Integrating multi-modal transportation data with low-cost air quality sensor data to improve understanding of traffic-related air pollution

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Motivations

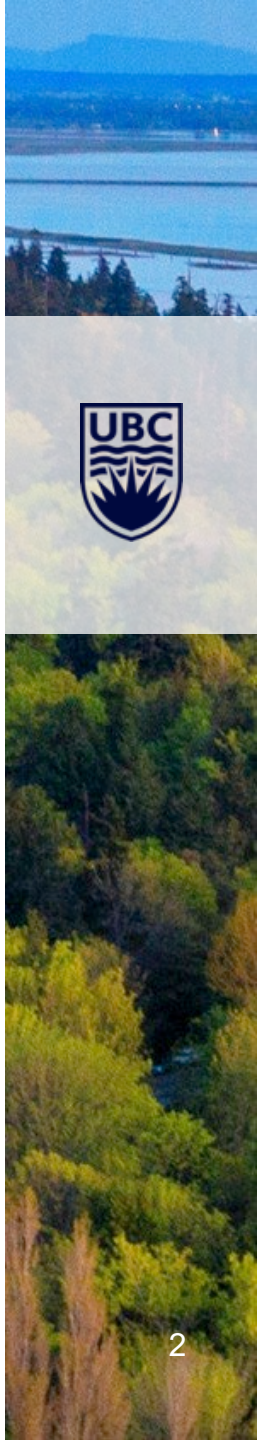
1) Urban intersection pollution is associated with numerous negative health effects in humans i.e., respiratory conditions & cardiovascular disease

2) Pollutant levels found in urban areas are highly variable and strongly correlated to local traffic emissions

Objectives

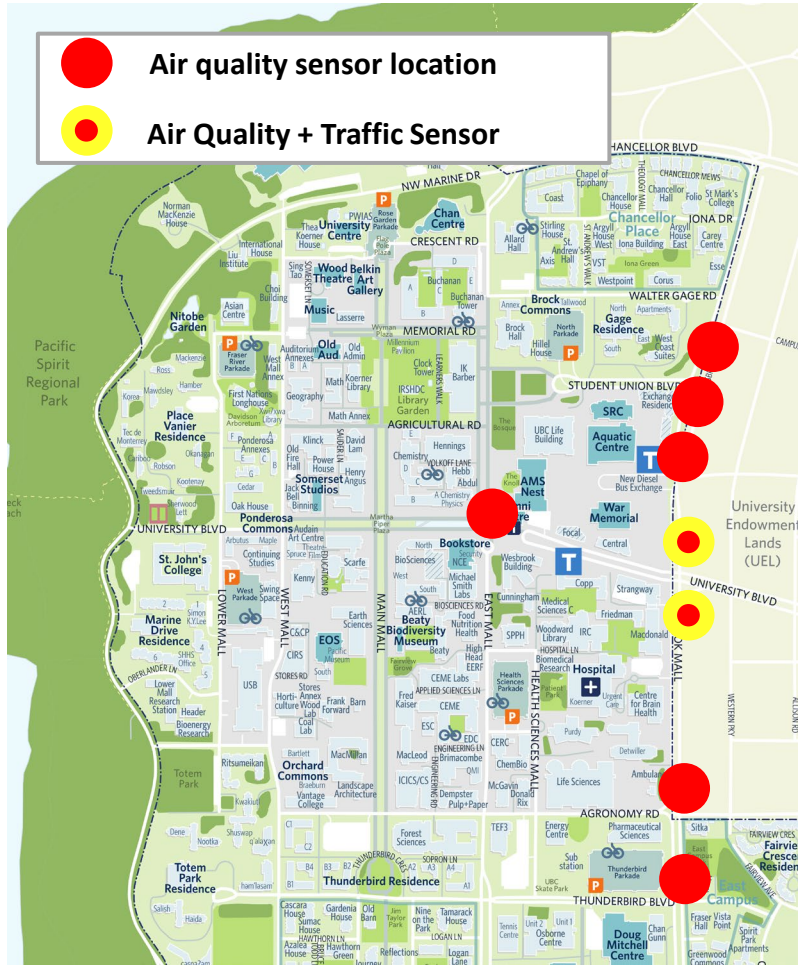
1) Incorporate multiple data streams to increase interpretability and transparency of air quality and increase stakeholder engagement

2) Merge air pollution data with multi-modal transportation data to understand correlations and relationships



Study Overview – Air Quality

- Air pollutant data collected through use of the Remote Air Quality Monitoring Platform (RAMP)
- 8 RAMP Sensors installed in June 2021 at UBC Vancouver
- 4 RAMP Sensors installed July 2021 at Metro Vancouver air monitoring station (Calibration)
- Measured 6 pollutants – CO, CO_2, NO, NO_2, O_3, PM



Pollution data – Calibration – Transportation Data – Results

Study Overview – Transportation

- Anonymized data collected by two Numina sensors at busy intersection on UBC campus
- Multi-modal - Delivers counts and paths of cars, trucks, buses, pedestrians and cyclists
- Sensor accuracy assessed by external project collaborator - Anas Chaaban

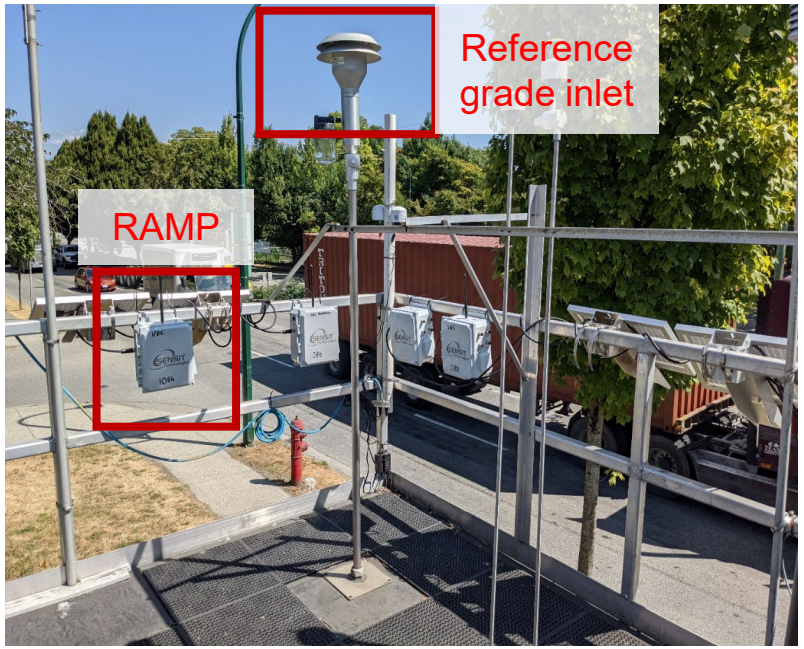
Air Quality Sensor Calibration

- 8 RAMP sensors on UBC Campus
- 4 RAMP sensors at Clark Drive Near Road Monitoring Station (~12km)
- Highly trafficked intersection
- Mix of vehicle types – cars, trucks etc.
- Representative of UBC intersections

Pollution data – Transportation Data – **Calibration** – Results

Air Quality Sensor Calibration

- RAMP sensor calibration utilized the Generalized Calibration model
    - Gas pollutant model[1]
    - Particulate matter model[2]
- Calibration performance
    - Average error range: 2% - 26%
    - R^2 range: 0.92 – 0.98

