Investigating multi-stressor impacts on air quality in Alberta: Heat waves & wildfire smoke

2025 CPANS ANNUAL CONFERENCE

BUILDING RESILIENT COMMUNITIES

Harshita Pawar, Ph.D.
harshita.pawar@gmail.com

About me

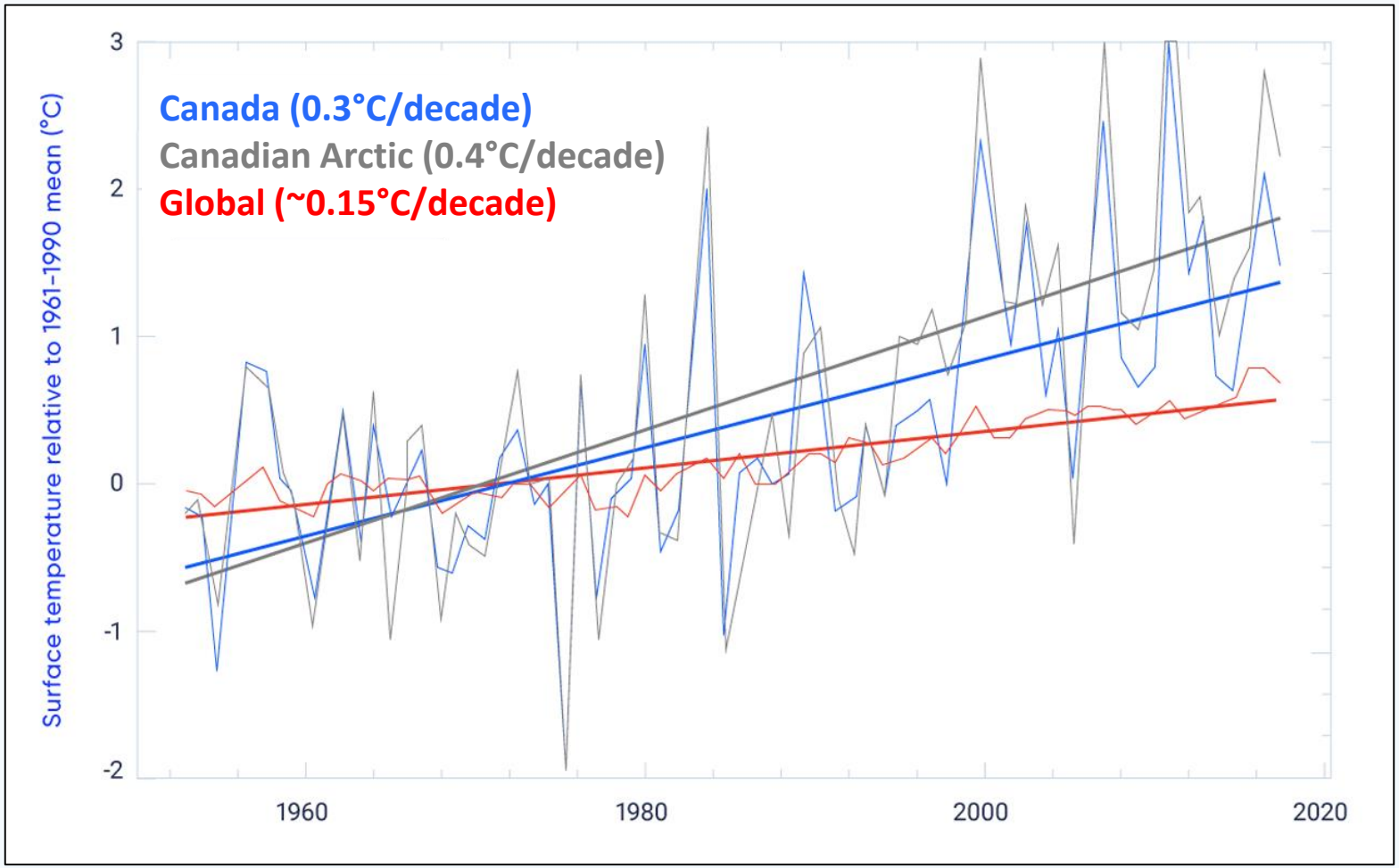
- **Ph.D. in Atmospheric Sciences** (IISER Mohali, India), focused on sources of particulate matter pollution in northwestern India
- Former **Senior Development Editor** at the *American Chemical Society*, managing editorial operations for environmental science journals
- **Expertise**: ambient air monitoring (particulate and gas-phase pollutants, VOCs), environmental data analysis, and field instrumentation
- Currently based in Brooks, AB and relocating to Calgary at the end of May
- New to Canada and actively engaging with the air quality research community

