Distributed low-cost sensor network for air quality measurements and wildfire monitoring at remote communities

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CENTRE FOR SENSORS AND SYSTEM INTEGRATION

APPLIED RESEARCH

Presentation Layout

- Introduction
- Low-cost Air Quality Sensor
- Wildfire Detection by low-cost sensors
- Community-based Monitoring
- Summary
- Acknowledgments

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Introduction

- Low-cost air quality sensors provide opportunity of wide area distributed monitoring.
- Custom integration of these sensors can provide a tool for near real-time information on wildfire events.
- Remote areas can be monitored through low-cost systems.

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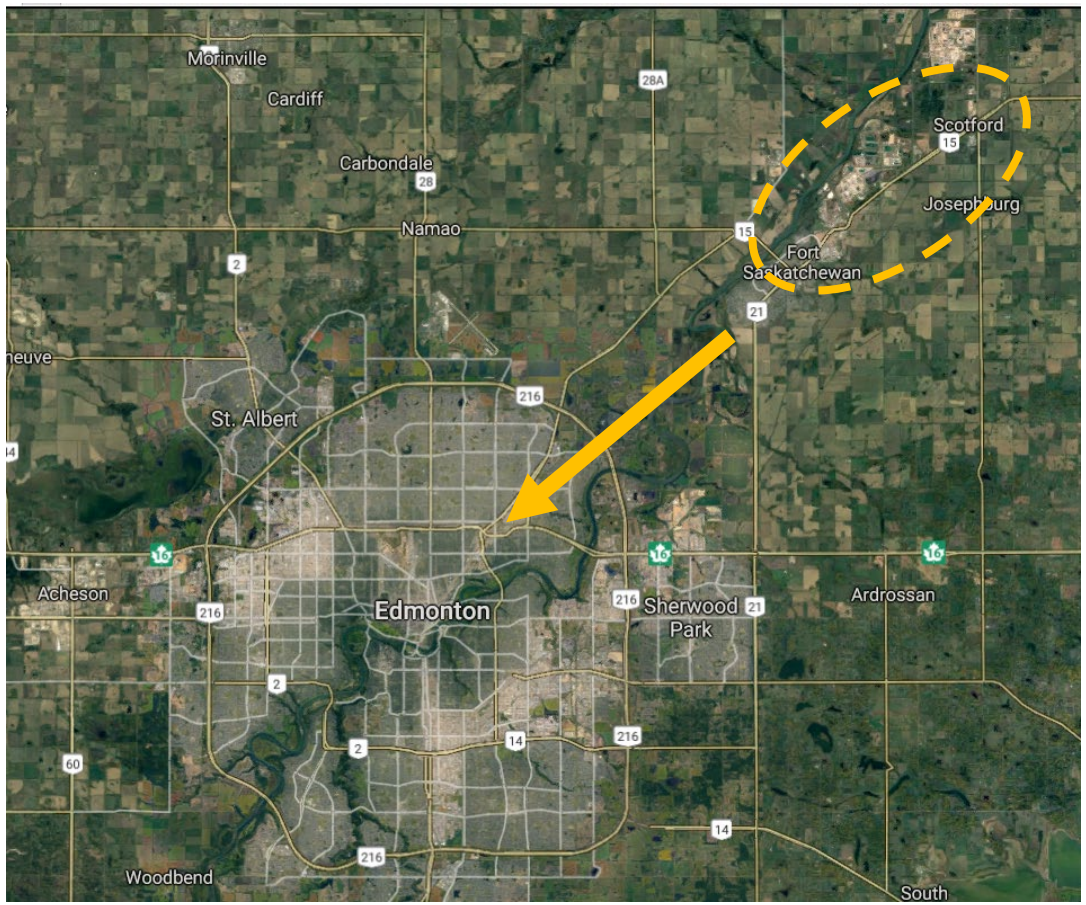
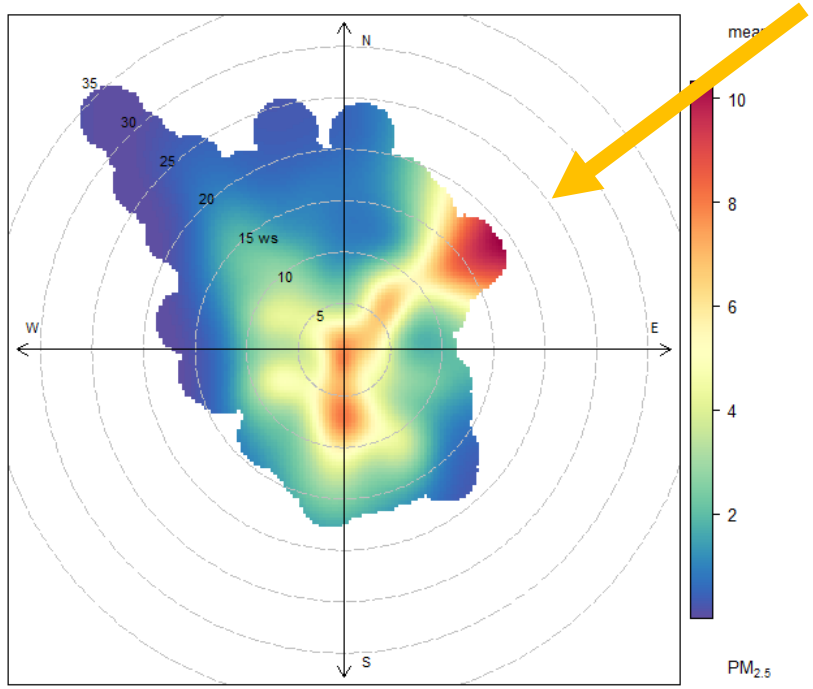
Low-Cost Air Quality Sensor





Polar plot of $PM_{2.5}$ data collected by *a* PM2.5 sensor indicates upwind sources at northeast.

A&WMA's 112th Annual Conference & Exhibition
Québec City, Québec, June 25-28, 2019, Paper # 593487

