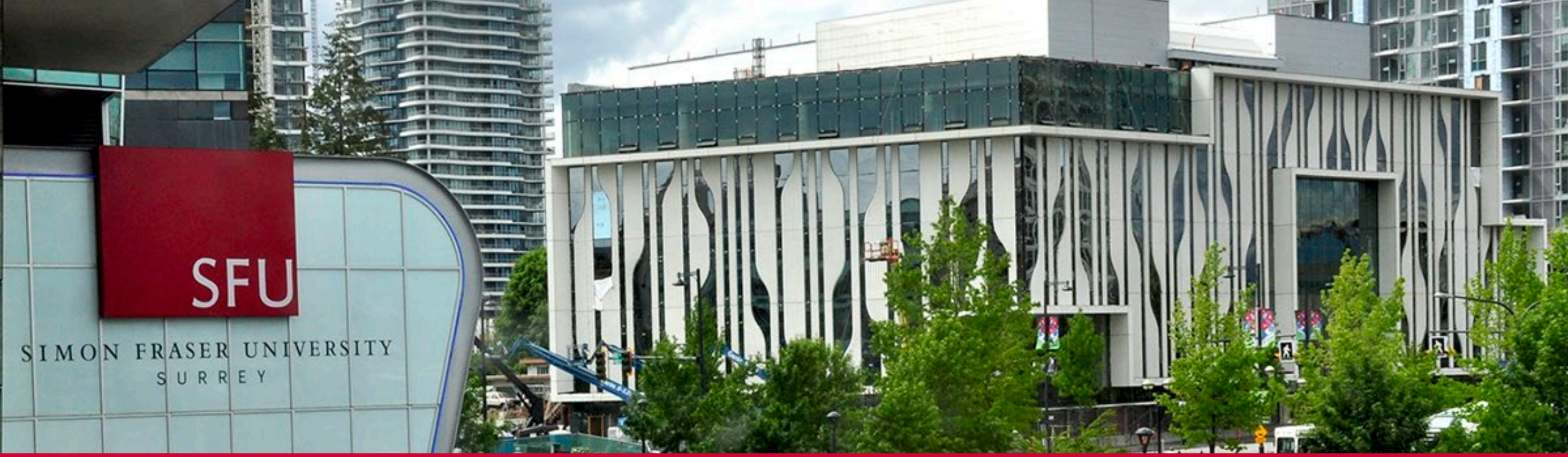

Sensitivity Analysis of Ambient NO2 Concentration to Primary Emission Sources in Alberta, Canada using WRF/CMAQ Modeling

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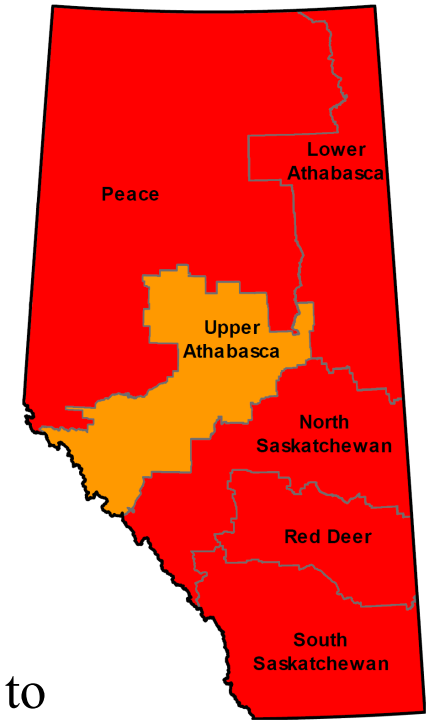
22nd Annual
CMAS
Conference
Oct. 16-18, 2023 | Chapel Hill, NC

Outline

Motivation

Canadian Ambient Air Quality Standards (CAAQS)

- Alberta air zones have exceeded the 2020 NO2 CAAQS[3]
- New and more stringent standards for NO2 concentration will be in effect starting 2025
- Annual average NO2 threshold will be reduced from 17 ppb to 12 ppb



CAAQS Status

- How can the integration of WRF/CMAQ modeling and data-driven models be employed to formulate impactful strategies for achieving the National Ambient Air Quality Standards (NAAQS) NO2 goals?

References:
https://www.casahome.org/attachments/CAAQS%20and%20NO2%202018-08-09.pdf

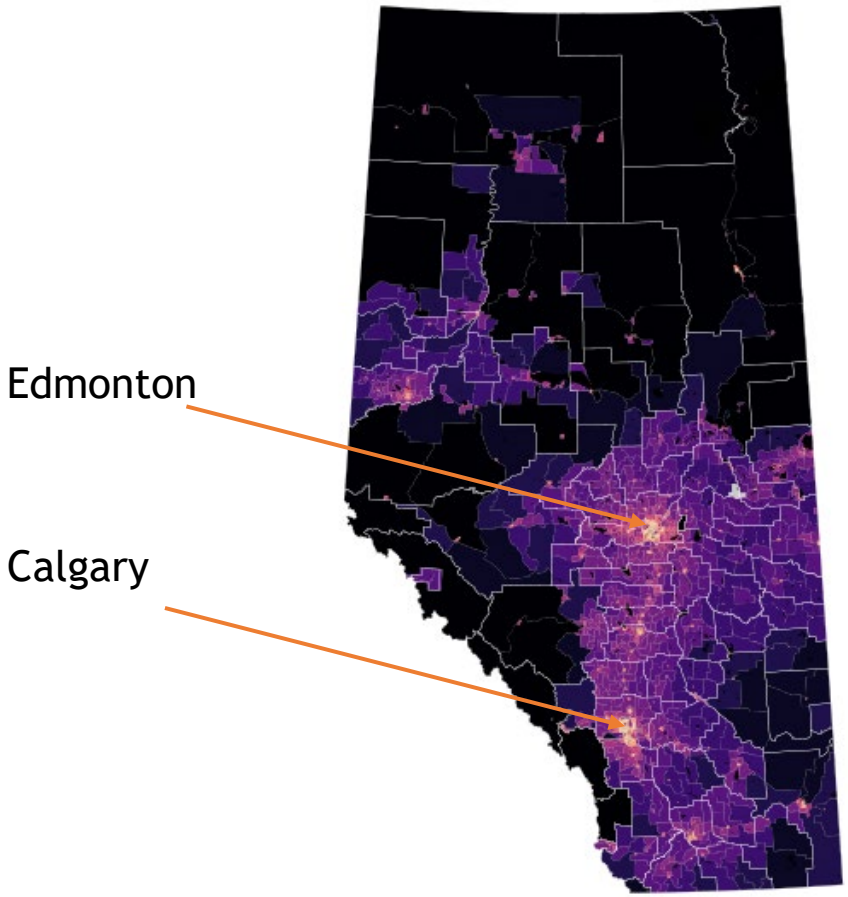
Study Area

- Area of 661,848 km² almost larger than any state in USA other than Texas and Alaska.
- Population 4.6 million;
- The 7th most livable city in the world, Calgary, is located in Alberta
- Alberta is home to the stunning Banff and Lake Louise.
- Alberta's oil sands has the fourth-largest proven oil reserves in the world.
- Alberta is the highest NOx emitter in Canada with 681 ktons/year