harshita.pawar@gmail.com
linkedin.com/in/harshita-pawar-ph-d-a50128155

Overview

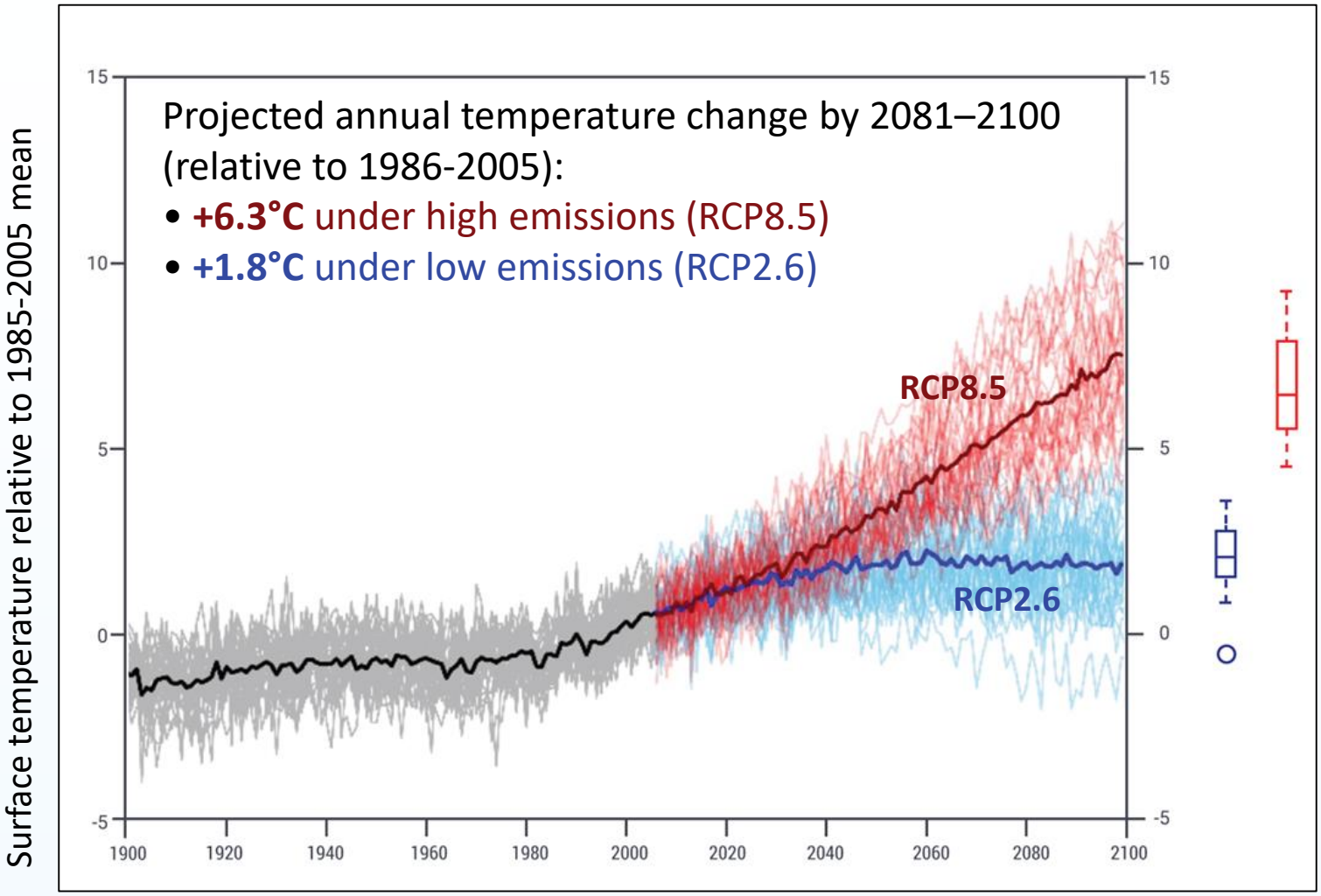
- **Why this matters**: Heat extremes are rising in the backdrop on an unprecedented wildfire season impacting air quality
- **Climate signals**: Alberta is warming faster, with more heatwaves and fire seasons
- **Air quality impacts**: Elevated ozone and $PM_{2.5}$ observed during recent extreme events
- **2023 case study**: Multi-week smoke exposure across Alberta; recurring $PM_{2.5}$ peaks in 2024
- **Compound risk lens**: Emerging evidence of heat-smoke co-occurrence, with spatial burden
- **What next**: Steps toward integrated monitoring, early warning, and climate-health resilience

