

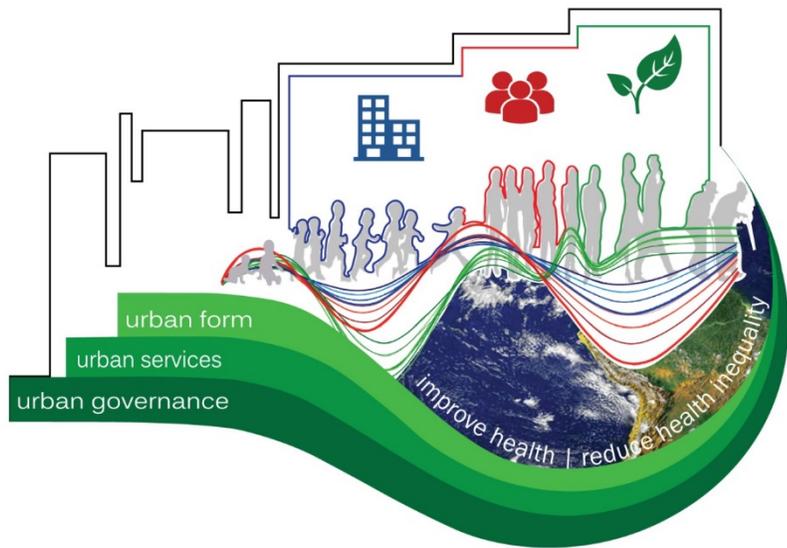
# Air Quality Modeling for Urban Environments Using Deep Neural Networks and Very High- Resolution Satellite Imagery

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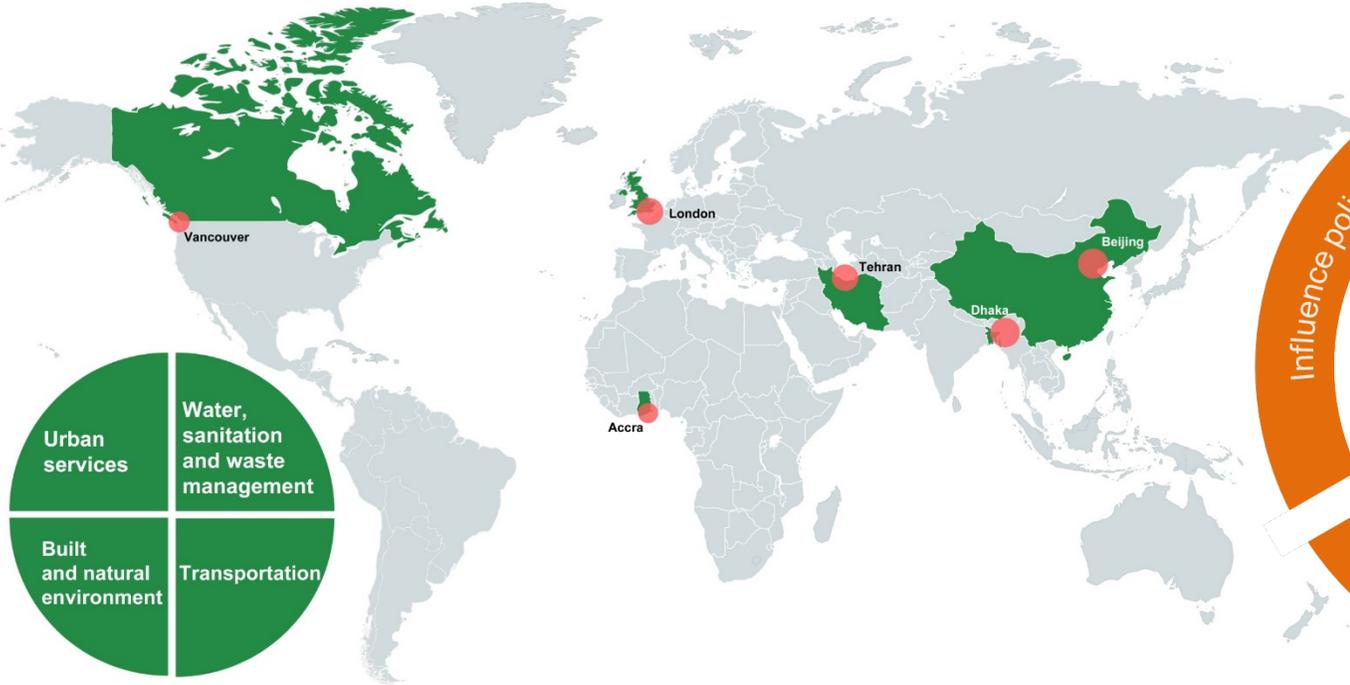
<sup>1</sup>NASA ARC, <sup>2</sup>USRA, <sup>3</sup>Imperial College, <sup>4</sup>UBC