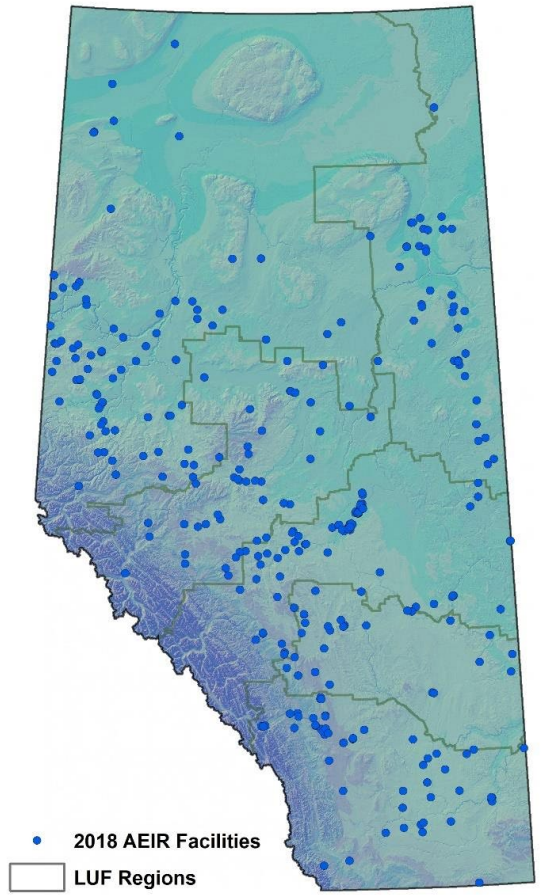
Canada and Alberta

References:
List of municipalities in Alberta. (2023, July 19). In Wikipedia.
www.alberta.ca

Study Area



Population Density in Alberta

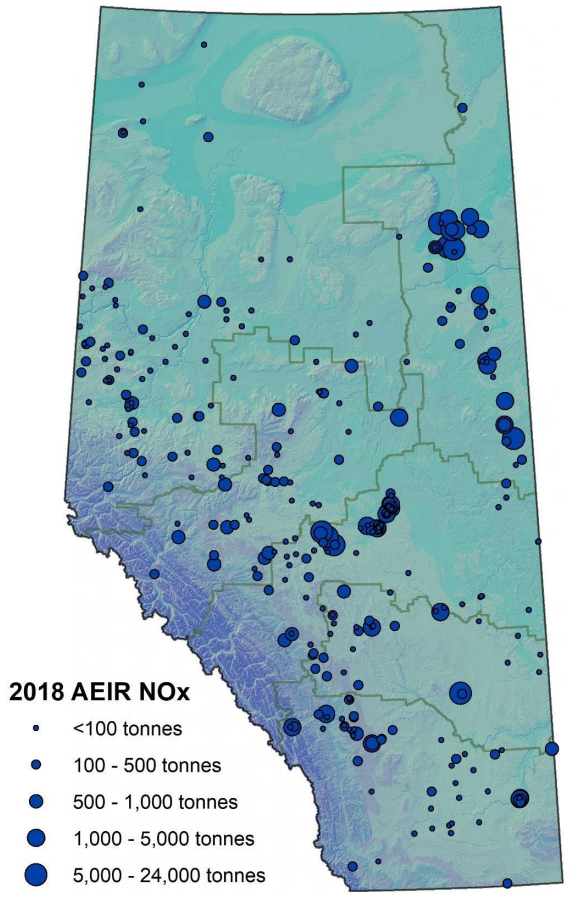


Spatial Distribution of 2018 AEIR Facilities

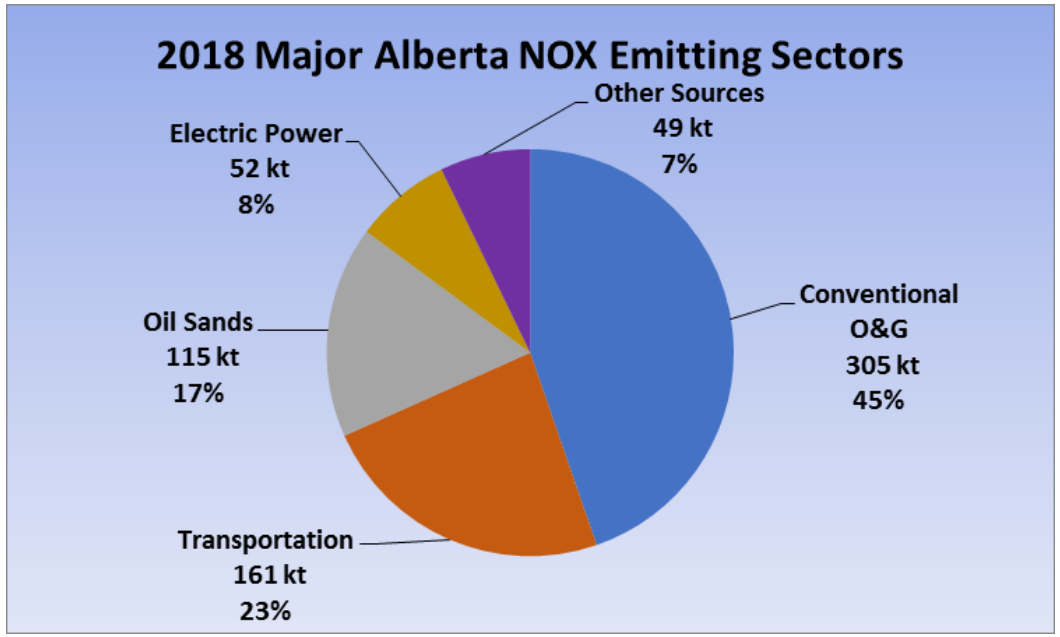
AEIR: Annual Emissions Inventory Reporting

References:
Results of the Alberta Annual Emissions Inventory Reporting Program: 2018 Inventory Year
Demographics of Alberta. (2023, July 7). In Wikipedia.

