Can we improve air pollution estimates when extending land-use regression models to adjacent cities or backward in time?

OEH Seminar
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Conflict of Interest Statement

- I do not have any conflicts of interest

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Presentation Framework

- Discuss the strengths and weakness of land-use regression (LUR) model
- Highlight research objectives explored for improving LUR model estimations when extending these models over space and time
- For each research objective:

➢ Detail the methodology

➢ Discuss the key findings

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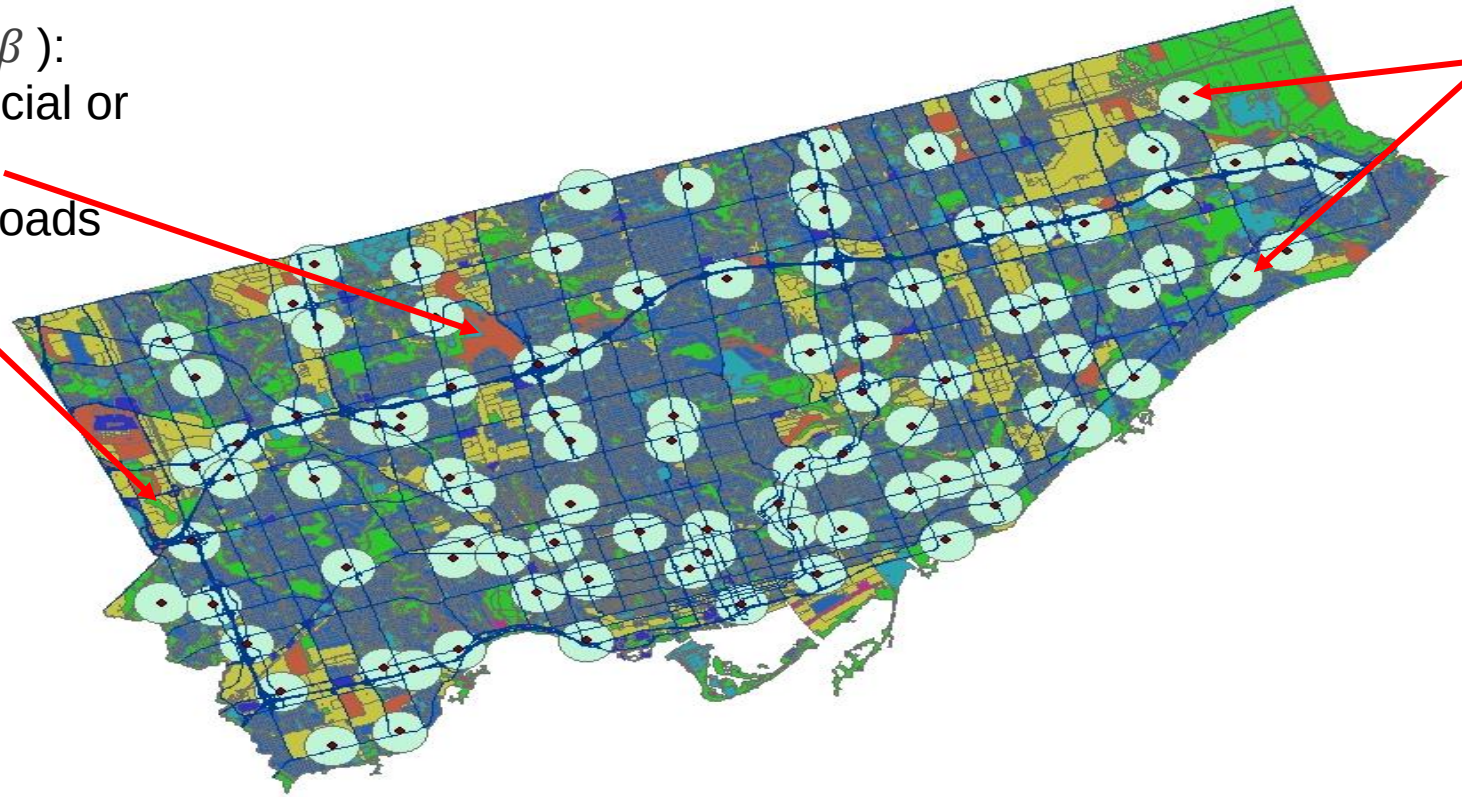
What is a land-use regression (LUR) model?

$$\text{Concentration} = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + .. + \beta_y x_y$$

$x \; and \; \beta$ represent land use variables and the relationship between these variables and pollutant concentrations

Land-use Variables (β):
Industrial or Commercial or Residential areas
Highways or Major Roads



Measured Concentrations (x):
Fixed or Mobile

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LUR models are commonly used in health studies

THE LANCET

ARTICLES | VOLUME 389, ISSUE 10070, P718-726, FEBRUARY 18, 2017

Living near major roads and the incidence of dementia, Parkinson's disease, and multiple sclerosis: a population-based cohort study

Hong Chen, PhD • Jeffrey C Kwong, MD • Ray Copes, MD • Karen Tu, MD • Paul J Villeneuve, PhD • Aaron van Donkelaar, PhD • et al. Show all authors

Published: January 04, 2017 • DOI: https://doi.org/10.1016/S0140-6736(16)32399-6 • Check for updates

ehp Environmental Health Perspectives

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Research

A Cohort Study of Traffic-Related Air Pollution Impacts on Birth Outcomes

Michael Brauer, Cornel Lencar, Lillian Tamburic, Mieke Koehoorn, Paul Demers, and Catherine Karr

Published: 1 May 2008 | https://doi.org/10.1289/ehp.10952 | Cited by: 268

Epidemiology. 24(1):35–43, JAN 2013

DOI: 10.1097/EDE.0b013e318276c005, PMID: 23222554

Issn Print: 1044-3983

Publication Date: 2013/01/01

Long-Term Exposure to Traffic-Related Air Pollution and Cardiovascular Mortality

Hong Chen;Mark Goldberg;Richard Burnett;Michael Jerrett;Amanda Wheeler;Paul Villeneuve;

ELSEVIER

Environment International

Volume 65, April 2014, Pages 83-92

open access

Presence of other allergic disease modifies the effect of early childhood traffic-related air pollution exposure on asthma prevalence

Sharon D. Dell [a, b], Michael Jerrett [c], Bernard Beckerman [c], Jeffrey R. Brook [d, e], Richard G. Foty [a], Nicolas L. Gilbert [f], Laura Marshall [a], J. David Miller [g], Teresa To [a, e], Stephen D. Walter [h], David M. Stieb [i]

While LUR models are useful tools, they perform poorly when extended across space

- Models developed for one city should be estimate air pollution in another city that has similar infrastructure, topography and climate.

- At the provincial-scale, NO_2 LUR model developed for Winnipeg (R^2 =0.77) showed poor performance when used to estimate concentrations in Edmonton (R^2 =0.39) (Allen et al. 2011).

- At the neighbourhood-scale, particle number concentration LUR model (R^2 =0.42) poorly predicted concentrations for different neighbourhoods (R^2 =0.04-0.12) in Boston (Patton et al. 2015).

They also perform poorly when extended across time

- Models developed for specific time-period should be estimate air pollution in another time-period only if the relationship between land-use variables and air pollution is constant.

- When extending backward in time, Vancouver NO_2 LUR model developed for 2010 (R^2 =0.63) showed poor predictive power when temporally extended to 2003 (R^2 =0.44) (Henderson et al., 2011).

- In UK, NO_2 LUR model developed for 2009 (R^2 =0.57-0.62) showed poor performance when extended backward in time to estimate 2001 measurements (R^2 : 0.34-0.45) (Gulliver et al., 2013).