Pathways to  
Equitable  
Healthy  
Cities



# Pathways to equitable healthy cities

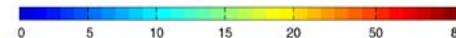
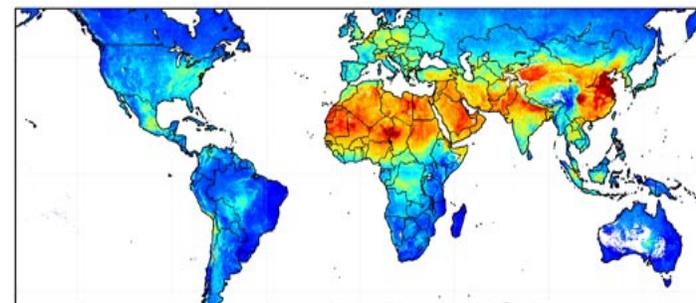
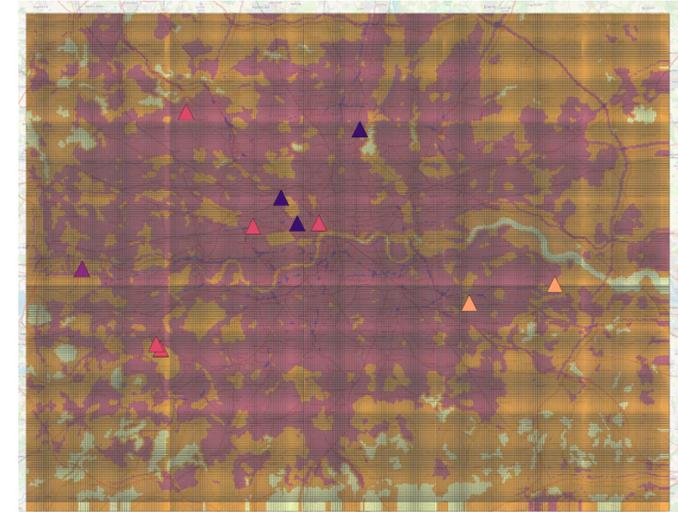
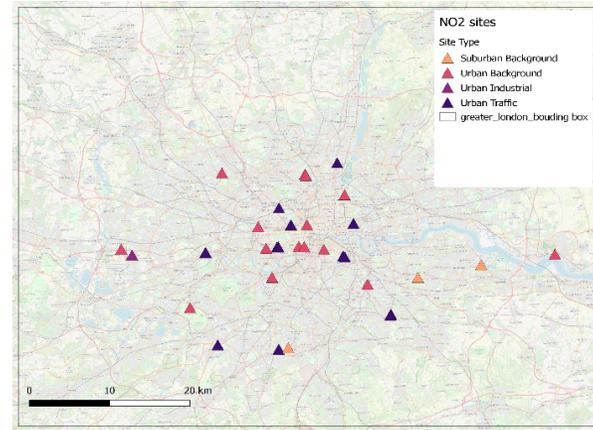


# Long-Term Exposure to Particulate Matter (PM) and Health Affects

- Chronic exposure to ambient PM<sub>2.5</sub> attributed 2.9M deaths in 2017 (WHO)
- Long-term exposure to air pollution impacts health, derives urban planning, decision making.
- Long-term variation in air pollution is well studied in developed urban environments, mostly using Land Use Regression (LUR) models.

# How is air quality currently estimated?

- Ground Stations
  - + High spatial resolution
  - Low spatial coverage
  - Requires physical infrastructure
- LUR Models
  - + 100+m spatial resolution
  - Requires significant data collection
  - Can only be produced where underlying data products are available
- Satellite based models
  - 1+km spatial resolution (highly dependent on resolution of sat imagery)
  - + Global availability



# Main Objective

- Can we leverage the global availability of sat imagery with the high spatial coverage and resolution of LUR models?
- Can air pollution be inferred directly from satellite images?
- Can high resolution snapshots of the urban features explain the association between local air pollution and the urban environment ?

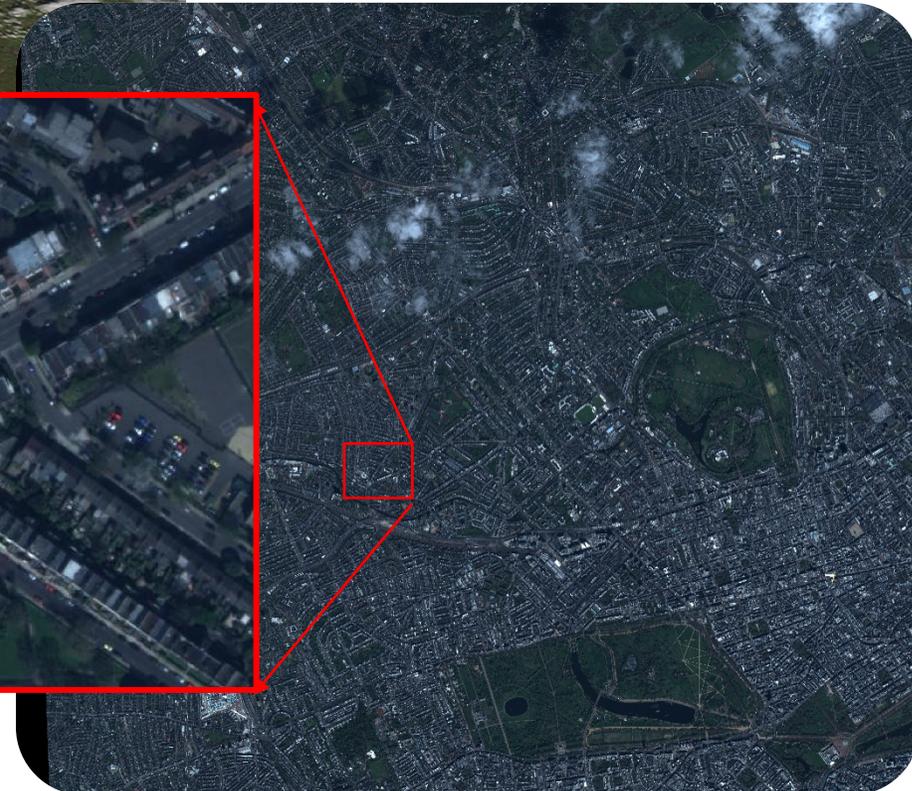
$f(\text{[Images]}) \rightarrow \text{Air pollution concentration maps}$

Learn a mapping function  $f$  of images in developed cities to sensor measurements of air pollutants