Emission inventory of Alberta Province



Locations and Proportional Tonnages of 2018 NOX Emitting AEIR Facilities



2018 APEI Alberta Major Emitting Anthropogenic Sectors

APEI: Air Pollutant Emissions Inventory

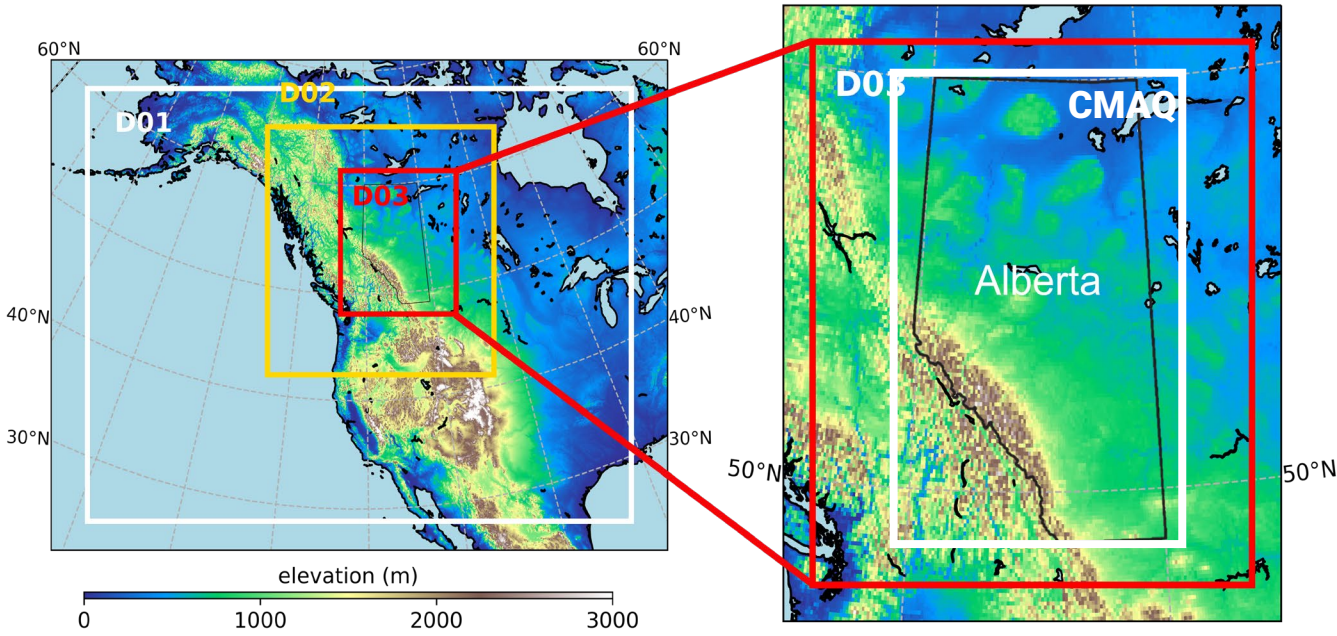
References:

Results of the Alberta Annual Emissions Inventory Reporting Program: 2018 Inventory Year

Computational Domain

Details of domains

Domain	Horizontal Grid (i x j)	Horizontal grid size (km x km)	Vertical Layer	Total # of Elements
WRF_D1	157 x 121	36 x 36	32	607,904
WRF_D2	196 x 208	12 x 12	32	1,304,576
WRF_D3	301 x 361	4 x 4	32	3,477,152
CMAQ	201 x 306	4 x 4	32	1,968,192

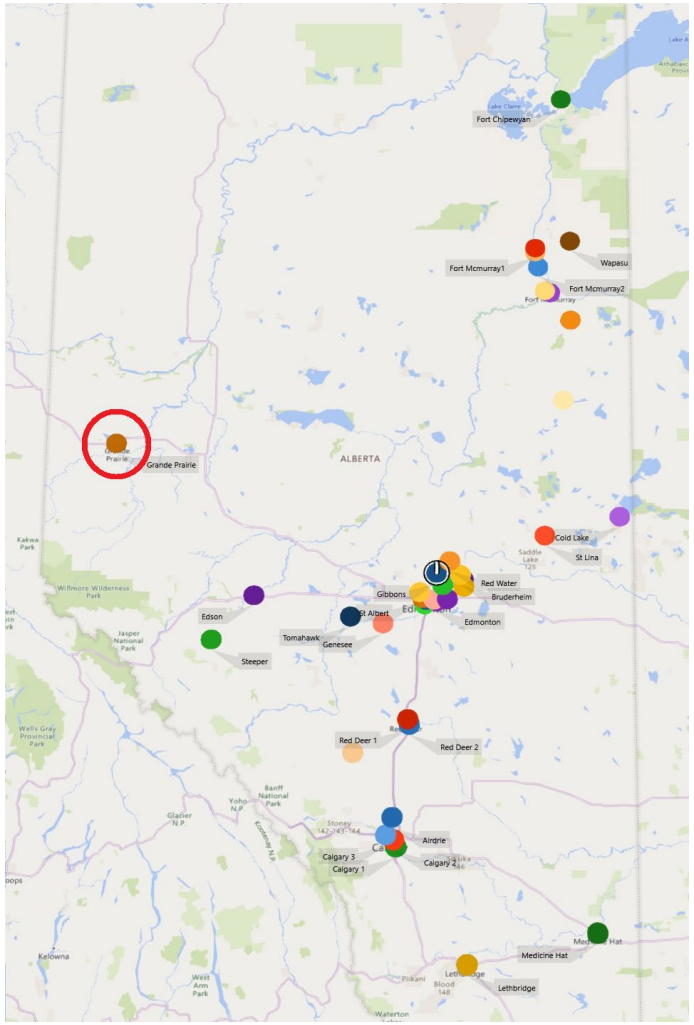


Validation

- Observation data from 40 NAPS program stations
- Ground level hourly averaged observation data were compared to the modeling results