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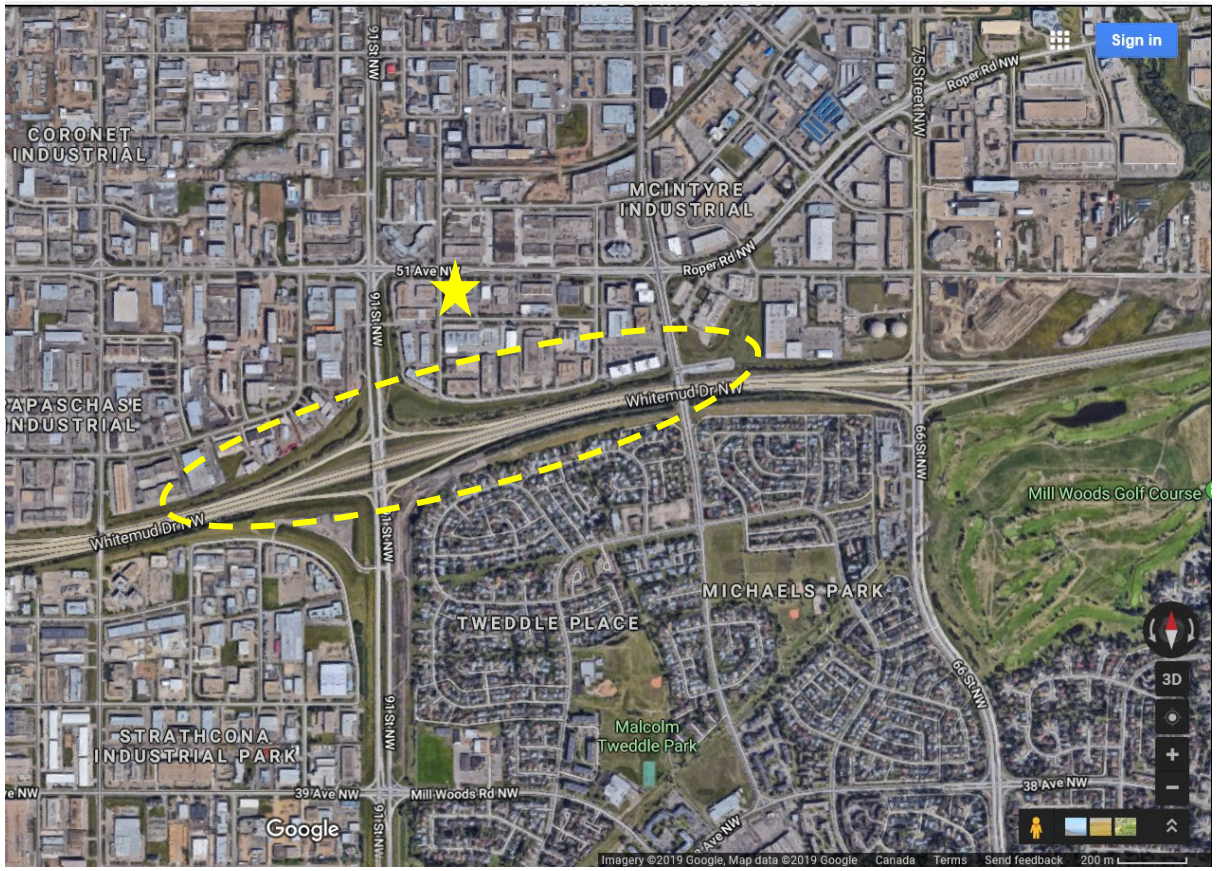
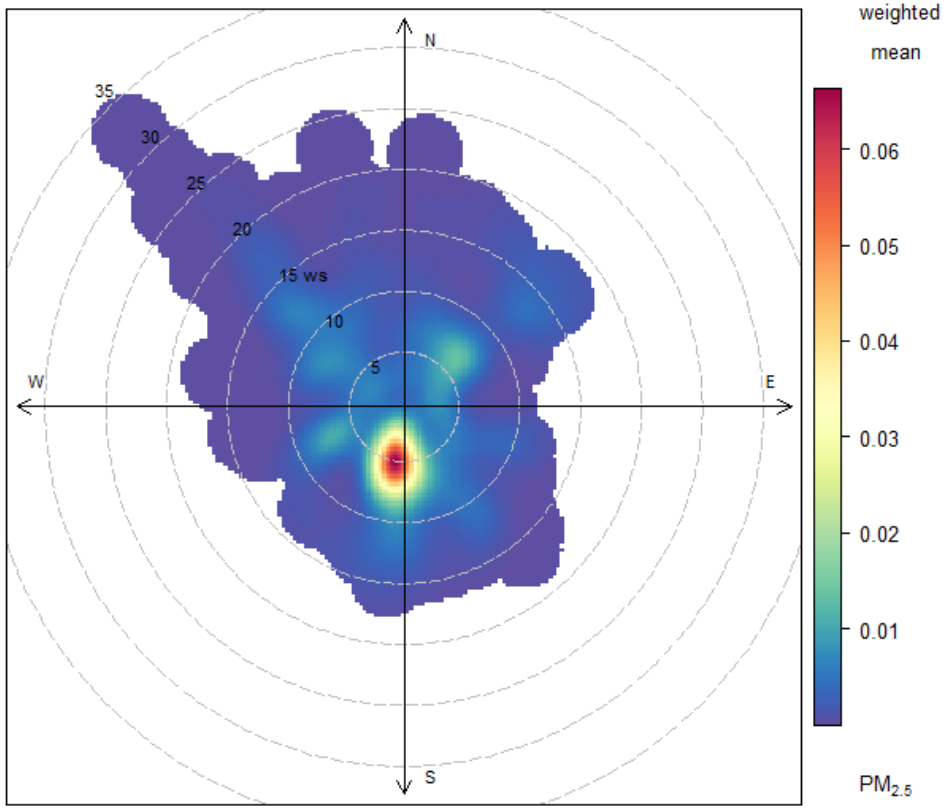
Low-Cost Sensor Deployment





Weighted mean polar plot of $PM_{2.5}$ indicates strong contributions from the highway 14 located in the south

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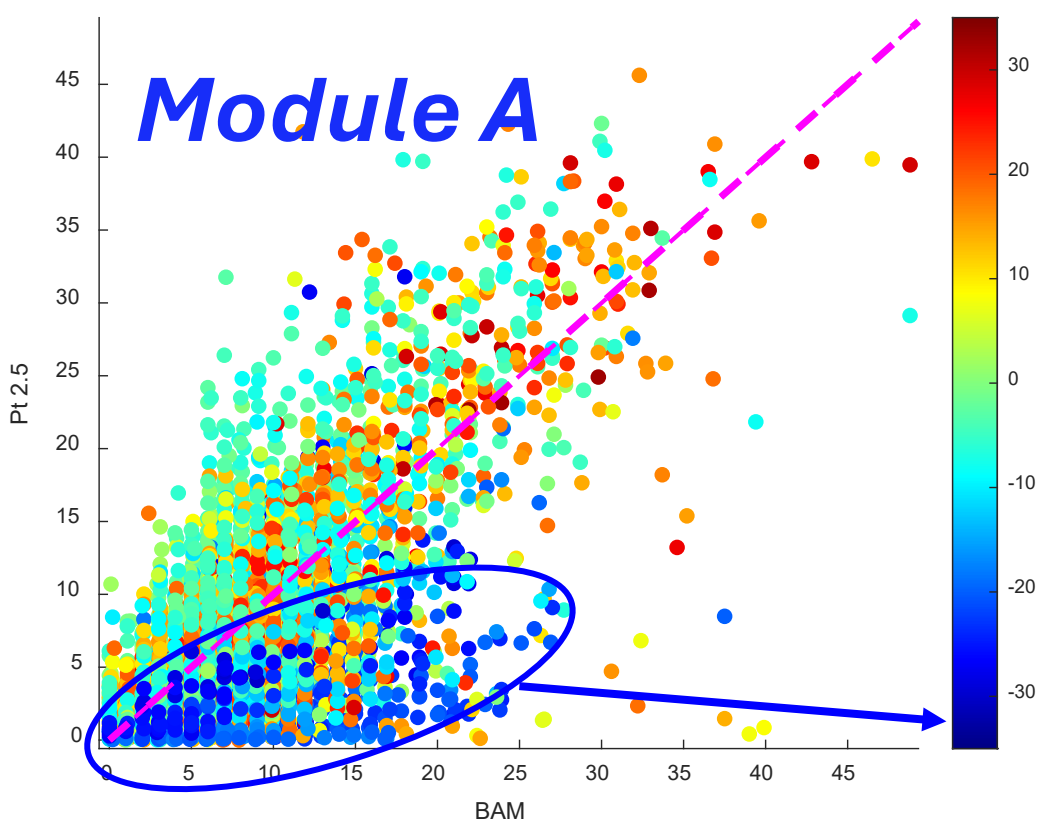
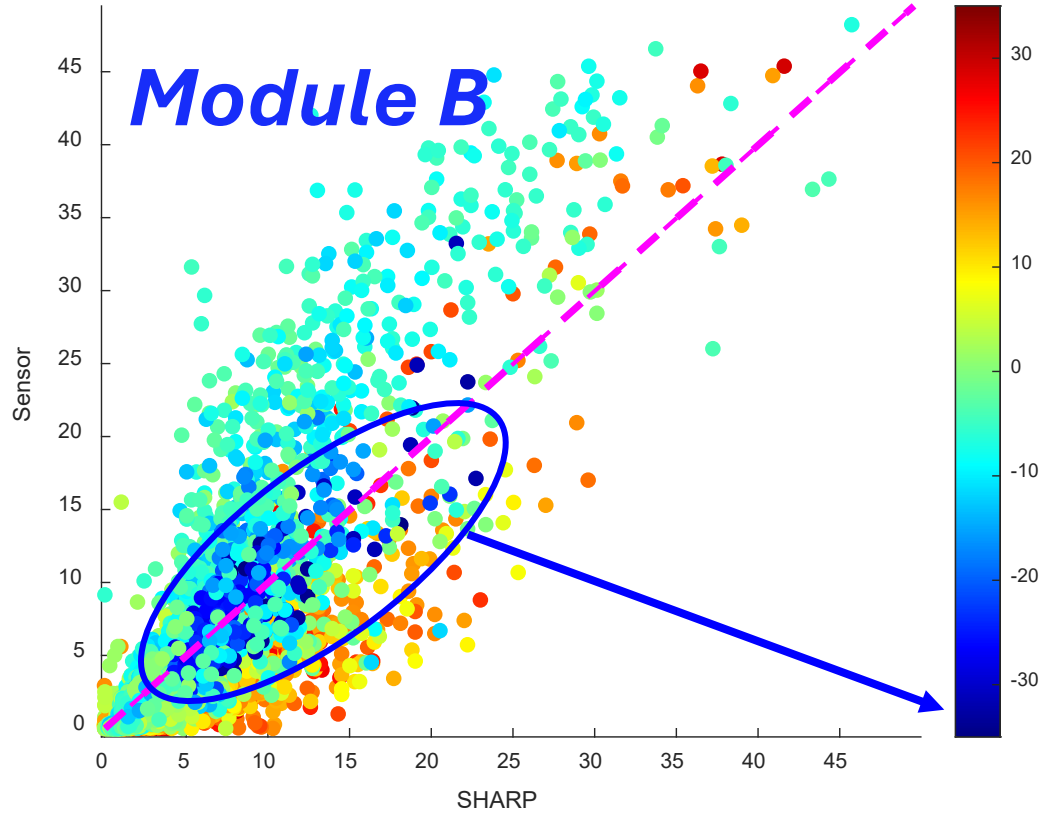
Low-Cost Sensor Performance





- Consistent under-bias in sensor reading for Module A at $T_{ambient}$ < -20 °C.
- Good correlation of same sensor with FEM analyzer for Module B at $T_{ambient}$ < -20 °C.
- Module B is a later version with improved micro-station architecture.