Canada's warming trend is twice the global average



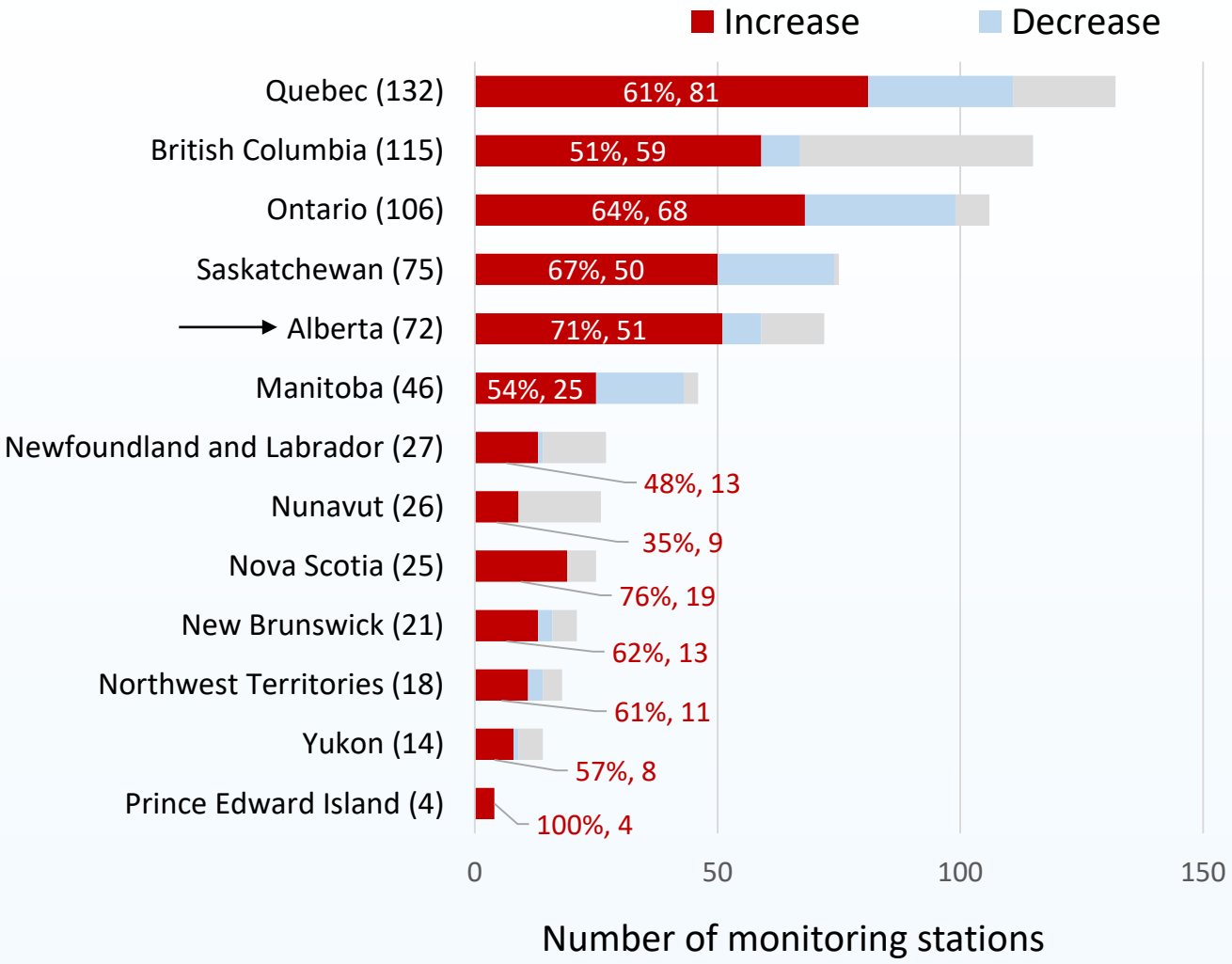
Source: Bush, E. and Lemmen: Canada's Changing Climate Report (2019)

Canada is expected to warm further this century



Source: Climate Research Division, Environment and Climate Change Canada

Extreme heat events have increased with warming

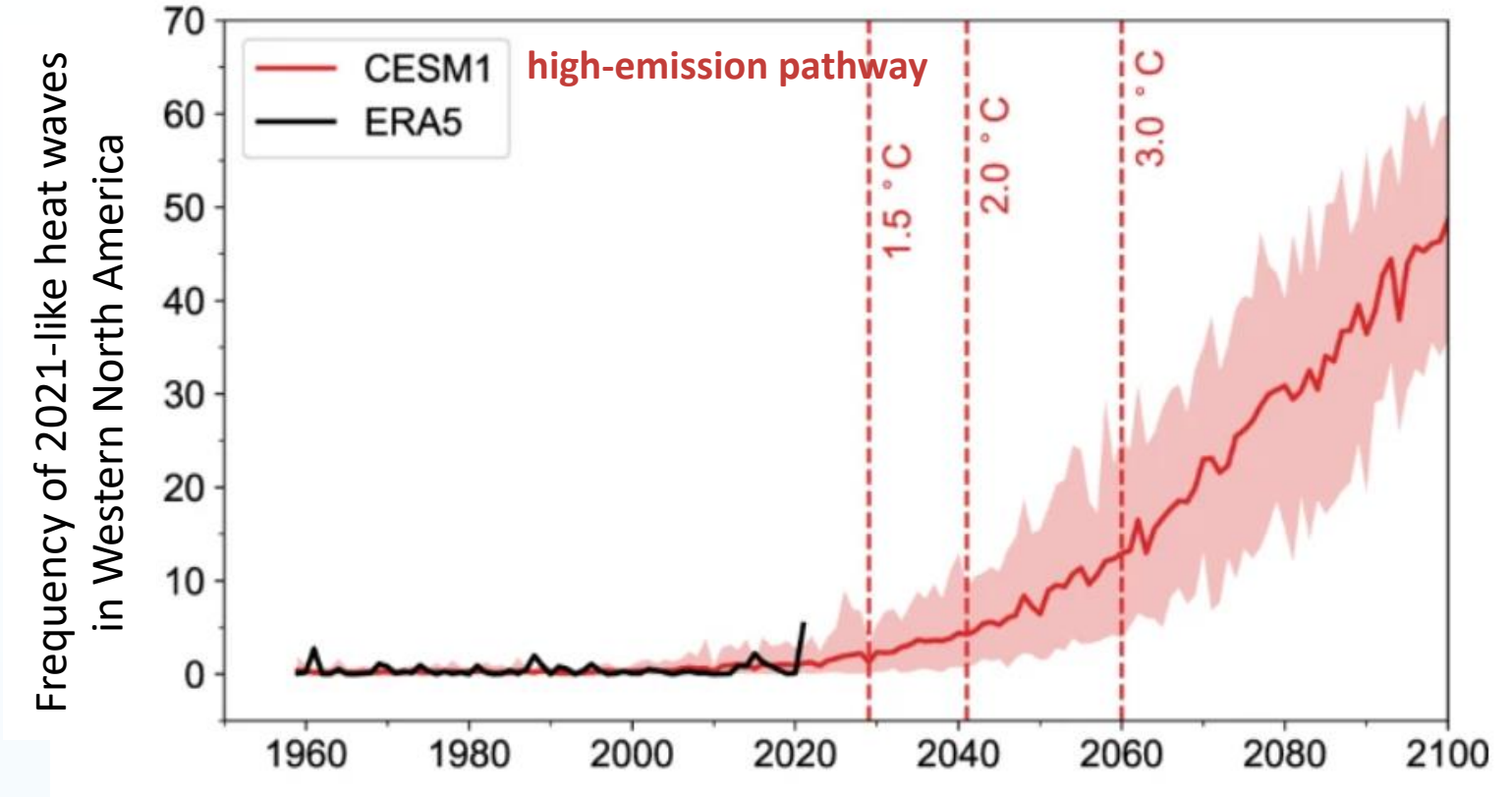


From 1948 to 2023, of the 681 stations across Canada having at least 30 years of observations

60% (411 stations) experienced an increase in the number of days of extreme heat events.

