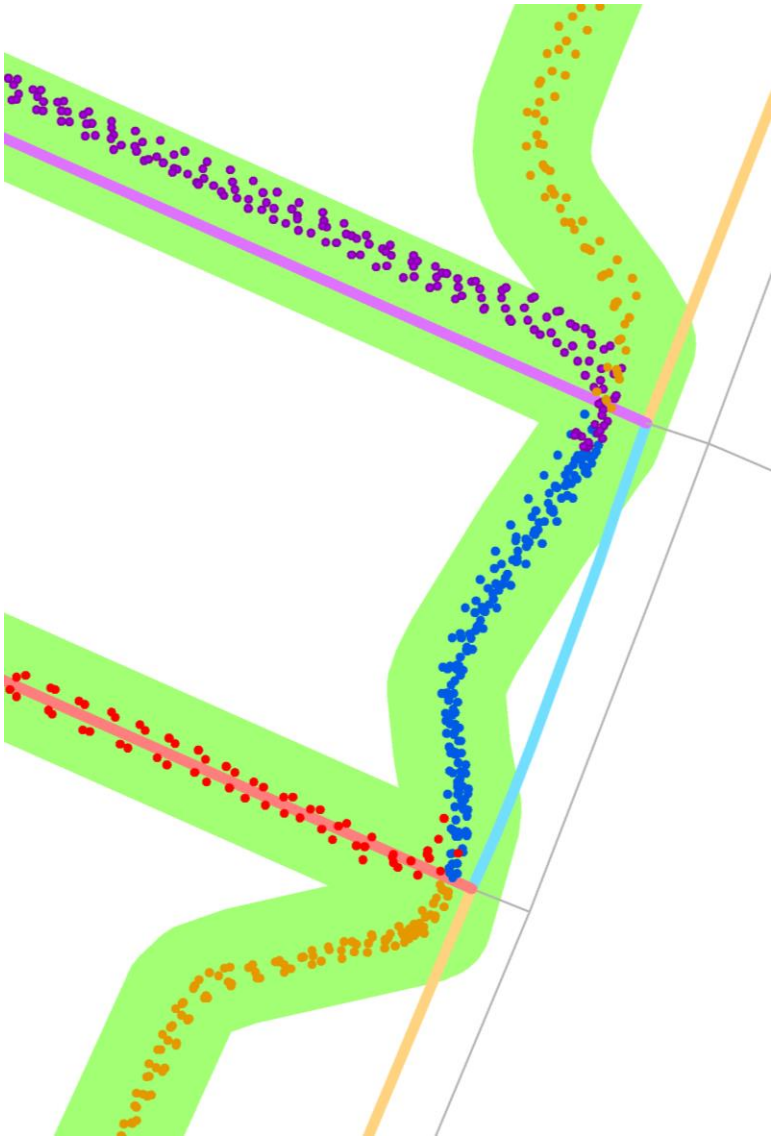
Time block	Time
1	7 am to 9 am
2	9 am to 11 am
3	11 am to 1 pm
4	1 pm to 3 pm
5	3 pm to 5 pm
6	5 pm to 7 pm

