Modelling the Spatio-Temporal Distribution of Ambient Nitrogen Dioxide and Investigating the Effects of Public Transit Policies on Population Exposure

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Introduction

Challenges

- Transportation is associated with **air pollution**.

- People are **living and working** close to busy streets and individual exposure remains a concern.

Challenges

- In **Canada**, air pollution yearly is associated about with 5500 deaths yearly

Background

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. Dell[d, e], R. Foty[f], D. Stieb[g]

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],

Environment International
Volume 74, January 2015, Pages 240–248

Exposure to traffic-related air pollution and the risk of developing breast cancer among women in eight Canadian provinces: A case–control study

Perry Hystad[a], Paul J. Villeneuve[b], Mark S. Goldberg[c, d], Dan L. Crouse[e], Kenneth Johnson[f], the

Postmenopausal Breast Cancer Is Associated with Exposure Traffic-Related Air Pollution in Montreal, Canada: A Case-Control Study

Crouse, Dan L; Goldberg, Mark S; Ross, Nancy A; Chen, Hong; Labrèche, France. Environmental Health Perspectives 118.11 (Nov 2010): 1578-83.

Environmental Research
Volume 115, May 2012, Pages 18–25

Neurobehavioral effects of exposure to traffic-related air pollution and transportation noise in primary schoolchildren ☆ ☆☆

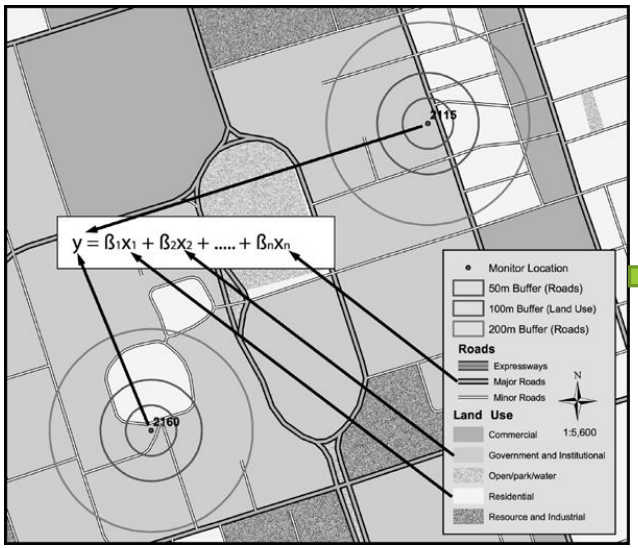
Elise van Kempen[a], Paul Fischer[a], Nicole Janssen[a], Danny Houthuijs[a], Irene van Kamp[a], Stephen Stansfeld[b], Flemming Cassee[a]

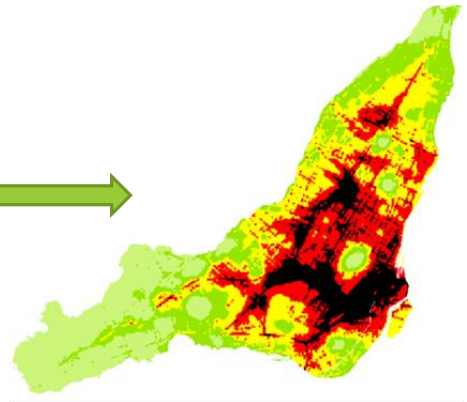
Traffic-related air pollution and prostate cancer risk: a case–control study in Montreal, Canada

Marie-Élise Parent[1], Mark S Goldberg[2,3], Dan L Crouse[4], Nancy A Ross[5], Hong Chen[6], Marie-France Valois[2,3], Alexandre Liautaud[7]

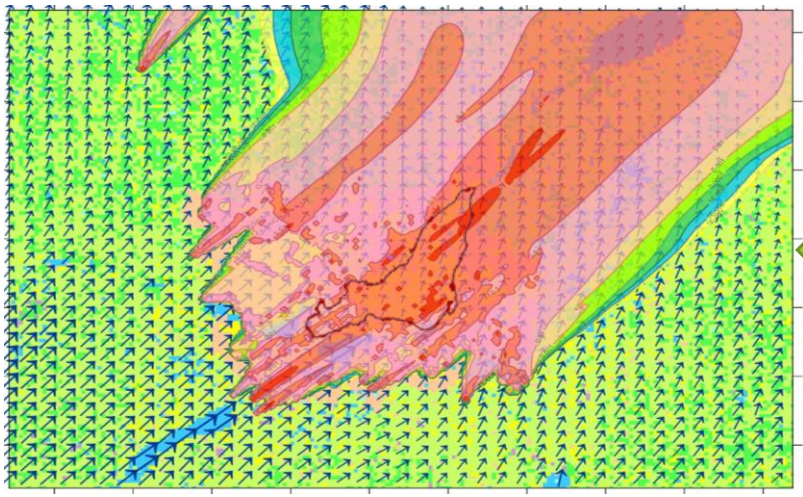
Tools

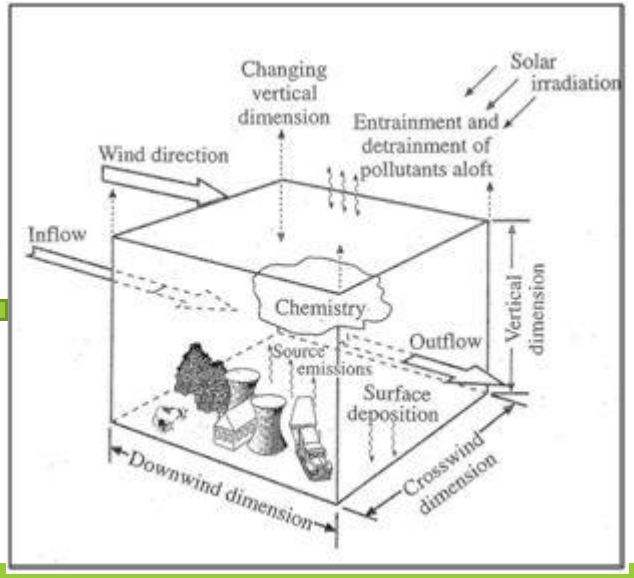
Land use regression **(LUR)** model





Emission-dispersion models





Objectives

We have developed a transportation emission dispersion model to:

Objective 1

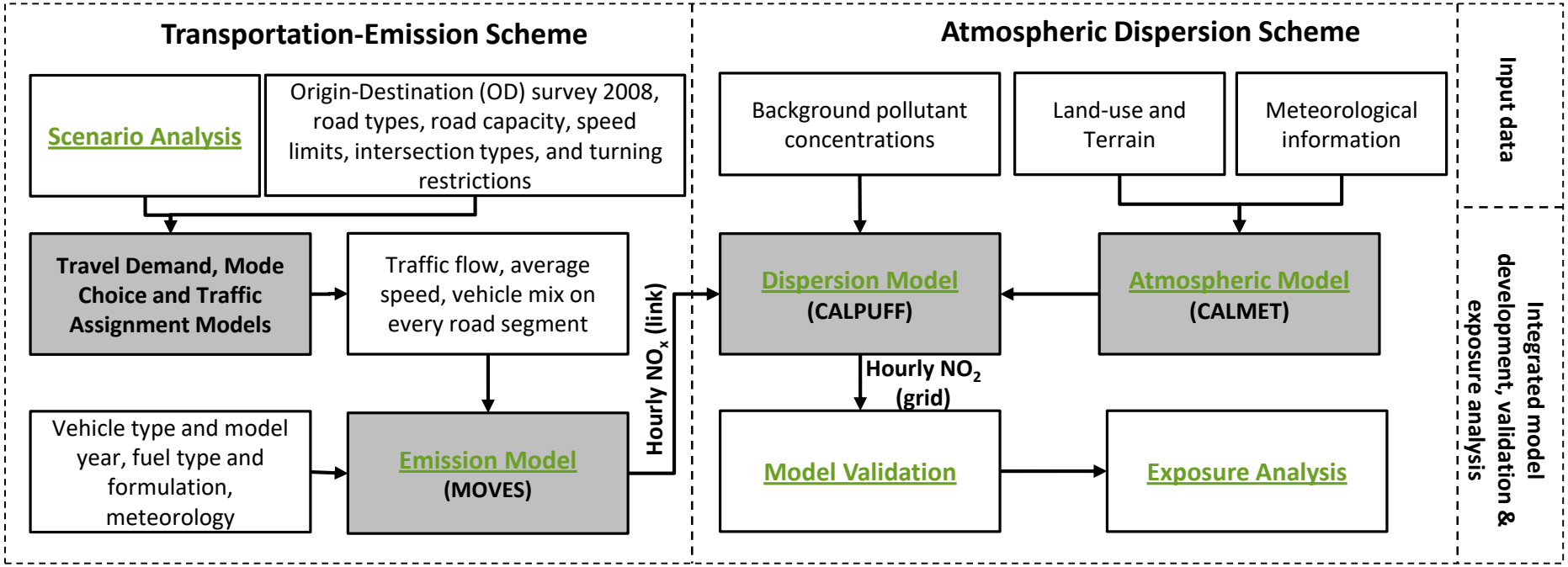
I. Demonstrate the impact of population mobility on air pollution exposure