# High Resolution Satellite Imagery - Maxar

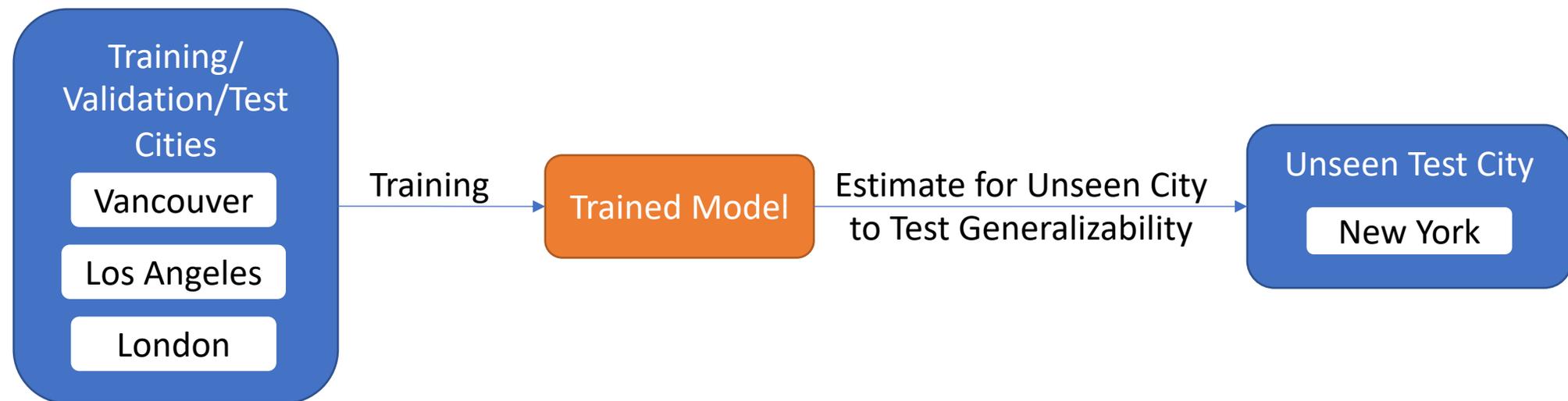


Maxar WorldView2 1.85m RGB

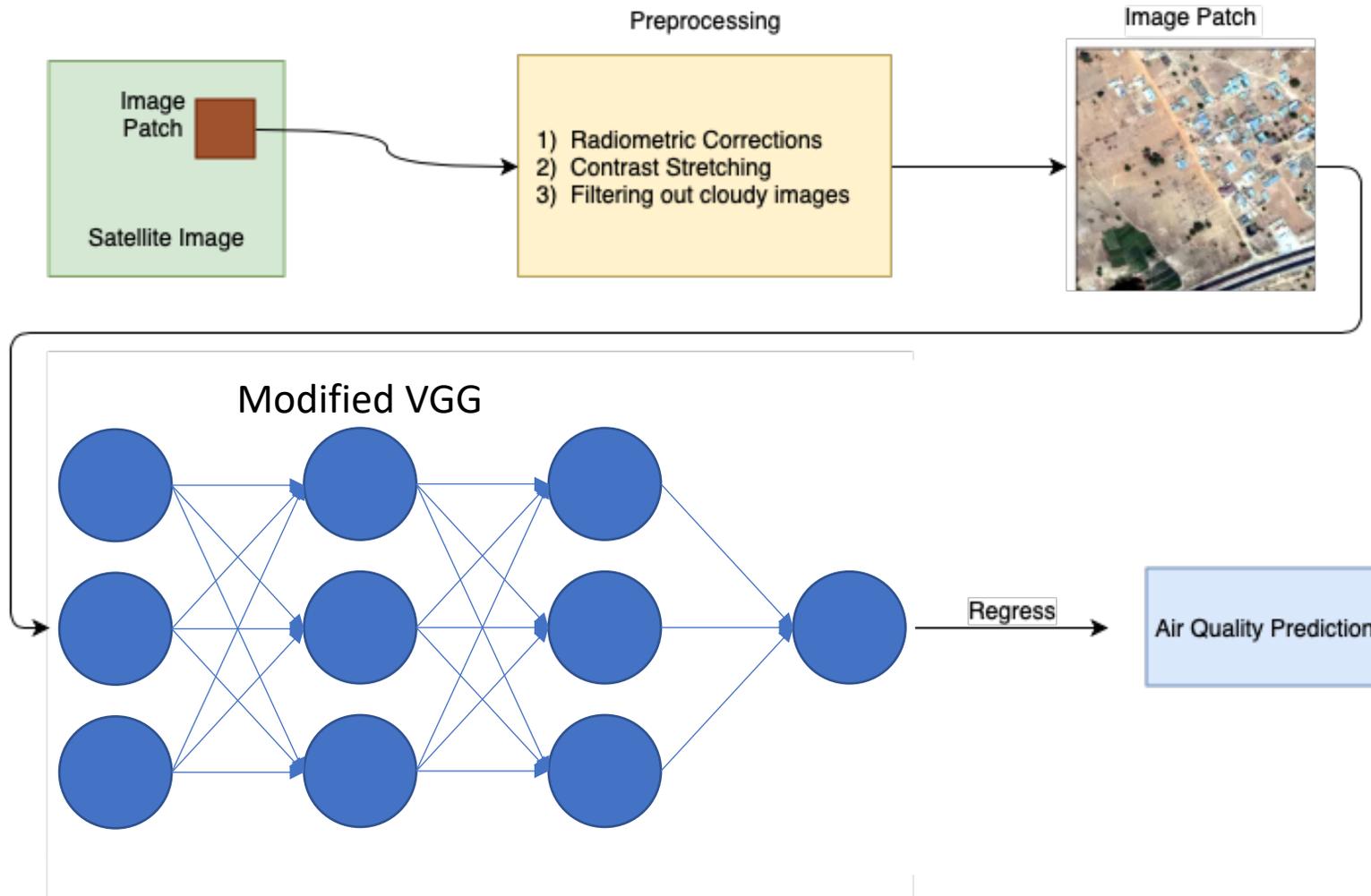


# Study Regions and Data

- Study Cities: London, Vancouver, Los Angeles, New York
- Study Year: 2010
- Using MAXAR RGB imagery with 2.5m spatial resolution
- Using modeled LUR air quality (PM<sub>2.5</sub> & NO<sub>2</sub>) data