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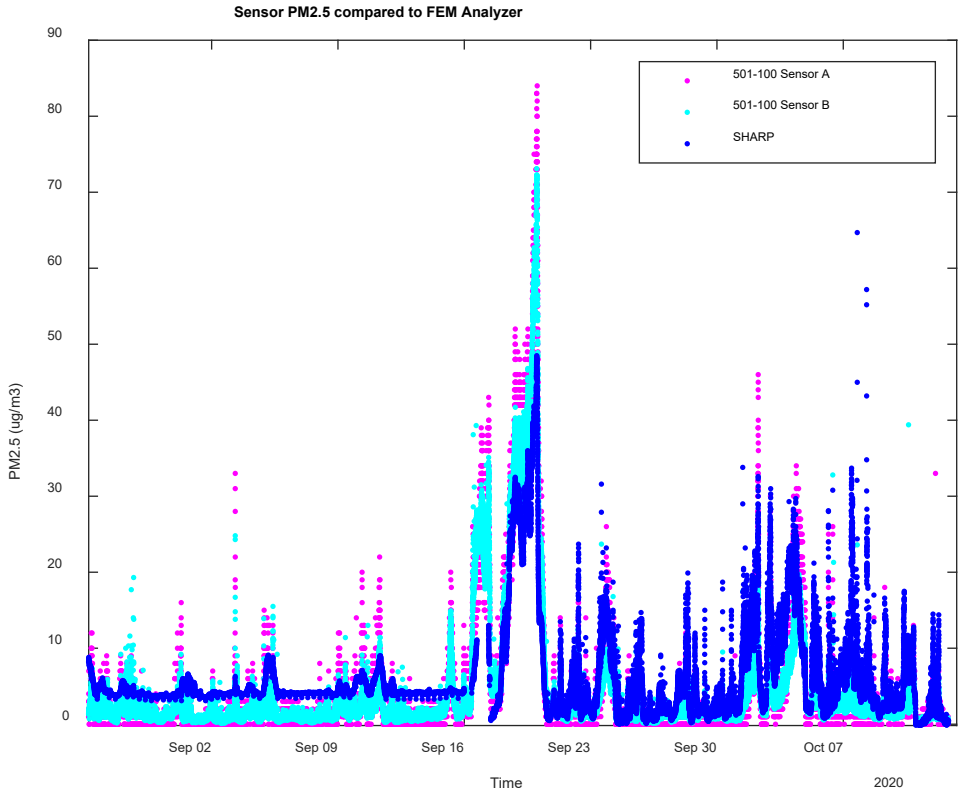
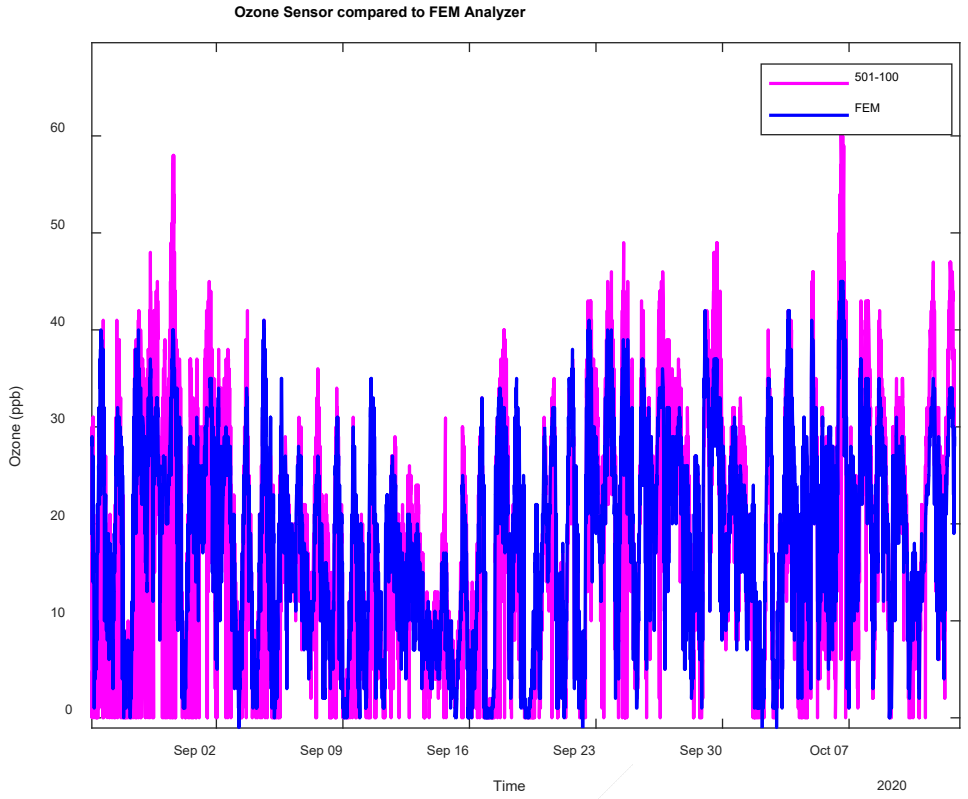
Low-Cost Sensor Performance

Module C





$PM_{2.5}$ (left) and Ozone (right) data in comparison to FEM Analyzers

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Wildfire Detection by low-cost sensors

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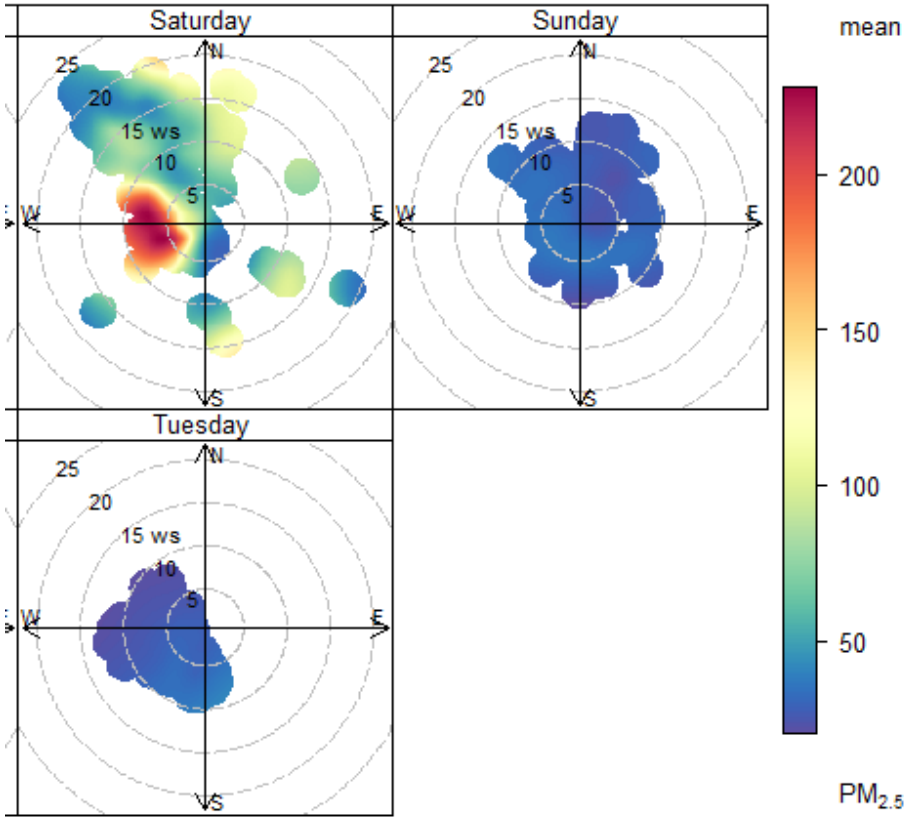
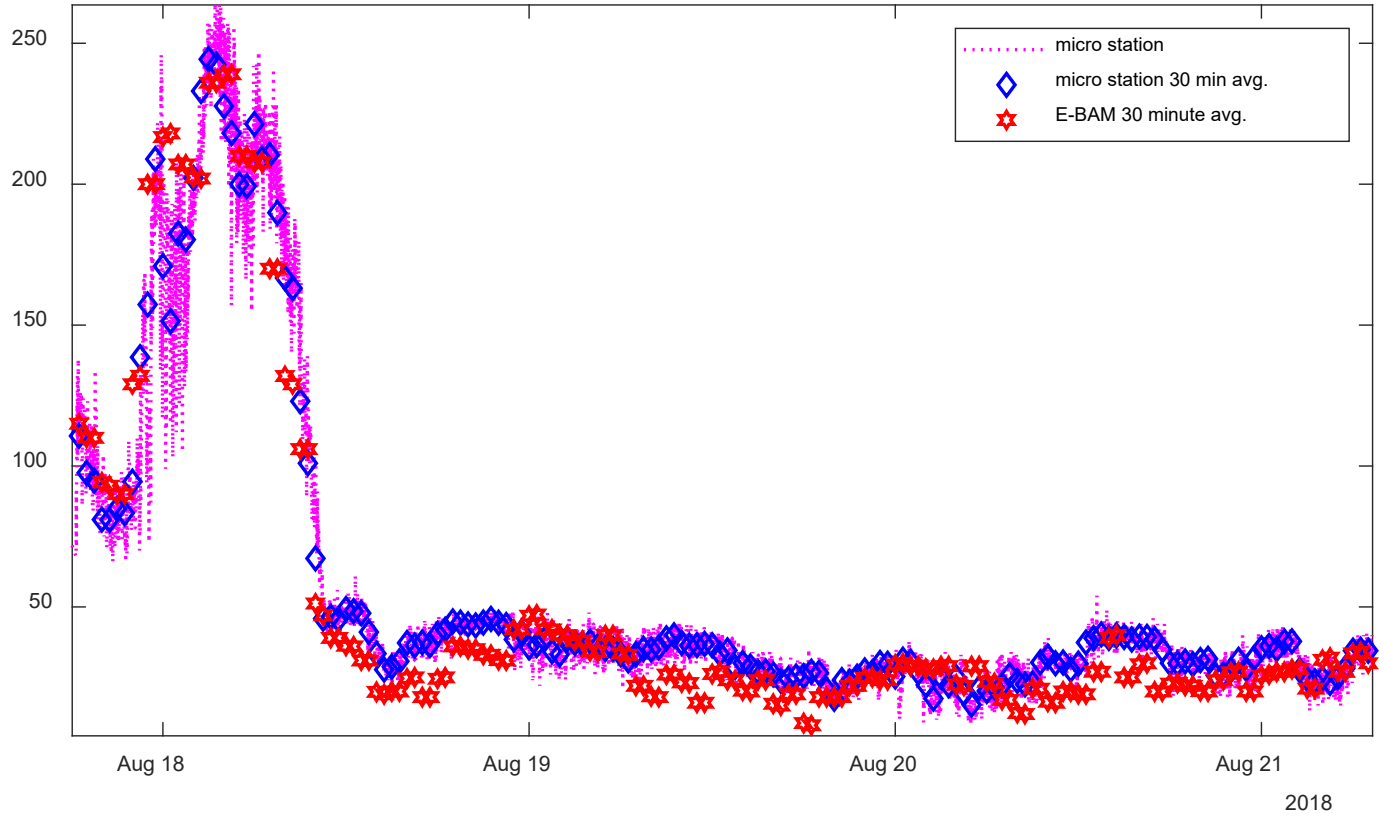
Wildfire Detection Accuracy