Objective 2

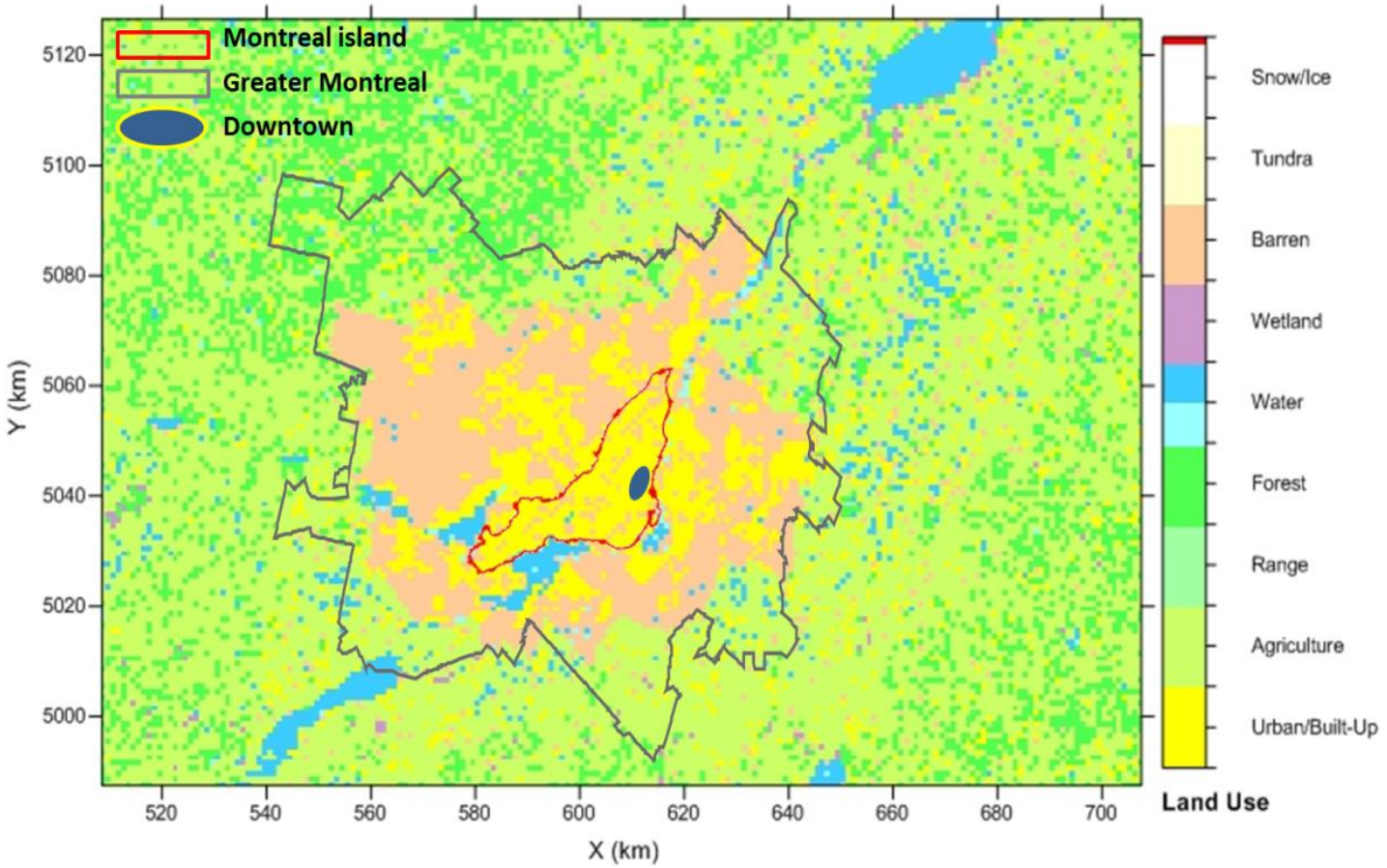
II. Assess the effects of transit investments in the metropolitan area on air quality and exposure