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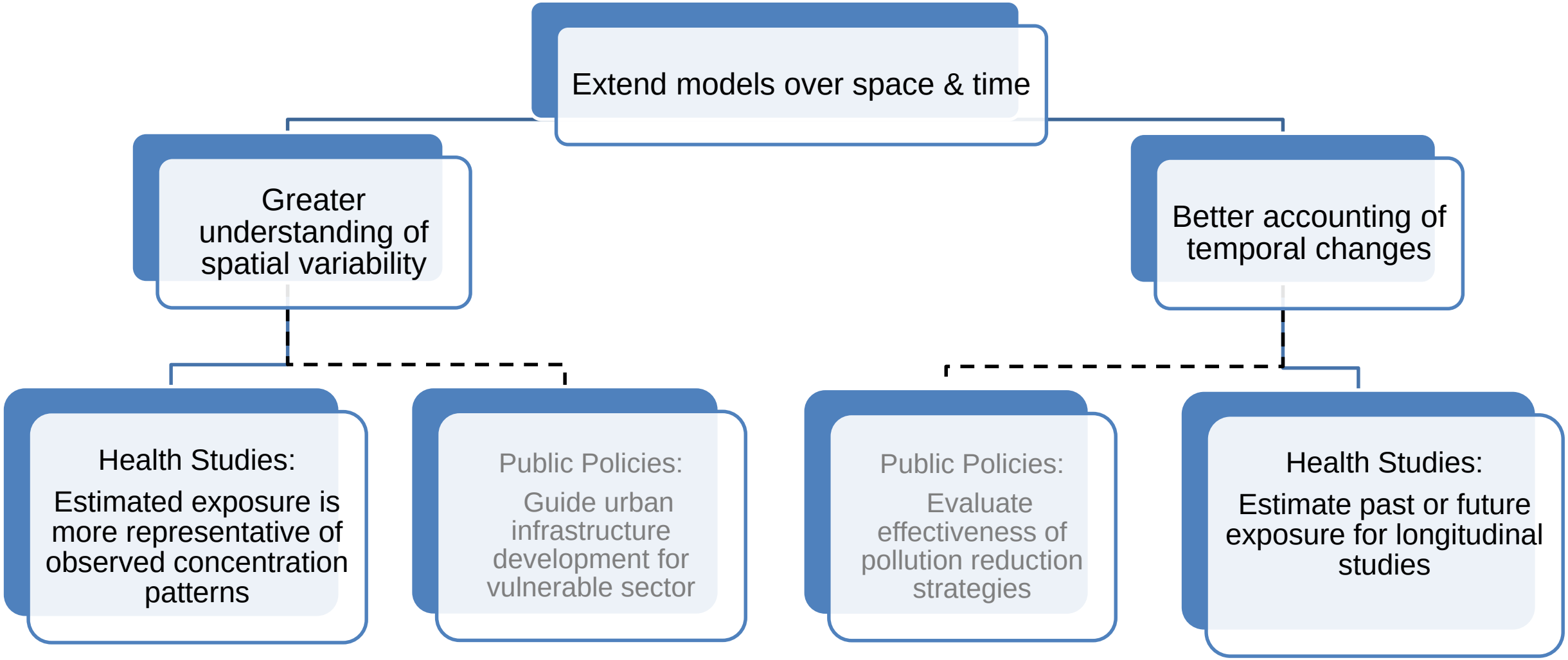
Air pollution estimates from land-use regression models are spatially and temporally static



Research Objectives for Improving Land-Use Regression Model

Spatially extending models

Objective 1: Characterize the spatial variability of resolved TRAP at the neighbourhood scale

Objective 2: Determine if using temporally resolved concentrations to develop LUR models will improve estimations when spatially extended

Temporally extending models

Research Objectives for Improving Land-Use Regression Model

Spatially extending models

Objective 1: Characterize the spatial variability of resolved TRAP at the neighbourhood scale

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Temporally extending models

Objective 3: Determine if using spatiotemporal vs traditional spatial LUR model will improve the predictive performance when temporally extended

Objective 4: Quantity the improvement in predictive performance when temporally extending LUR models with wider range of the land-use predictor variables

LUR models were based on mobile sampled data

- MAPLE measurements:
  - Summer 2015
  - Subset of Greater Toronto Area
  - Pollutants of Interest: BC, UFP, NO, NO_2

- CRUISER measurements:
  - Summer 2015, fall 2015 and winter 2016
  - Greater Toronto Area
  - Pollutant of Interest: NO_2