Preliminary analysis of cycling data

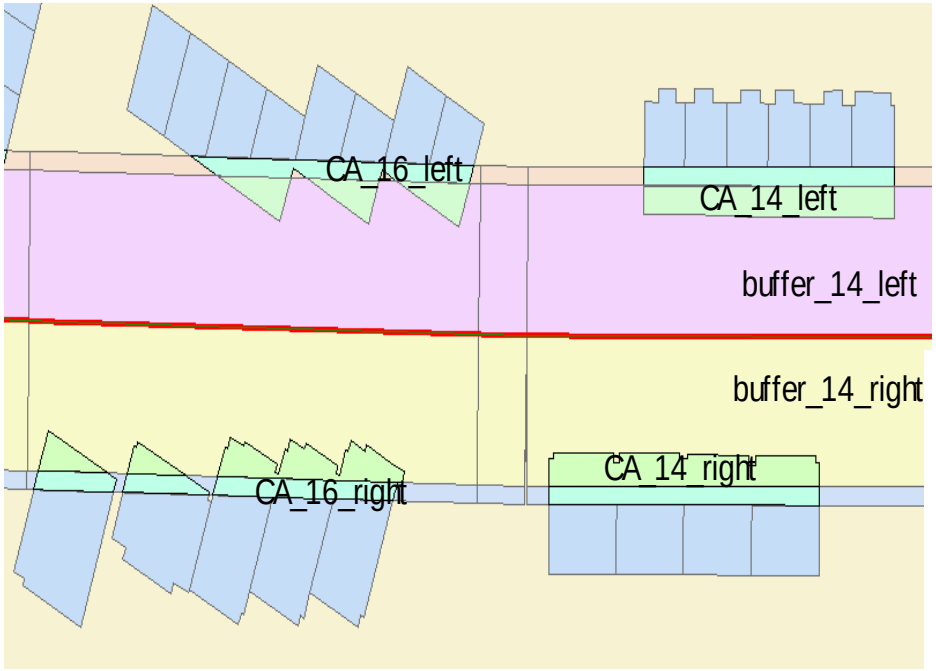
Database

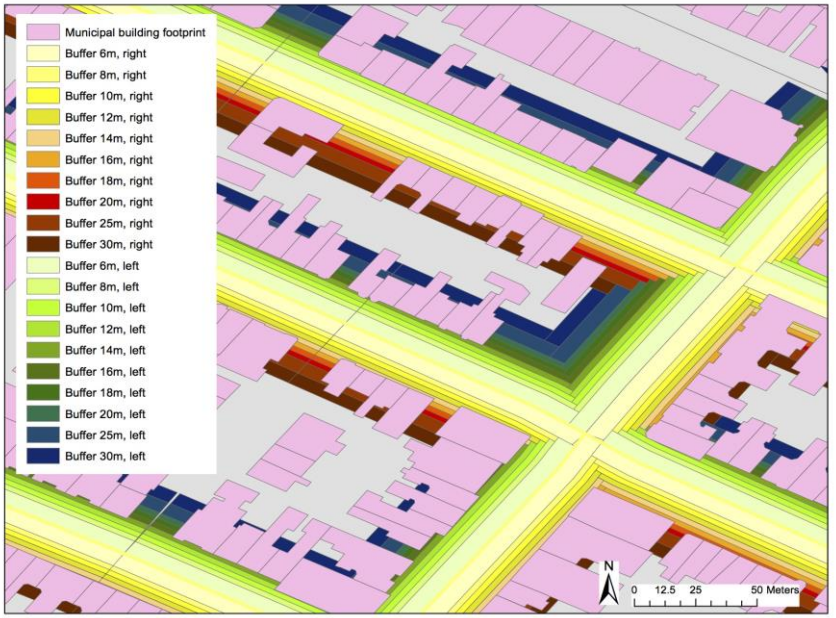
- Every GPS point is given a unique ID and associated with:
  - Air pollution level
  - Road segment (approx. 3900)
  - Day
  - Time
  - Meteorology (wind speed, direction, RH, temperature)
- Average air pollutant concentration per segment per visit is the outcome variable (UFP, BC, noise)
- Coefficient of variation for each segment/visit