Methodology

Model Development

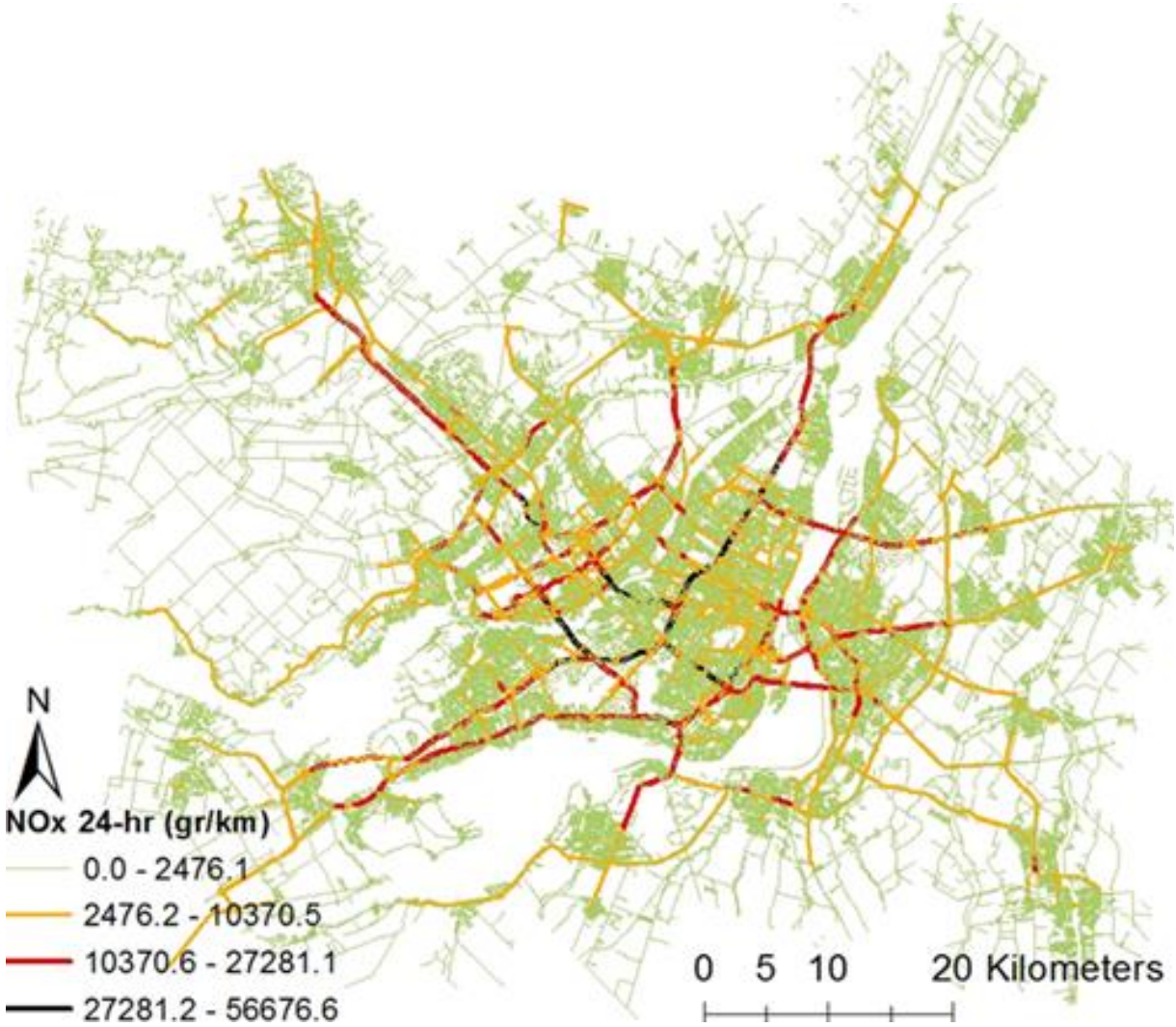


Study area

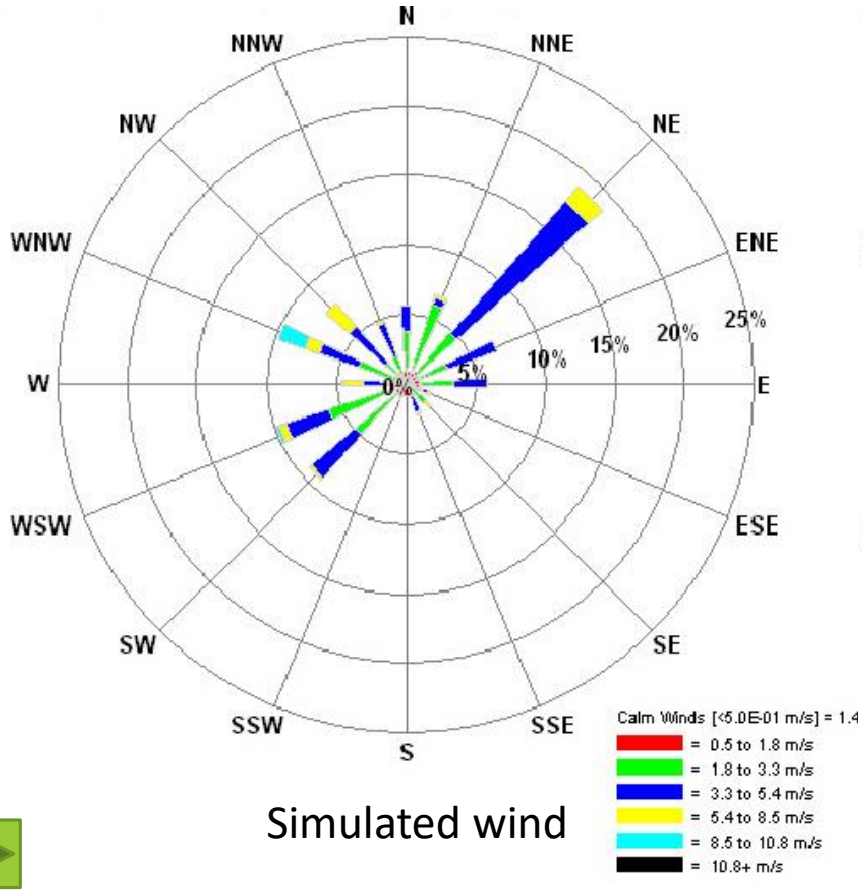

Montreal island
Greater Montreal
Downtown
Y (km)
5120
5100
5080
5060
5040
5020
5000
520
540
560
580
600
620
640
660
680
700
X (km)
Snow/Ice
Tundra
Barren
Wetland
Water
Forest
Range
Agriculture
Urban/Built-Up
Land Use