Elevated PM2.5 during wildfire smoke. Elevated plume originated from wildfire in the west and southwest of Edmonton

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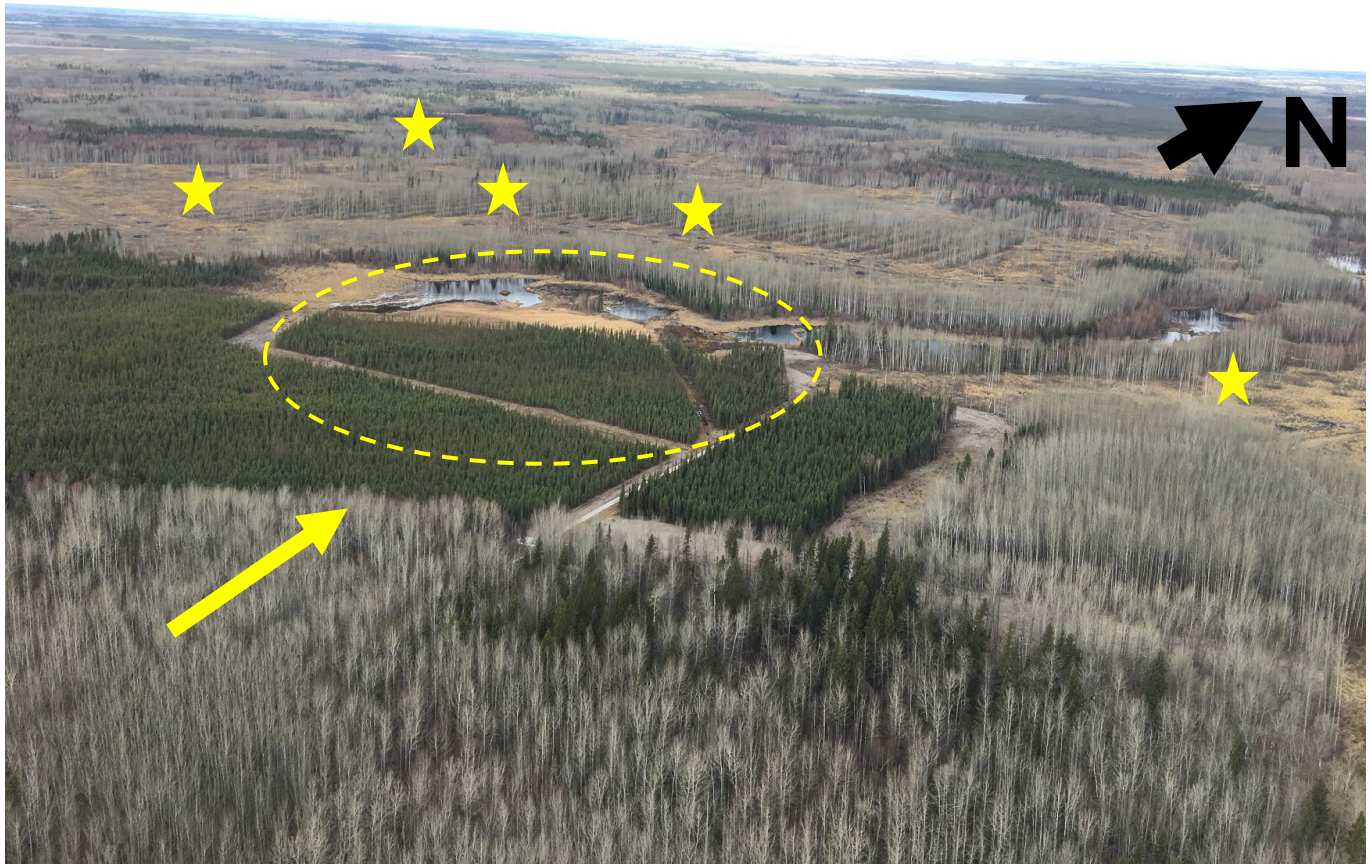
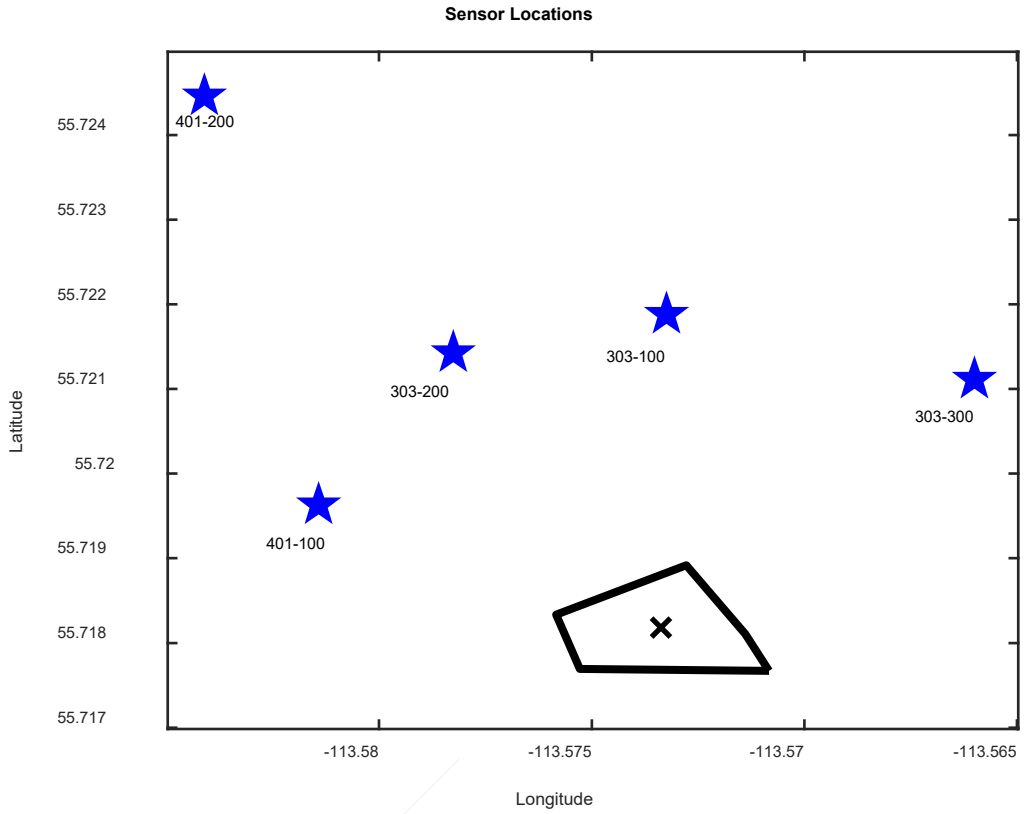
Prescribed Fire Monitoring by low-cost sensors