# Object-based Regression

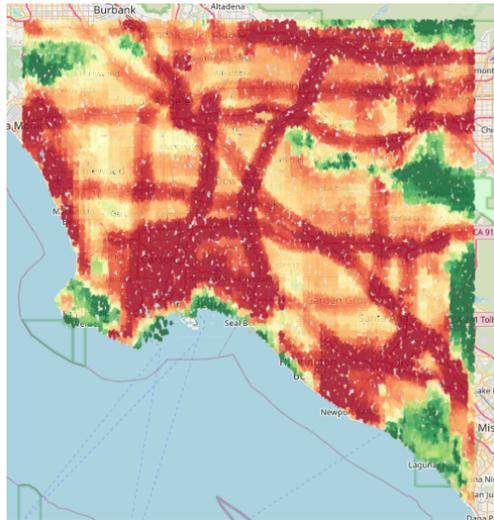


- Model architecture is slightly modified VGG
- Fully connected classification layers are replaced with naïve fully connected layers for regression
- VGG extracts object features from the satellite imagery and uses them to estimate air quality

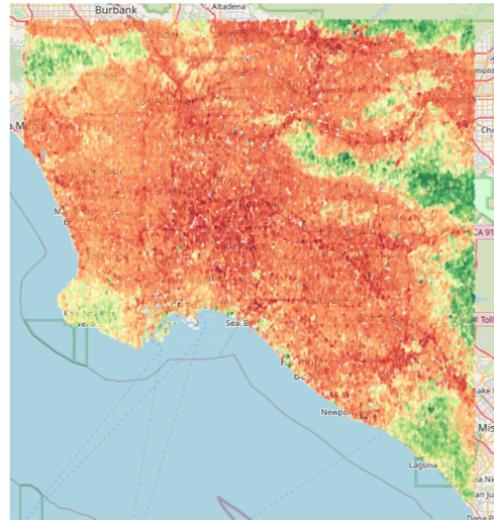
# Results – PM2.5

Los Angeles

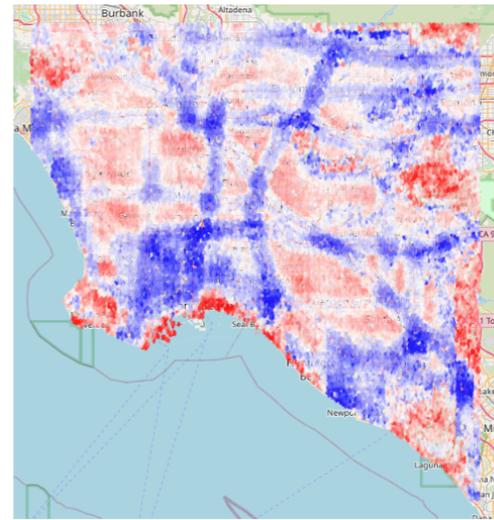
(a) Target Data



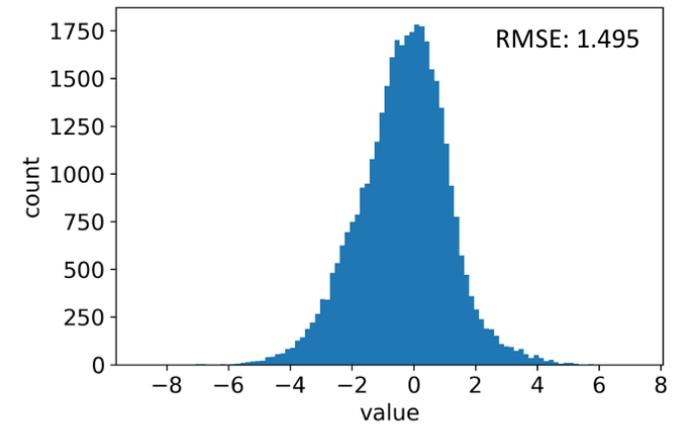
(b) Model Estimate



(c) Model Error



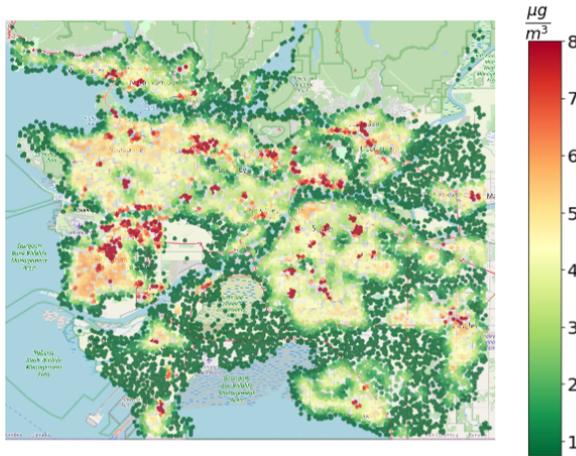
(d) Model Error Histogram