NO_x emissions at link level

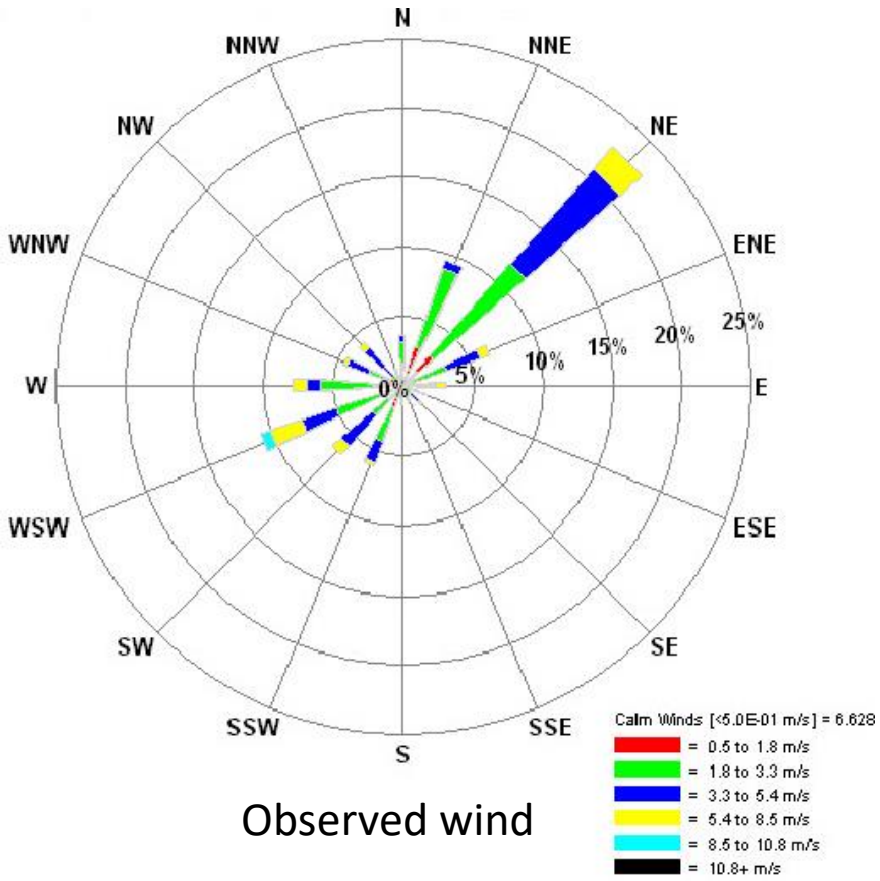
127,217 links



Simulation of winds



Simulated wind

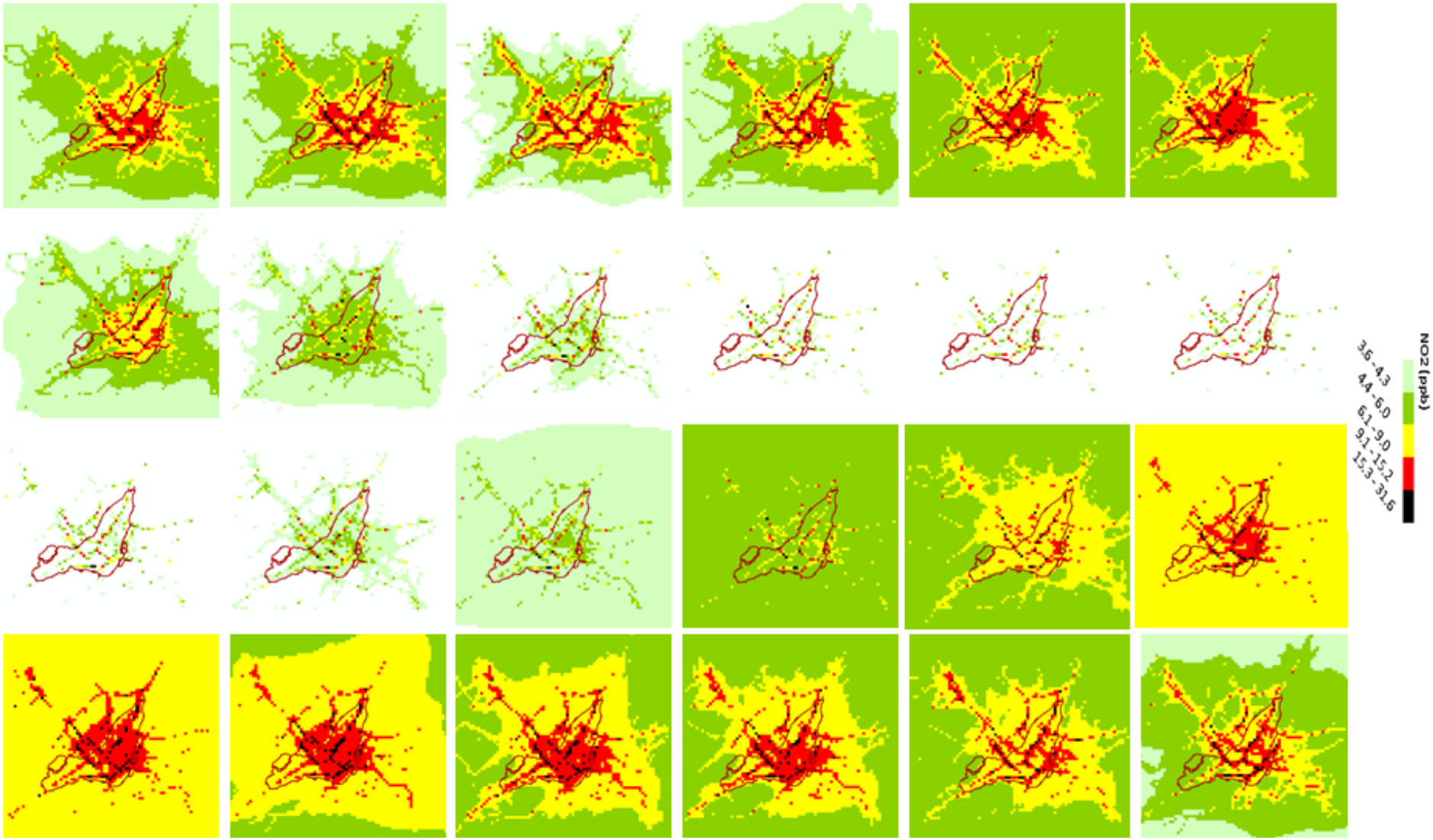


Observed wind

Model set-up

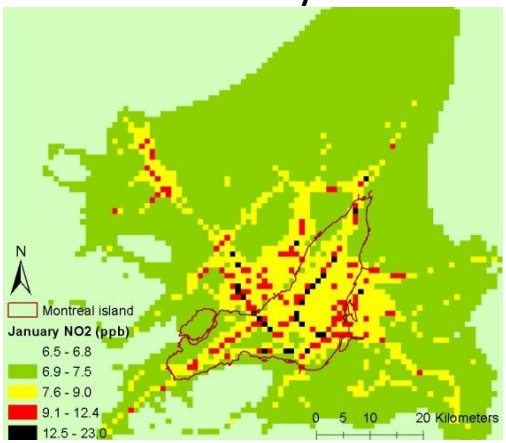
Total number of links sources	375200	
Spatial Resolution	1x1km	
Simulation period	4 weeks	January
		April
		August
		October
Jobs submitted to super computers of Compute Canada	4 weeks x 2 (base and horizon year) x 2 (scenarios) = 16 jobs	
Computational time	Each jobs takes 24hours of runtime Approx. 16 to 20 days in total (without time in queue)	