A network of 5 sensor modules deployed at prescribed wildfire

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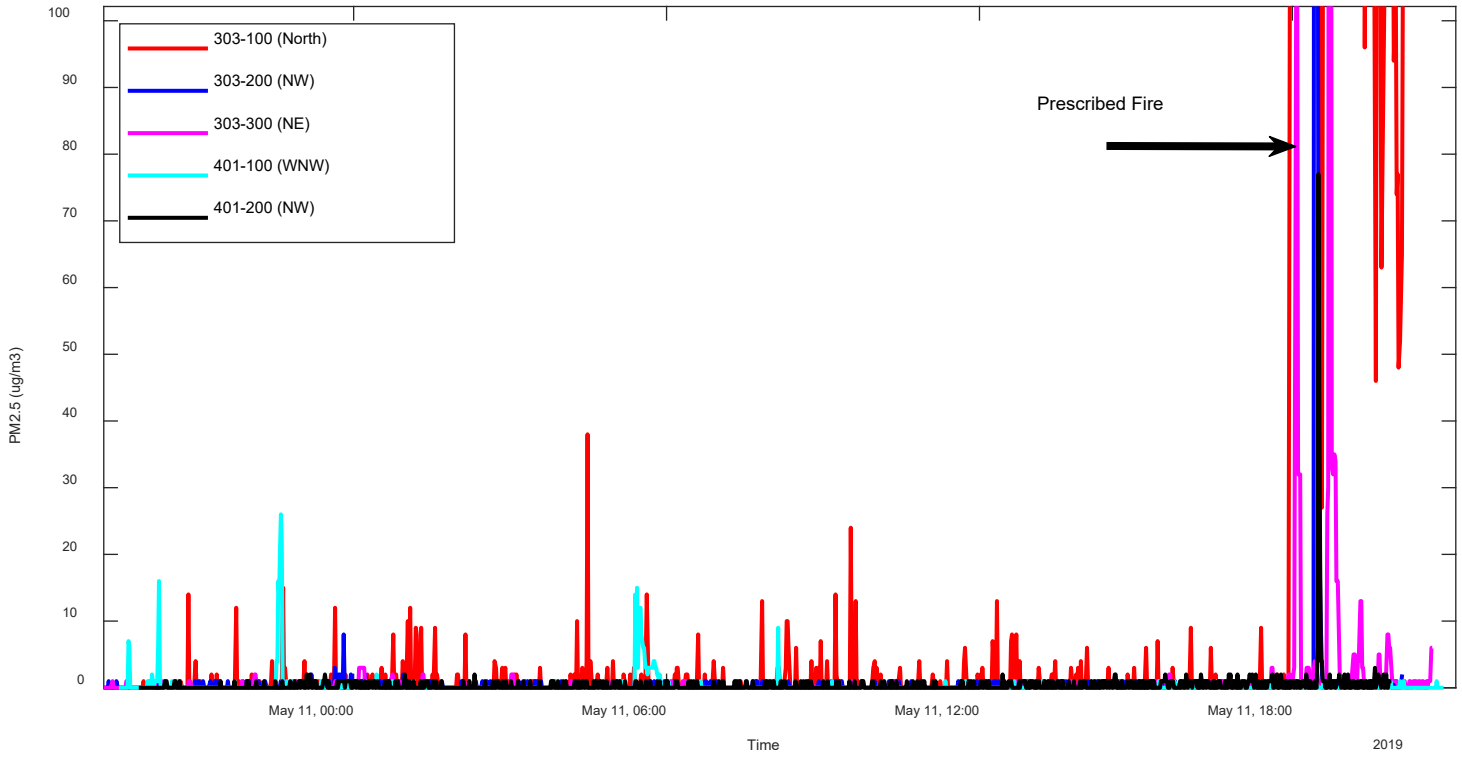
Prescribed Wildfire Monitoring



Air Quality monitoring during prescribed wildfire

- Background $PM_{2.5}$ levels were low, and below the sensor minimum detection level (MDL) in most of the cases.
- No nearby emission sources.

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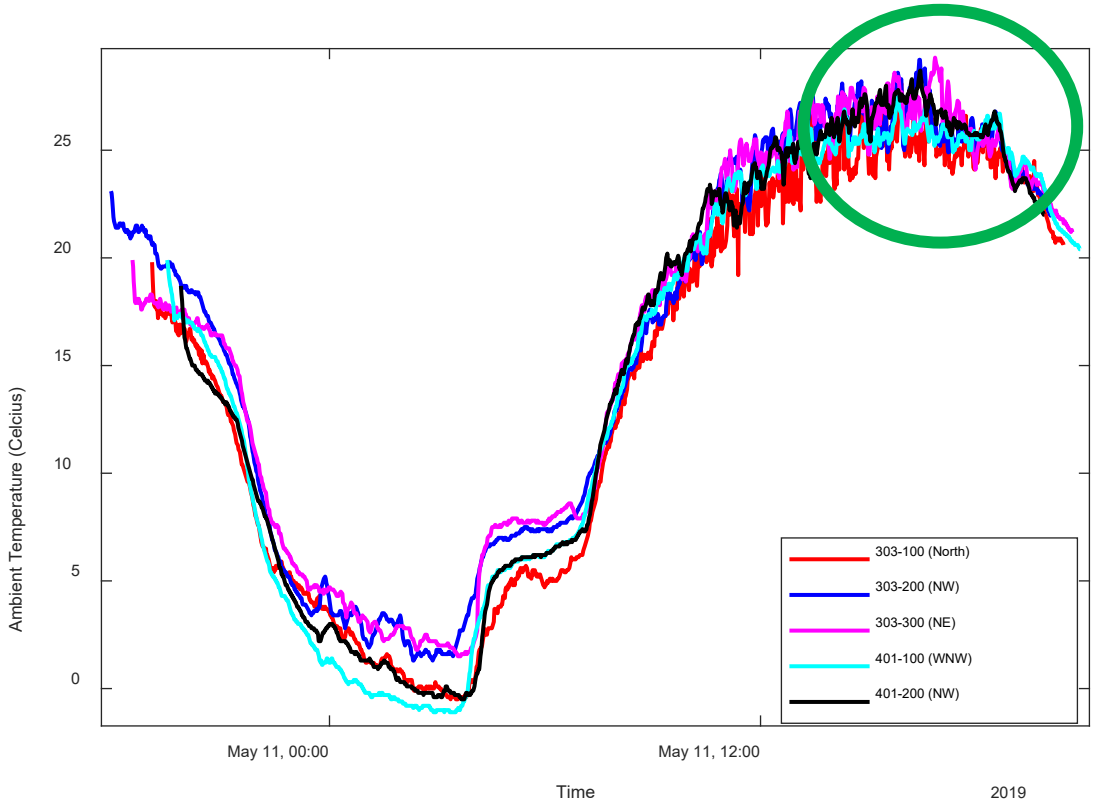
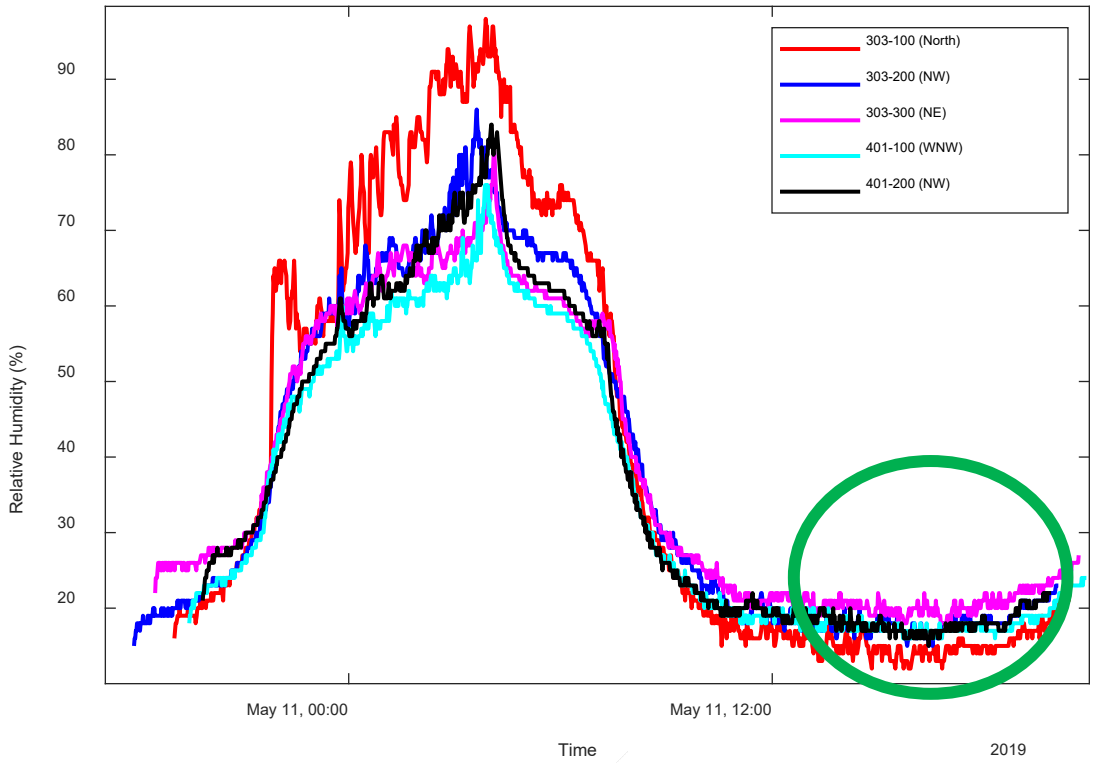
Fire Weather Condition Monitoring