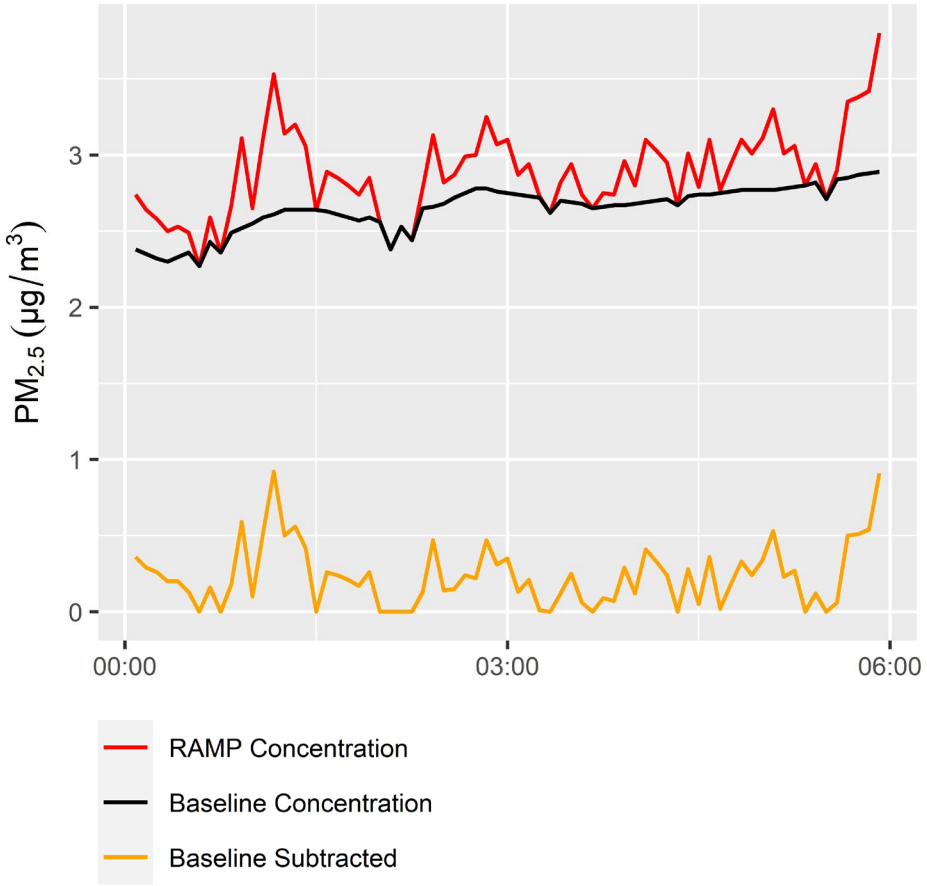


RAMP installed at Clark Drive Metro Vancouver air monitoring station

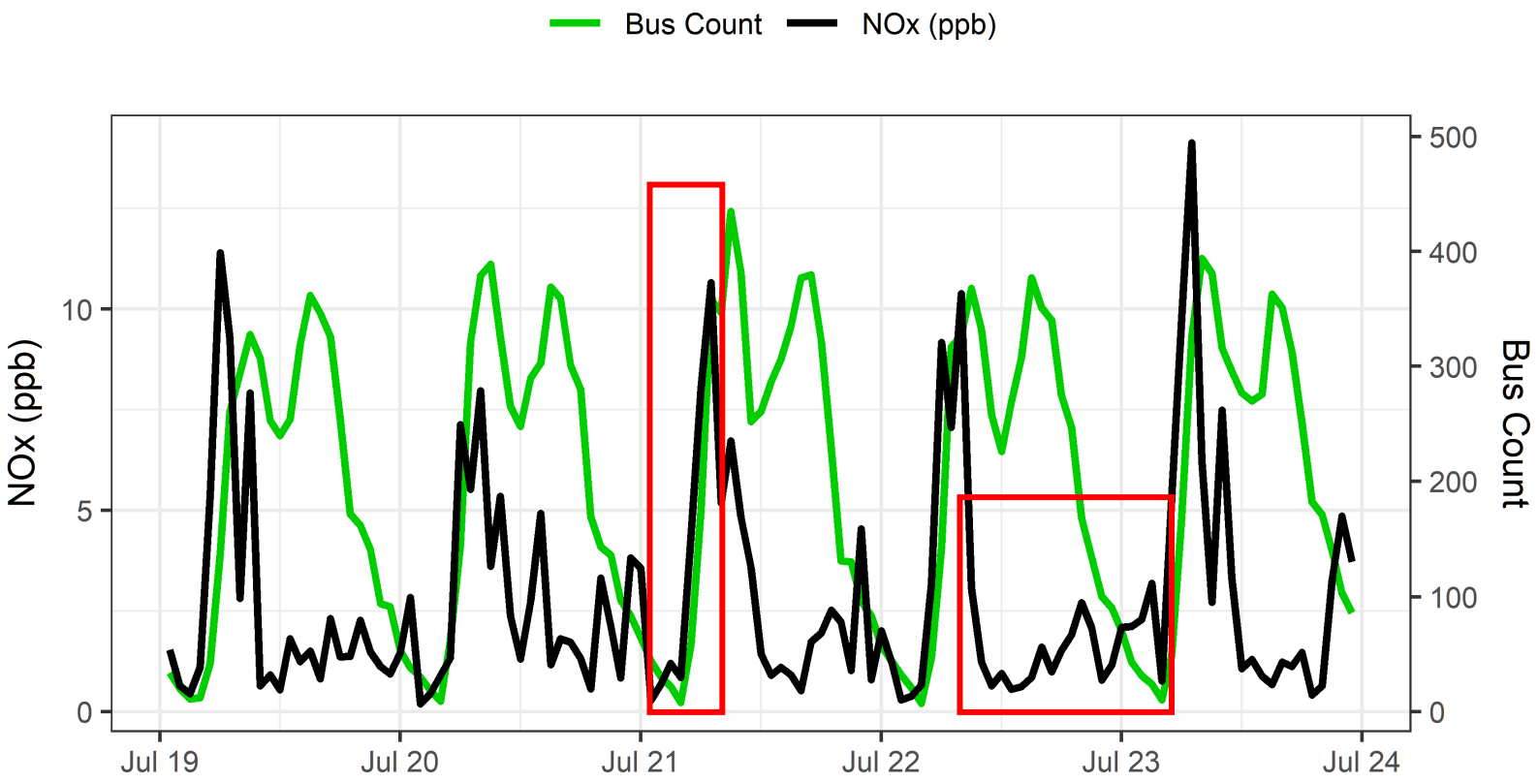
[1] Malings, C., Tanzer, R., Hauryliuk, A., Kumar, S. P. N., Zimmerman, N., Kara, L. B., Presto, A. A., & Subramanian, R. (2019). Development of a general calibration model and long-term performance evaluation of low-cost sensors for air pollutant gas monitoring. Atmospheric Measurement Techniques, 12(2), 903–920. https://doi.org/10.5194/amt-12-903-2019
[2] Malings, C., Tanzer, R., Hauryliuk, A., Saha, P. K., Robinson, A. L., Presto, A. A., & Subramanian, R. (2020). Fine particle mass monitoring with low-cost sensors: Corrections and long-term performance evaluation. Aerosol Science and Technology, 54(2), 160–174. https://doi.org/10.1080/02786826.2019.1623863

Two Data Streams

- Background concentration subtraction
  - Utilized baseline rollingBall function
  - Isolate transportation effects
  - Correlated analysis
- Total concentration
  - Pedestrian behaviour