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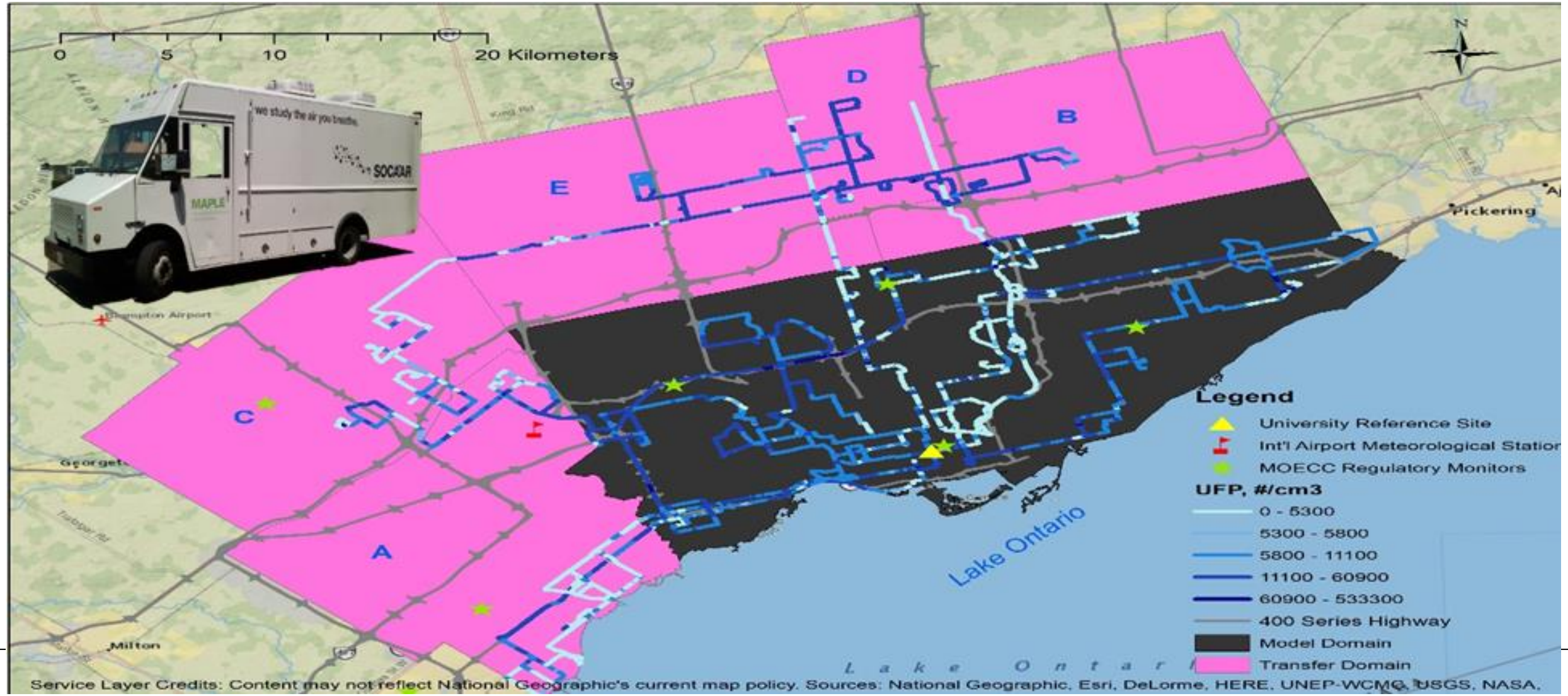
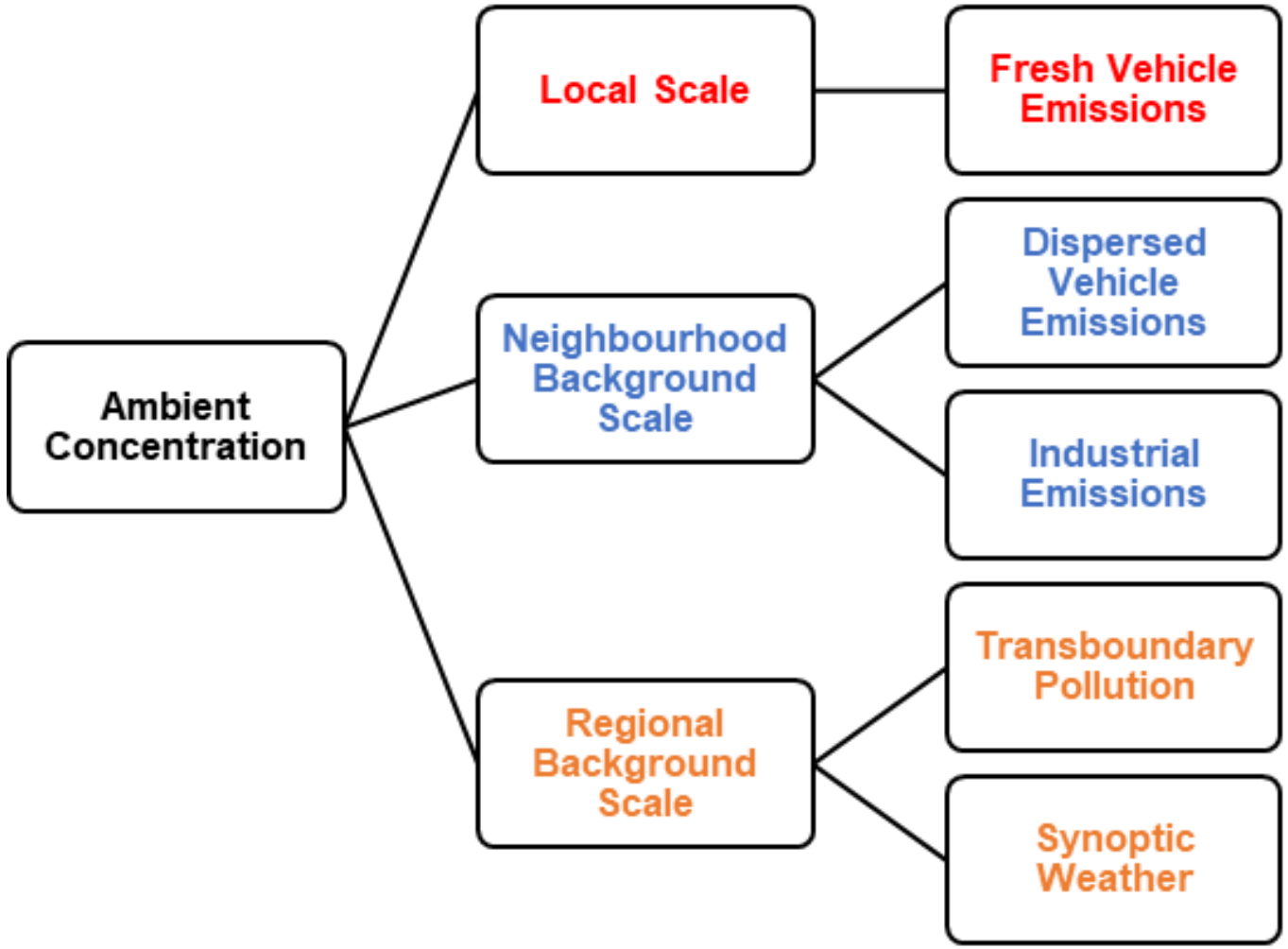
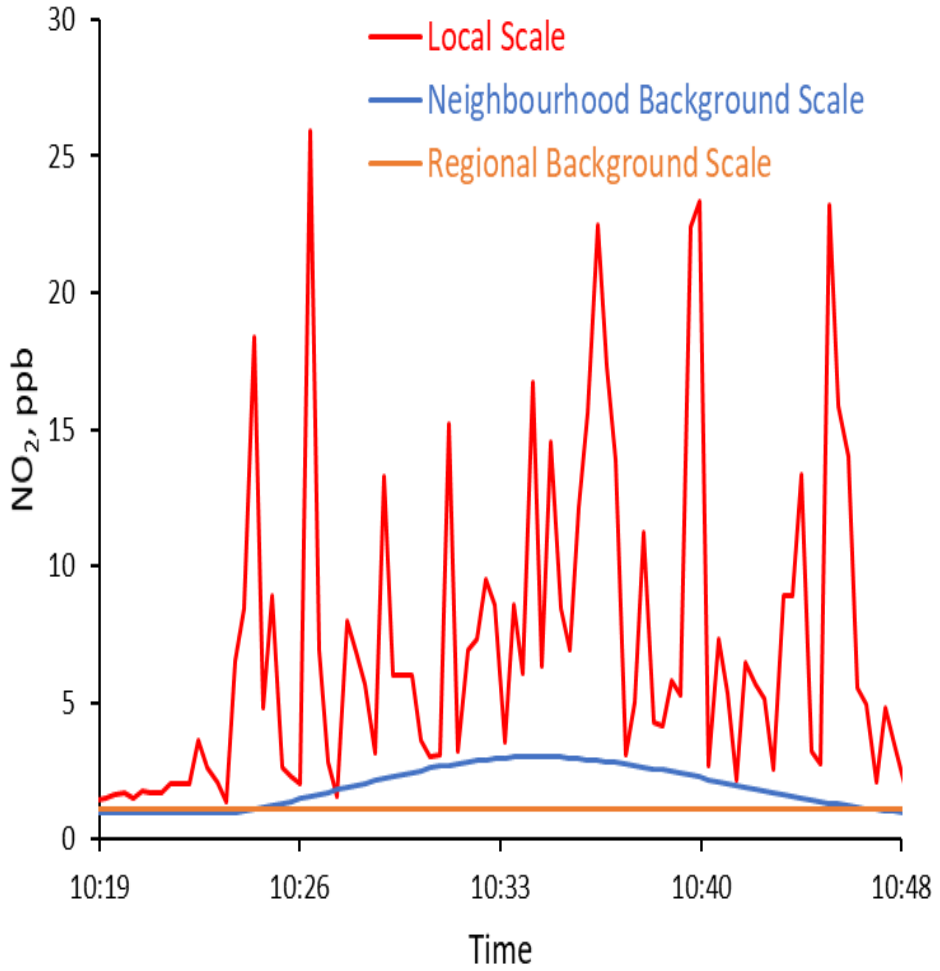
How to improve TRAP estimates when extending models to adjacent cities?