Allocating GPS points to road segments



Land-use and built environment around each road segment





Land-use and built environment around each road segment

List of LU + BE characteristics

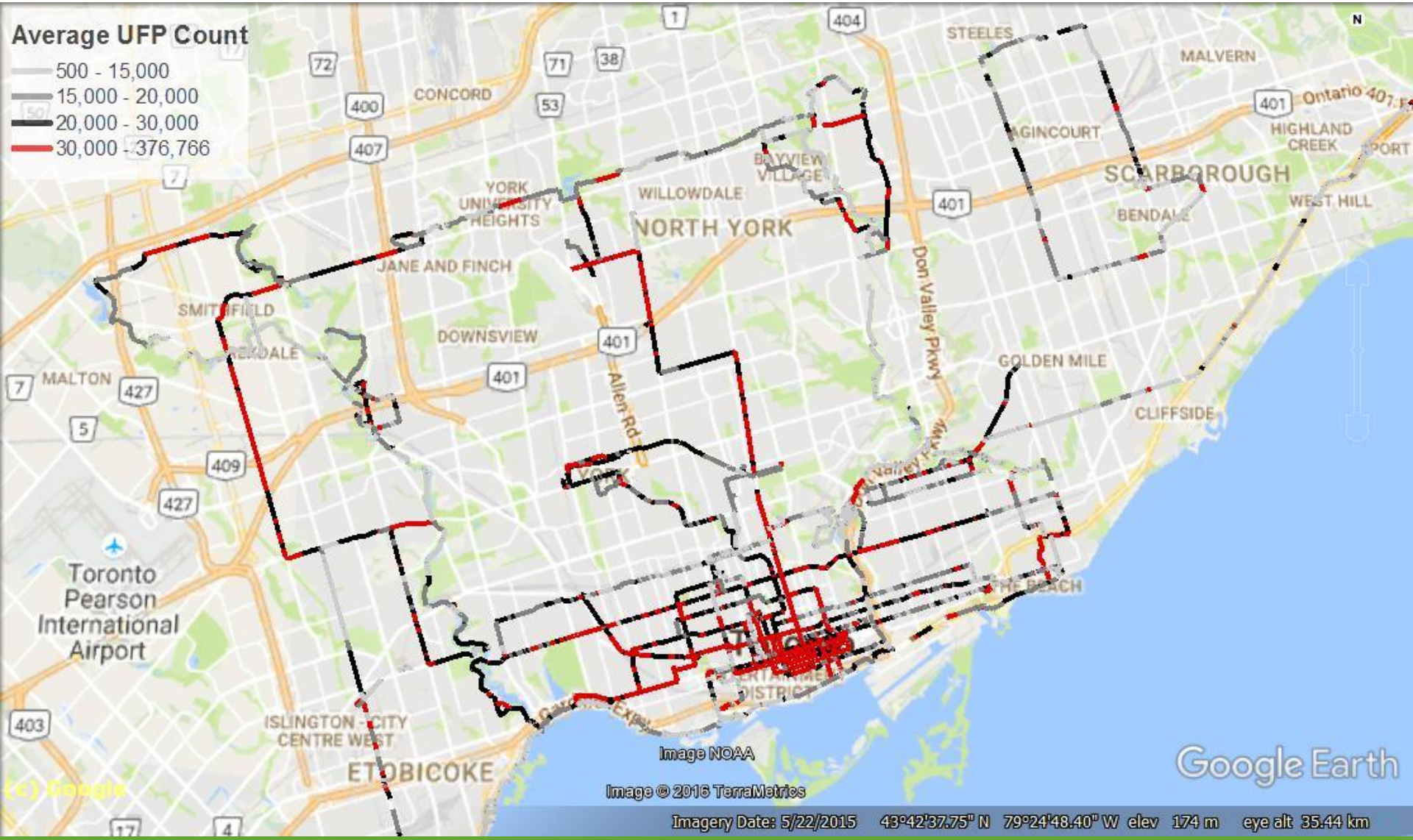
Buffers of
25, 50, 100, 200,
300, 500, 1000m

