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Small Air Quality Sensor Applications to Improve Community Engagement in Western Canada

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INTRODUCTION

Environment and Climate Change Canada understands the important role that low cost air quality sensors could play for public knowledge around air quality; and therefore, has taken the initiative to study their performance. The instruments used for the purpose of this study are the PurpleAir (Particulate Matter, PM) and the Aeroqual AQY (PM, O_3, NO_2). These sensors are becoming more accessible for citizen scientists and may create community service and air quality prediction opportunities.

Air Quality Health Index (AQHI) was developed as a rating system to help the Canadian public understand when to stay indoors and reduce their exposure to air pollution.[1] AQHI is indexed from 1-10+ corresponding to different levels of health risks depending on the concentration of the pollutants:[1]

- 1-3 "Low Risk"
- 4-6 "Moderate Risk"
- 7-10 "High Risk"
- 10+ "Very High Risk"

Figure 1: The colour coded AQHI rating system, grouped into different levels of health risks.[1]

- AQHI is calculated based on the concentrations of O_3, $PM_{2.5}$ and NO_2.[1]
- **$PM_{2.5}$:** PM with a diameter of 2.5 microns or less, making it small enough to enter the respiratory system.[2] $PM_{2.5}$ can be attributed to both anthropogenic and natural sources, as either a primary or secondary pollutant.
- **O_3:** Forms in the lower atmosphere in the presence of sunlight, by photochemical reactions between volatile organic compounds and NO_x.[2]
- **NO_2:** Pollutant with natural and anthropogenic sources such as combustion. Contributes to the formation of $PM_{2.5}$ and O_3.[1]
- High concentrations of these pollutants are harmful to cardiovascular and respiratory health.[1]

Spatial and temporal variations of NO_2, O_3 and $PM_{2.5}$ concentrations can influence AQHI.

- Stagnant conditions such as slow winds or low mixing heights result in a buildup of pollutants near the surface.[3]
- High $PM_{2.5}$ can be influenced by seasonal and localized events such as forest fires.[1]
- O_3 has highest average concentrations during the spring and summer months, due to increased sunlight.[2]
- NO_2, O_3 and $PM_{2.5}$ each contribute additively to AQHI as illustrated in Figure 2.

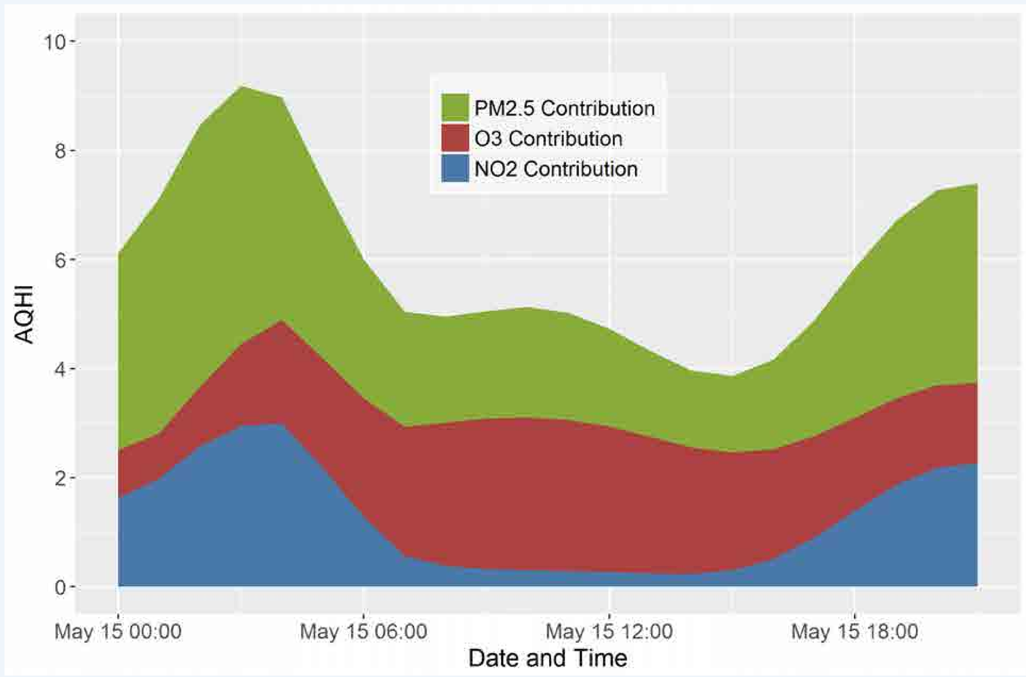

Figure 2: $PM_{2.5}$, O_3 and NO_2 contributed to overall AQHI during a time period of increased pollution in Edmonton, AB due to smoke from Saskatchewan wildfires in May 2018.