Source: raw surface air temperature data (2024) from Environment and Climate Change Canada

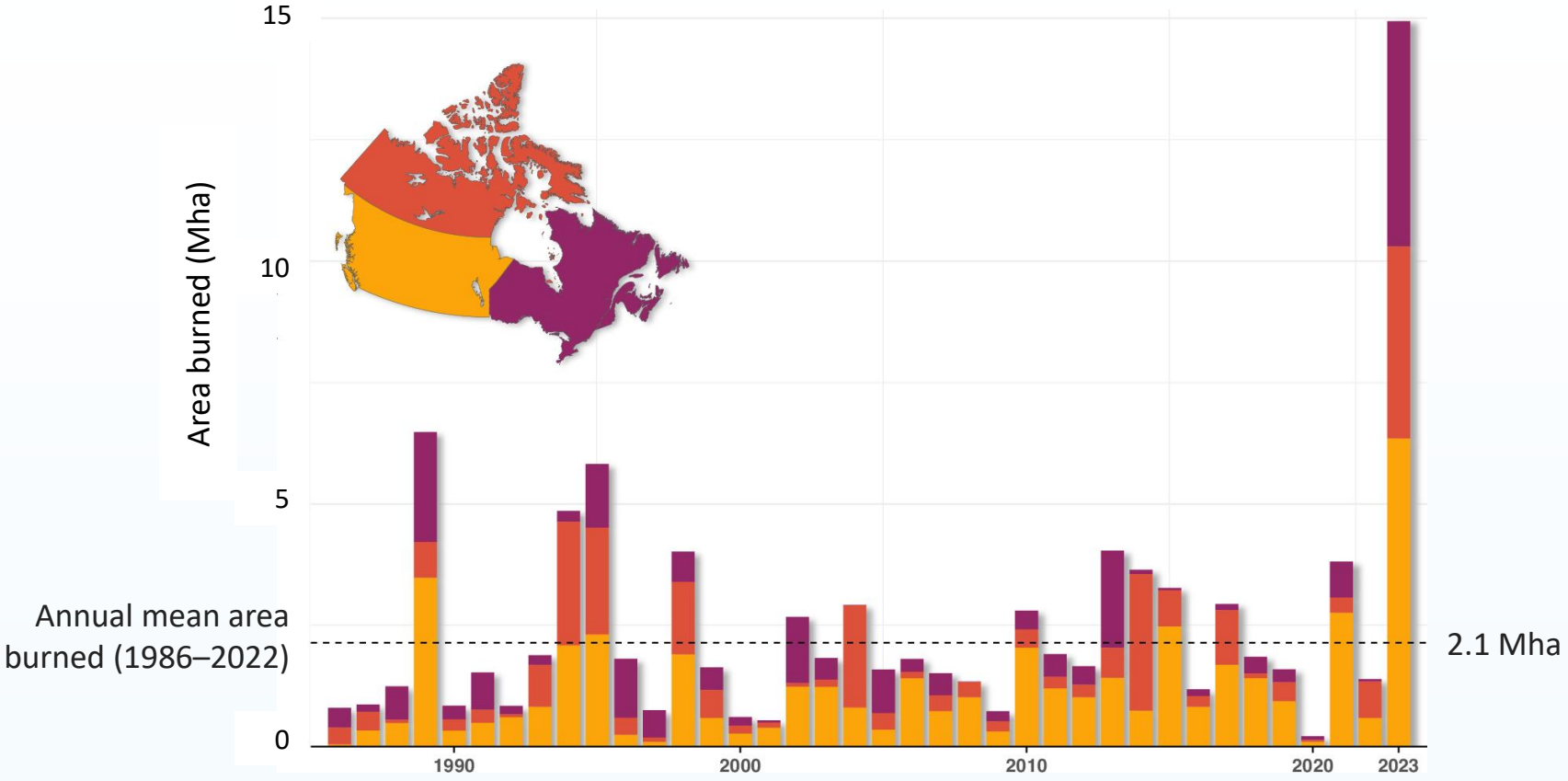
Extreme 2021-like heat events expected to become much more likely



Under a high-emission pathway, 2021-like extreme heatwaves in Western North America could become up to **40 times more likely** by the end of the century.