Hourly NO_2 concentrations

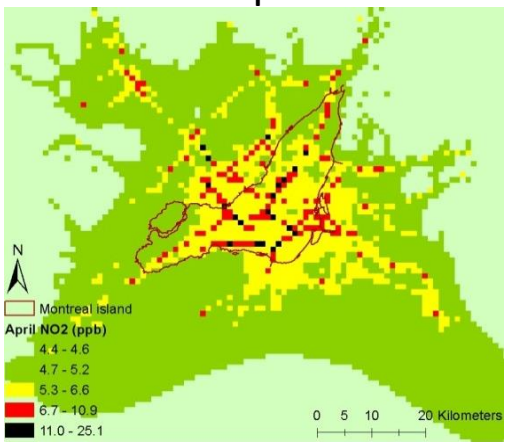


Monthly average NO_2 concentrations

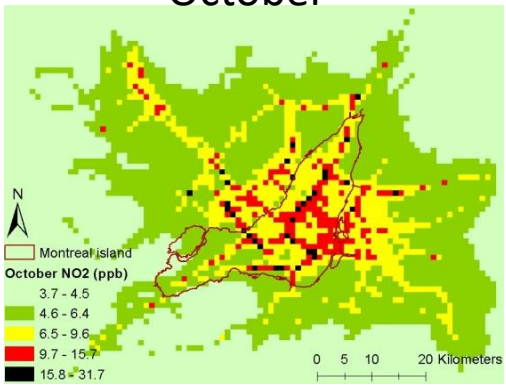
January



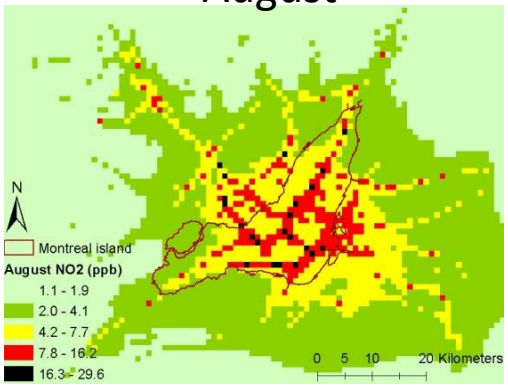
April



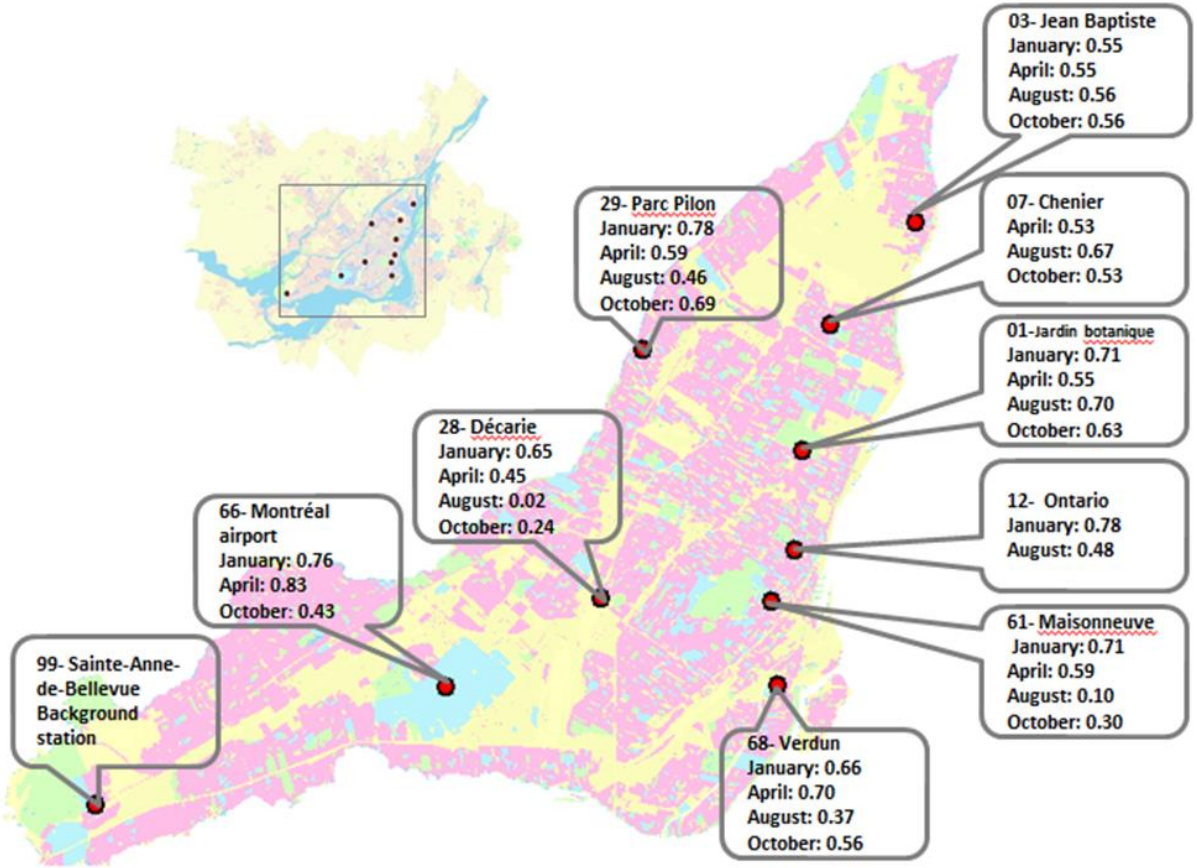
October



August



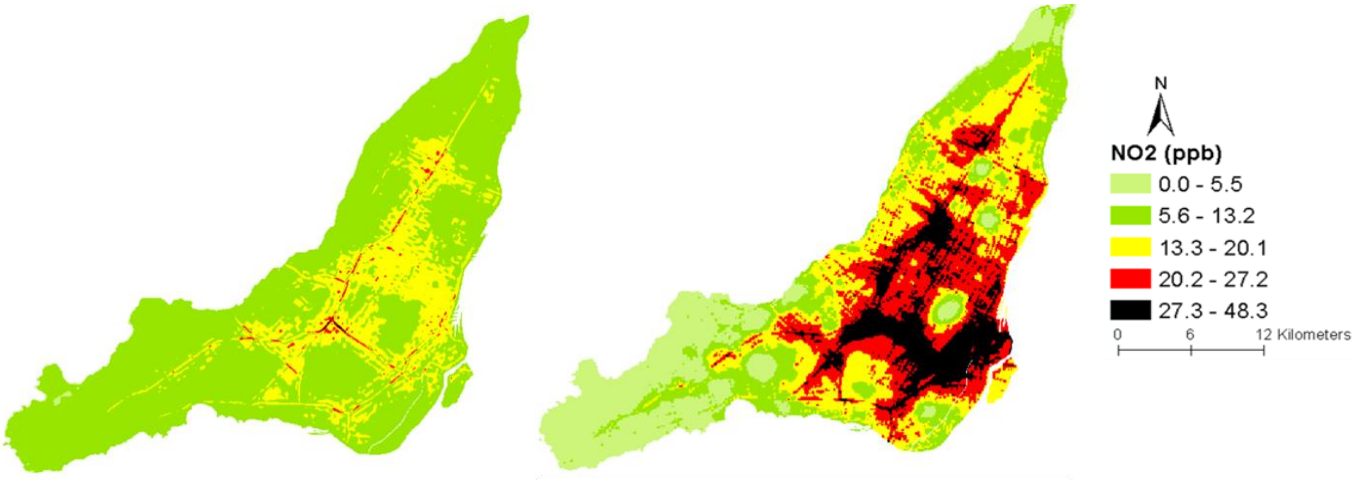
Validating against fixed stations



Performance measures	January	April	October	August	Acceptable Value
Normalized absolute difference (*NAD*)	0.39	0.34	0.28	0.40	<0.5
Fractional mean bias (*FB*)	0.23	0.67	0.46	0.56	-0.67 to 0.67
Normalized mean-square error (*NMSE*)	1.23	1.45	1.01	6.92	<6

Methodology

- Comparison of dispersion and LUR model outputs



Crouse et al. 2009 (NO2-LUR 1)

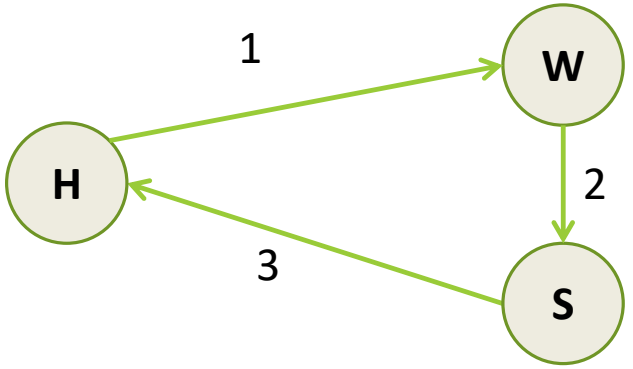
Deville-Cavellin et al. 2015 (NO2-LUR 2)

Spearman correlation	Simulated NO_2			
	Yearly	Weekly	Daily	Hourly
N	87060	87060	87060	87060
NO_2-LUR (1)[a]	0.78**	0.77**	0.76**	0.62**
NO_2-LUR (2)[b]	0.76**	0.74**	0.72**	0.62**

**Correlation is significant at the 0.01 level

Deriving exposures for individuals

- Individual Trajectories



H: Home

W (Work) and S (Shopping): Activity stops

H, W and S: Stops

- $24\text{-hour mobility} = H + Trip_1 + W + Trip_2 + S + Trip_3 + H$

Individual daily exposure

$$C^{i}_{NO_2} = \frac{\sum_{t=1}^{n}\left(\sum_{k=1}^{m}\left[C^{k}_{NO_2-t}(\mathrm{t}) \times t^{k}_{trip}(\mathrm{t}) + C^{k}_{NO_2-s}(\mathrm{t}) \times t^{k}_{stop}(\mathrm{t})\right]\right)_t}{N}$$

where *N* is the sum of trip and stop durations

$t^{k}_{trip}(t)$ total time an individual spent at every trip (in hours)

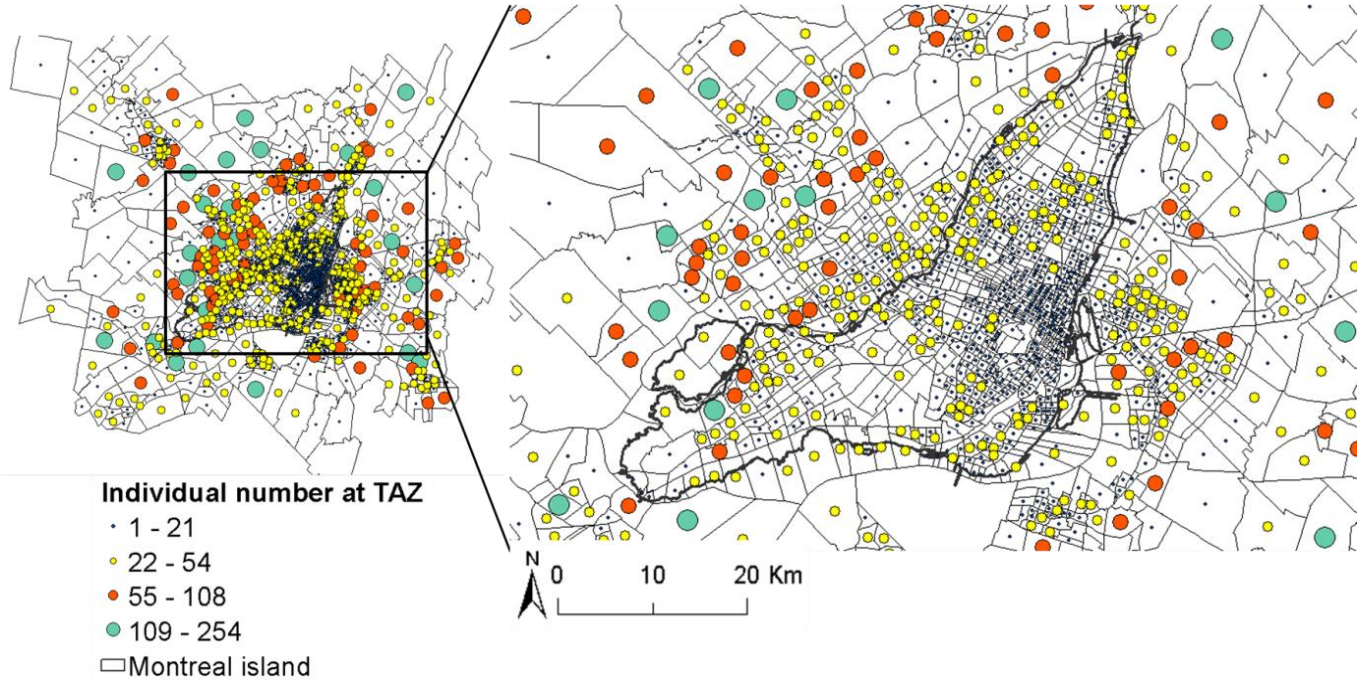
$t^{k}_{stop}(\mathrm{t})$ total time an individual spent at every stop (in hours)

$C^{k}_{NO_2-s}(\mathrm{t})$ is the NO_2 concentration during stop time at end of trip *k* at time *t*

$C^{k}_{NO_2-t}(\mathrm{t})$ is the NO_2 concentration for part of trip *k* at time *t*