Parameter used for validation process

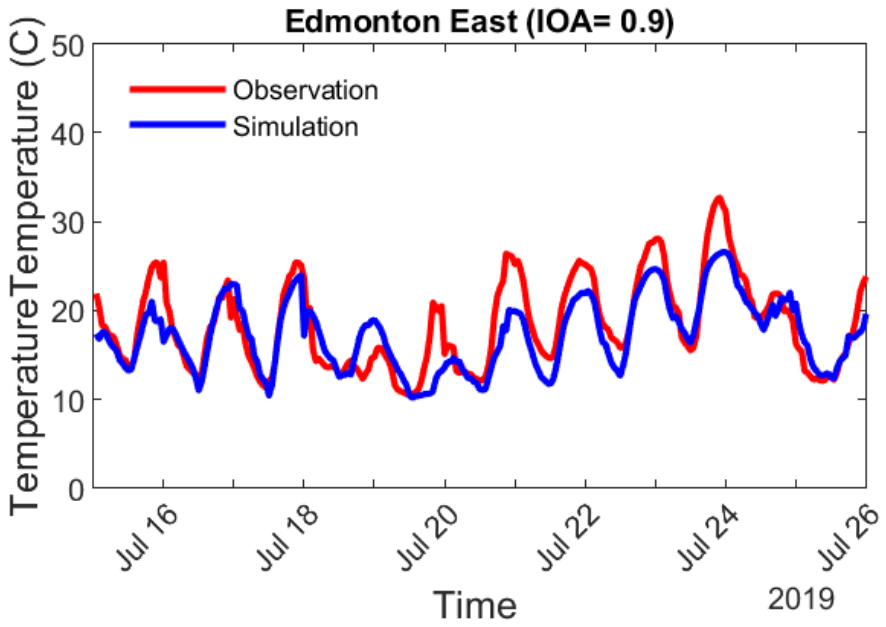
Model	Validation Parameter
WRF	2 (m) Temperature
	10 (m) Wind Speed
CMAQ	NO_2
	O_3

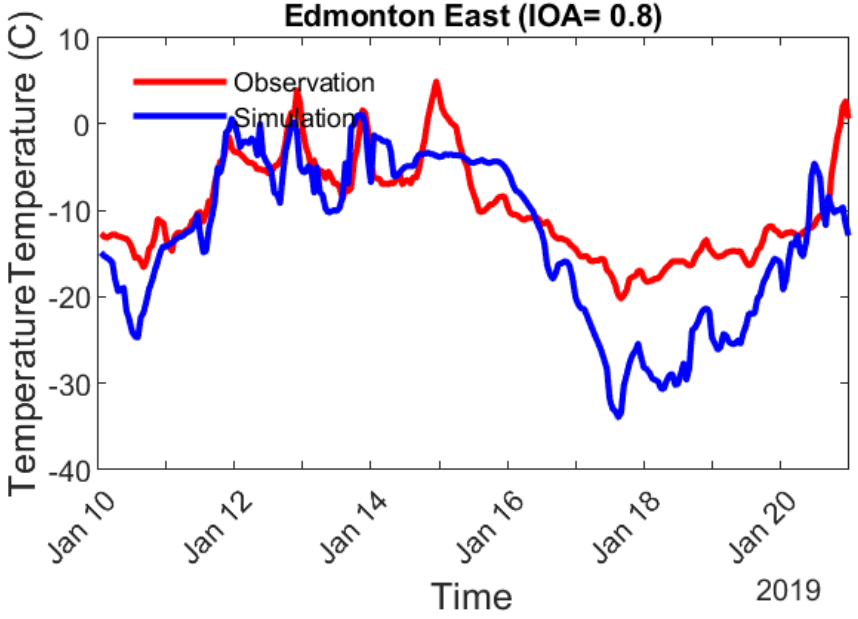


NAPS monitoring stations

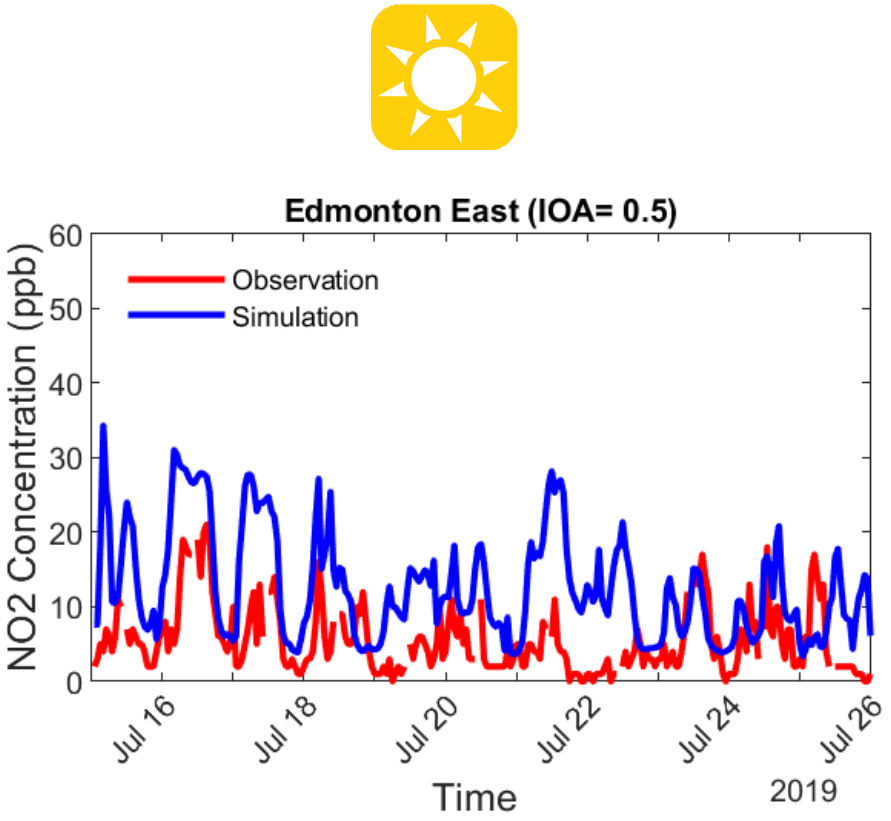
NAPS: National Air Pollution Surveillance Program