Source: *Zhang, W. et al. Nat Commun 14, 1690 (2023)*

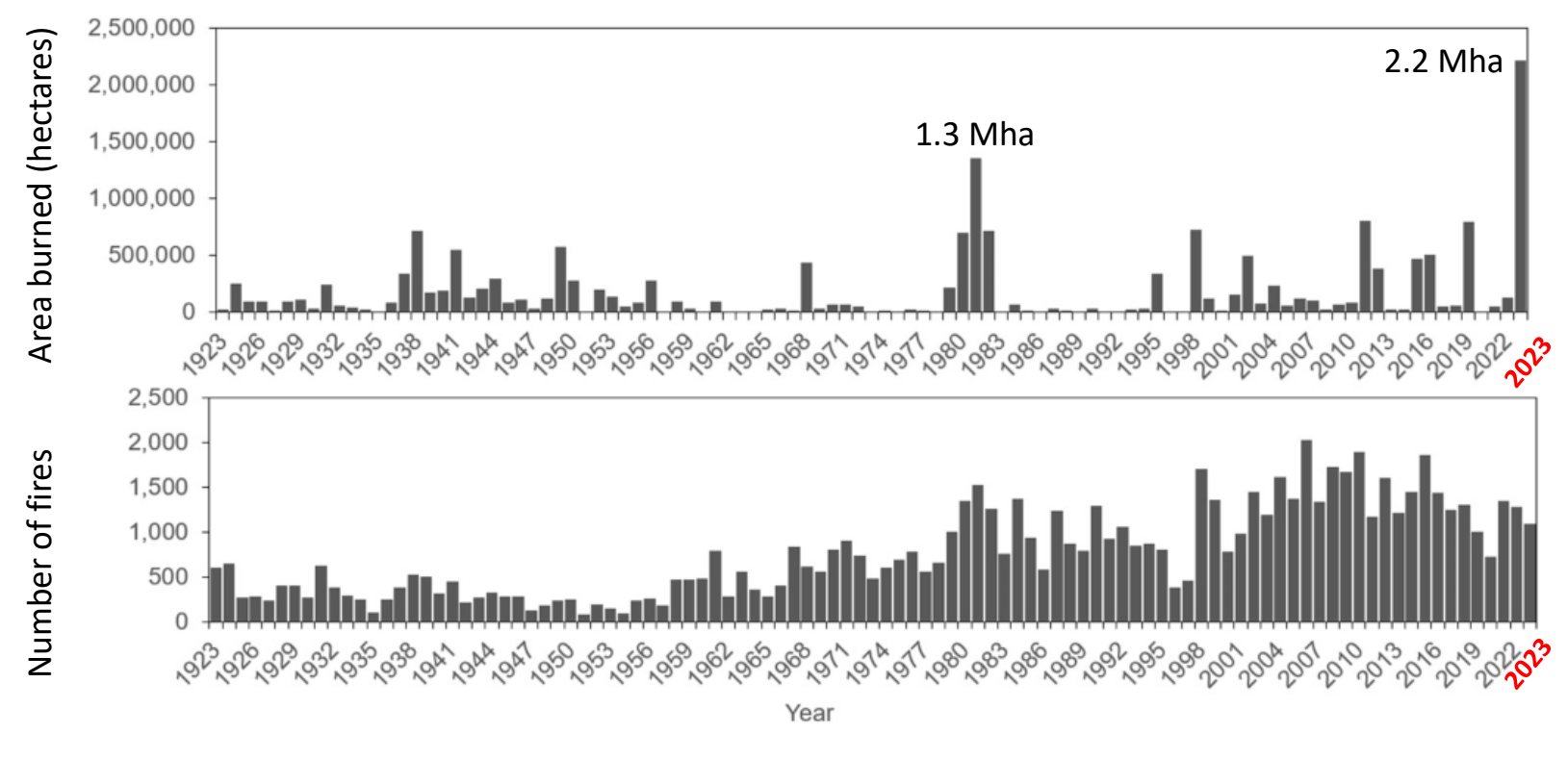
2023 marked Canada's largest fire season on record



The unprecedented 2023-fire season was driven by a combination of **lightning ignitions**, **persistent drought**, and **record-breaking fire weather conditions**.

Source: *Jain et al., 2024, Nature Communications*; *Young et al., 2024, Climate and Atmospheric Science*

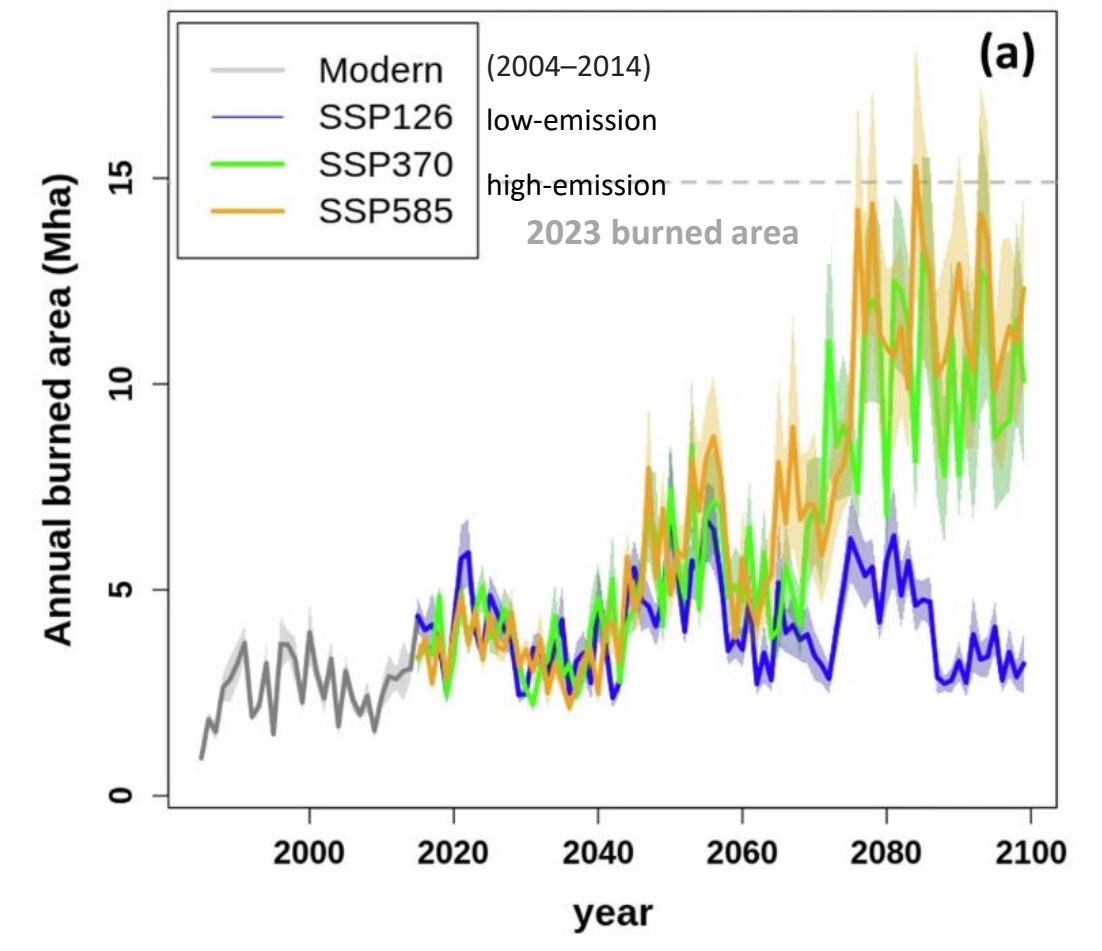
*"Alberta's 2023 wildfires redefined what is possible under a warming climate"**