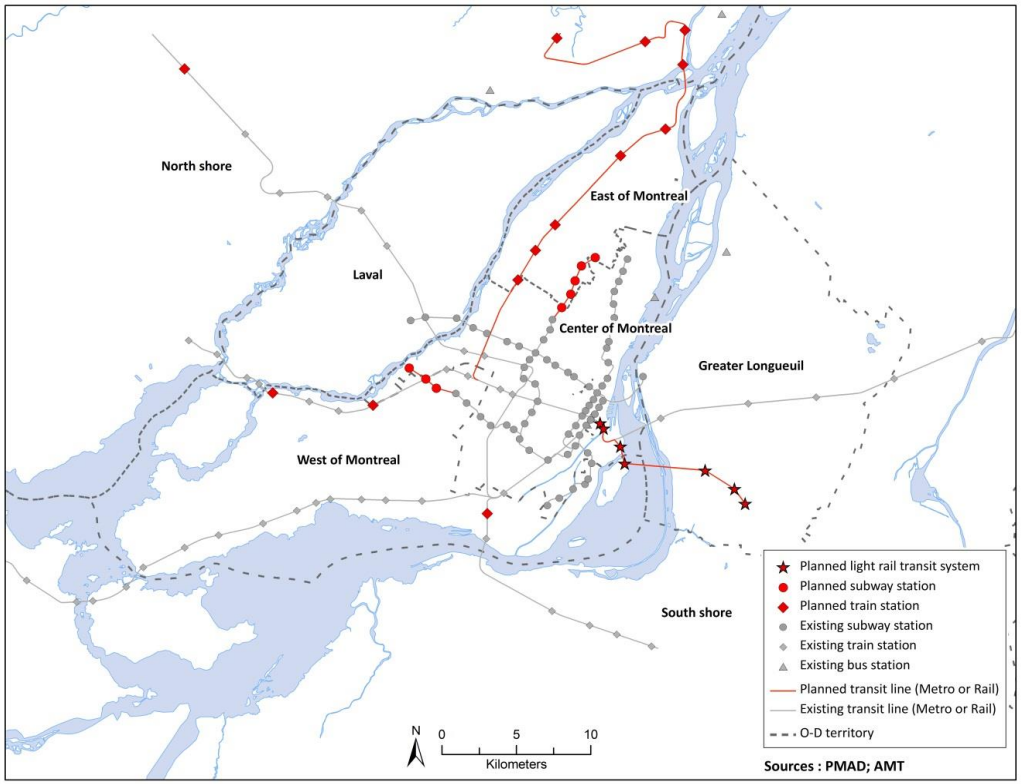
Methodology

- Sample of 29,219 Individuals



Scenario Analysis

i. 2008-baseline year
ii. 2031-business-as-usual (BAU)
iii. 2008-Transit scenario
iv. 2031-Transit scenario



✓By 2031, region's projected growth would be about 600,000 new residents

Plan Métropolitain d'Aménagement et de Développement (PMAD; 2011)

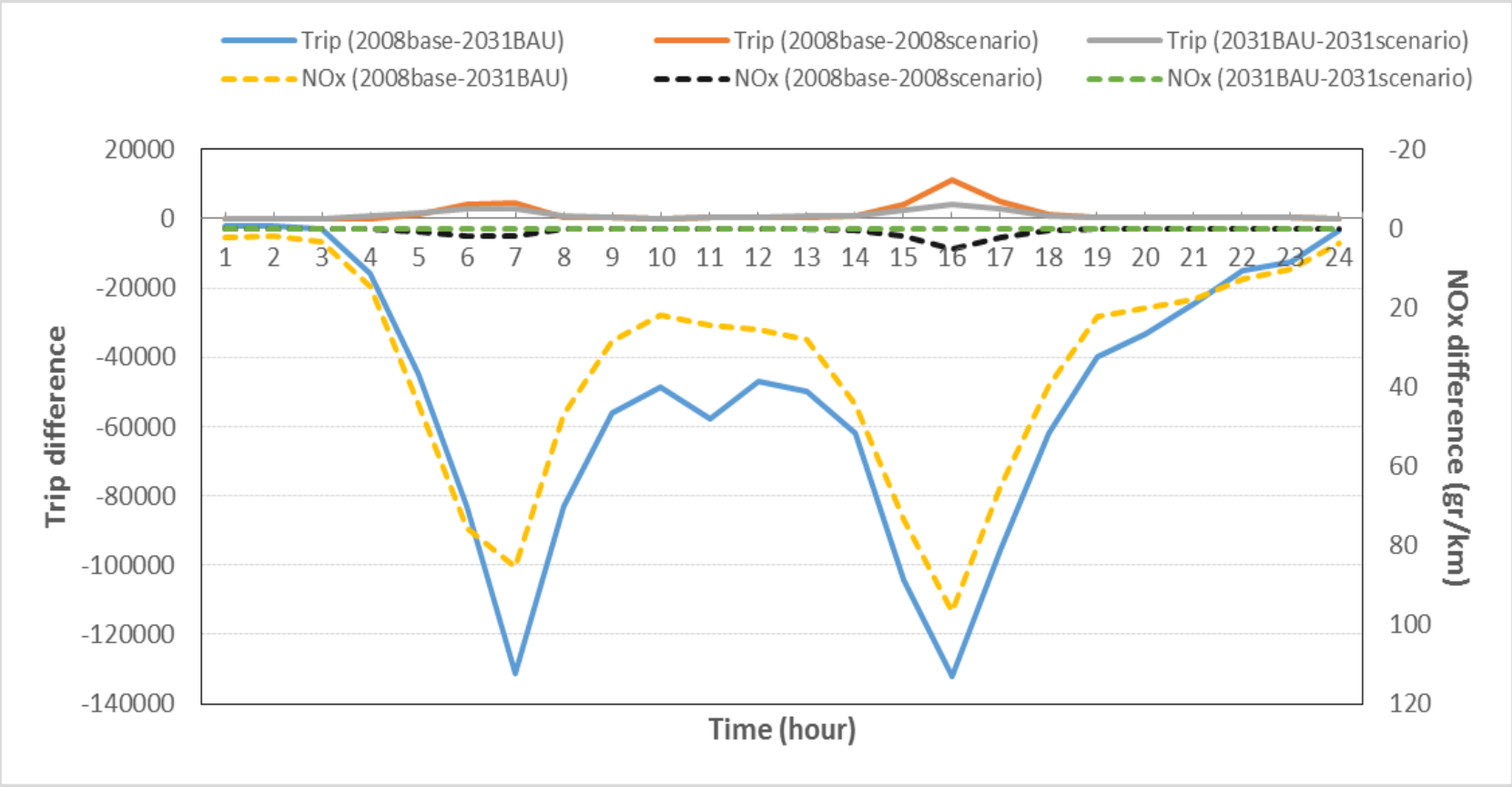
Results

Number of trips by mode

Trips Categories	Base 2008	Transit 2008	BAU 2031	Transit 2031
Drive	3,626,805	3,599,976	4,833,805	4,809,305
Passenger	761,791	750,495	984,546	978,194
Transit	1,190,343	1,224,232	138,8346	1,416,476
Walk	754,025	746,965	866,582	861,138
Bike	143,321	143,321	174,224	172,409
Park/Kiss and Ride	150,381	160,266	207,798	218,687
Other mode	433,494	434,906	618,858	617,950
Total number of trips	7,060,161	7,060,161	9,074,160	9,074,160

- ✓ The VKT reduction is1.8% and 1% in 2008 and 2031 transit scenarios compared to their corresponding base years

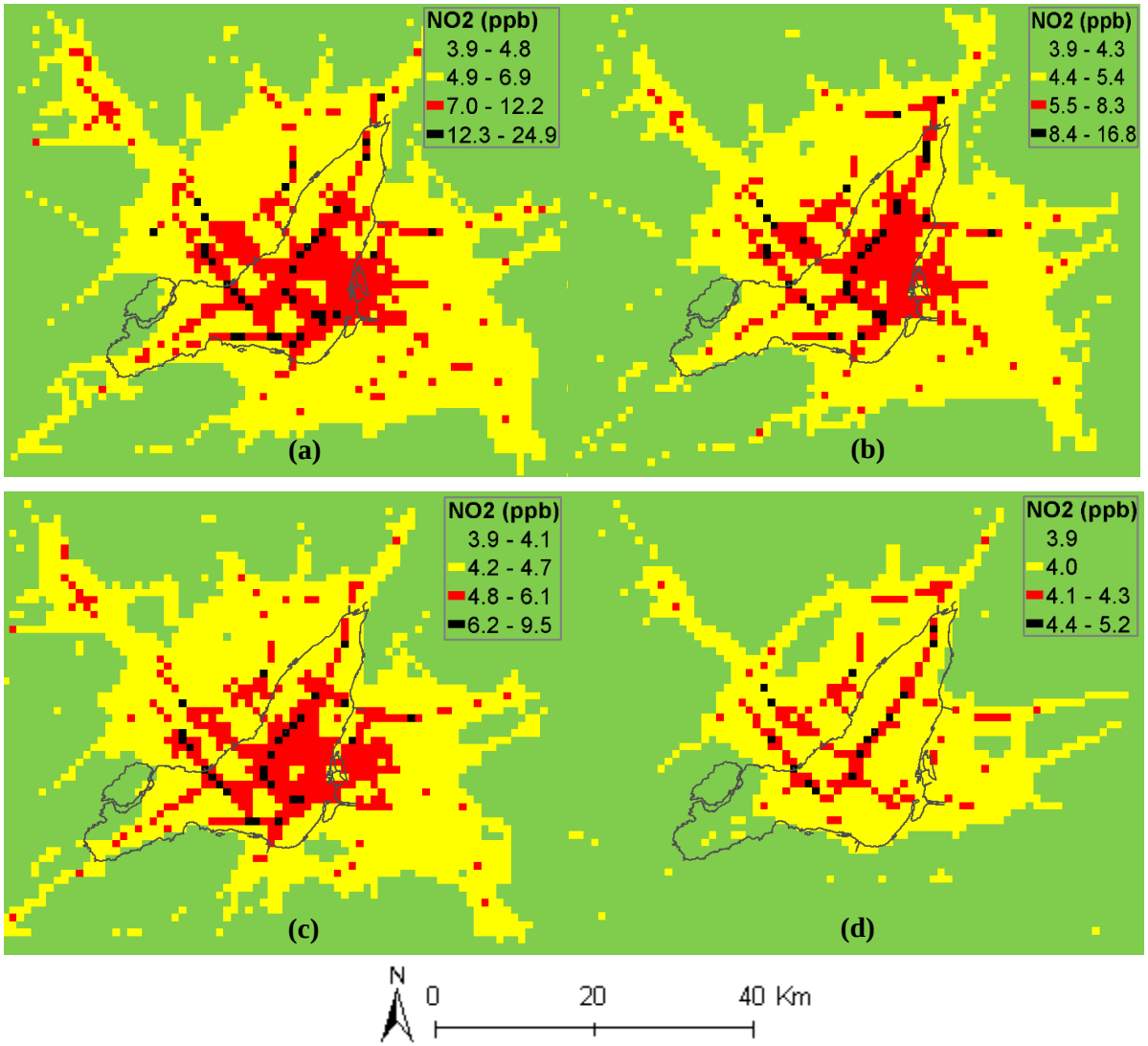
Difference in number of driving trips and hourly NO_x emissions