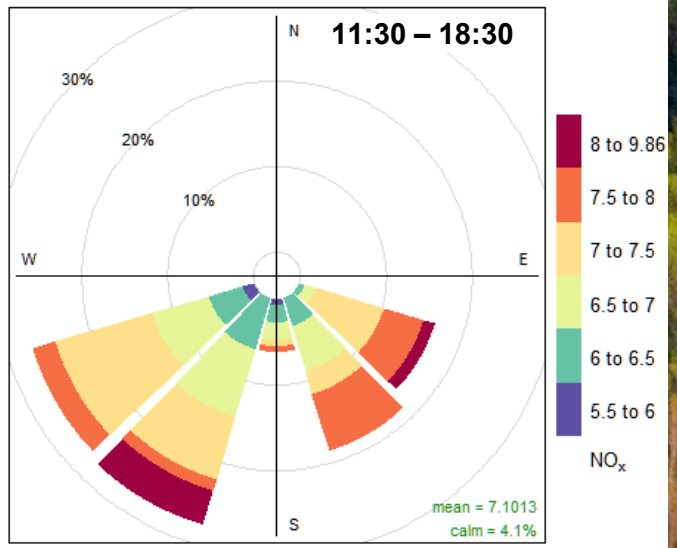


NOx & Buses - Morning correlations



Background concentration NOx (ppb) vs Bus Count - July 19 to July 23 2021

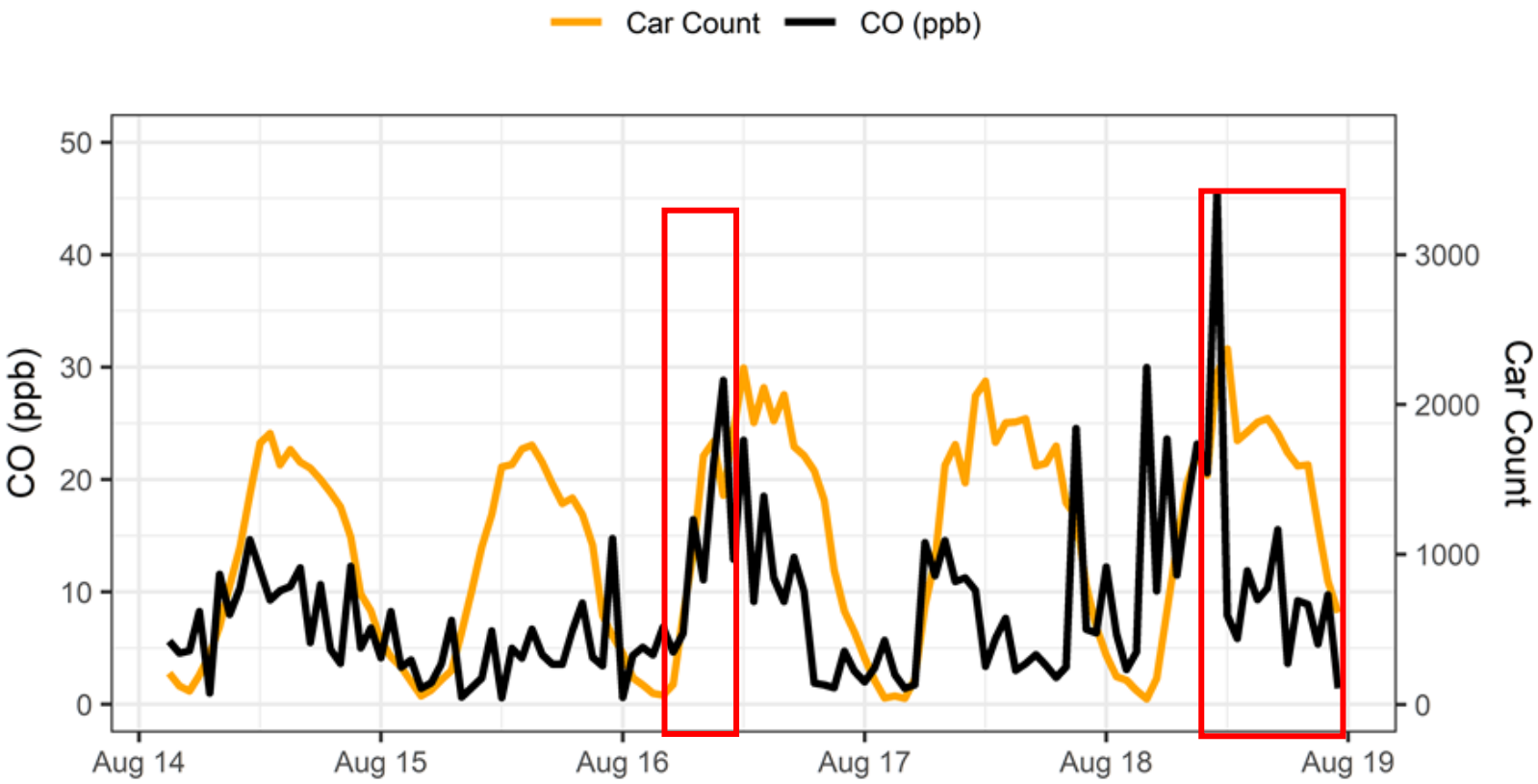
- Morning rise in bus count correlates to daily spike in NOx levels
- Similar bus count trend each day
  - Clear morning peak
- NOx levels peak in morning and reduce throughout the day
  - Inflow effect – South East winds (~55%)



Frequency of counts by wind direction (%)

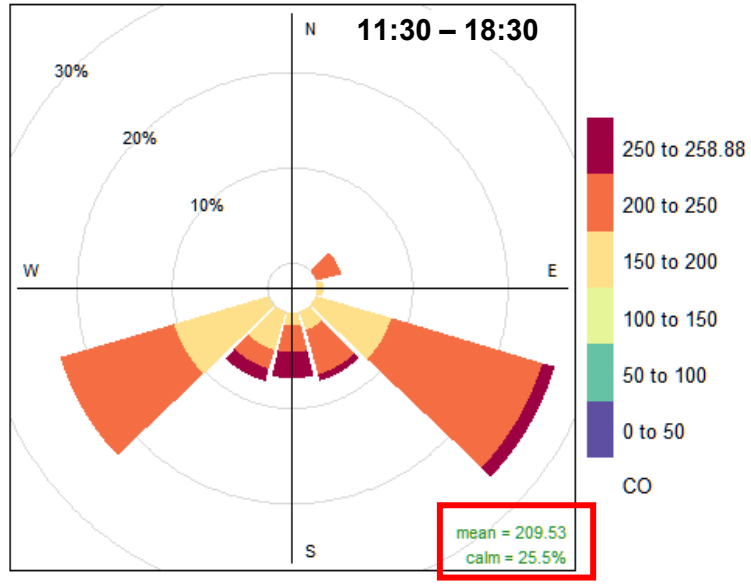
Wind Data: UBC Weather Forecasting Research Team