Resolved and unresolved LUR models were spatially extended from urban to suburban areas



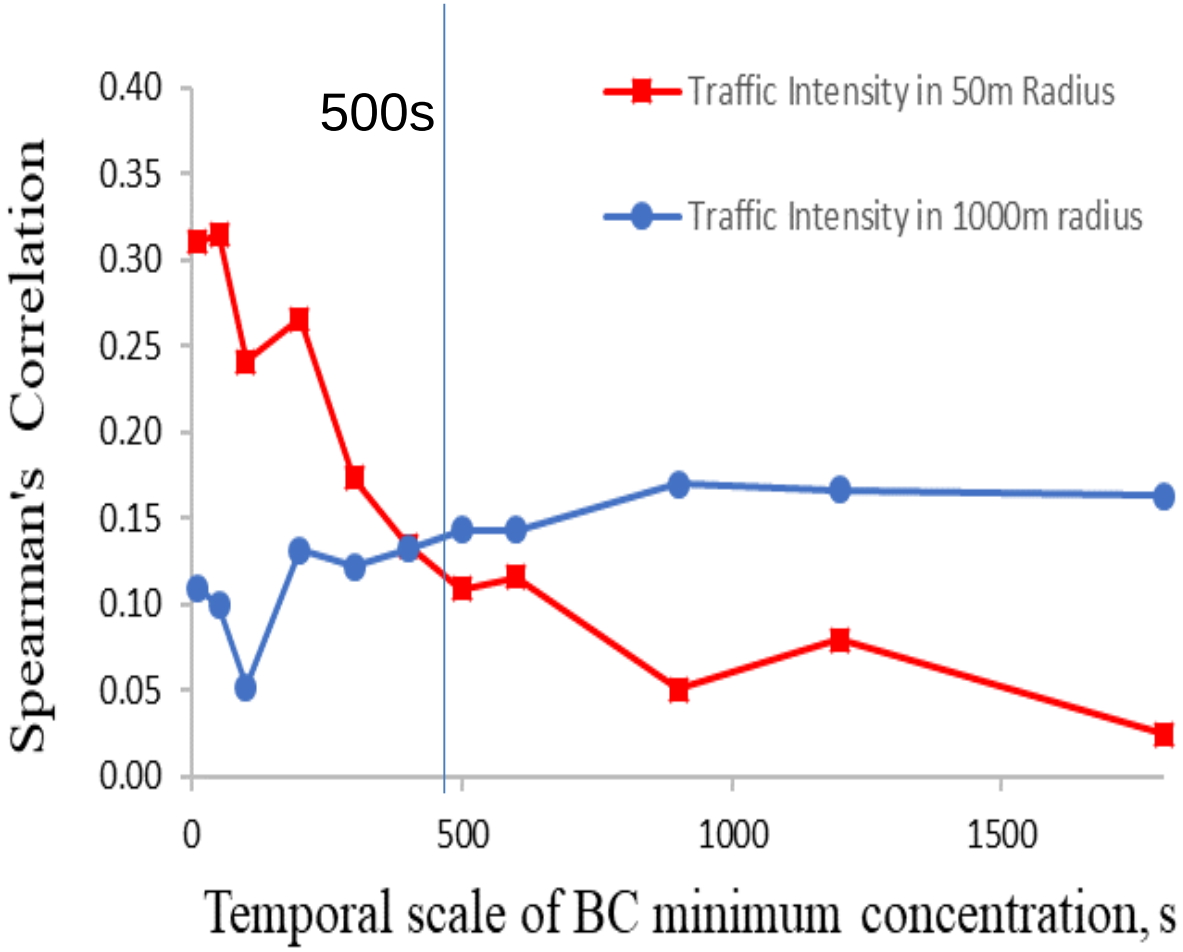
Resolved concentrations are derived from the spline of minimums - a time-series approach

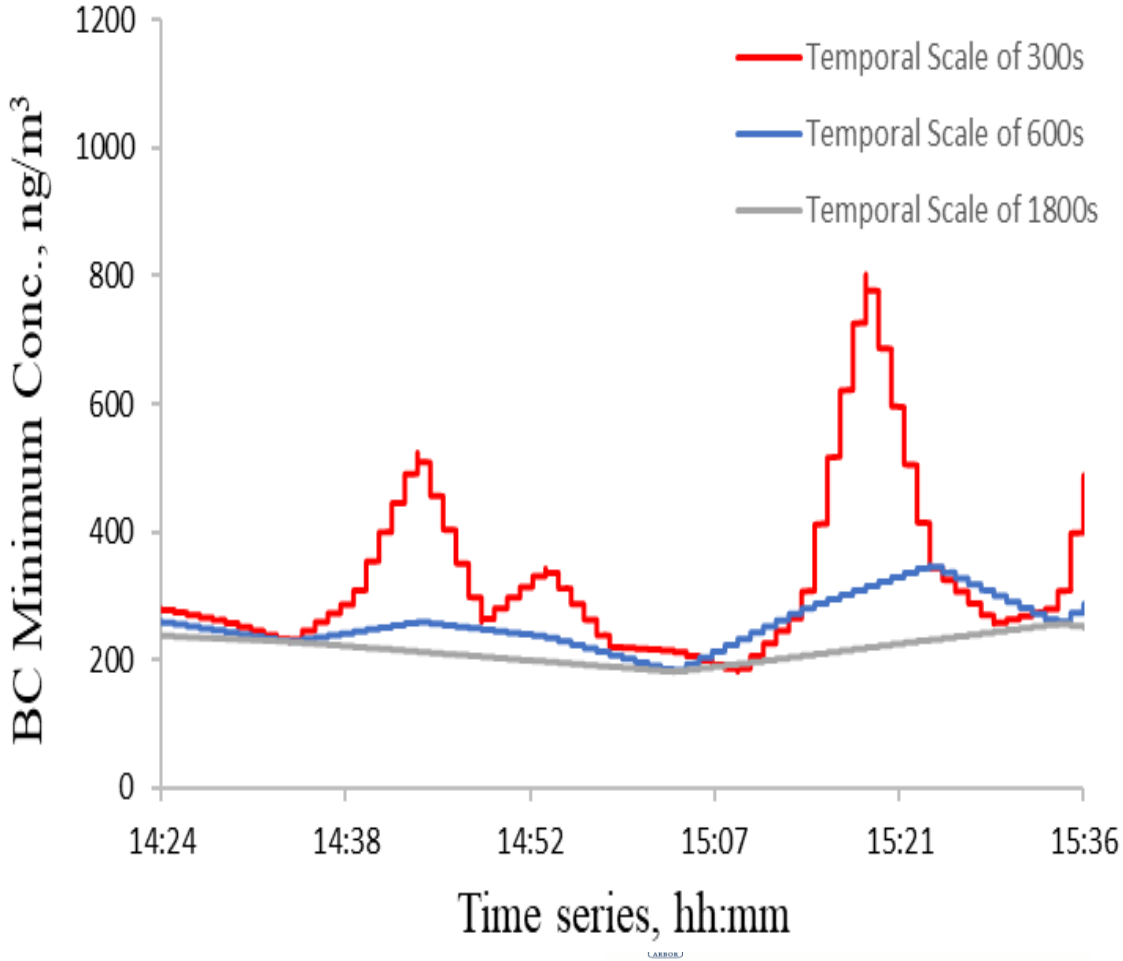




Shairsingh et al., 2018. Atmos. Env.