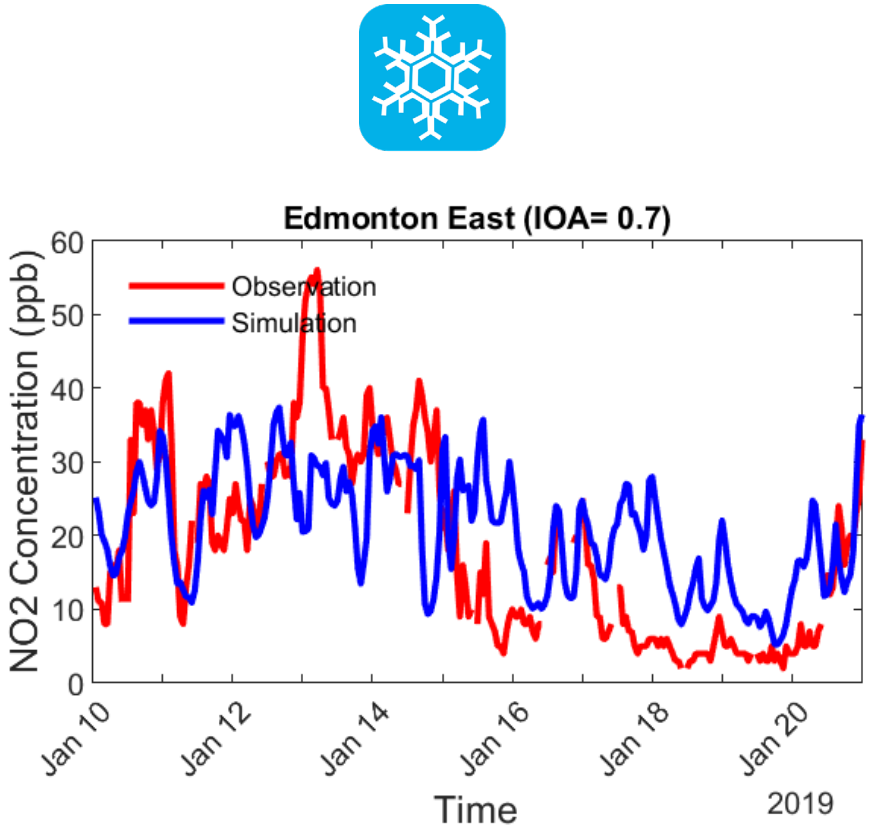
Validation-WRF



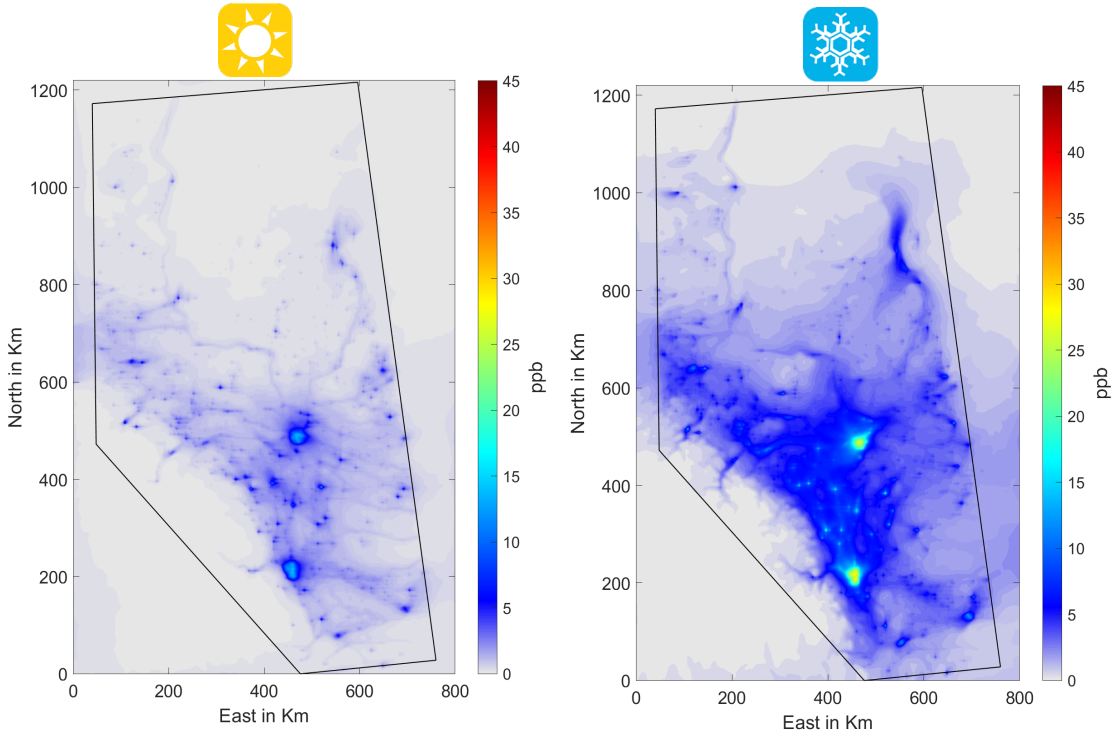


Validation-CMAQ

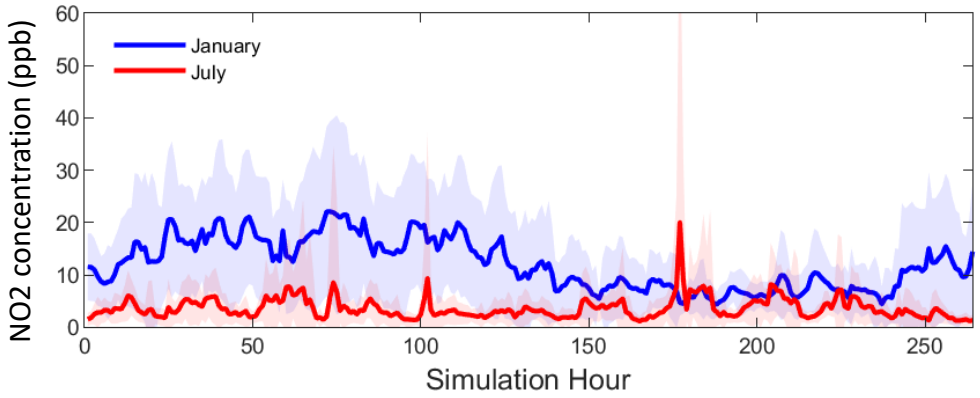




Base case outputs – No emission changes

