Measuring Particulate Matter Concentrations in the GTA using Low-cost Sensors

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Introduction

- Particulate matter (PM) is a mixture of solid particles and liquid droplets
- PM is classified based on the diameter of the particle or droplet
  - $PM_{2.5}$: particles or droplets with diameter < 2.5 microns
- Exposure to PM can lead to adverse health effects
- In cities such as the GTA, traffic is a major source of particulate matter. Other sources include industrial activities and domestic fuel burning [1].

Instrument

Fig. 1: PurpleAir PA-II particulate sensor zip tied to a fence

- Low-cost particulate matter sensor developed by PurpleAir
- Consists of two Plantower PMS 5003 laser counters
- Measures $PM_{2.5}$, $PM_{1.0}$, PM_{10}, temperature, humidity, and pressure
- Live measurements can be found on the PurpleAir real-time map

Fig. 2: PurpleAir real-time map displaying all sensors in the GTA

map.purpleair.com

Objectives

- Deploy twenty-seven PurpleAir sensors evenly across the GTA

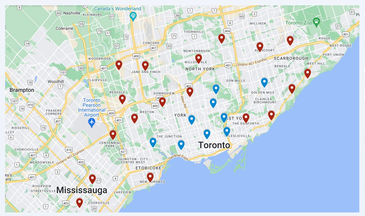

Fig. 3: Deployment map of our twenty-seven sensors

Red: potential

Blue: deployed

- Collect data on the air quality of different neighborhoods
- Investigate the existence of relationships between air quality and neighborhood demographic.

Correction Model

- PurpleAir sensors are optical sensors that can be affected by environmental factors such as temperature and ambient humidity
- To account for these factors, we apply a correction model

Step one:

- Collocate all twenty-seven sensors on the Mclennan Physical Laboraties rooftop
- Set one sensor, MP2, to be the "benchmark" sensor
- Perform simple linear regressions on each sensor against the benchmark sensor, and obtain calibration coefficients and intercepts

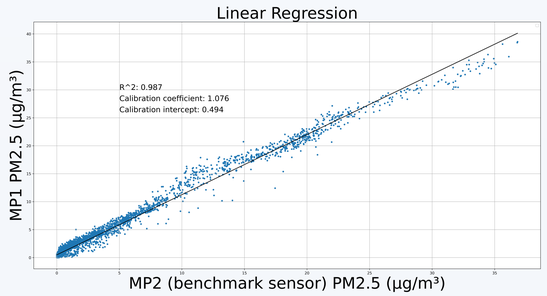

Fig. 4: Simple linear regression of MP1 v.s. MP2 (benchmark sensor)

Step two:

- Collocate MP2 with a regulatory-grade instrument, the Thermo 5030 Synchronized Hybrid Ambient Real-time Particulate Monitor (SHARP)
- Apply multivariate linear regression model with temperature (T), relative humidity (RH), and dew point (DP)

Correction equation [2]:

$$PM2.5_{corrected} = \beta_0 + \beta_1(PM_{2.5}) + \beta_2 T + \beta_3 RH + \beta_4 DP$$

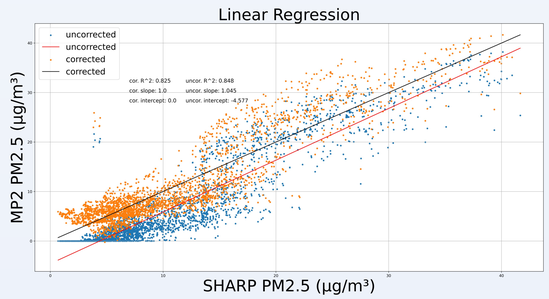

Fig. 5: Simple linear regression of MP2 v.s. SHARP before and after correction

Step three:

- Using the calibration coefficient and intercept obtained from step one, put the twenty-six sensors on the standard of the benchmark sensor
- Using the correction coefficients and intercept obtained from step two, put the twenty-six sensors on the standard of the regulatory-grade SHARP instrument

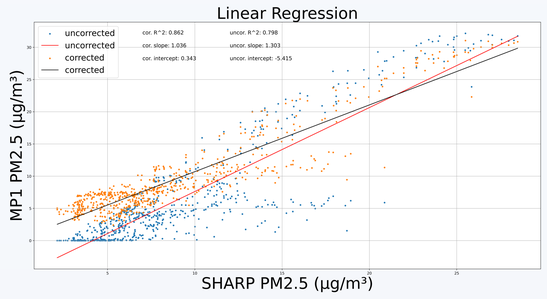

Fig. 6: Simple linear regression of MP1 v.s. SHARP before and after correction

Deployment of sensors

As of August 5th, 2022, we have deployed eight sensors at various businesses and churches in the GTA.