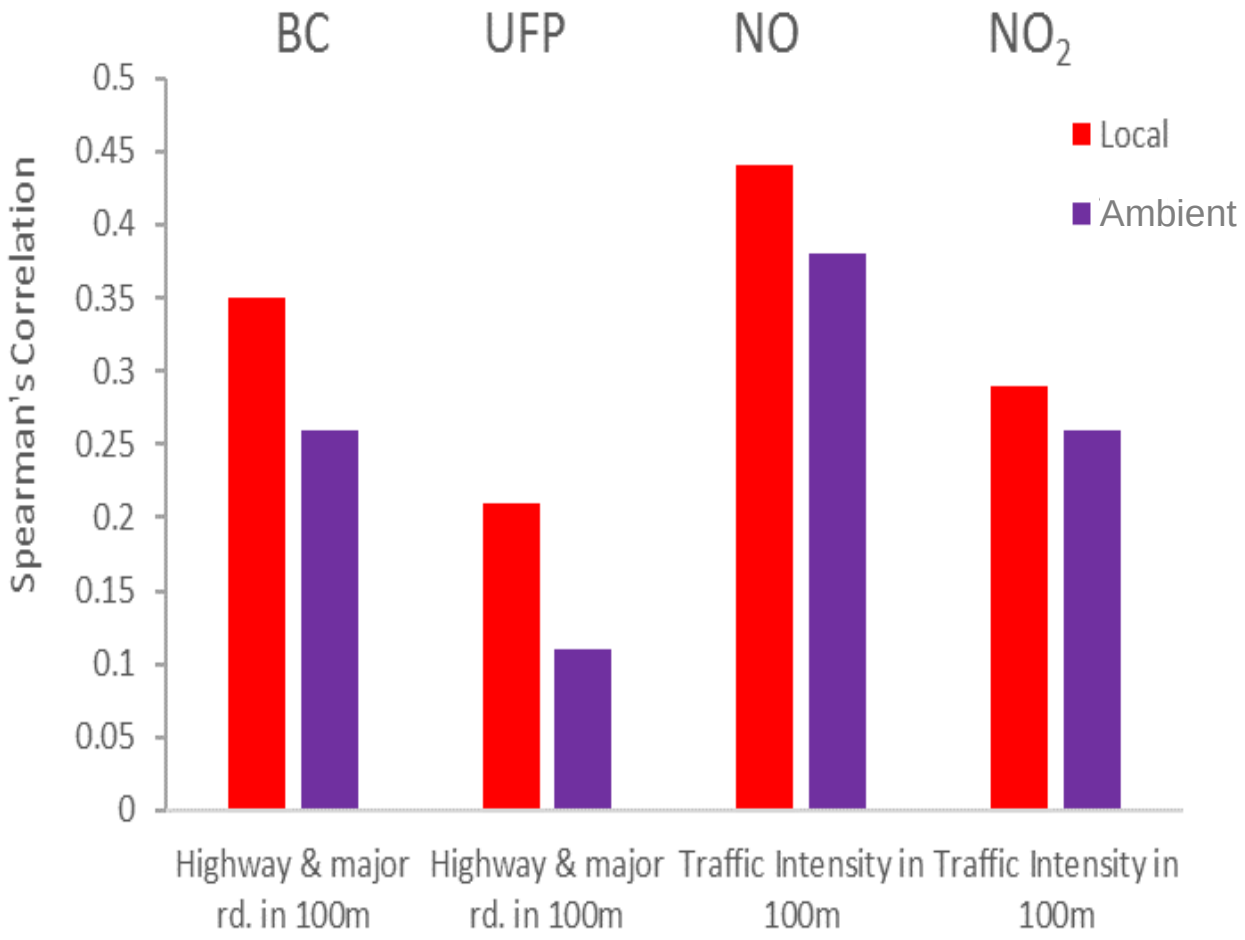
Minimum conc. at smaller temporal scale was better correlated with traffic intensity in a smaller buffer radius

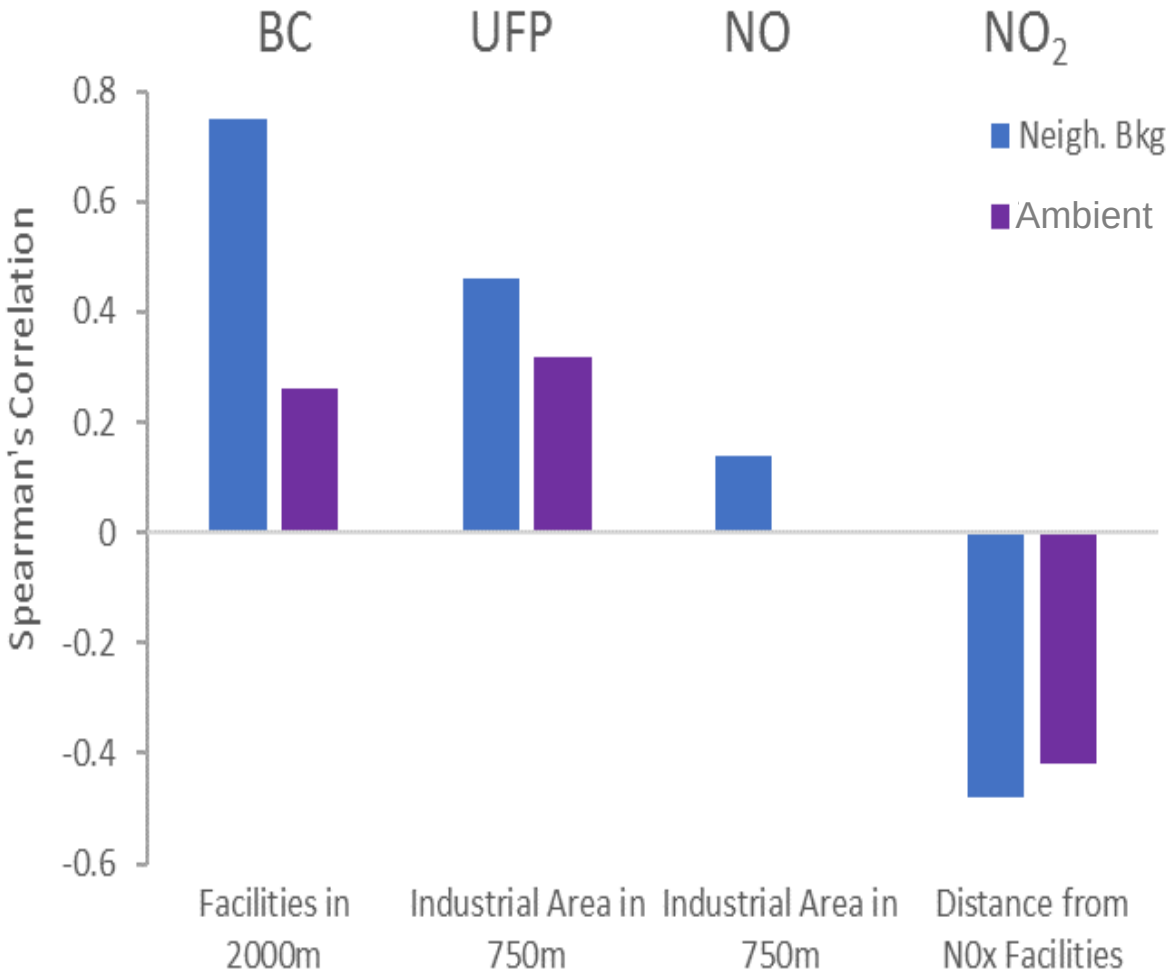




Shairsingh et al., 2018. Atmos. Env.

The variability of the resolved signals follow the variability of different land-use practices better than ambient conc.





Shairsingh et al., 2018. Atmos. Env.