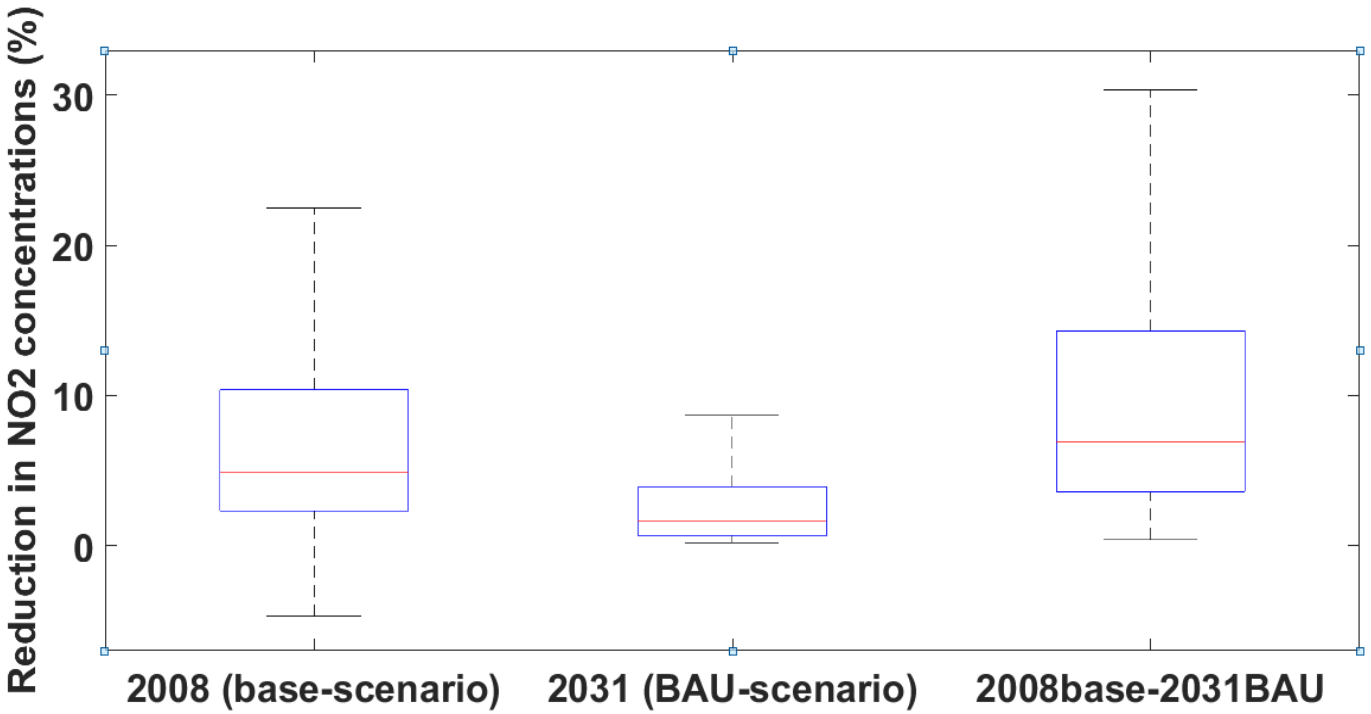
NO_2 concentrations

2008

2031

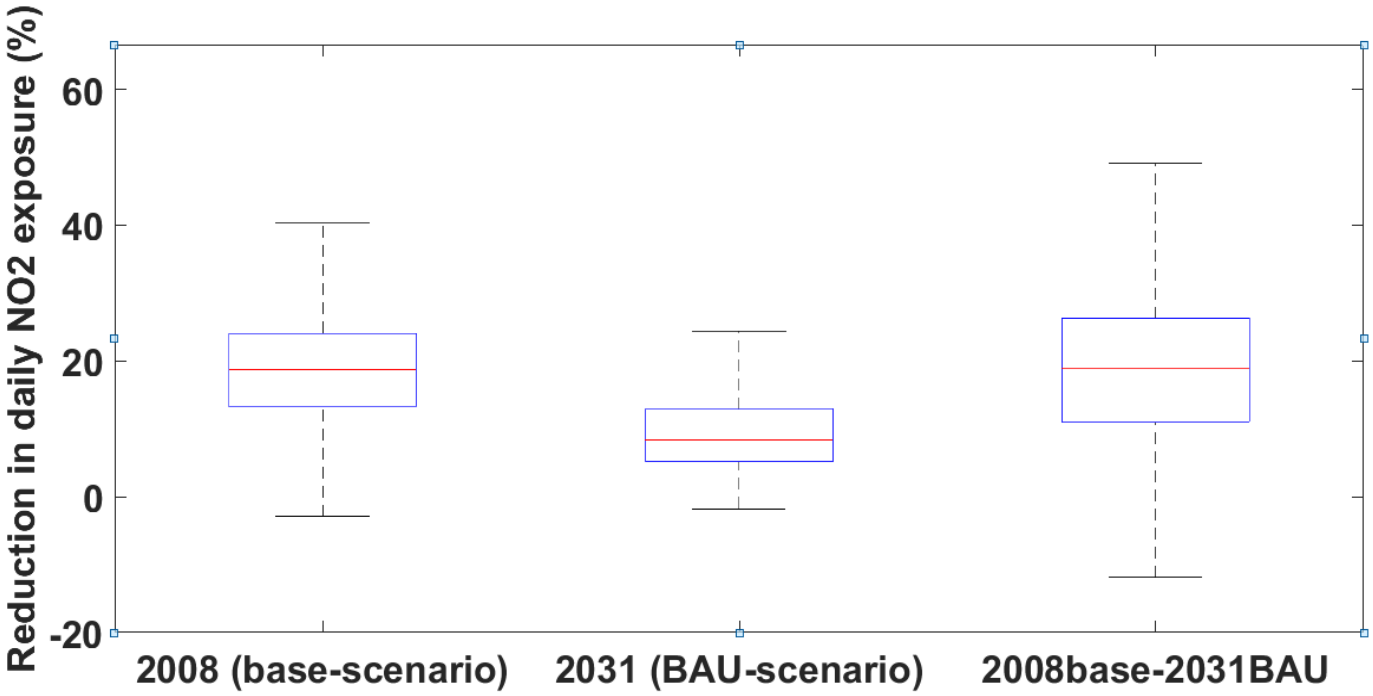


NO_2 concentrations

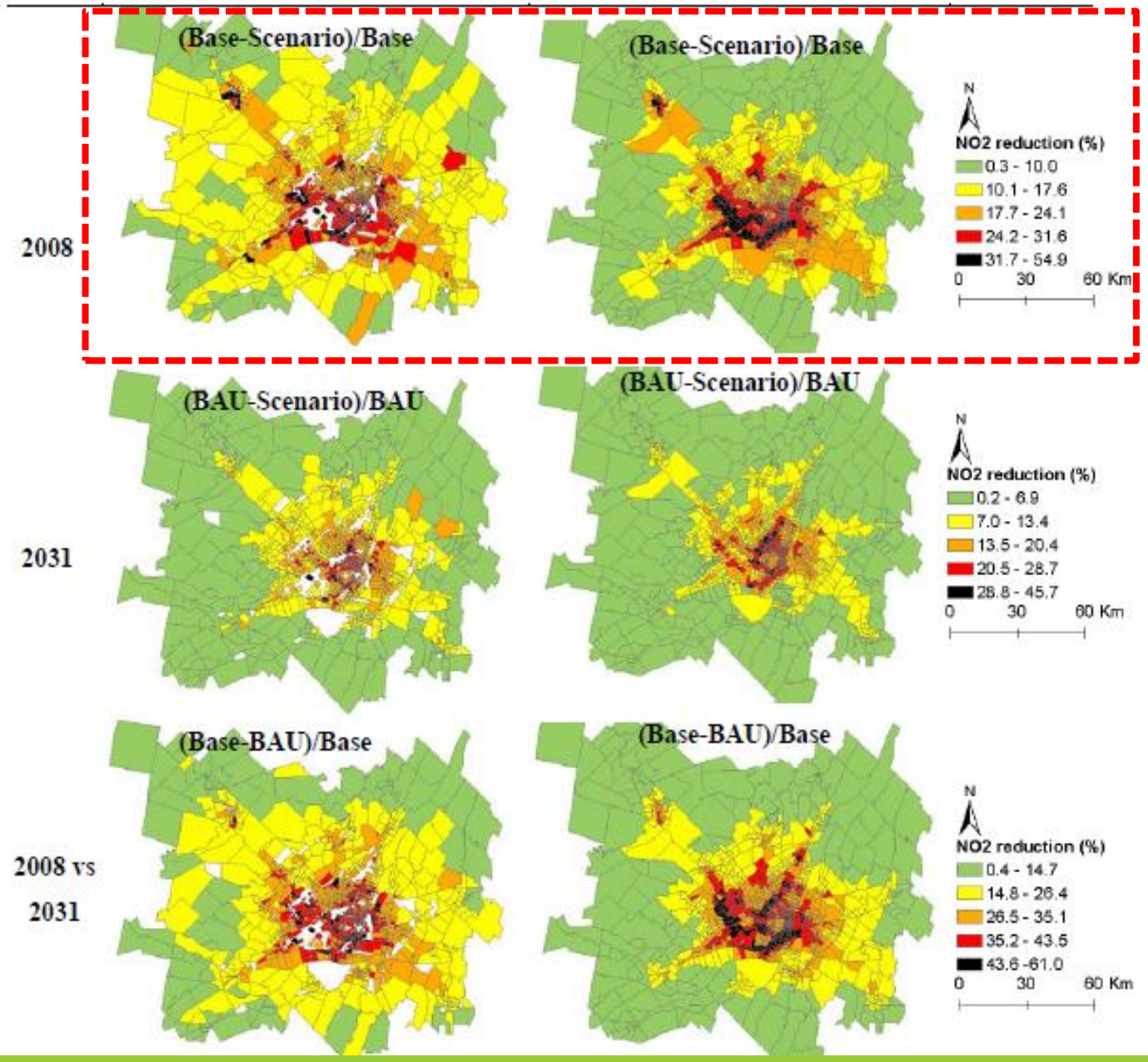


✓We observed a reduction in NO_2 concentrations in 2031 BAU by 8% compared to the 2008 base.

NO_2 exposures

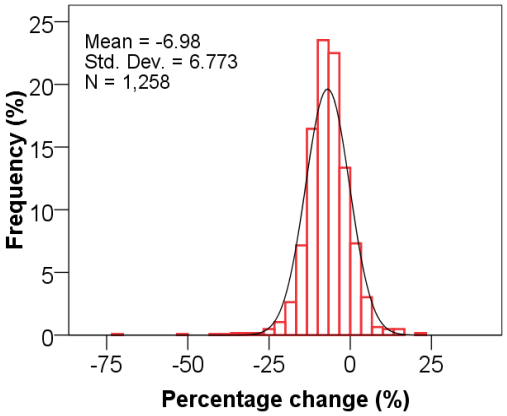


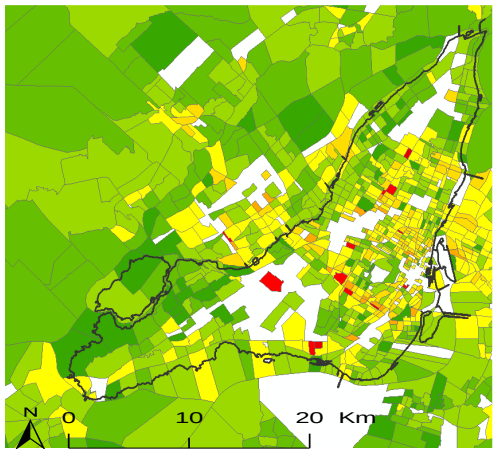
✓We observed a reduction in NO_2 exposures in 2031 BAU by 19% compared to the 2008 base.


Percentage reduction in daily exposure
Percentage reduction in average NO2
2008
(Base-Scenario)/Base
(Base-Scenario)/Base
NO2 reduction (%)
0.3 - 10.0
10.1 - 17.6
17.7 - 24.1
24.2 - 31.6
31.7 - 54.9
0 30 60 Km
2031
(BAU-Scenario)/BAU
(BAU-Scenario)/BAU
NO2 reduction (%)
0.2 - 6.9
7.0 - 13.4
13.5 - 20.4
20.5 - 28.7
28.8 - 45.7
0 30 60 Km
2008 vs 2031
(Base-BAU)/Base
(Base-BAU)/Base
NO2 reduction (%)
0.4 - 14.7
14.8 - 26.4
26.5 - 35.1
35.2 - 43.5
43.6 -61.0
0 30 60 Km

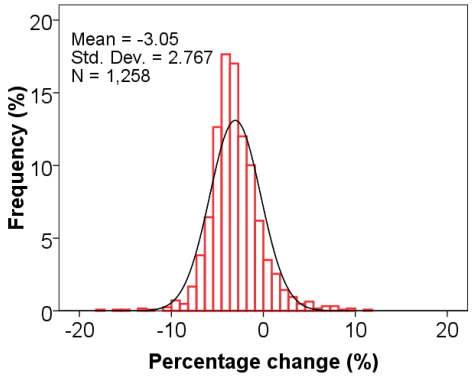