In this study we evaluate the performance of PurpleAir and Aeroqual AQY sensors against Federal Equivalent Method (FEM) monitors in field conditions. These preliminary results will contribute to development of a community-oriented air quality monitoring program based on AQHI.

METHODS

PurpleAir and Aeroqual AQY sensors were co-located with FEM monitors in four locations to undergo a performance evaluation since June 2018. Each location contained multiple sensors to measure different constituents in a variety of environments:

- **Vancouver Trailer (Pacific Environmental Science Centre):** 3 PurpleAir, Thermo 5030i Sharp (PM monitor)
- **Abbotsford Trailer:** 3 PurpleAir, Thermo 5030i Sharp
- **Edmonton Trailer (MJ Greenwood):** 7 PurpleAir, Aeroqual AQY, Thermo 49i (O_3), 2B OEM-106L (O_3), Thermo 42i (NO_x), GRIMM EDM180 (PM monitor)
- **Tripod (20 km SW of Edmonton):** 2 PurpleAir, Aeroqual AQY, 2B OEM-106L, Vaisala WXT (Temperature and Humidity monitor), (tripod data compared to FEM data from Genesee AQ station, 24km SW)

To explore potential drift behavior, a month of data were used to derive the linear correlations between each PurpleAir sensor and the FEM monitor. These linear correlations were used to correct daily averaged PurpleAir data. Potential drift was quantified as the difference between corrected PurpleAir data and FEM data.