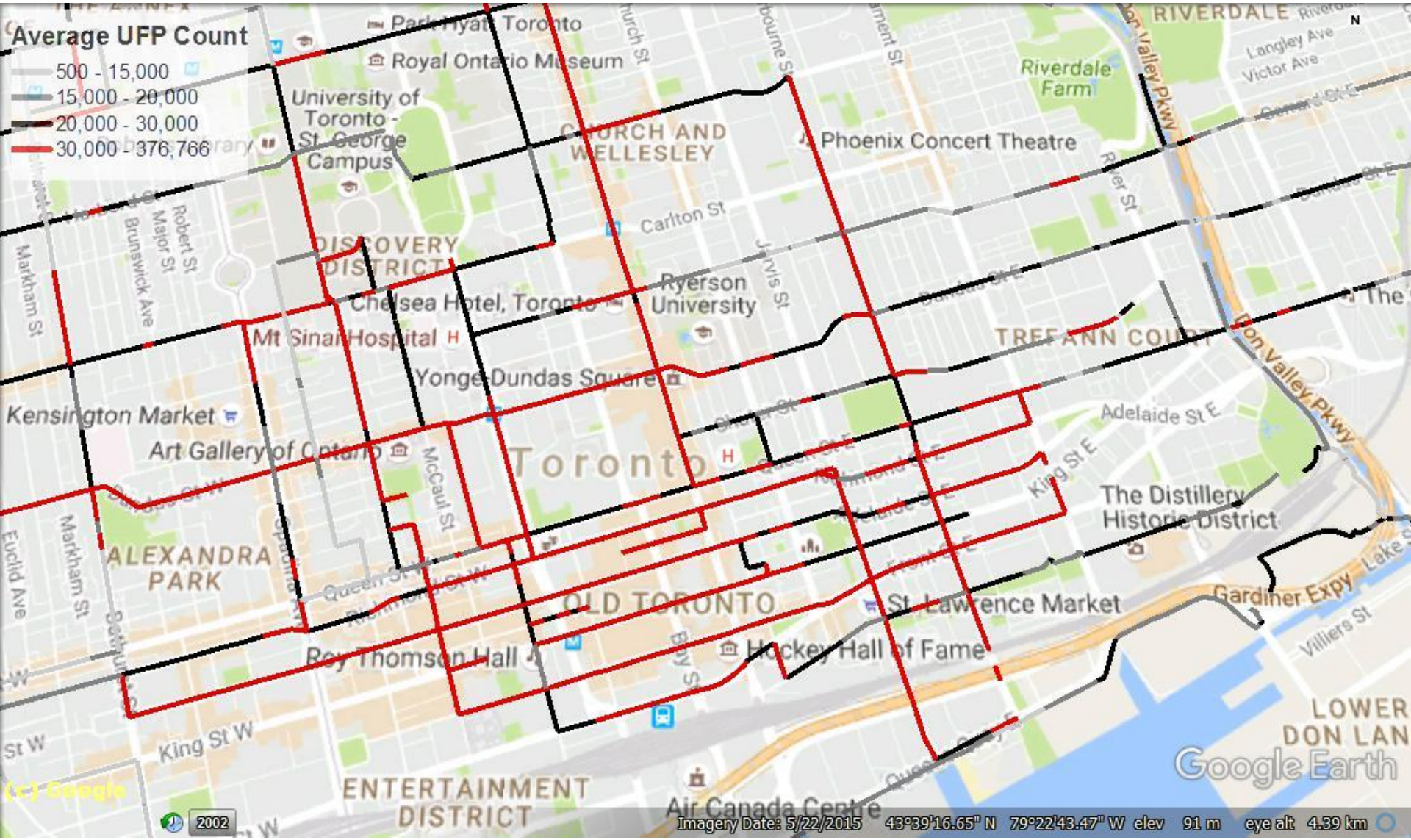
- Distance from the shore (m) (d_shore)
- Distance from the closest railline (m) (d_railline)
- Distance from the closest major road (m) (d_majrd)
- Distance from the closest highway (m) (d_highway)
- Distance from the closest airport (m) (d_airport)
- Distance to the closest NOx emitting chimney (m) (d_NPRI_NOx)
- Distance to the closest PM emitting chimney (m) (d_NPRI_PM)
- Area of the buildings (m2) (build_25m to build_1000m)
- Area of the commercial land use (m2) (com_25m to com_1000m)
- Area of the governmental and institutional land use (m2) (gov_25m to gov_1000m)
- Area of the resource and industrial land use (m2) (ind_25m to ind_1000m)
- Area of the open area land use (m2) (open_25m to open_1000m)
- Area of the parks land use (m2) (park_25m to park_1000m)
- Area of the residential land use (m2) (resid_25m to resid_1000m)
- Area of the waterbody land use (m2) (water_25m to water_1000m)
- Length of the bus routes (m) (busline_25m to busline_route_1000m)
- Length of the major roads (type 4) (m) (majrd_25m to majrd_1000m)
- Length of the highways (types 1, 2 and 3) (m) (highway_25m to highway_1000m)
- Length of the roads (types 1, 2, 3, 4, 5 and 6) (m) (roads_25m to roads_1000m)
- Number of bus stops (count) (bus_25m to bus_1000m)
- Number of intersections (count) (inter_25m to inter_1000m)
- Number of trees (count) (trees_25m to trees_1000m)
- Population (count) (pop_500m to pop_1000m)
- Average height of buildings (m) (build_height_25m to build_height_100m)
- Maximum height of buildings (m) (max_build_height_25m to max_build_height_100m)
- Number of NOx emitting chimneys (count) (NPRI_NOx_25m to NPRI_NOx_1000m)
- Number of PM emitting chimneys (count) (NPRI_PM_25m to NPRI_PM_1000m)
- Length of rail lines (m) (rai_25m to rail_1000m)

Descriptive statistics (by segment)

	Mean	Std Dev	Min	Percentiles			
				25th	50th	75th	100th
Average ultrafine particles (particles / cm^3)	23436	15837	500	14447	19969	28603	376766
Average Black Carbon (ng/m^3)	1761	2839	15	757	1235	1822	103046
LAeq (dB)	72.83	4.06	55	71	73	75	89