Diurnal cycle of Temperature and Humidity.
Relatively warm and dry condition at the time of fire.

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Fire Spread During Prescribed Fire

Flaming

Smoldering

Time lapse since ignition:

1 minute

3 minutes

6+2 minutes

Fire spread from south to north perimeter in 6 minutes

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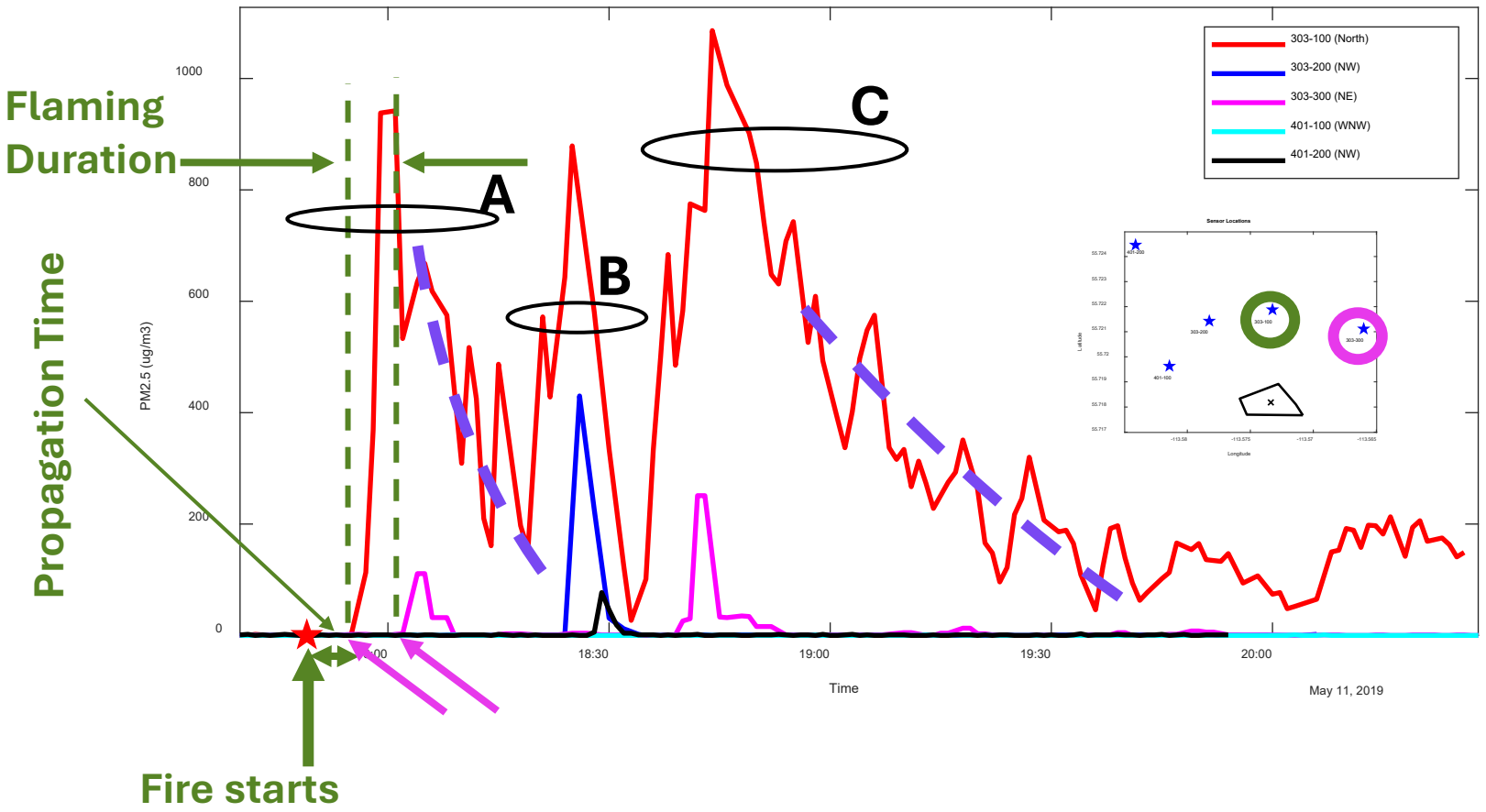
Smoke (PM2.5) Detection



- Time delay for smoke to reach sensor.
- Duration of enhancement relates to Flaming duration.
- Time for smoke to reach at sensors are different.
- Smoke intensity levels are different.
- Three distinct wavefronts of smoke.
- Smoke decays at different rates.

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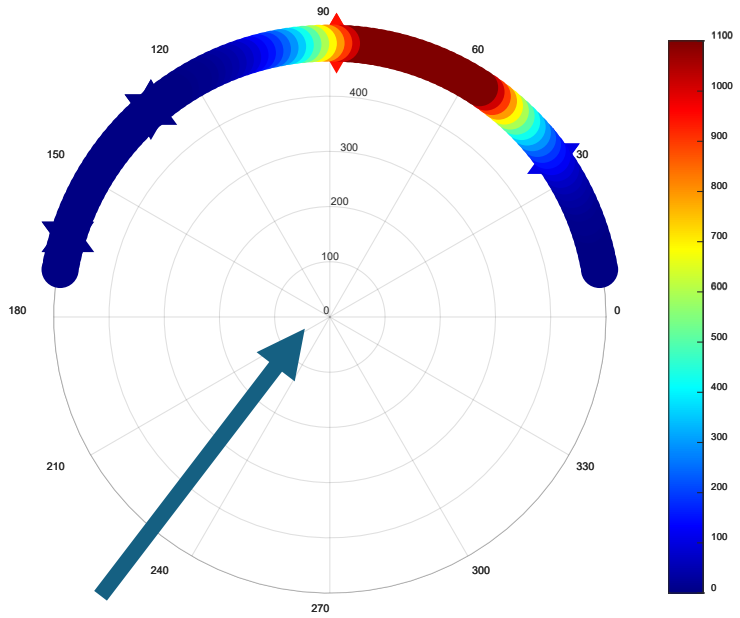
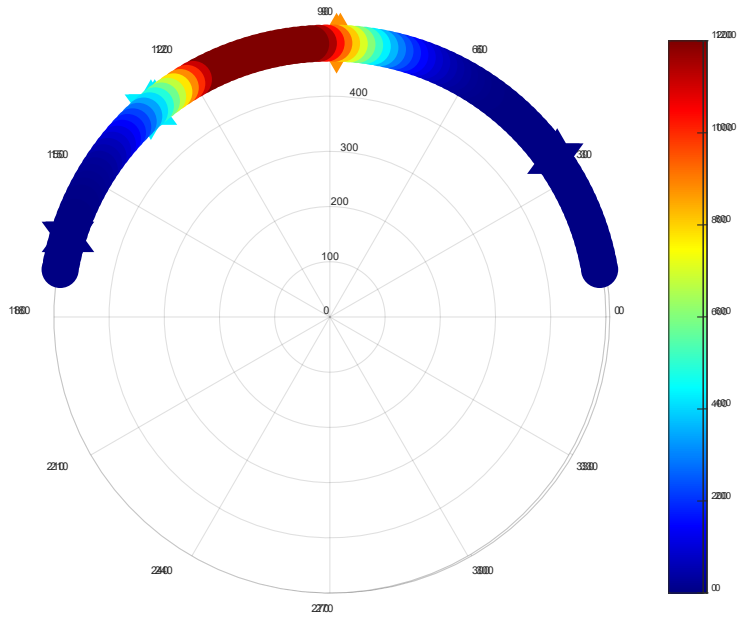
Smoke Plume Pattern