Alberta's 2023 wildfire season was the largest on record, with **2.2 Mha burned**. This was **63% more than the previous peak** (1.3 Mha in 1981)**, despite a typical number of fires in 2023.**

**Beverly, J. L., & Schroeder, D. (2024). Canadian Journal of Forest Research, 55, 1-19.*

Unprecedented wildfire seasons could become commonplace without climate action

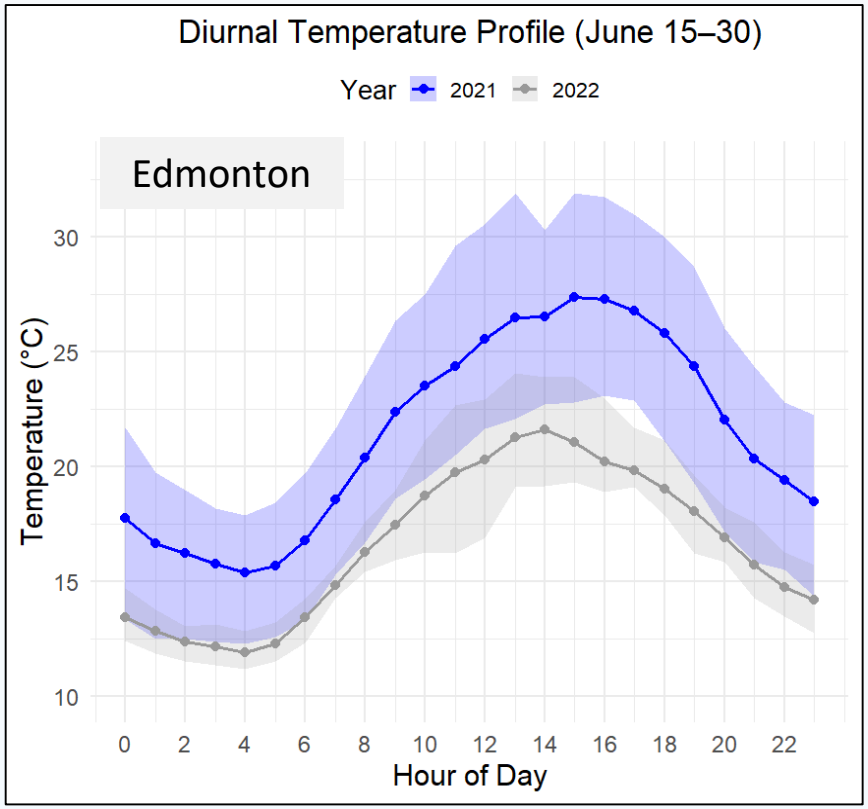


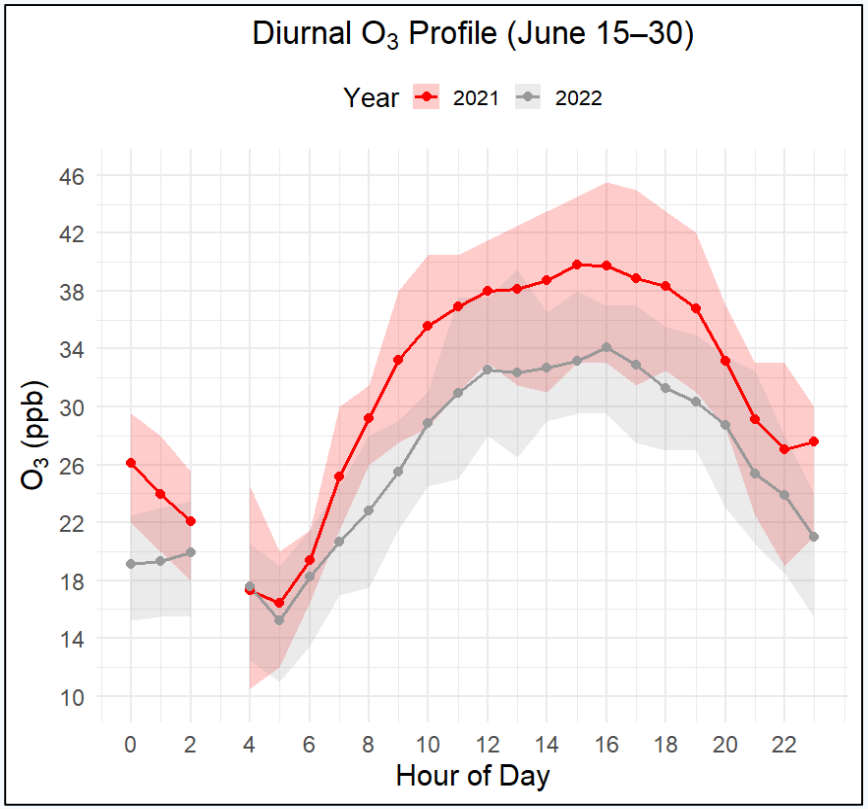
By mid-to-late century, years like 2023, which burned over 15 Mha, could occur regularly under high-emission scenarios (**SSP370**, **SSP585**).