Land-use regression model development

- All concentrations were averaged to a road segment centroid (based a GPS value)
- Land-use predictor variables were extracted for each segment centroid
- Predictor variables were ranked based on Spearman's correlation between variables and measured concentrations
- The highest-ranking predictor variable in each sub-category was added in a supervised stepwise linear regression
- Only variables that increased the R^2 by more than 1% were kept in the model
- Any variables with Variance of Inflation > 3 and statistical insignificant ($p > 0.1$) were removed from the final model

UFP local, neighbourhood- and regional- background LUR models showed dissimilar predictor variables

- Regional background model (R^2= 0.54) contained temporal variables (relative humidity, regional background concentration at reference site)

- Local (R^2= 0.12) and neighbourhood (R^2= 0.10) background model shared similar spatial variables but different buffer radii:

➢ Length of major rds. & highways in 100m buffer for local model but 1500m for neighbourhood background model

➢ Industrial area in 100m buffer for local model but 2000m for neighbourhood background model

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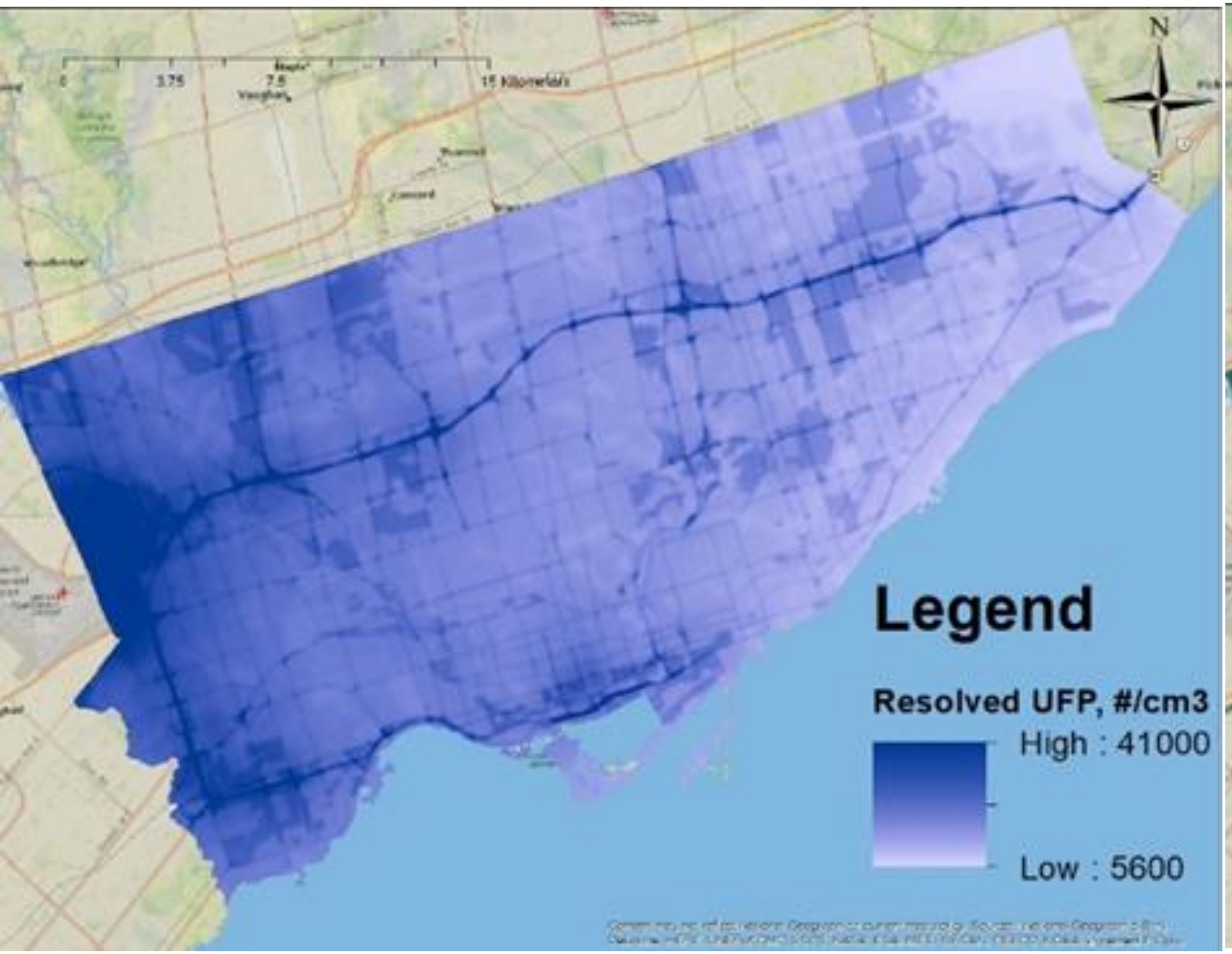
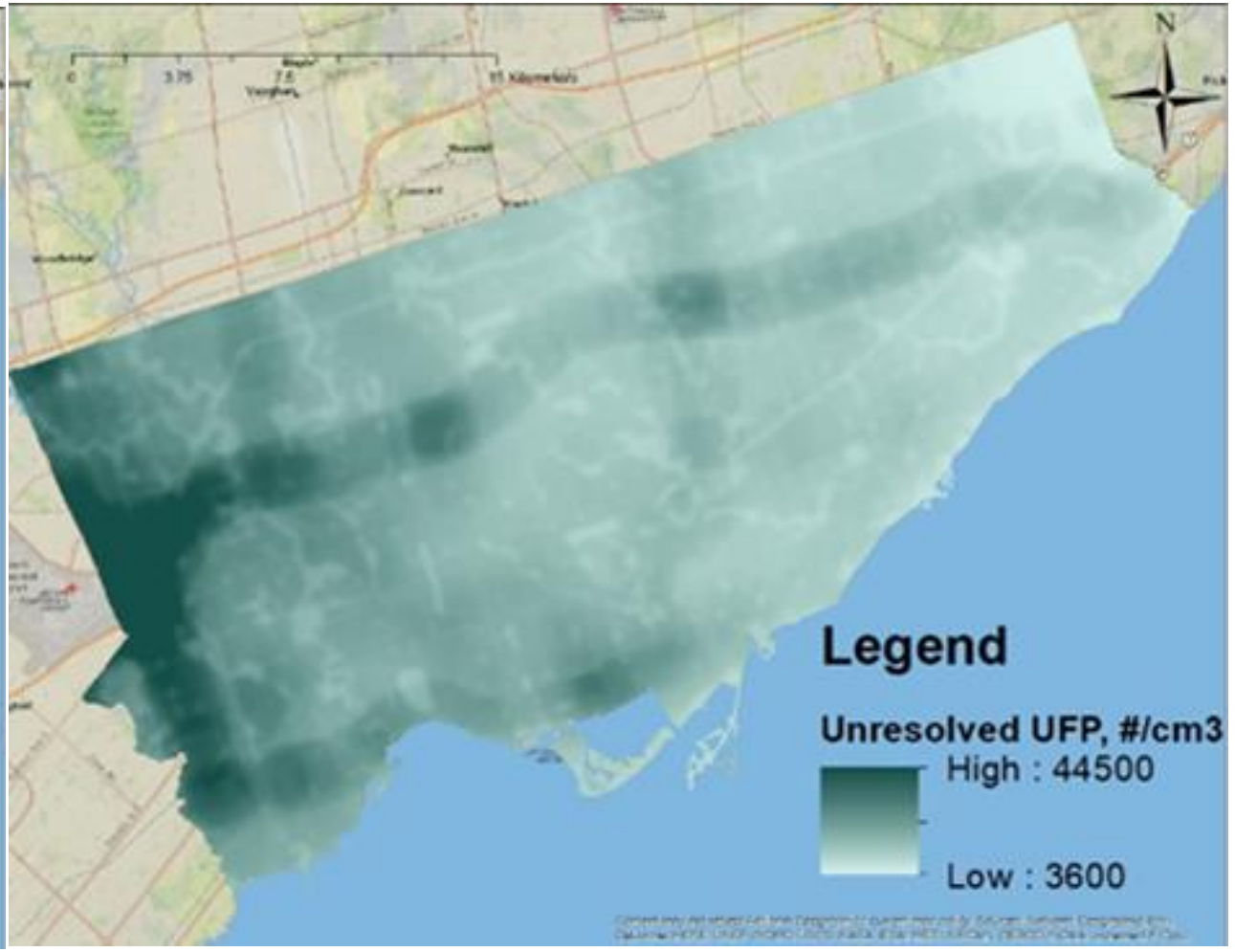
Resolved and unresolved models had different predictor variables which resulted in different concentration surfaces