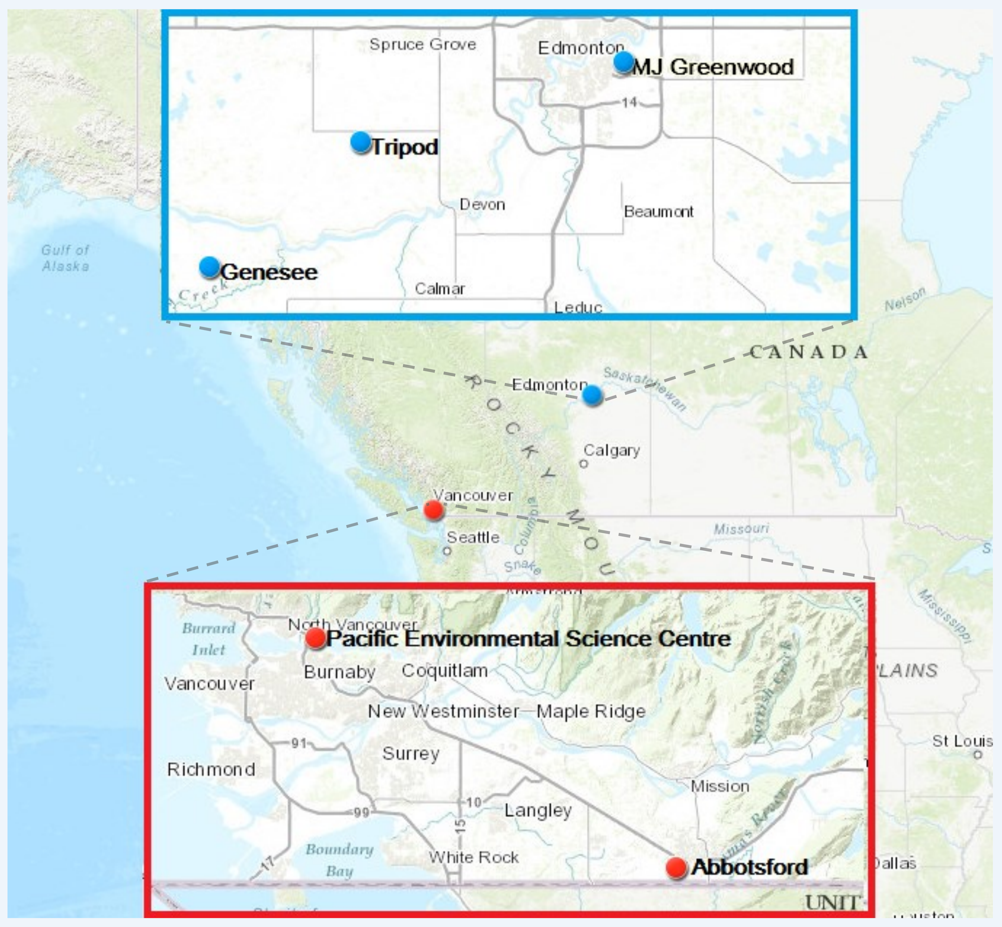

Figure 3. Sensor location throughout Edmonton, AB and Vancouver, BC.

Figure 4. Self-contained tripod deployed SW of Edmonton containing PurpleAir sensors, Aeroqual AQY, 2B OEM-106L and Vaisala WXT with solar/battery power.

PRELIMINARY RESULTS

For clarity, we present only the preliminary results for $PM_{2.5}$ at the MJ Greenwood site in Edmonton.

Correlation Analysis (Figure 5)

	PurpleAir	Aeroqual
PurpleAir	r^2 = 0.97-0.99	r^2 = 0.94-0.97
GRIMM	r^2 = 0.95-0.97	r^2 = 0.91

Forest Fire Case Study (Figure 6)

- Range of 0-300 µg/m^3
- PurpleAir had a linear response but overestimated $PM_{2.5}$
- Other authors report overestimation when $PM_{2.5}$ > 10 µg/m^3, and non-linear response when $PM_{2.5}$ > 40 µg/m^3.[4]