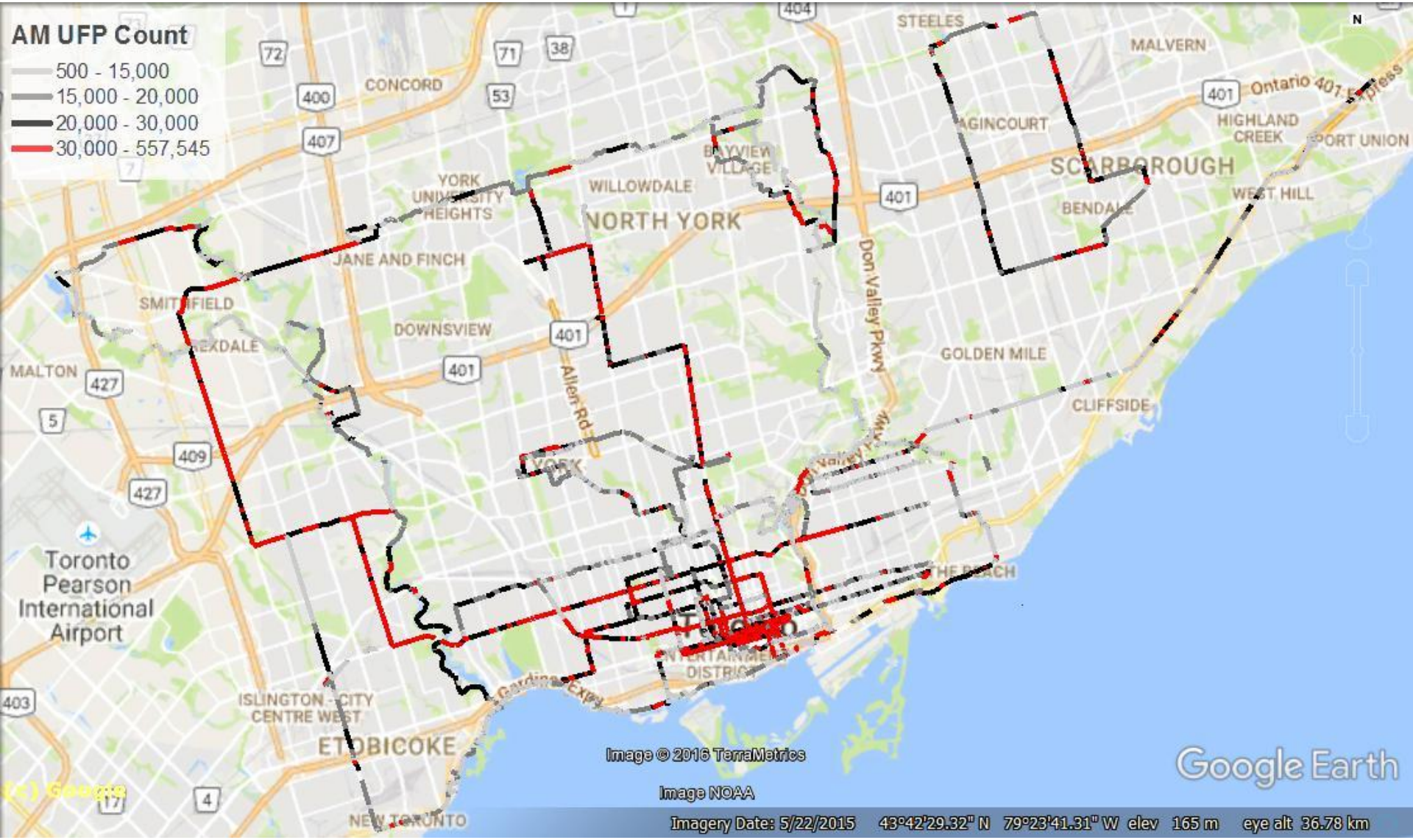
UFP along bicycle facilities



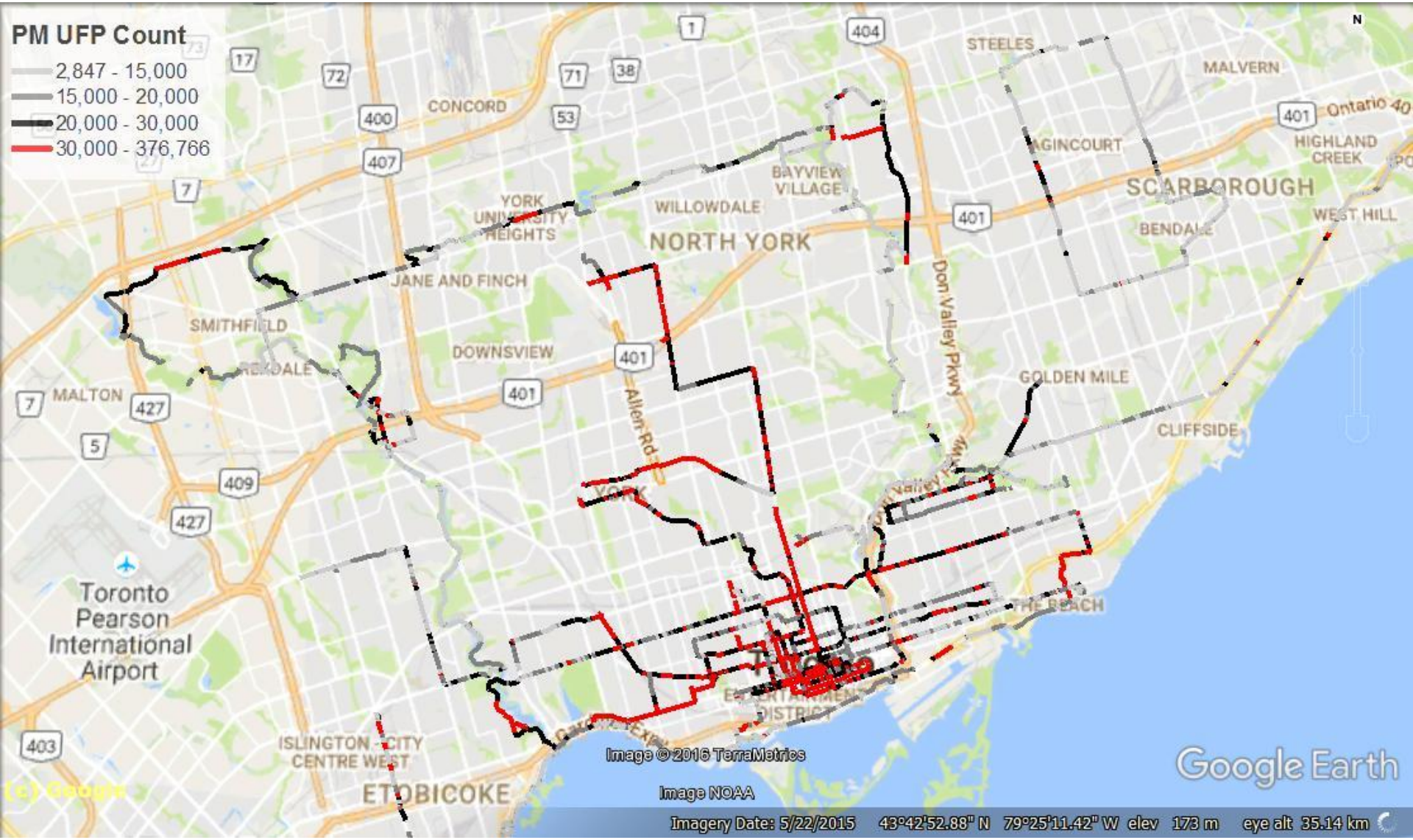

Average UFP Count
500 - 15,000
15,000 - 20,000
20,000 - 30,000
30,000 - 376,766
Park Hyatt Toronto
Royal Ontario Museum
University of Toronto - St. George Campus
CHURCH AND WELLESLEY
Phoenix Concert Theatre
Riverdale Farm
RIVERDALE
Langley Ave
Victor Ave
Don Valley Pkwy
Carlton St
DISCOVERY DISTRICT
Chelsea Hotel, Toronto
Ryerson University
Mt Sinai Hospital
Yonge-Dundas Square
TREFANN COURT
Kensington Market
Art Gallery of Ontario
Toronto
Adelaide St E
King St E
The Distillery Historic District
ALEXANDRA PARK
OLD TORONTO
St. Lawrence Market
Gardiner Expy
Roy Thomson Hall
Hockey Hall of Fame
Villiers St
LOWER DON LAN
King St W
ENTERTAINMENT DISTRICT
Air Canada Centre
Google Earth
(c) Google
2002
Imagery Date: 5/22/2015 43°39'16.65" N 79°22'43.47" W elev 91 m eye alt 4.39 km