Data from Existing and Deployed Sensors

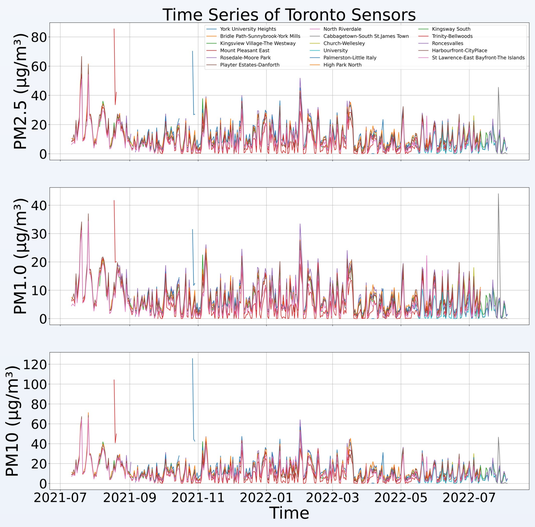

Fig. 7: Time series of $PM_{2.5}$, $PM_{1.0}$, PM_{10} data from PurpleAir sensors in various neighborhoods of the GTA

Results

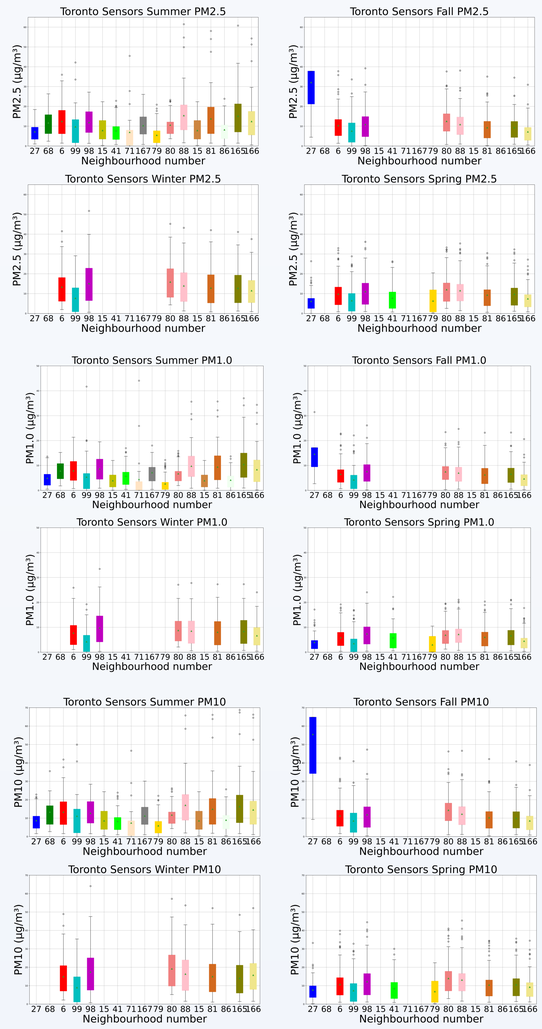

Fig. 8 : Box plots of seasonal $PM_{2.5}$, $PM_{1.0}$, PM_{10} of seventeen different GTA neighborhoods arranged north to south

References

[1]Karagulian et al. (2015) Contributions to cities' ambient particulate matter (PM): A systematic review of local source contributions at global level, Atmospheric Environment, Volume 120, 475-483, https://doi.org/10.1016/j.atmosenv.2015.08.087

[2]Malings et al. (2020) Fine particle mass monitoring with low-cost sensors: Corrections and long-term performance evaluation, Aerosol Science and Technology, 54:2, 160-174, DOI: 10.1080/02786826.2019.1623863

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