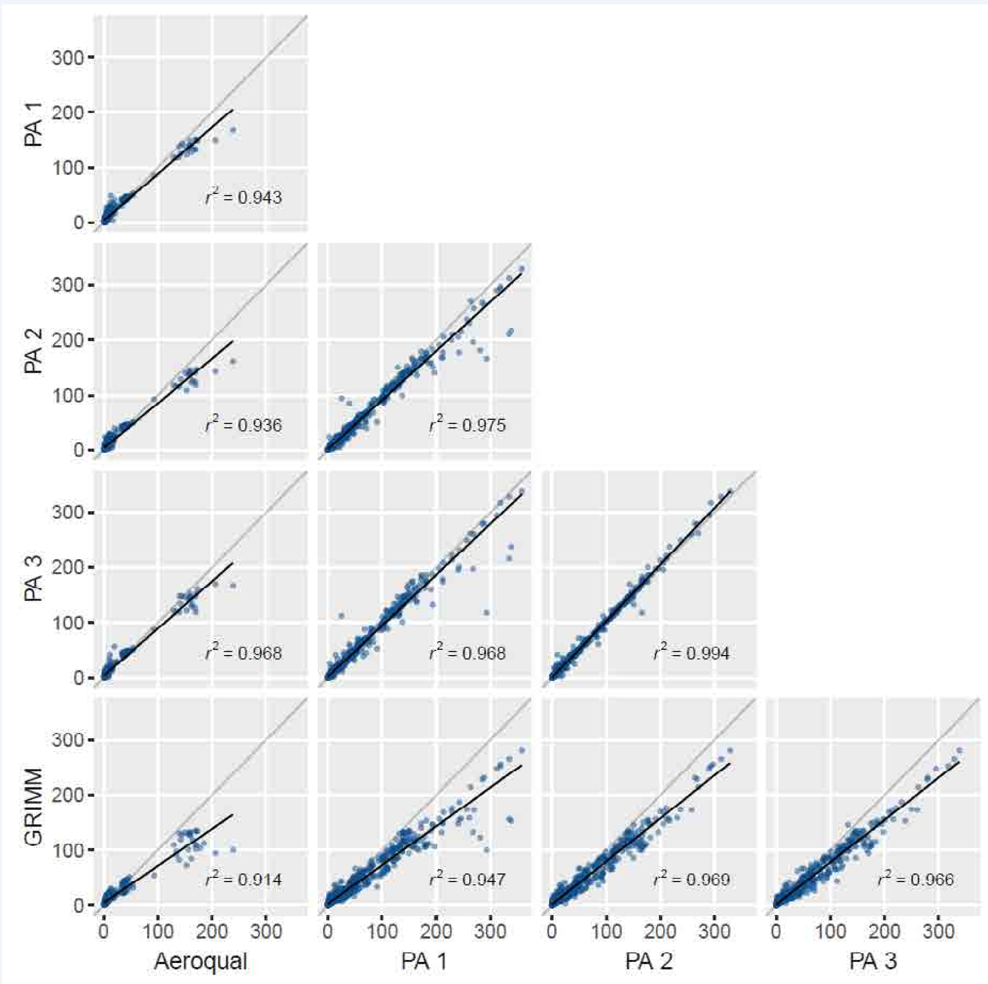

Figure 5. Correlation matrix between 3 PurpleAir Sensors, Aeroqual AQY sensor and the GRIMM monitor for the period of June - August 2018 in Edmonton, AB. Hourly averaged $PM_{2.5}$ values in µg/m^3.

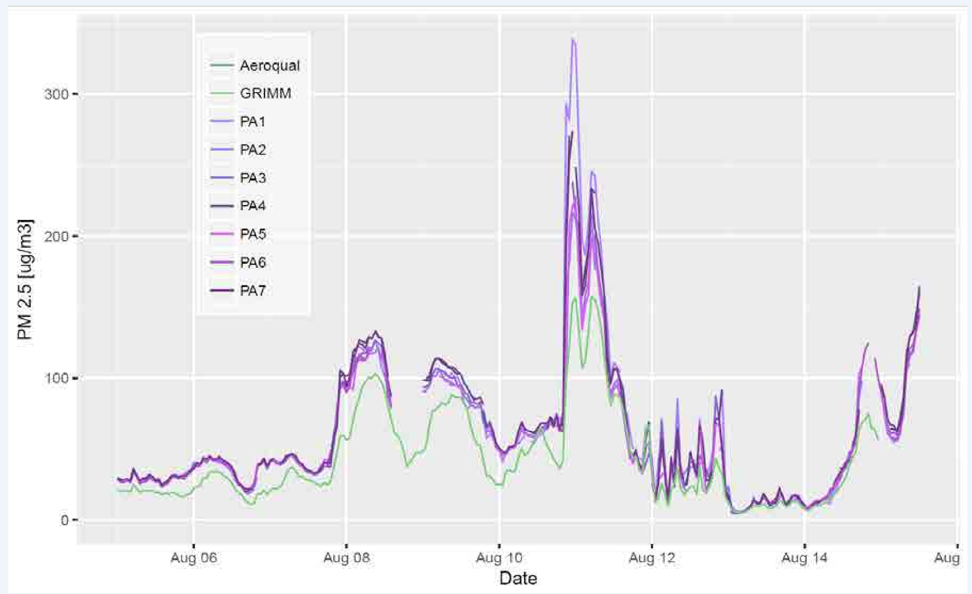

Figure 6. Hourly uncorrected data from August 2018 showing increased $PM_{2.5}$ concentrations recorded by multiple small sensors and GRIMM monitor during a significant smoke event in Edmonton, AB.

Drift Analysis (Figure 7)

- Absolute difference increases gradually over time (Figure 7)
- Confounding factors (eg. $PM_{2.5}$ concentration, T, RH, P) still to be assessed and considered in calibration
- Future effort will explore other calibration approaches such as multiple linear regression