CO & Cars - Morning correlation / Afternoon meteorological effects



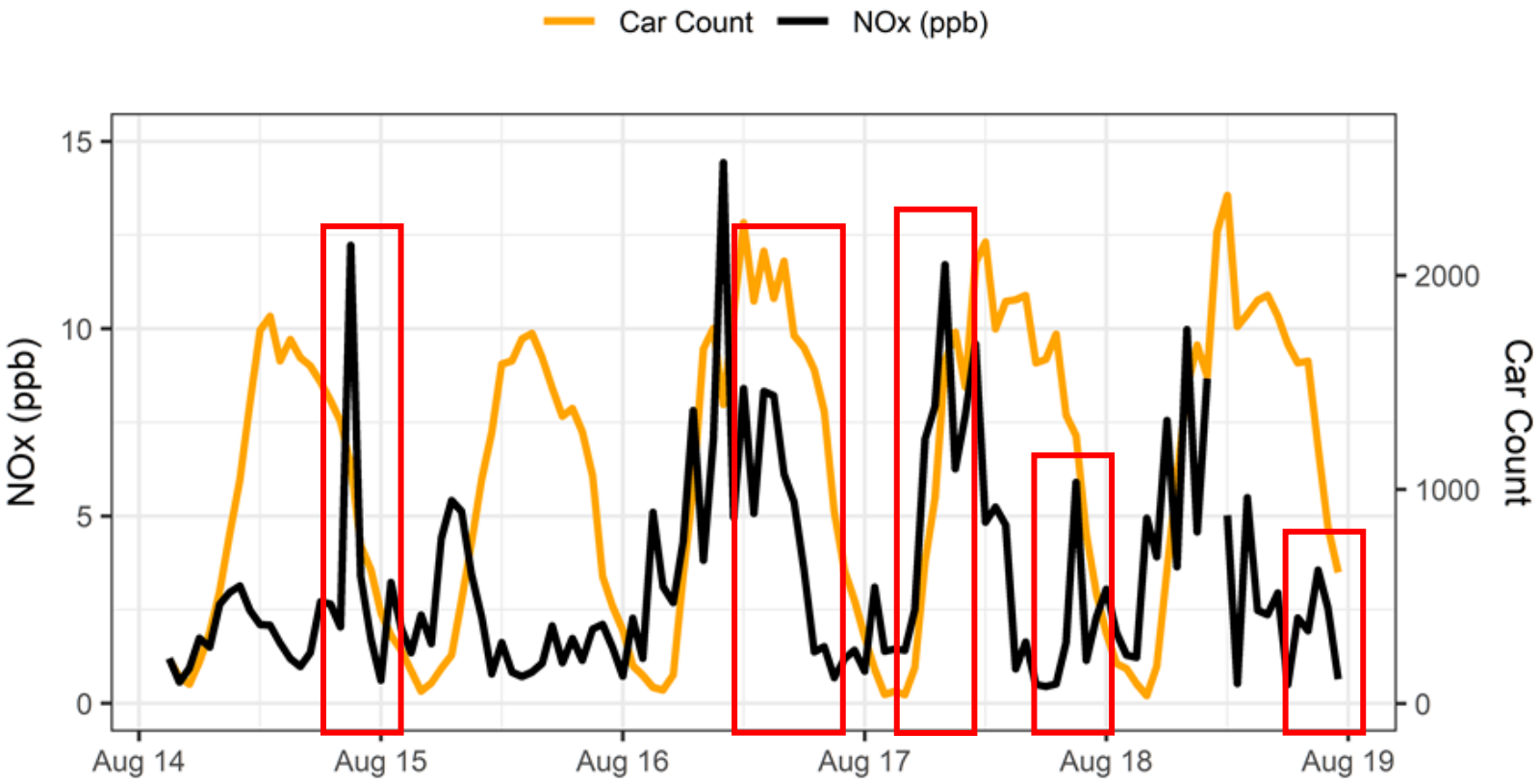
Background concentration CO (ppb) vs Car Count - Aug 14 to Aug 18 2021

- Morning rise in car count frequently correlates to increased CO levels
- Similar car count trend each day – Midday peak
- CO levels reduce gradually throughout afternoon
  - Mild inflow effect (~25%)
  - Calm air (~26%)



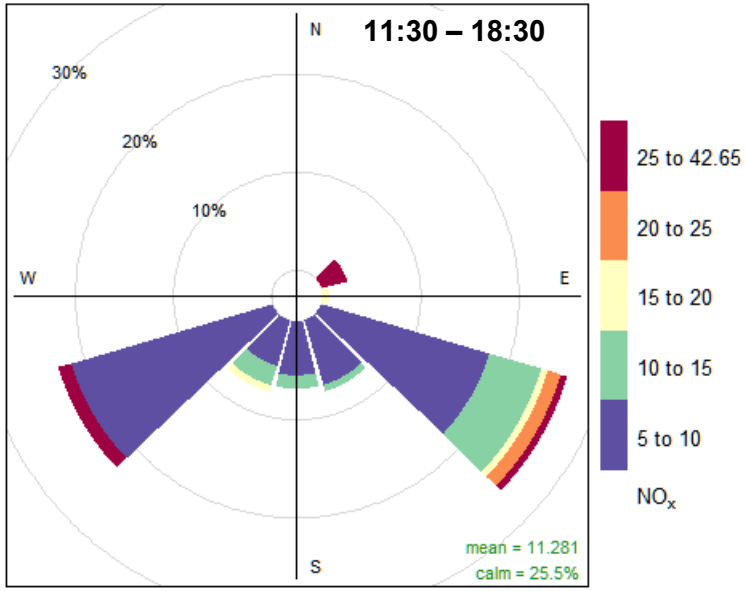
Frequency of counts by wind direction (%)

NOx & Cars - Morning correlation / Afternoon spikes



Background concentration NOx (ppb) vs Car Count - Aug 14 to Aug 18 2021

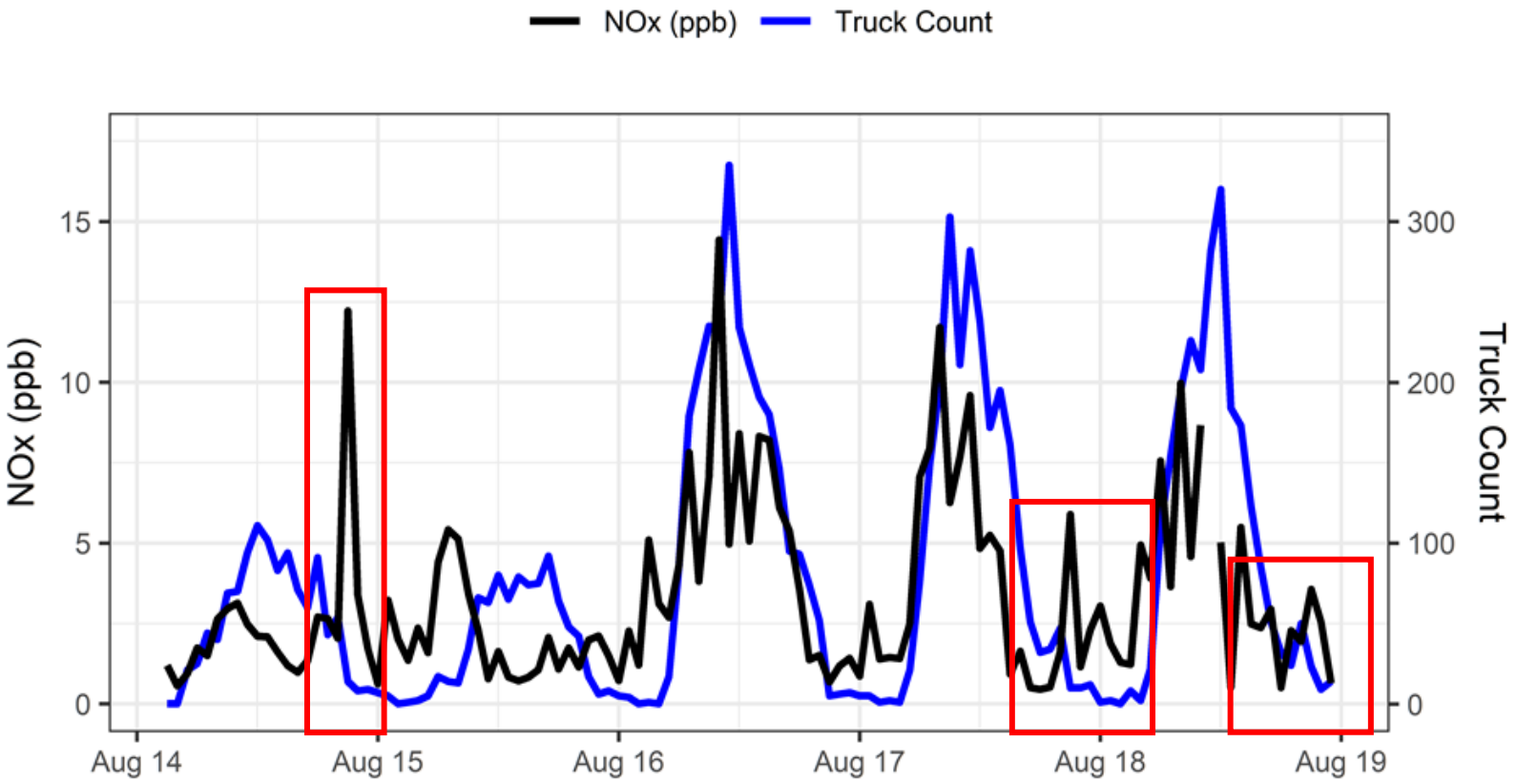
- Morning rise in car count correlates to increased NOx levels
- NOx levels peak in morning & gradually reduce
  - Mild inflow effect
  - Calm air (~26%)
- Additional NOx spikes in evening of Aug 14, 17 and 18