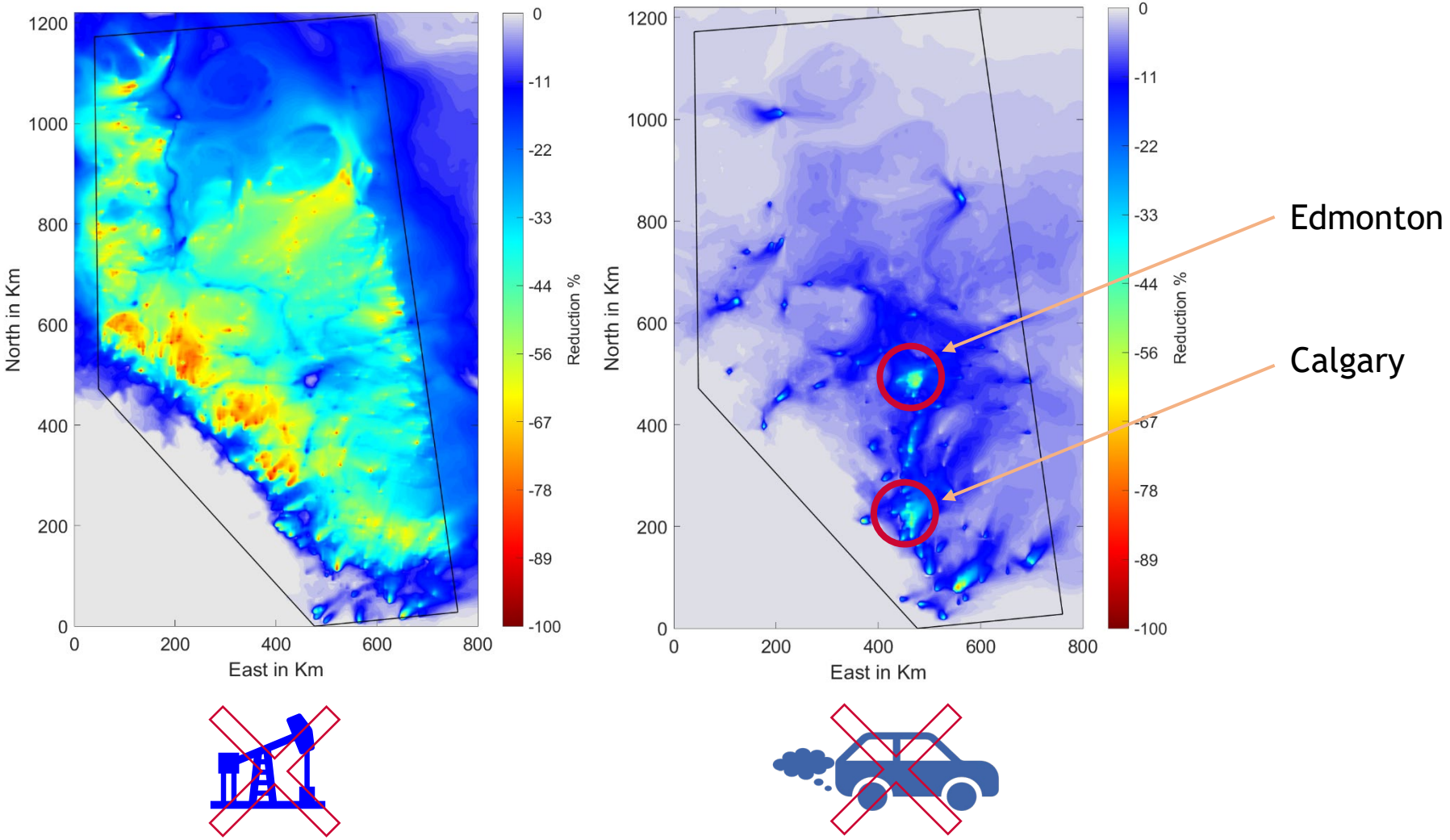


NO2 concentration



Brute force sensitivity analysis

Average NO2 Reduction by removal of each primary emission source



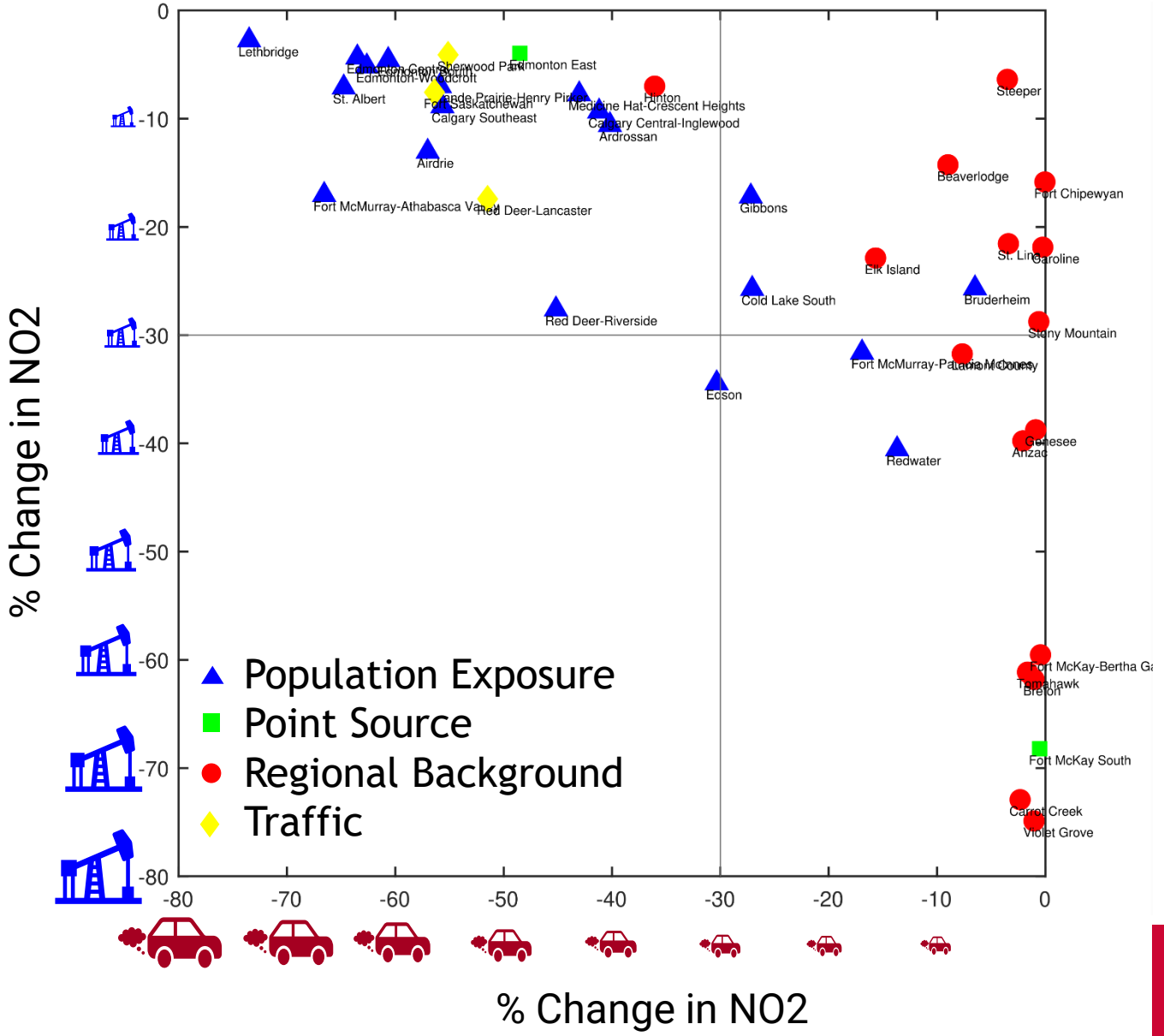
Results

Zero-out Scenario:

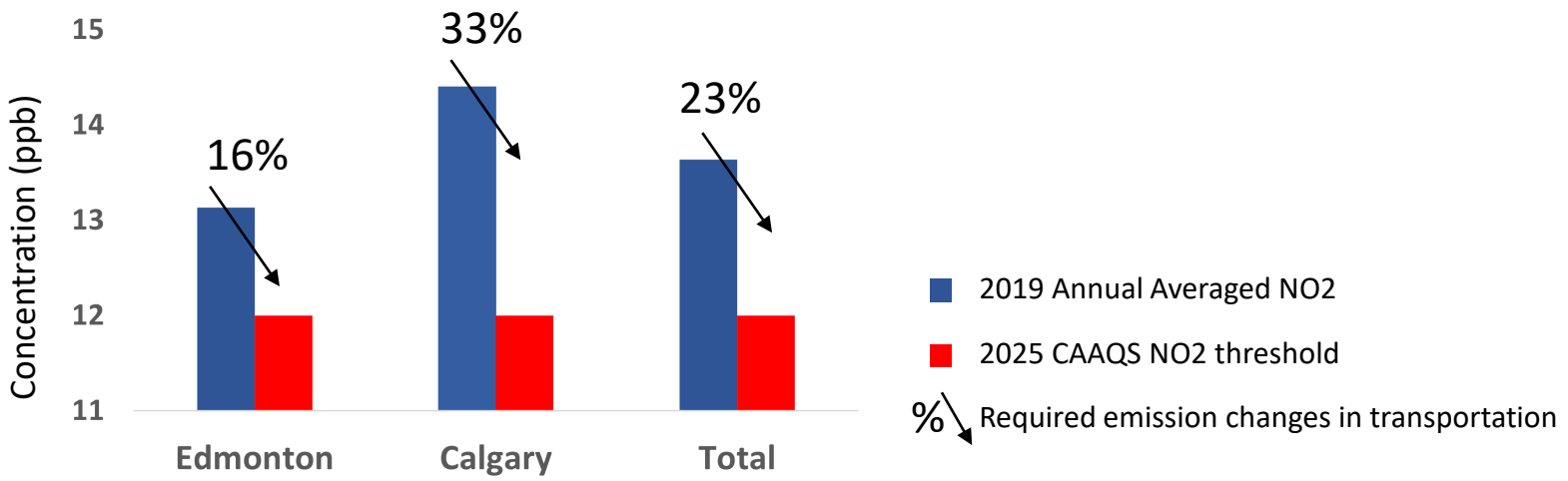
- Different response of each category of AQMs is observed.
- PE stations are more affected by zeroing out the mobile sources.
- RB stations are more affected by zeroing out the UOG sources.

PE: Population exposure

RB: Regional background



Results – Meeting CAAQS 2025 Objectives

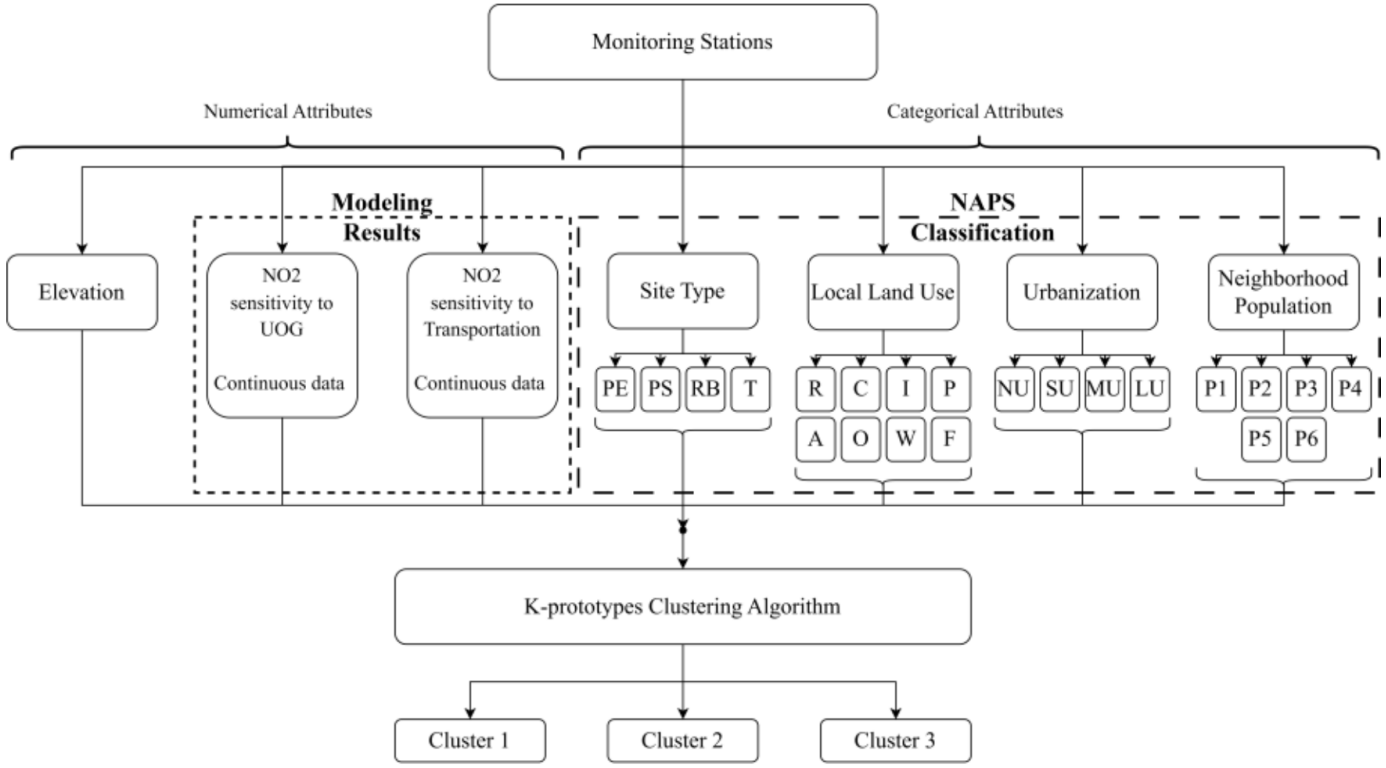


Canadian Ambient Air Quality Standards

Management Level	NO_2 annual (ppb)	
	2020	2025
Red (CAAQS)	> 17.0	> 12.0
Orange	7.1 to 17.0	7.1 to 12.0
Yellow	2.1 to 7.0	2.1 to 7.0
Green	≤ 2.0	≤ 2.0