Mobility vs Home Exposure

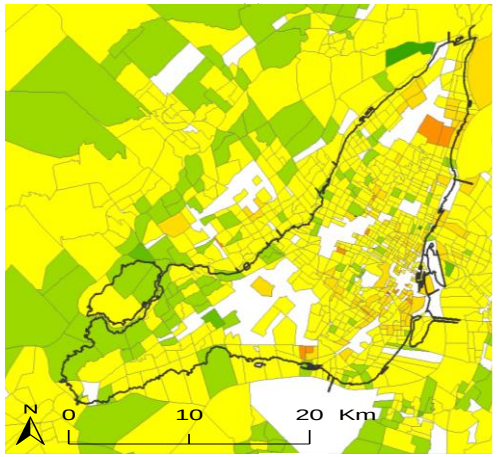
2008 base





2031 BAU





Montreal island

Percentage change (%)

- <-15.0
- -14.9 - -10.0
- -9.9 - -5.0
- -4.9 - 0.0
- 0.1 - 5.0
- 5.1 - 10.0
- 10.1 - 15.0
- >15.0

Conclusion

- We observed significant reductions in NO_2 concentrations in downtown due to transit scenario compared to baseline year
- Individual exposures were reduced throughout all TAZs, including the suburbs due to population mobility patterns
- Ignoring population mobility would result in daily exposures that are underestimated/overestimated for individuals living in peripheral areas and downtown respectively
- The impact of the transit policy in either year is smaller than the impact of technology

Acknowledgements

Collaborators

- Montreal Department of Public Health

Funding sources

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Thank you!

Questions?

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