Frequency of counts by wind direction (%)

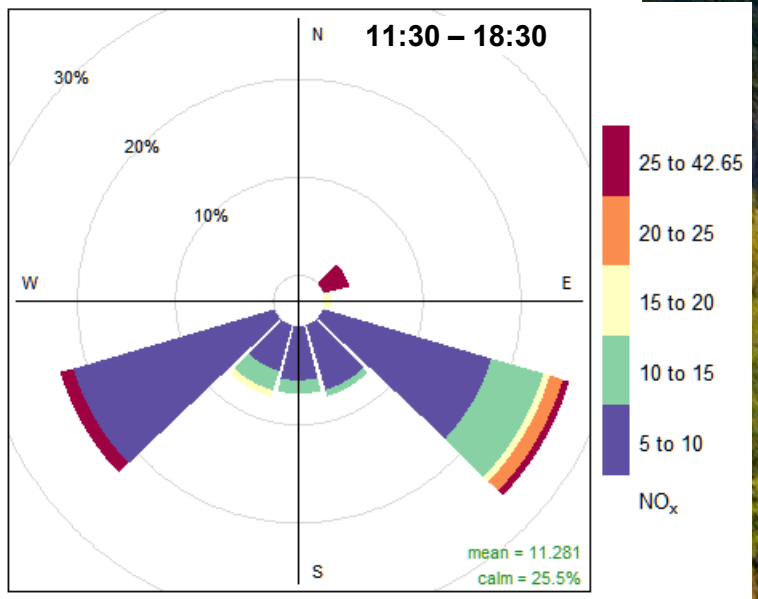
Pollution data – Calibration – Transportation Data – **Results**

NOx & Trucks - Afternoon spike correlations



Background concentration NOx (ppb) vs Truck Count - Aug 14 to Aug 18 2021

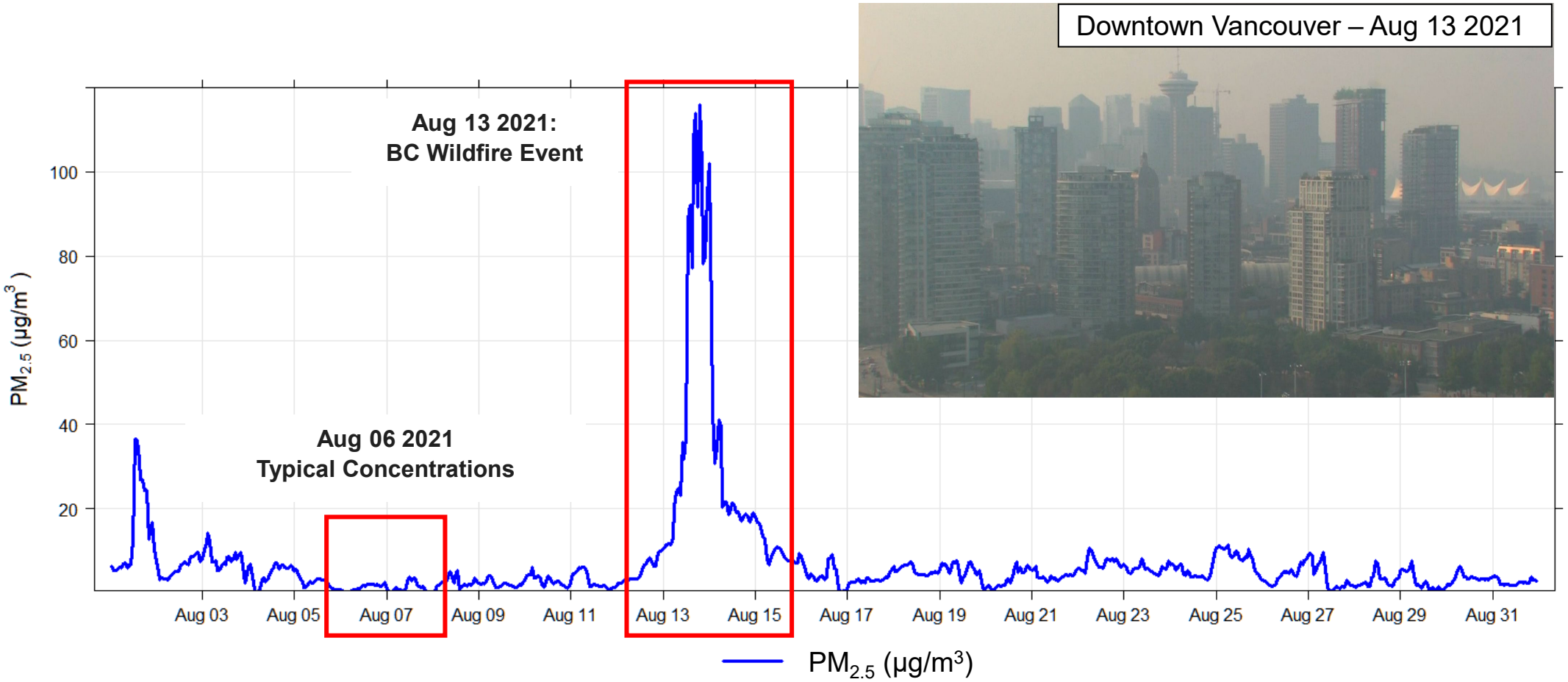
- Additional NOx spikes on Aug 17 and 18
  - Coincide with evening increase in Truck count
- Large NOx spike Aug 14
  - Possible construction activity



Frequency of counts by wind direction (%)