Average UFP Count
500 - 15,000
15,000 - 20,000
20,000 - 30,000
30,000 - 376,766
The Toronto Congress Centre
Eglinton Ave W
ROCKCLIFFE - SMYTHE
Lambton Golf & Country Club
THE JUNCTION
DOVERCOURT PARK
ERINGATE - CENTENNIAL - WEST DEANE
Islington Golf Club
Centennial Park
SIX POINTS
EATONVILLE
SUNNYLEA
Humber Marshes Park
High Park
RONCESVALLES VILLAGE
PARKDALE
SUNNYSIDE
MARKLAND WOOD
ISLINGTON - CITY CENTRE WEST
HUMBER BAY
ETOBICOKE
IKEA Etobicoke
MIMICO
Humber Bay Park West
Gardiner Expy
Lake Shore Blvd W
Image © 2016 TerraMetrics
Google Earth
Imagery Date: 5/22/2015 43°38'46.80" N 79°31'03.90" W elev 115 m eye alt 11.91 km

AM


AM UFP Count
500 - 15,000
15,000 - 20,000
20,000 - 30,000
30,000 - 557,545
CONCORD
YORK UNIVERSITY HEIGHTS
WILLOWDALE
BAYVIEW VILLAGE
NORTH YORK
STEELES
MALVERN
AGINCOURT
HIGHLAND CREEK
PORT UNION
SCARBOROUGH
WEST HILL
BENDALE
JANE AND FINCH
SMITHFIELD
DOWNSVIEW
MALTON
Allen Rd
Don Valley Pkwy
GOLDEN MILE
CLIFFSIDE
Toronto Pearson International Airport
ISLINGTON - CITY CENTRE WEST
ETOBICOKE
NEW TORONTO
Image © 2016 TerraMetrics
Image NOAA
Google Earth
Imagery Date: 5/22/2015 43°42'29.32" N 79°23'41.31" W elev 165 m eye alt 36.78 km