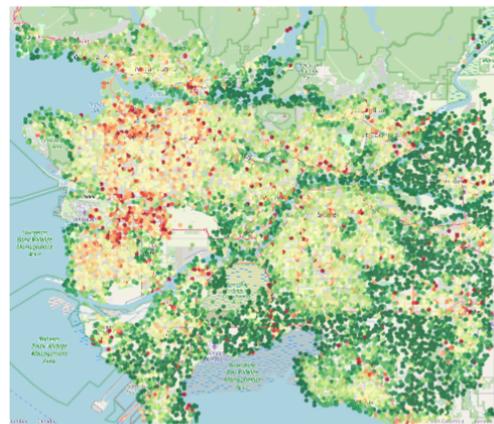
# Results – PM2.5

Vancouver

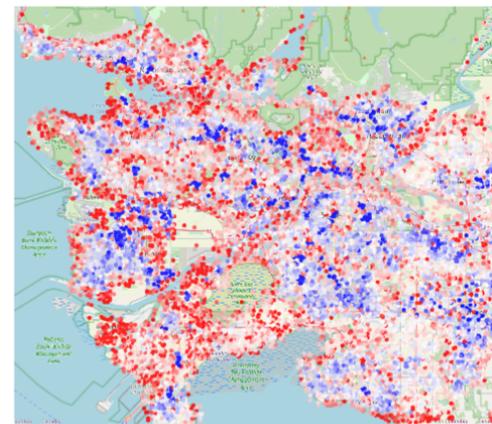
(a) Target Data



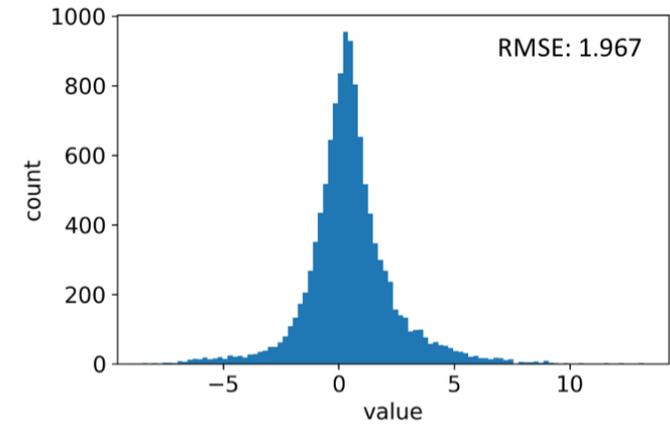
(b) Model Estimate



(c) Model Error



(d) Model Error Histogram

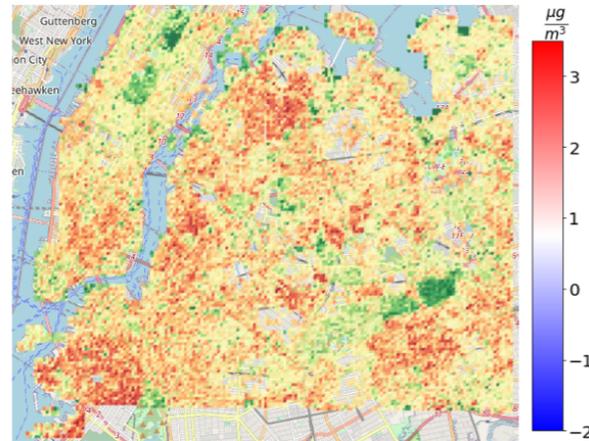


# Results – PM2.5

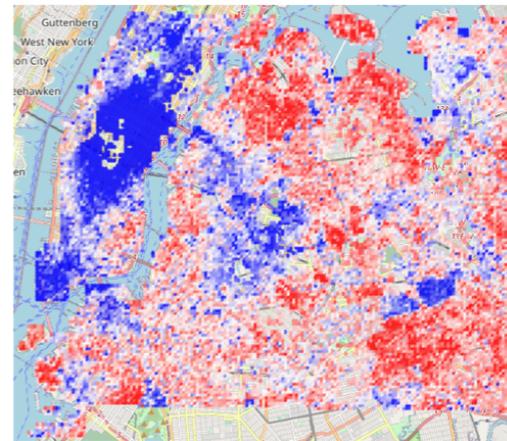
(a) Target Data



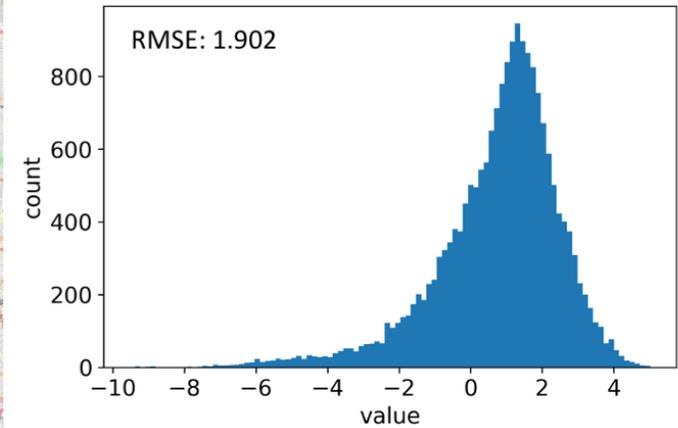
(b) Model Estimate



(c) Model Error



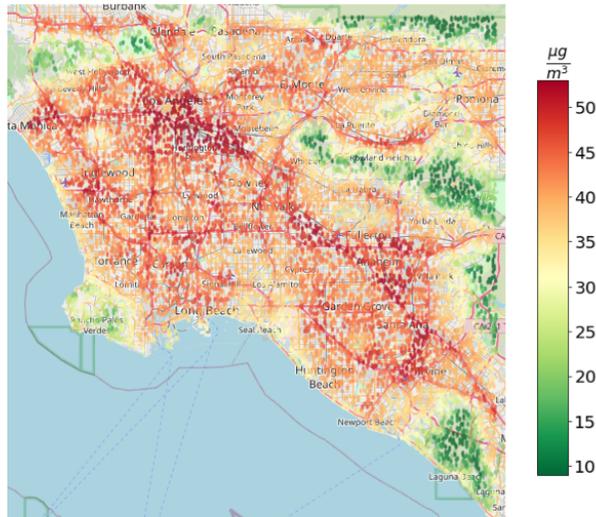
(d) Model Error Histogram



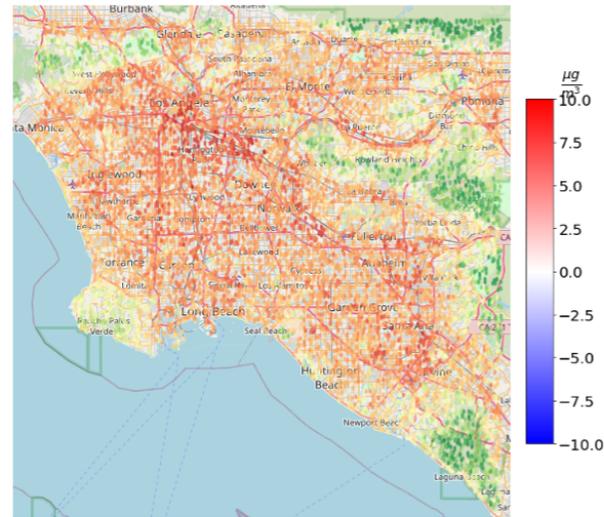
New York City

# Results – NO<sub>2</sub>

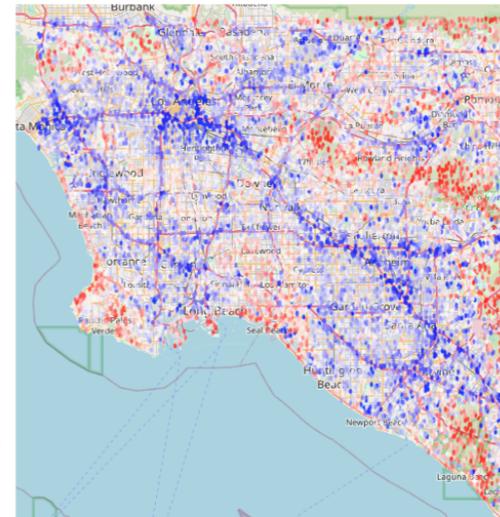