Pollution data – Calibration – Transportation Data – **Results**

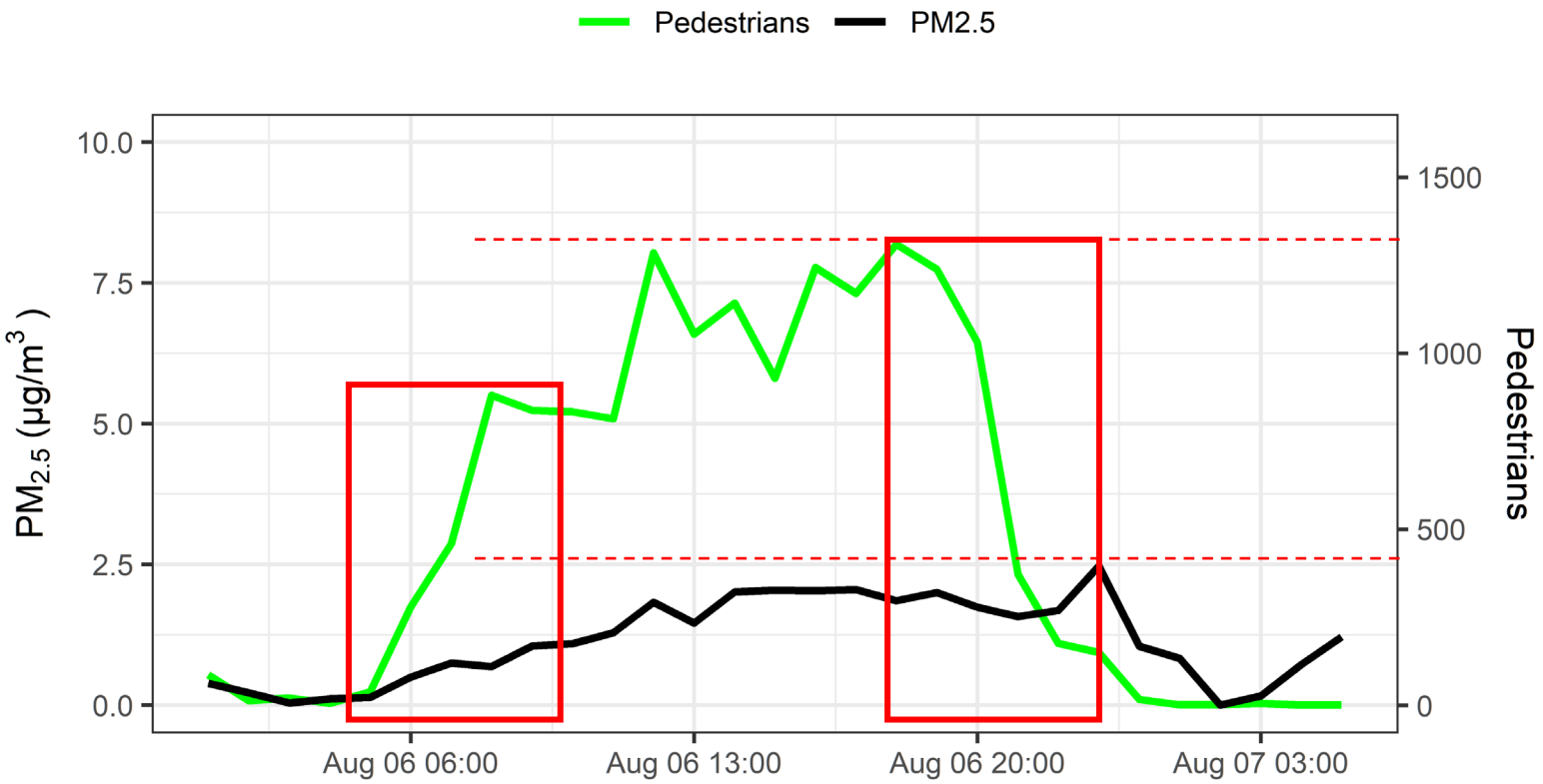
Particulate Matter – August 2021



Monthly trend of $PM_{2.5}$ (August 2021) – Total Concentration

PM & Pedestrians - Typical Day

Friday August 06, 2021 – Max Temperature: 25C | Mean Temperature: 21.0C | **Pedestrians: 15,393**

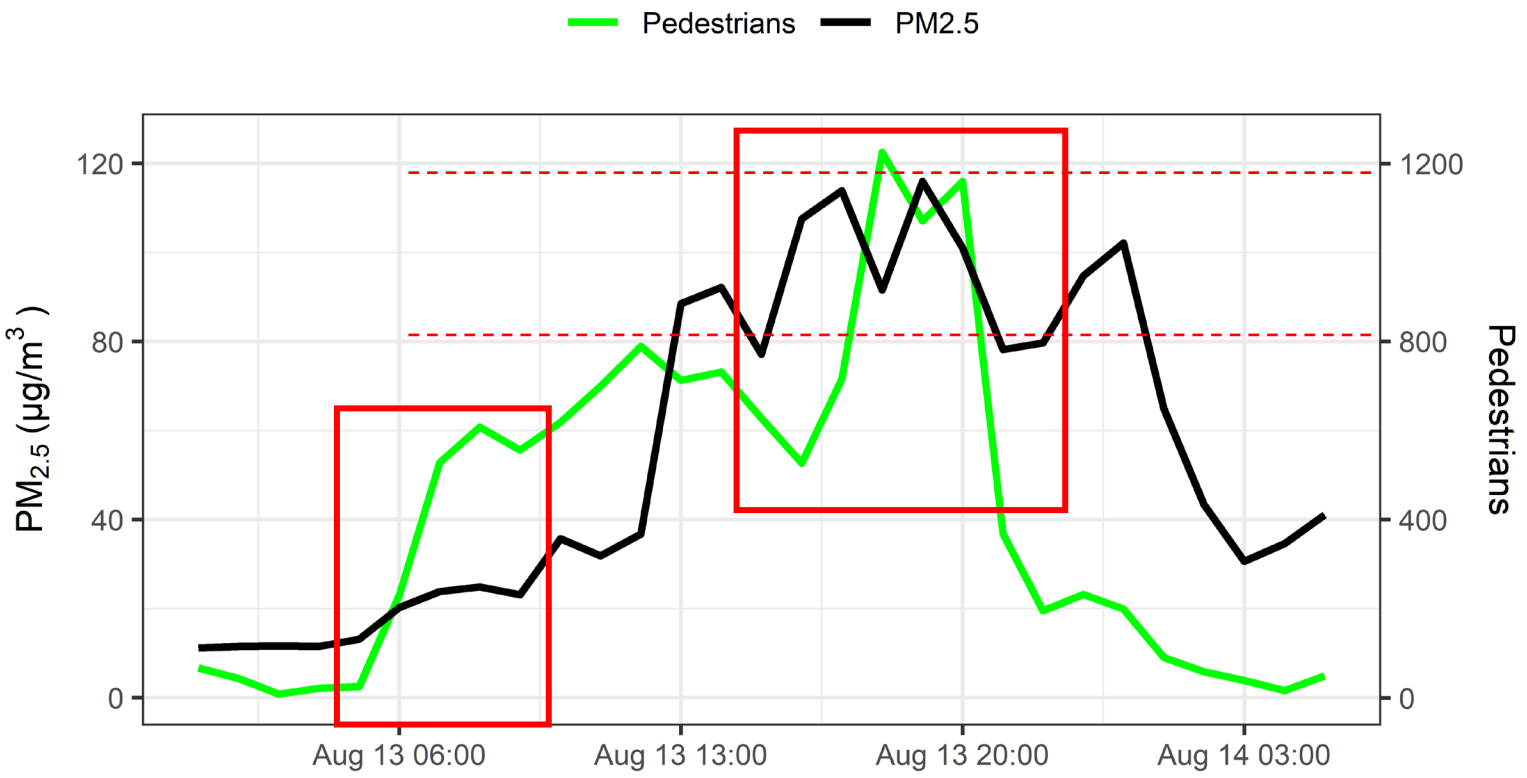


Total Concentration $PM_{2.5}$ (µg/m^3) vs Pedestrians - Aug 06 2021

- Sharp rise in pedestrian count in early morning
- Midday peak (~1300) – Lunch movement
- $PM_{2.5}$ peak (~2.5 µg/m^3)
- Sharp reduction in pedestrian count after 6pm

PM & Pedestrians - Wildfire

Friday August 13, 2021 – Max Temperature: 33C | Mean Temperature: 25.5C | **Pedestrians: 12,212 (-20%)**



Total Concentration $PM_{2.5}$ (µg/m^3) vs Pedestrians - Aug 13 2021

- Rise in pedestrian count early morning
- Midday pedestrian count: ~800
  - Pollution + Heat
- $PM_{2.5}$ peak (~120 µg/m^3)
- Significant rise in pedestrian count at approximately 5pm
  - Midday heat avoidance?
- Similar evening trends for Typical vs Wildfire
- Human behaviour?