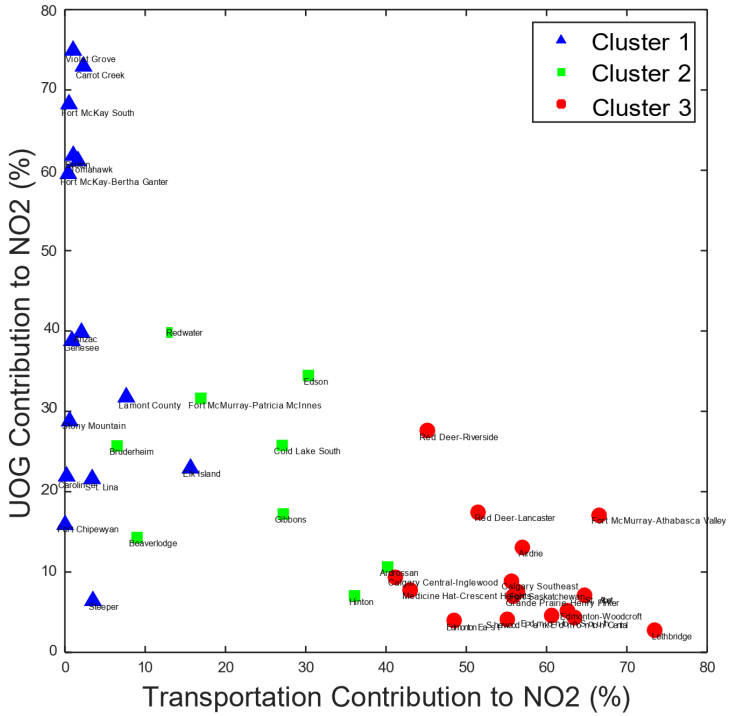
Re-Clustering Air Quality Monitoring Stations

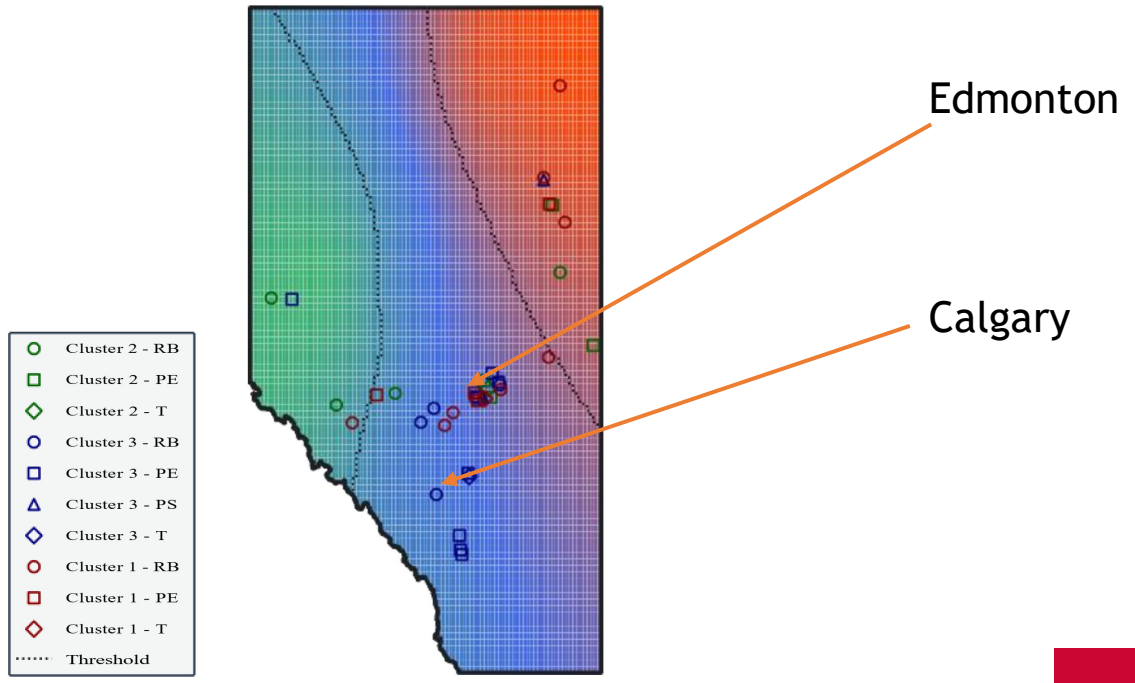
A classification approach using a k-prototypes algorithm is used to categorize AQM stations based on the impacts of primary NO2 sources. The algorithm minimizes distances and mismatches between data points and attribute values. The approach is compared to the Site Type classification and analyzed using statistical tests.



Re-Clustering Air Quality Monitoring Stations

- Most of the stations in Cluster 1 belong to the RB category and most of the stations in Cluster 3 belong to PE category.
- The spatial interpolation results shows stations in the area with blue color are affected by both UOG and mobile sources and can be categorized a a new category.





Conclusion

01

Population exposure stations are sensitive to transportation emission, while regional background stations are sensitive to UOG emission.

02

Although UOG emitted 49% of total NO_x in AB, but its contribution to NO_2 concentration in populated cities is less than 7%.

03

In warm season and cold season, more than 53% and 47% of NO_2 concentration originated from transportation sector, respectively.

04

23% reduction in the emission of transportation sector is needed to meet 2025 CAAQS.

Acknowledgment

- The support of the Alberta government (AB Parks and Protected Areas) in providing CMAQ-ready emission inputs is acknowledged;
- Funding support was provided by Environment and Climate Change Canada (ECCC) under for the project “Urban Transportation Emissions and GHGs; Technologies and Behavioral Shifts Towards Zero Emissions” under the Climate Action and Awareness Fund – Advancing Climate Change Science & Technology;

Thank You for Your Attention

Email

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