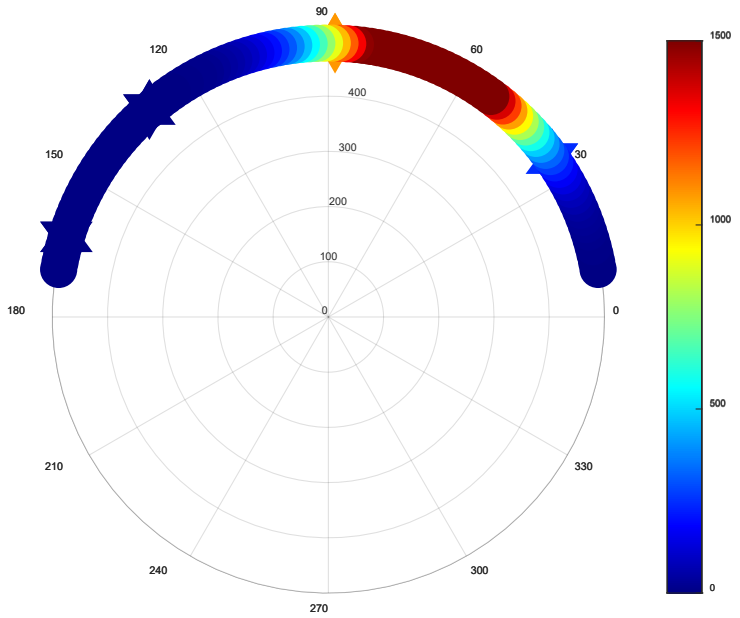
Smoke A

Time: 18:04



Smoke B

Time: 18:25



Smoke C

Time: 18:43

Smoke intensity varies at spatially

Smoke pattern varies with time

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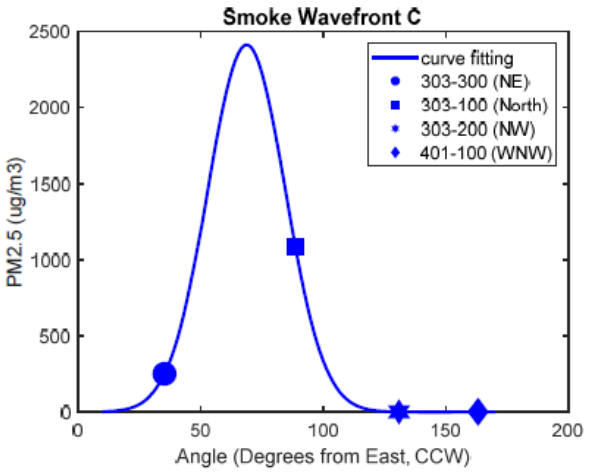
Quantification of emissions

Flow of $PM_{2.5}$:

$$Q = \int_{l_1}^{l_2} vn(l)Hdl,$$



Total Emission:

$$M_{PM_{2.5}} = \frac{Q}{n(t)_{max}} \int_{t_0}^{t_0+T} n(t)dt\,,$$

Combustion Phase	Smoke-Wave	$PM_{2.5}$ Mass M (kg)	Total Emission (kg)
Flaming	A	15.2	15.2
Smoldering	B	3.0	16.3
	C	13.3	

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Community-based Monitoring Plan

Wildland fire is a frequent event in many of the Alberta communities which are not covered under provincial air quality monitoring network.

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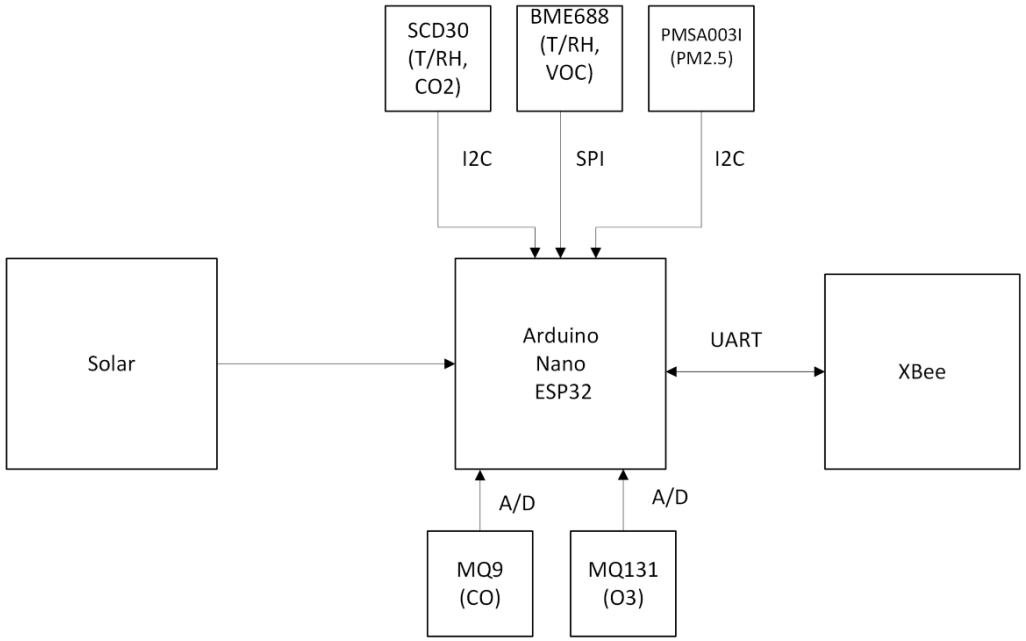
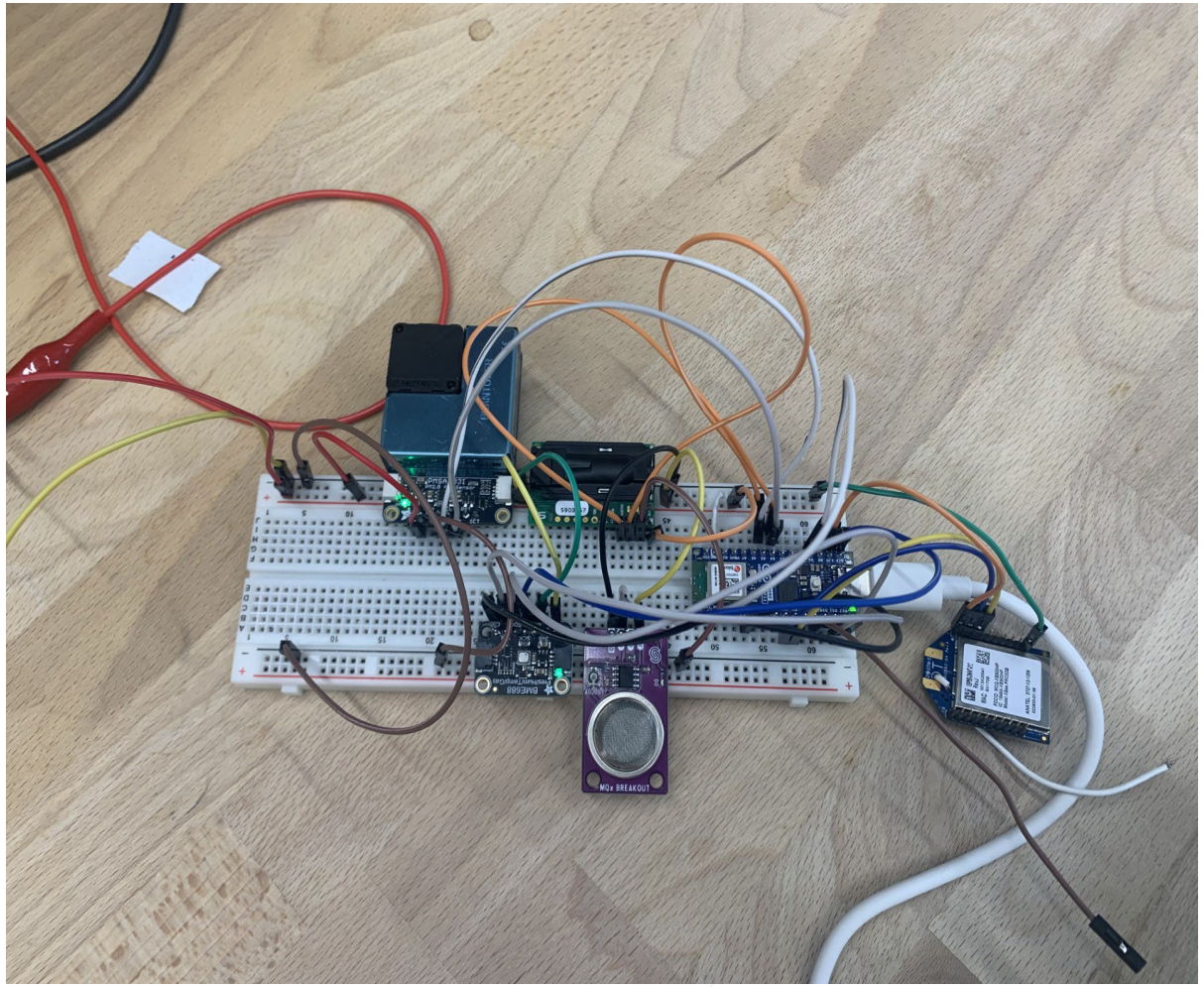
Sensor Integration for Wildfire Detection