Conclusions

1) Clear correlation between NOx concentrations and Bus count
2) Clear correlations between CO & NOx concentrations and Car count
3) High polluting vehicles i.e., trucks – evident influence on pollutant spike events
4) Inflow effect (“sea breeze”) strong influence on afternoon pollutant concentrations
5) Morning & afternoon pedestrian behaviour strongly influenced by heat/pollution

Future work

1) Pollutant plume detection
    - Identify plumes in pollutant and match to transportation data
2) Calculate Emissions Factors (EFs) –
    - Relating the quantity of pollutant released to specific transportation modes
3) Engagement with UBC Community in order to understand behaviour trends better

Thank You

For further questions, please email james.hindson@ubc.ca

Acknowledgements

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HELLO LAMP POST

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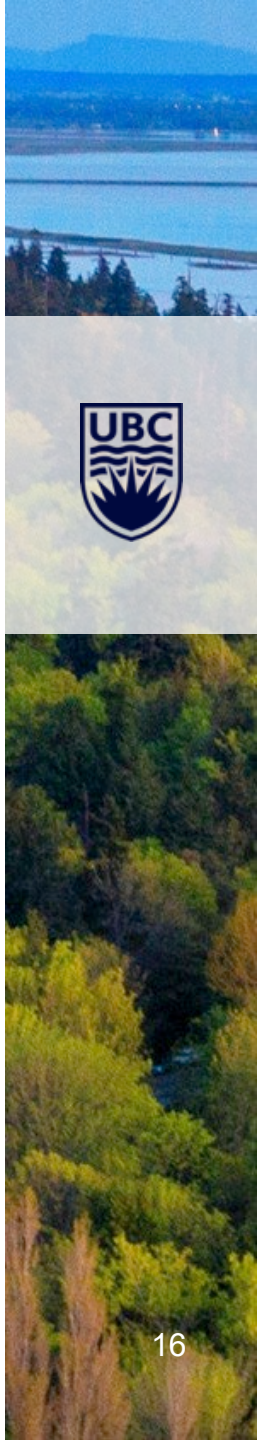
NUMINA

SENSIT Technologies



Other presentations at ASIC from our group

Poster Presentation (virtual)

“Using 5G network to enhance air quality sensing in cities”

Presenter: Surya Venkatesh Dhulipala

Date: May 12, 2022 (Thursday)

Time: 08:00 am - 08:30 am PT

Oral Presentation (virtual)

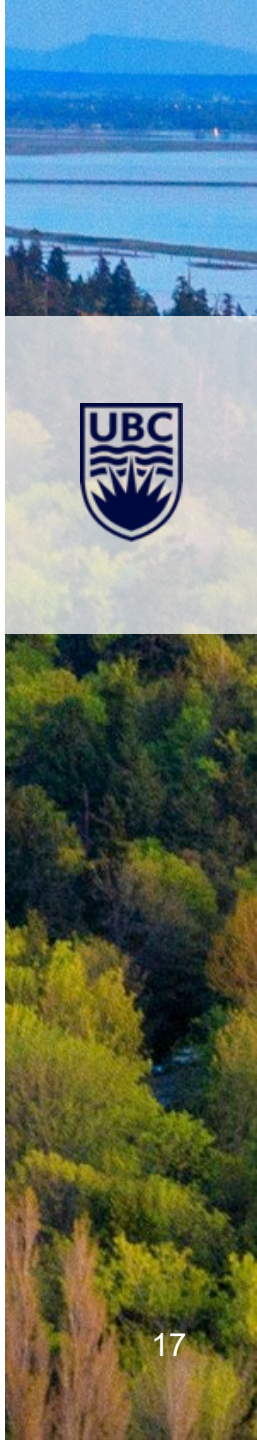
“Community engagement through text-based communication with air quality sensors”

Presenter: Surya Venkatesh Dhulipala

Date: May 12, 2022 (Thursday)

Time: 01:35 pm – 03:55 pm PT

Location: Ballroom A

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Calibration Performance

- Performance metrics i.e., how well testing data aligns with reference data

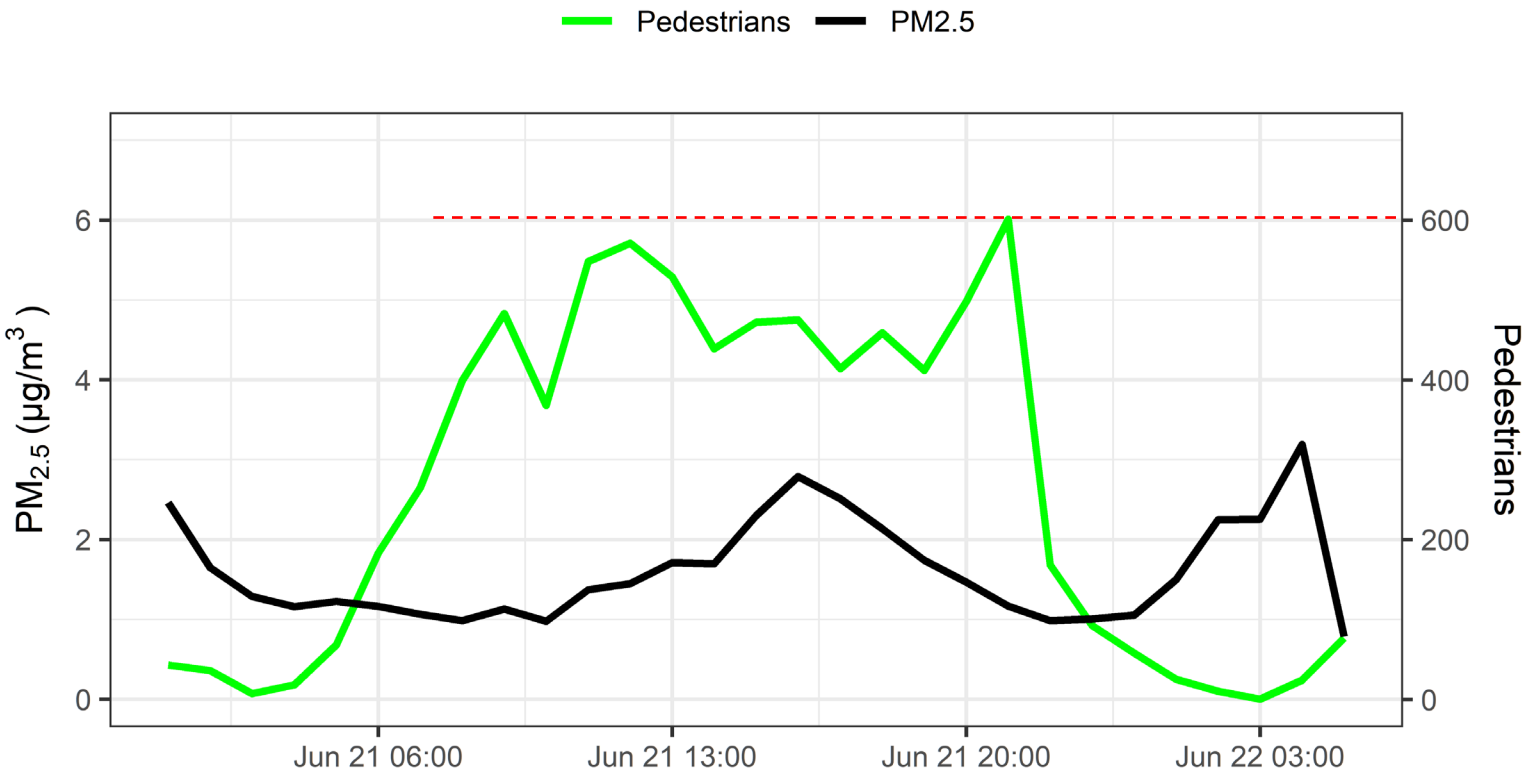
		Average Pearson R	Average CvMAE
Carbon Monoxide (CO)	**This study**	**0.95**	**8.8%**
	Zimmerman et al. (2018)[1]	0.95	14%
	Malings et al. (2019)[2]	0.88	20%
Nitrogen dioxide (NO_2)	**This study**	**0.93**	**15.1%**
	Zimmerman et al. (2018)	0.82	29%
	Malings et al. (2019)	0.69	42%
Carbon Dioxide (CO_2)	**This study**	**0.92**	**2.0%**
	Zimmerman et al. (2018)	0.88	2.2%
Ozone (O_3)	**This study**	**0.95**	**16.9%**
	Zimmerman et al. (2018)	0.93	15%
	Malings et al. (2019)	0.90	22%
Particulate Matter (PM)	**This study**	**0.98**	**26%**
	Liu & Zimmerman (2020)[3]	0.90	27%
	Malings et al. (2019)	0.91	14%