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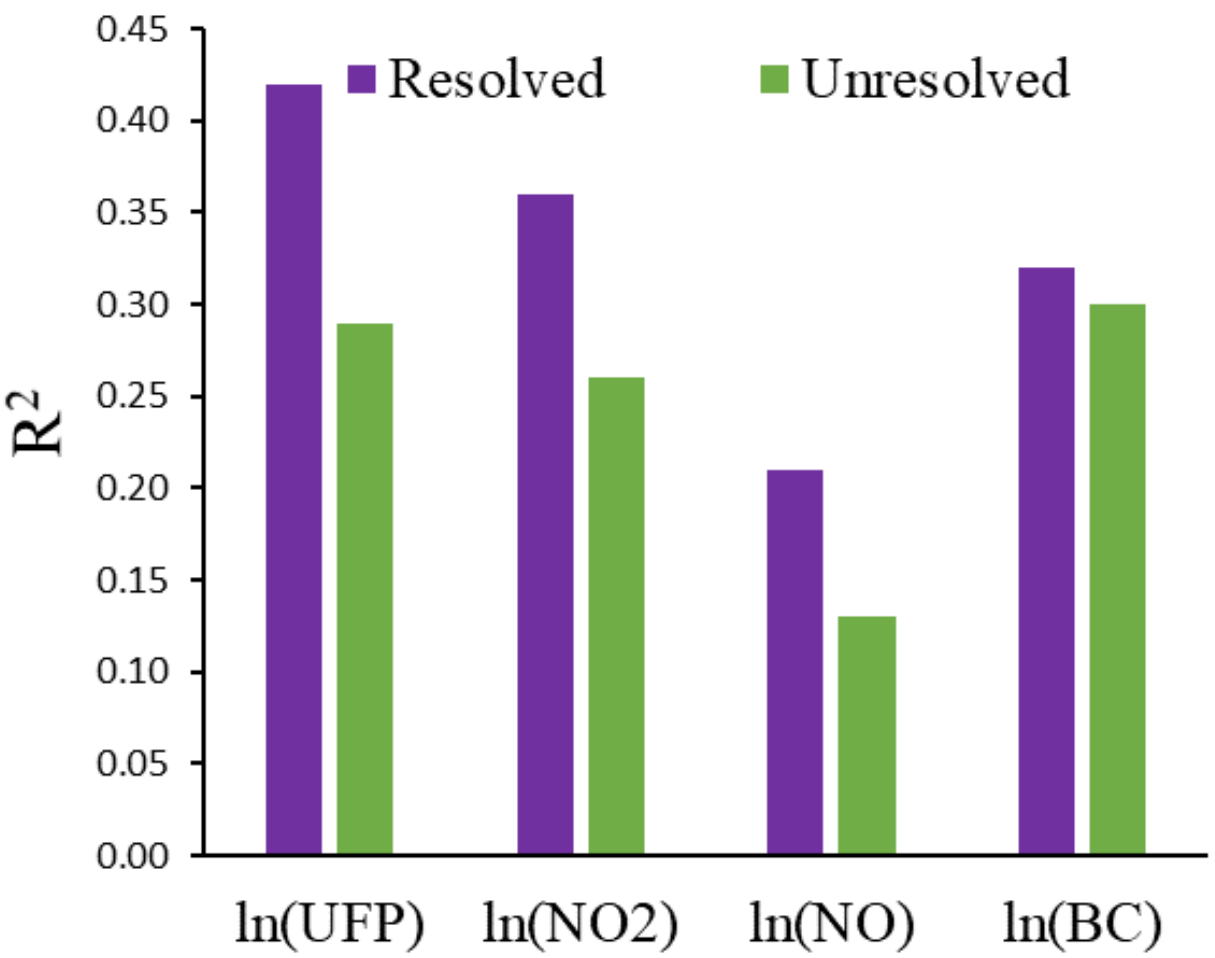
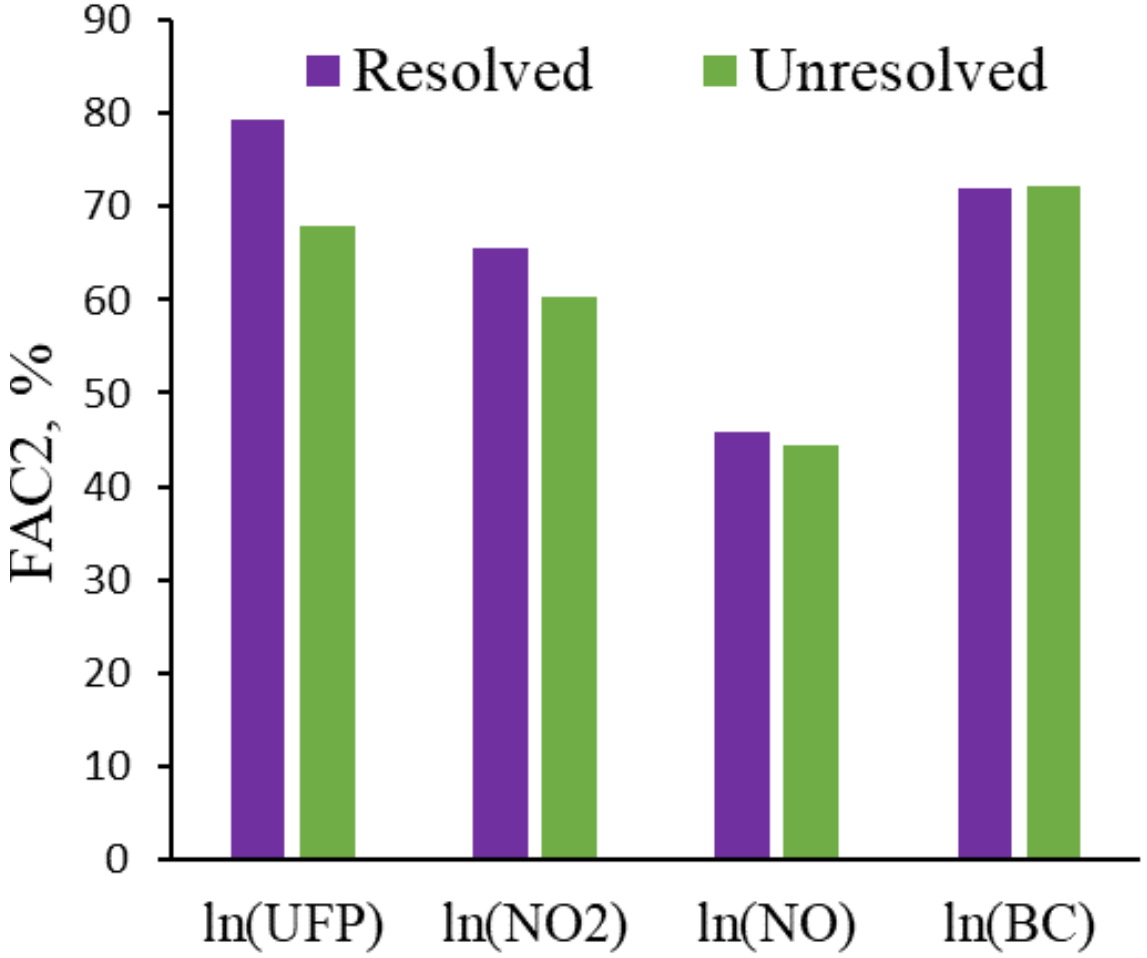
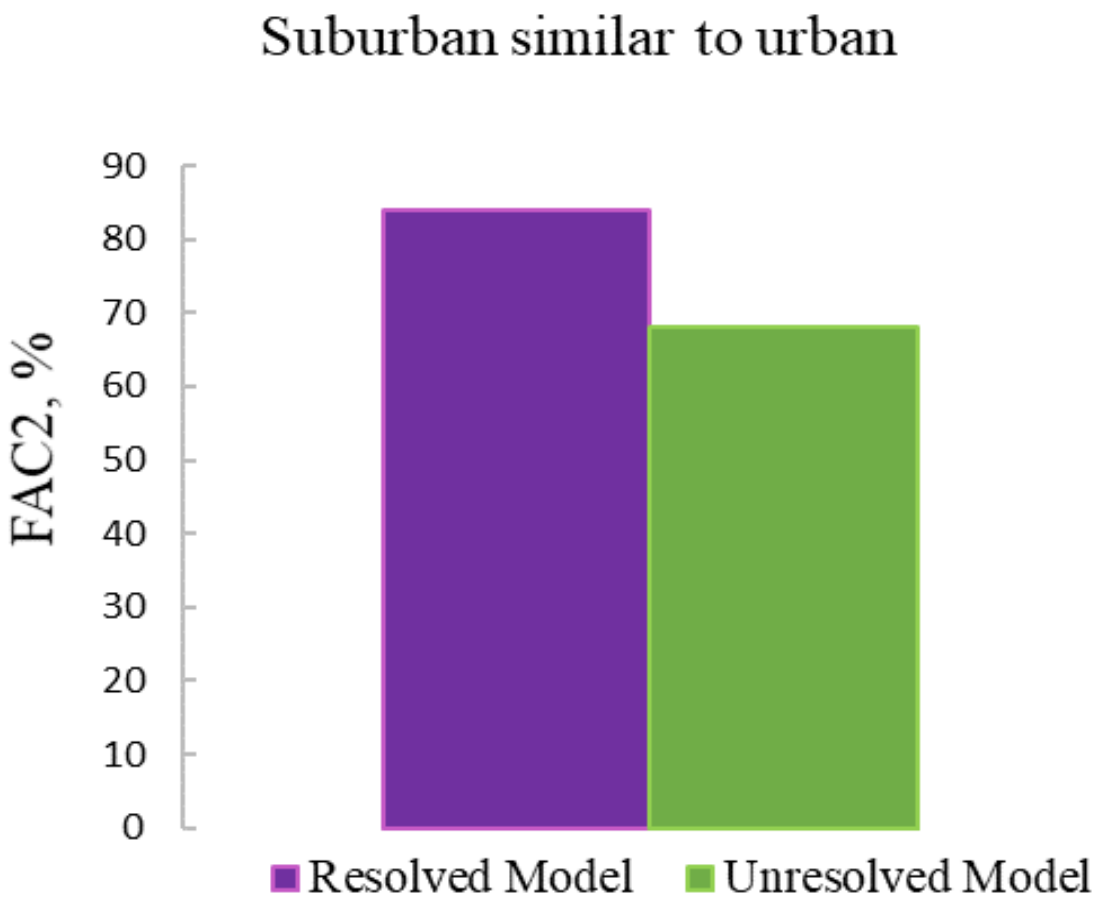
Resolved models outperformed unresolved models when spatially extended to dissimilar suburban areas