Functional diagram of sensor system



Breadboard prototype system

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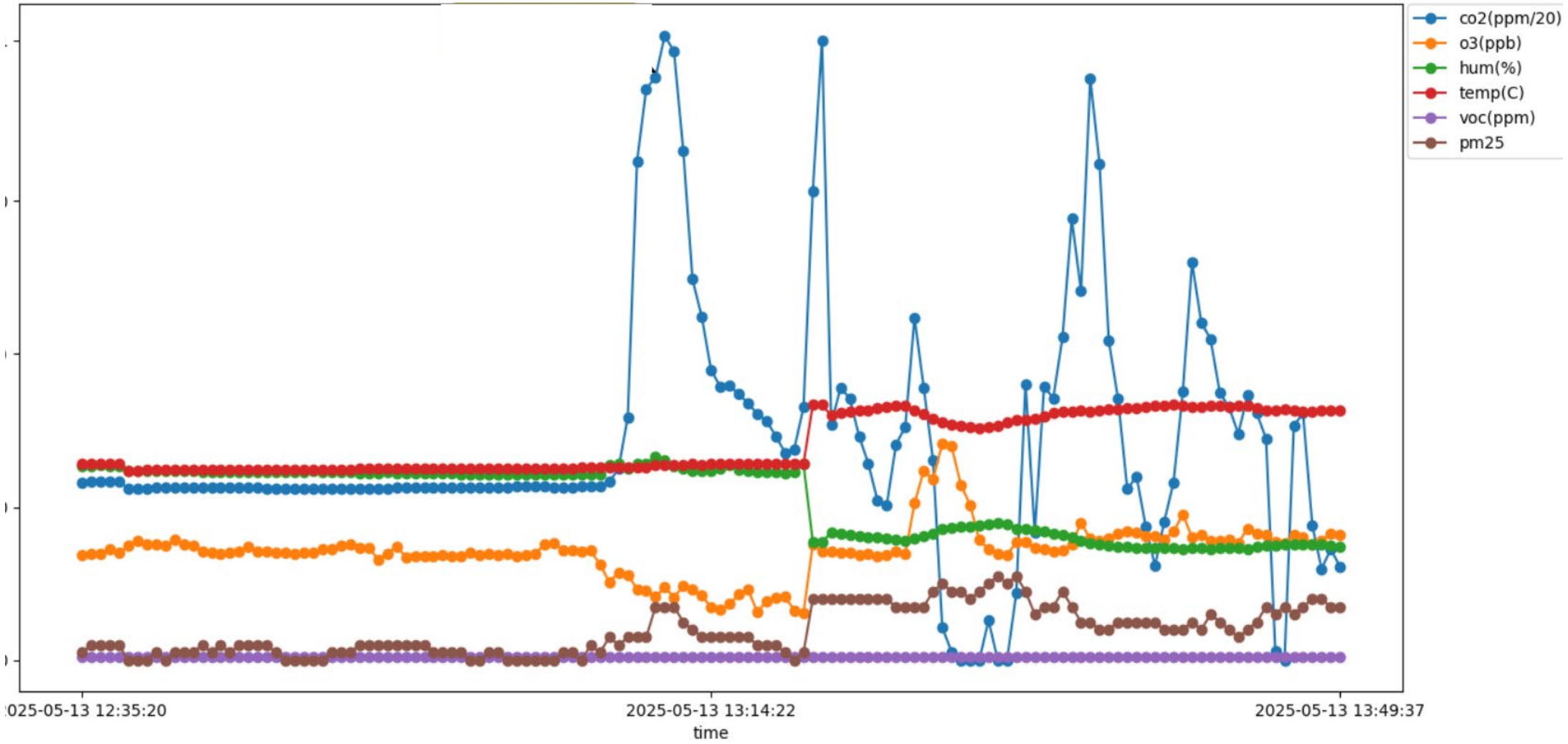
Real-time Monitoring of Air Parameters



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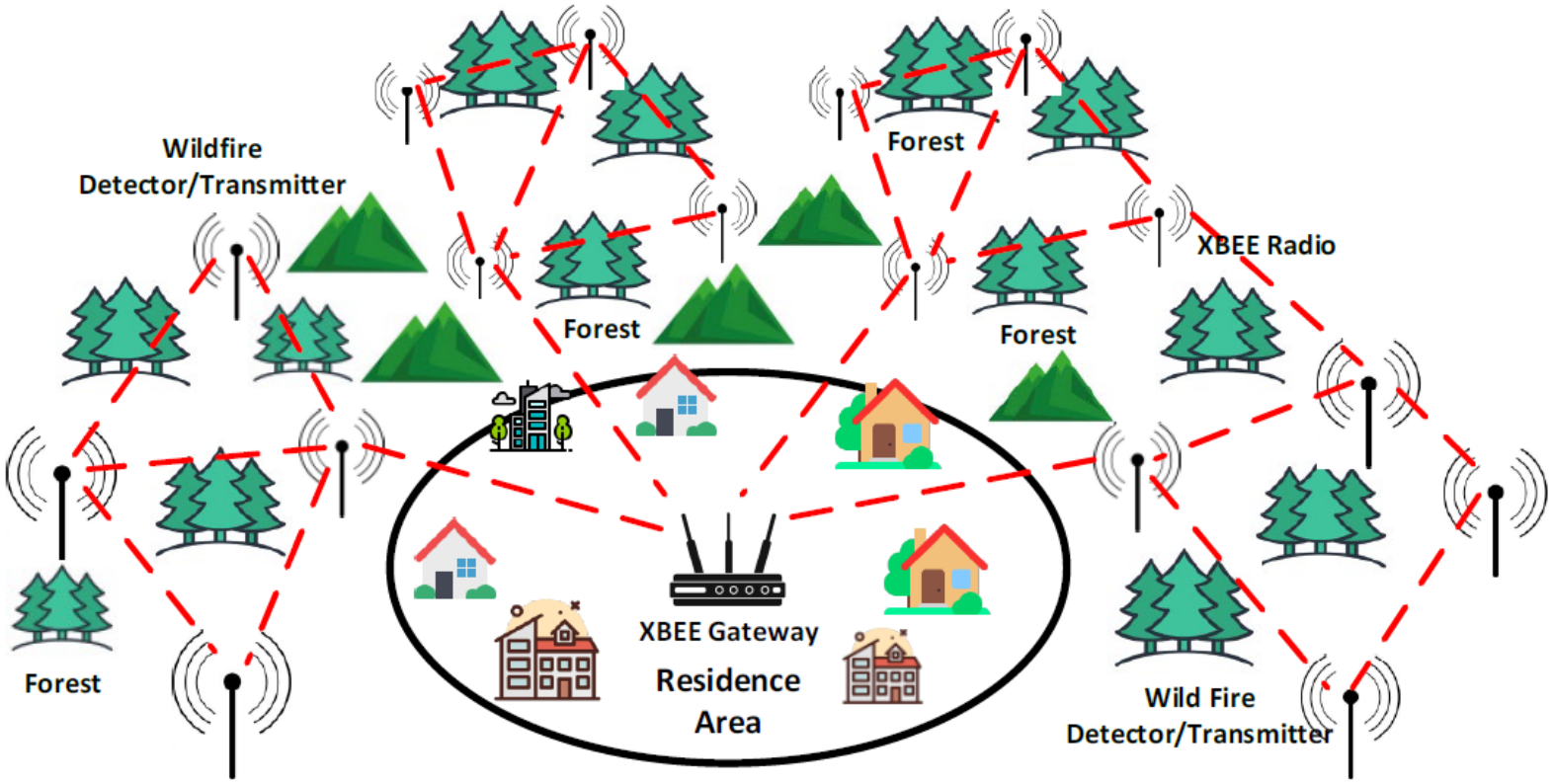
Distributed Sensor Network



A distributed network of low-cost sensor systems can be a solution for community-based air quality and wildfire monitoring

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Summary

- Low-cost air quality sensors can be custom integrated for remote deployment.
- Detection accuracy is sufficient for wildfire monitoring.
- Fire and smoke behavior can be studied through low-cost sensor deployment.
- Remote communities can implement smaller network for wildfire detection and mitigation.

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Acknowledgments:

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  - Innovation Fund Program
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Question & Answer

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