Burned area remains lower only if global warming is limited to 2°C under low-emission scenario (**SSP126**).

Source: *Curasi et al., 2024, npj Climate and Atmospheric Science*

Heat extremes linked to elevated ozone levels

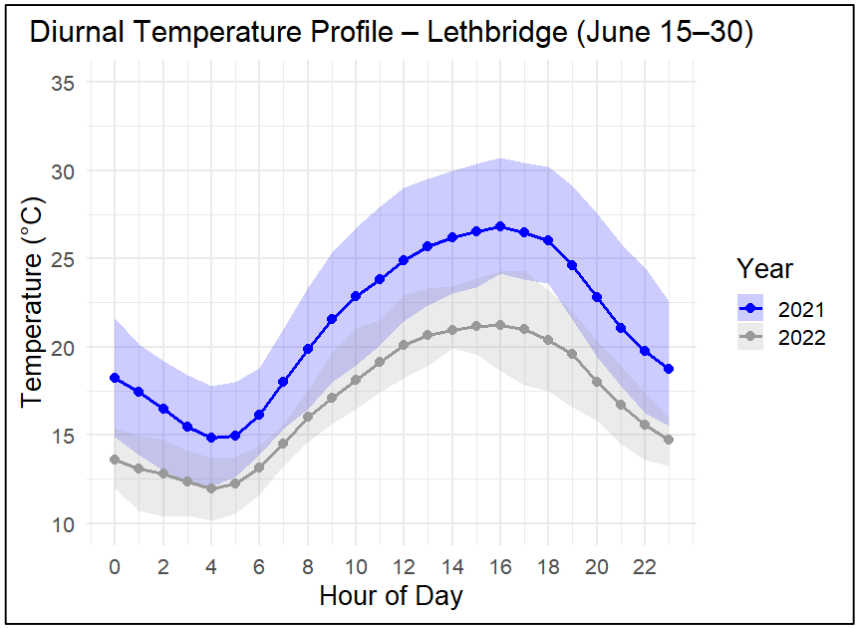


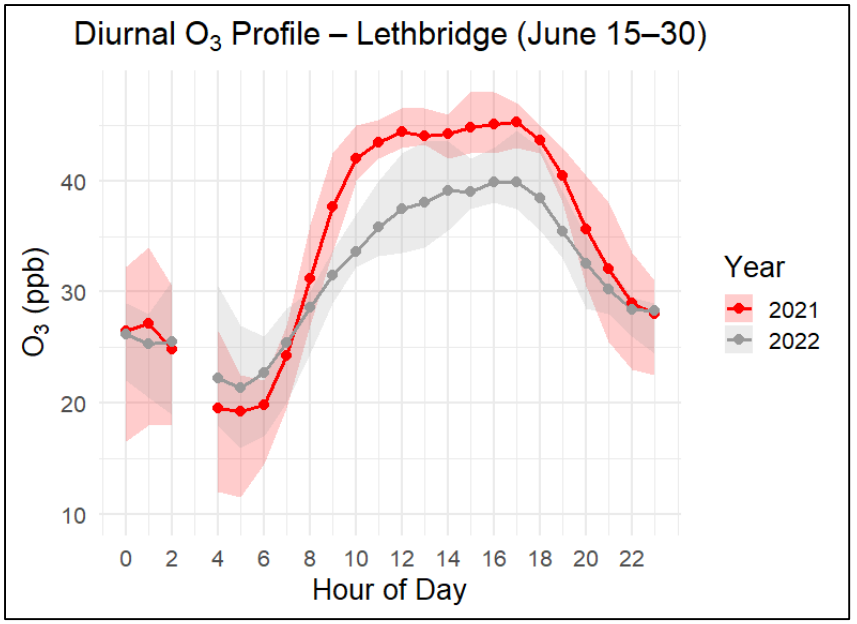


Hourly average ozone and temperature at Edmonton East station, June 15–30. Shaded areas show 25th -75th percentile. 2021 includes the buildup to the historic Pacific Northwest heat dome