(a) Target Data



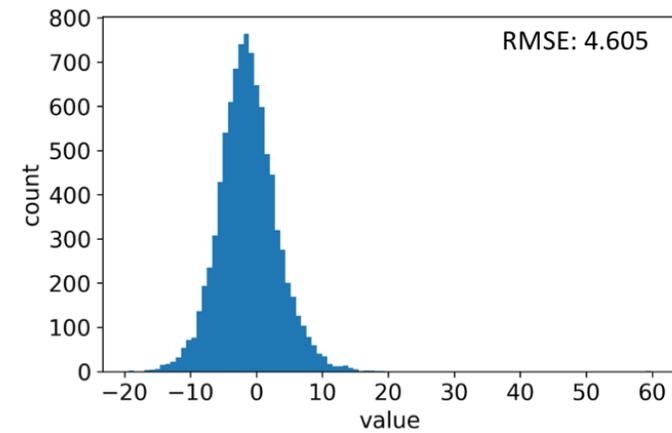
(b) Model Estimate



(c) Model Error



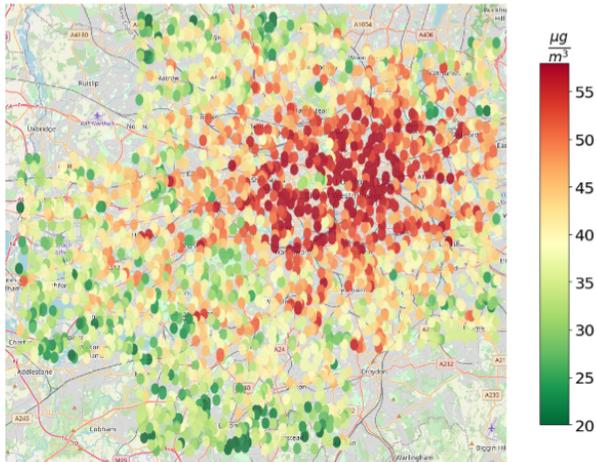
(d) Model Error Histogram



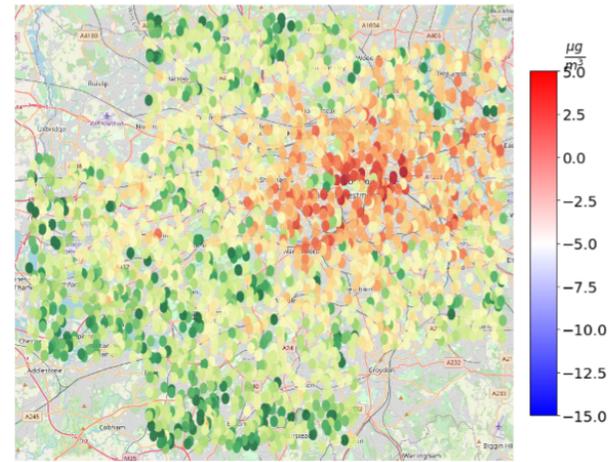
Los Angeles

# Results – NO<sub>2</sub>

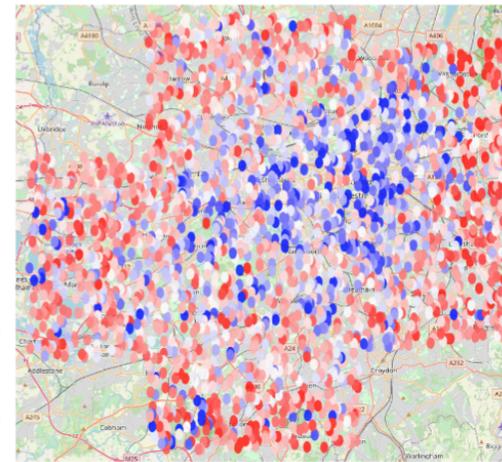
(a) Target Data



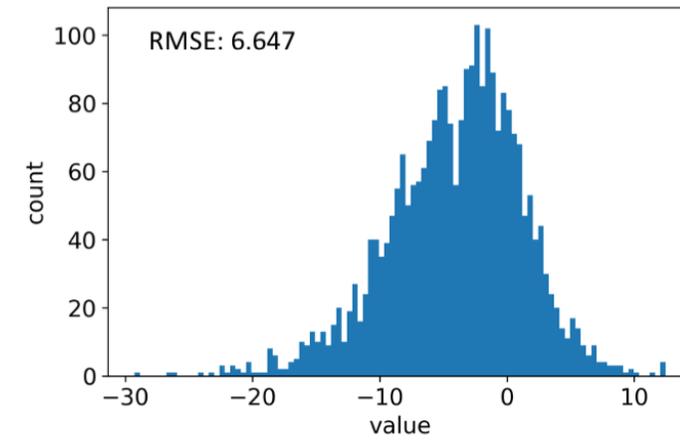
(b) Model Estimate



(c) Model Error



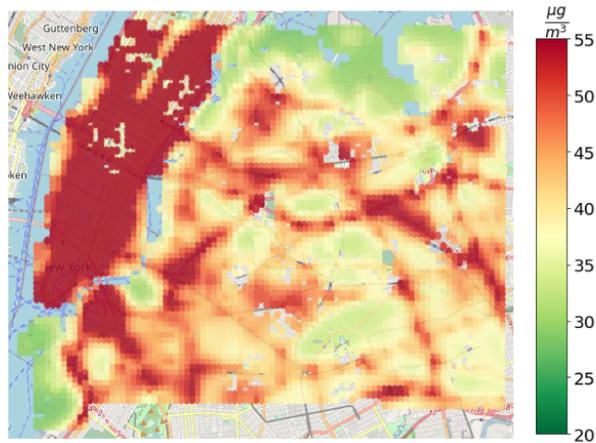
(d) Model Error Histogram



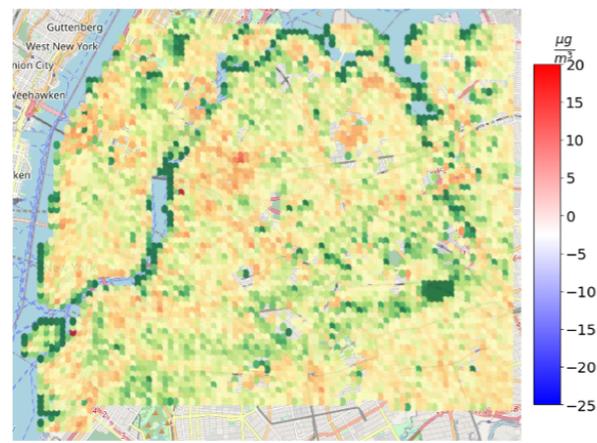
London

# Results – NO<sub>2</sub>

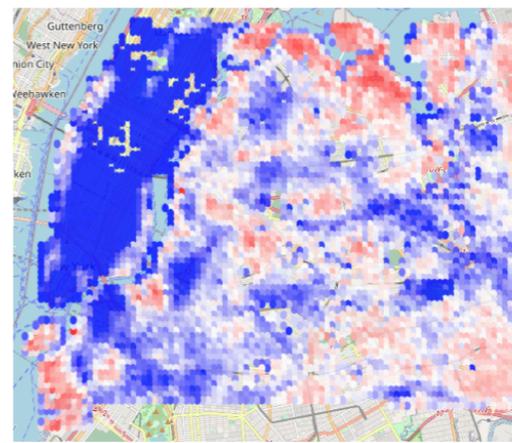
(a) Target Data