1. r– Pearson correlation coefficient - Linear correlation between testing data and the reference data
2. CvMAE - Coefficient of variation of the mean absolute error i.e., approximate percent error (e.g., ~9% for Carbon Monoxide)

[1] https://doi.org/10.5194/amt-11-291-2018
[2] https://doi.org/10.5194/amt-12-903-2019
[3] https://doi.org/10.1016/j.trd.2020.102635

PM & Pedestrian Behaviour – Summers Day

Monday June 21, 2021 – Max Temperature: 30.5C | Mean Temperature: 22.3C | **Pedestrians: 7700**

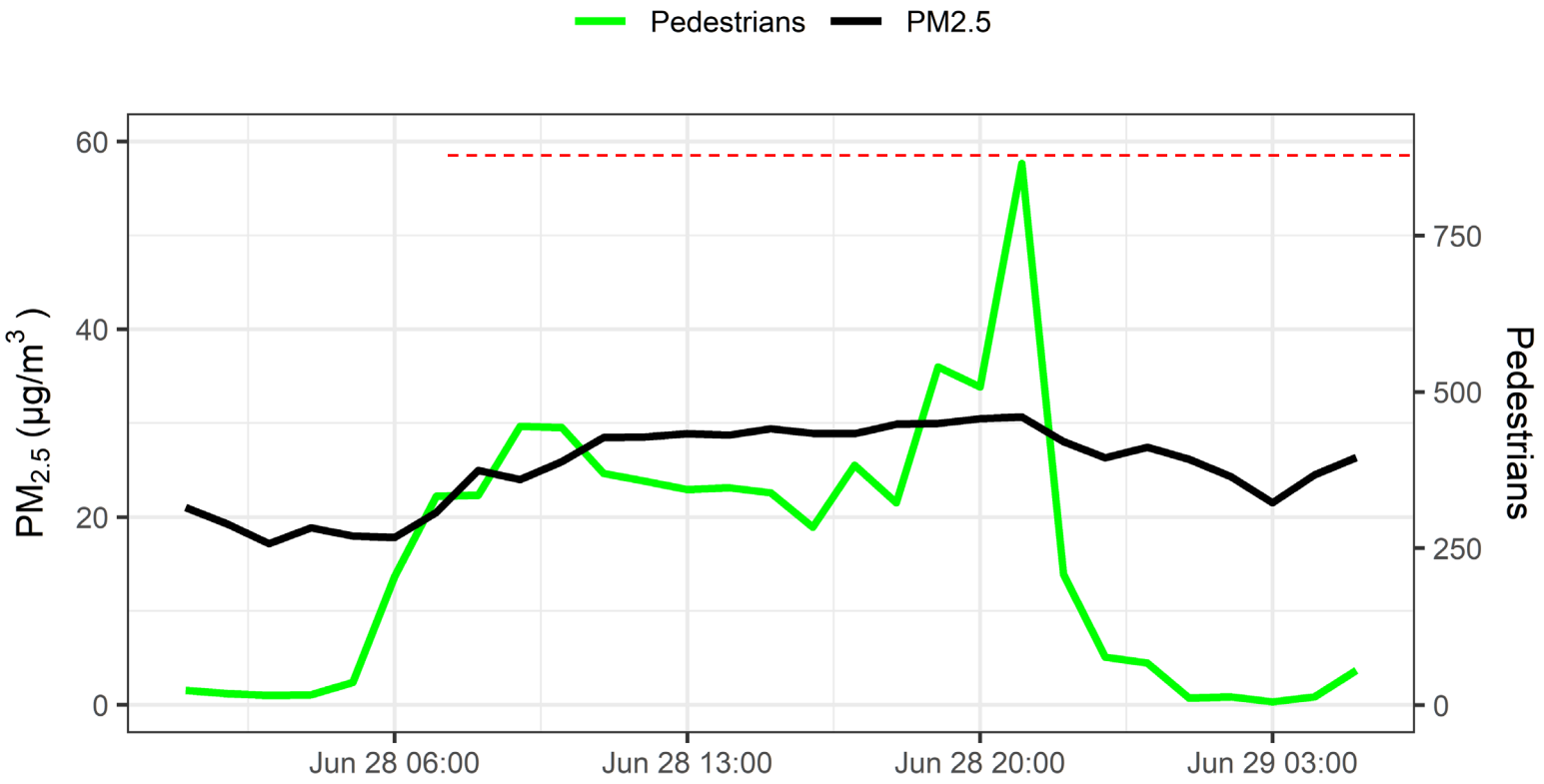


Total Concentration PM ($\mu g/m^3$) vs Pedestrians - June 21 2021

- Rise in pedestrian count early AM
- Midday pedestrian count: ~600
  - Heat
- PM peak (~3 $\mu g/m^3$)
- Steady pedestrian count throughout day
- Peak pedestrian count at 9pm followed by sharp reduction
- Human behaviour?

PM & Pedestrian Behaviour – Heat Dome Peak

Monday June 28, 2021 – Max Temperature: 41C | Mean Temperature: 31.3C | **Pedestrians: 7000 (-10%)**



Total Concentration PM (µg/m^3) vs Pedestrians - June 28 2021

- Rise in pedestrian count early AM
- Midday pedestrian count: ~400
  - Pollution + Heat
- PM peak (~30 µg/m^3)
- Significant rise in pedestrian count at approximately 5pm
  - Significant to midday counts – heat avoidance?
- Peak pedestrian count at 9pm followed by sharp reduction
- Human behaviour?