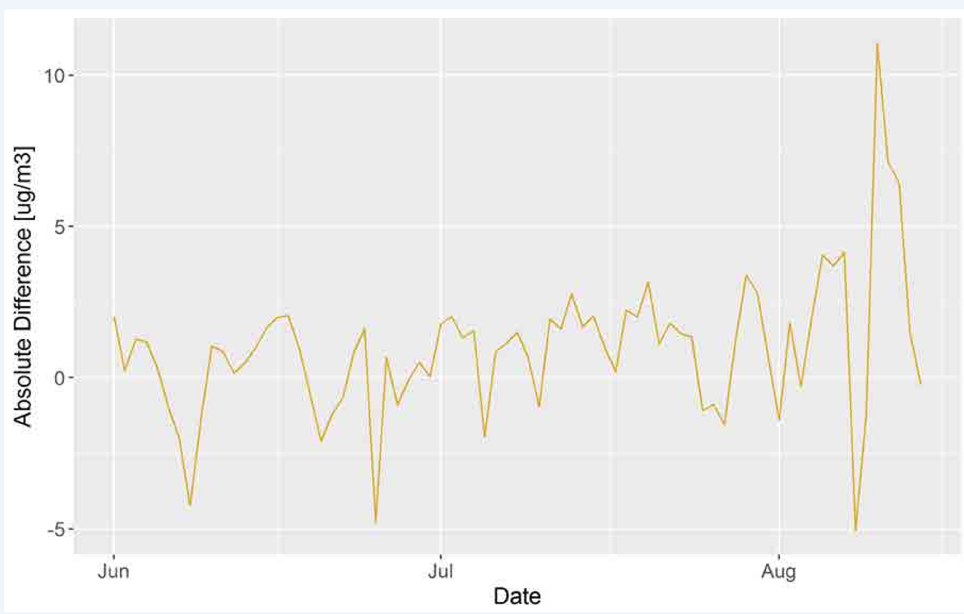

Figure 7. Absolute difference between corrected PurpleAir and GRIMM at MJ Greenwood, using daily averaged values.

FUTURE DIRECTION

The initial deployment and testing of the small air quality sensors throughout Canada are the first steps for future AQHI improvements and community engagement. The application of small air quality sensors will open up many prediction and service opportunities.

Future opportunities with small AQ sensors:

- Access to denser and wider-reaching network of AQ data
- Support for forecasters during AQ episodes
- Improvements in AQ forecast validation and post-processing
- Supporting communities underserved by permanent AQ infrastructure, including First Nations and northern communities (e.g. during forest fire smoke events)
- Provide neighborhood scale AQ data to augment existing networks to inform risk mitigation for public health (e.g. Olympic/PanAM and other events)
- Facilitates goal of delivering AQHI to at least 90% of population
- 2-D map products of AQHI health risks
- Provide support to regional partners and communities (citizen science)

Figure 8. Smoke impacts in Western Canada: Downtown Edmonton from University of Alberta weather camera (left: August 15, 2018; right: August 29, 2018).[5]

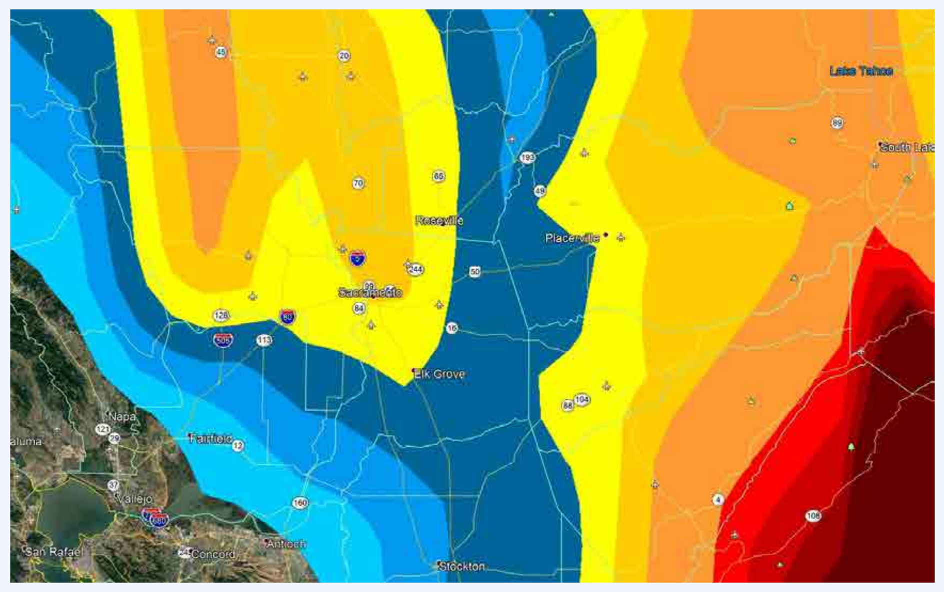

Figure 9. Map of $PM_{2.5}$ contribution to AQHI in Sacramento, CA using PurpleAir $PM_{2.5}$ data. These applications open up potential for neighborhood scale AQ prediction in Canada.

ACKNOWLEDGEMENTS

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