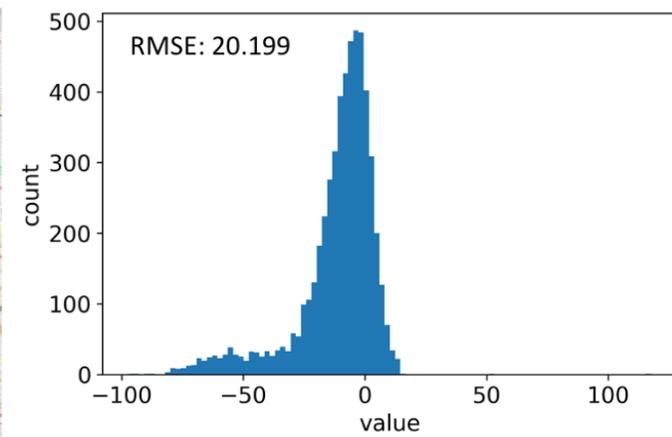
(b) Model Estimate



(c) Model Error

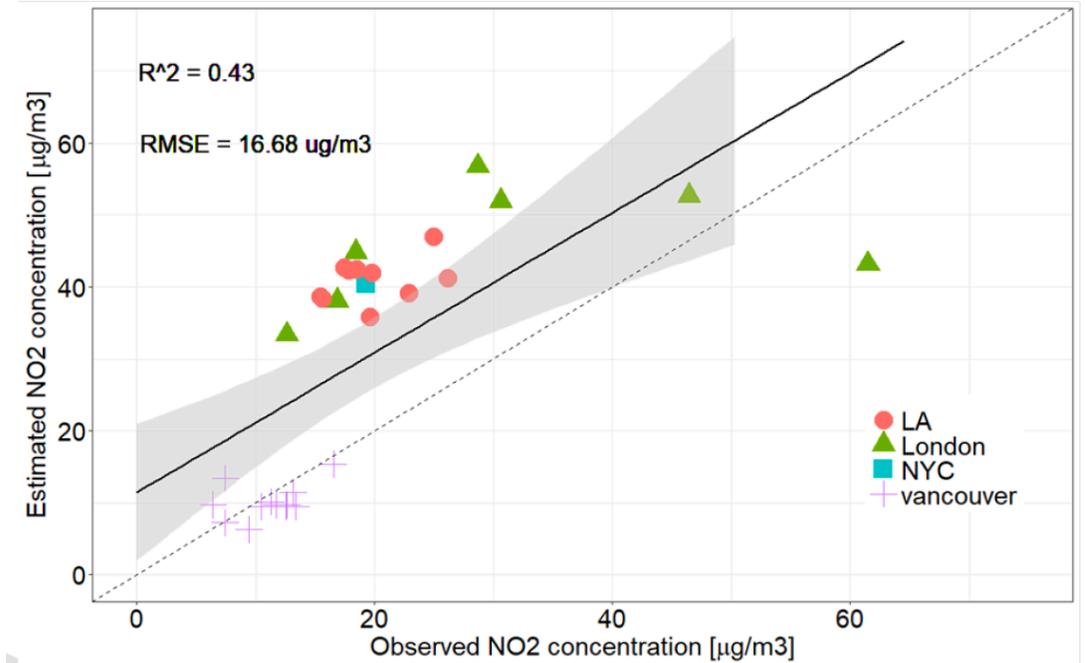
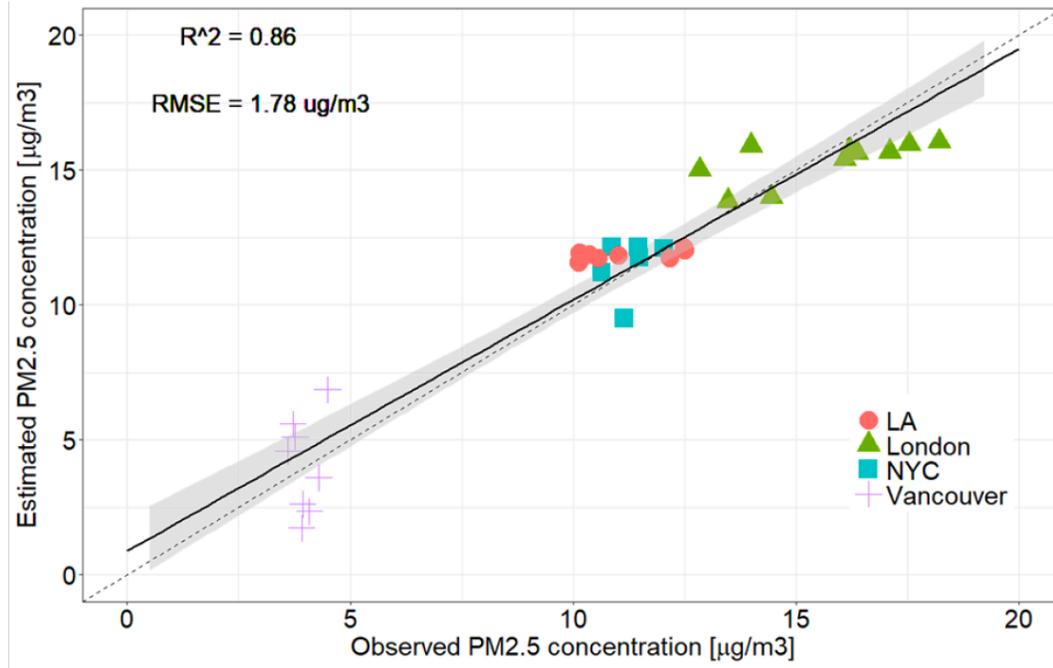


(d) Model Error Histogram



New York City

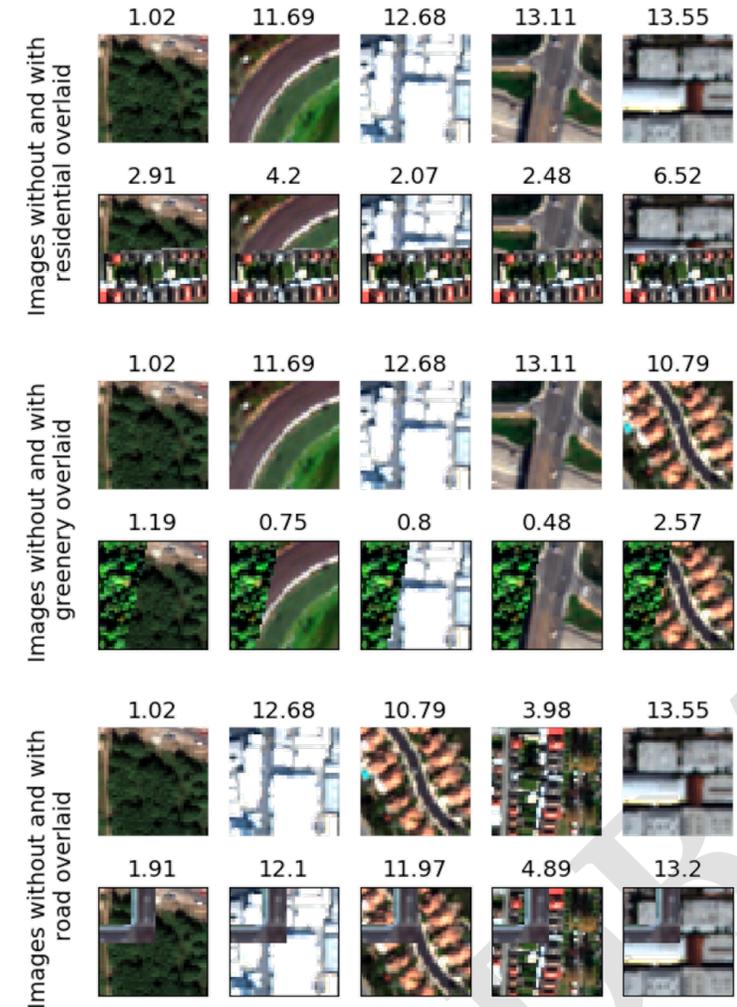
# Results – Ground Stations



# Feature Contribution

- Neural Networks aren't easily explainable
- Examine impact of certain features on predicted pollution levels

|                |             | Original Features |      |            |             |
|----------------|-------------|-------------------|------|------------|-------------|
|                |             | Greenery          | Road | Industrial | Residential |
| Added Features | Residential | ↑                 | ↓    | ↓          | —           |
|                | Greenery    | —                 | ↓    | ↓          | ↓           |
|                | Road        | ↑                 | —    | ↓          | ↑           |



# Next Steps/Improvements

- Incorporate more context information for better prediction on poor prediction areas
- Work on better generalization for more global coverage
- Looking into incorporating additional sat image sources

# Acknowledgements

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