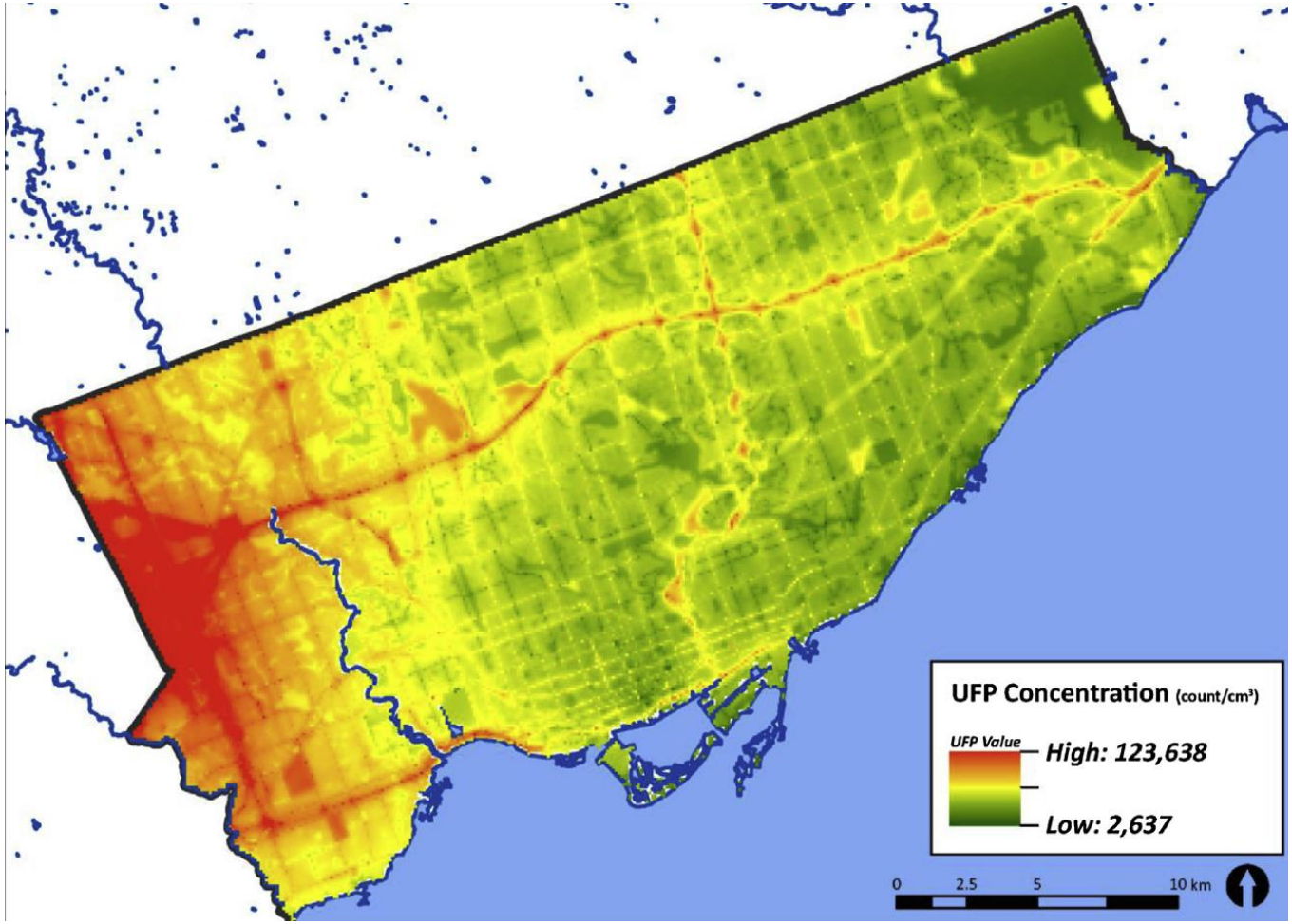
PM


PM UFP Count
2,847 - 15,000
15,000 - 20,000
20,000 - 30,000
30,000 - 376,766
CONCORD
YORK UNIVERSITY HEIGHTS
WILLOWDALE
BAYVIEW VILLAGE
NORTH YORK
STEELES
MALVERN
AGINCOURT
HIGHLAND CREEK
SCARBOROUGH
WEST HILL
BENDALE
JANE AND FINCH
SMITHFIELD
DOWNSVIEW
MALTON
GOLDEN MILE
CLIFFSIDE
Don Valley Pkwy
Allen Rd
Toronto Pearson International Airport
ISLINGTON - CITY CENTRE WEST
ETOBICOKE
THE BEACH
Image © 2016 TerraMetrics
Image NOAA
Google Earth
Imagery Date: 5/22/2015 43°42'52.88" N 79°25'11.42" W elev 173 m eye alt 35.14 km

Early models of air pollution along cycling facilities

Model	For LN of UFP average for increase of IQ if not otherwise indicated			
	Mean Change	95% CI for Mean Change	Mean Change	95% CI for Mean Change
	Mixed effect model Model 35		GLM Model 36	
AIC	32310.50		4487.440	
Adjusted R^2	0.2591		0.3566	
Windspeed	**-0.26**	-0.27, -0.24	-12.15	-13.17, -11.11
timeblock - A (6, 7 and 8) - Reference	1		NA	
timeblock - B (9 and 10)	-0.32	-0.35, -0.28		
timeblock - C (11 and 12)	-0.07	-0.12, -0.03		
timeblock - D (13 and 14)	0.04	0.00, 0.08		
timeblock - E (15 and 16)	-0.30	-0.34, -0.26		
timeblock - F (17, 18 and 19)	-0.31	-0.35, -0.26		
Relative Humidity	**-0.11**	-0.13, -0.09	-8.65	-9.90, -7.37
d_airport	**-0.15**	-0.17, -0.14	-12.21	-14.10, -10.28
build_1000m	**0.12**	0.10, 0.14	11.95	9.53, 14.43
park_1000m	**-0.019**	-0.036, -0.003		
max_build_height_25m	**0.06**	0.03, 0.08		
d_NPRI_NOx	**-0.05**	-0.07, -0.02		
trees_750m	**0.11**	0.08, 0.13	14.93	11.39, 18.59
d_shore	**-0.05**	-0.06, -0.03	-8.00	-9.82, -6.16
d_majrd	**-0.017**	-0.021, -0.014	-3.07	-4.00, -2.14
gov_1000m	**-0.014**	-0.024, -0.003		
open_1000m	**0.04**	0.03, 0.05	4.63	2.93, 6.35
highway_25m	**0.0008**	0.0005, 0.0011	0.12	0.07, 0.16

Developing predictive models



What is the potential of human-centric air pollution sensing in producing reliable air pollution maps?

What is the potential of human-centric air pollution sensing in producing reliable air pollution maps?

To evaluate the potential of embedded network of monitors in the generation of urban air quality maps useful for quantifying population exposure patterns