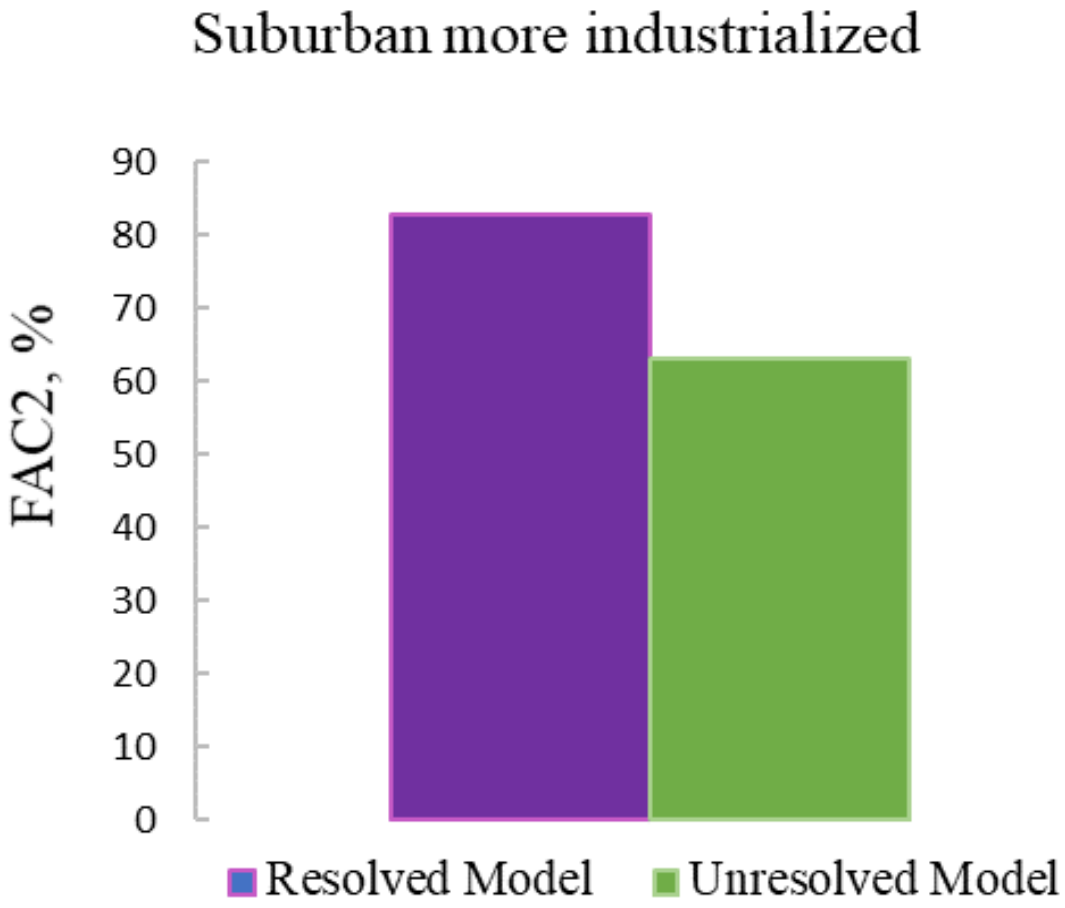




Shairsingh et al., 2018. Atmos. Env.

Resolved model estimated suburban exposure better than unresolved model for similar/different land-use to urban area





Summary of Key Findings:

- Temporally resolved concentrations showed different spatial scales due to a combination of dissimilar land-use practices

- Resolved models were better able to assess exposure than unresolved models when spatially extended to differing suburbs

Acknowledgements

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Thank you!

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