Source: Raw data from Alberta Air Data Warehouse

Heat extremes linked to elevated ozone levels



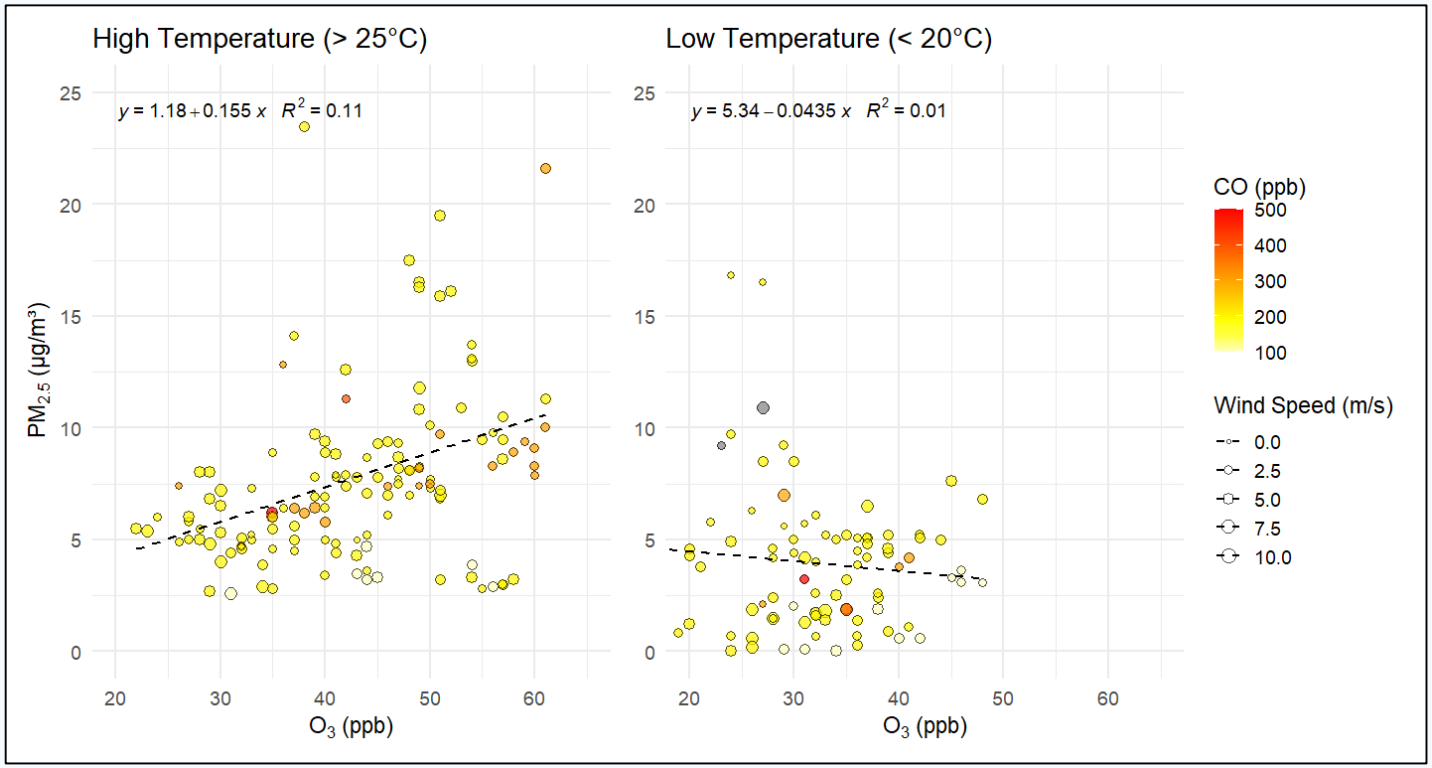


Hourly average ozone and temperature at Edmonton East station, June 15–30. Shaded areas show 25th -75th percentile. 2021 includes the buildup to the historic Pacific Northwest heat dome

Source: Raw data from Alberta Air Data Warehouse

Potential indicators of secondary $PM_{2.5}$ formation during high-temperature events

$PM_{2.5}$ vs O_3 at Edmonton East during daytime hours in June 2021, comparing high (>25°C) and low (<20°C) temperature conditions.



A positive O_3-$PM_{2.5}$ relationship under high temperatures suggests potential secondary PM formation enhanced by heat, precursors, and low wind speeds.

Source: Raw data from Alberta Air Data Warehouse

$PM_{2.5}$ exposure during the 2023 wildfire season

Edmonton

March-2023						
25	26	27	28	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31
1	2	3	4	5	6	7

May-2023						
29	30	1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31	1	2
3	4	5	6	7	8	9

June-2023						
27	28	29	30	31	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
1	2	3	4	5	6	7

Cold Lake

March-2023						
25	26	27	28	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31
1	2	3	4	5	6	7

May-2023						
29	30	1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31	1	2
3	4	5	6	7	8	9

June-2023						
27	28	29	30	31	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
1	2	3	4	5	6	7

Lethbridge

March-2023						
25	26	27	28	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31
1	2	3	4	5	6	7

May-2023						
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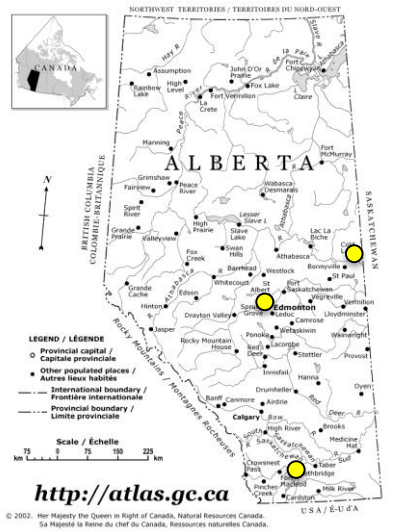
$PM_{2.5}$ ≤27 µg/m³ | 27–50 | 50–75 | 75–100 | >100 µg/m³



Cold Lake

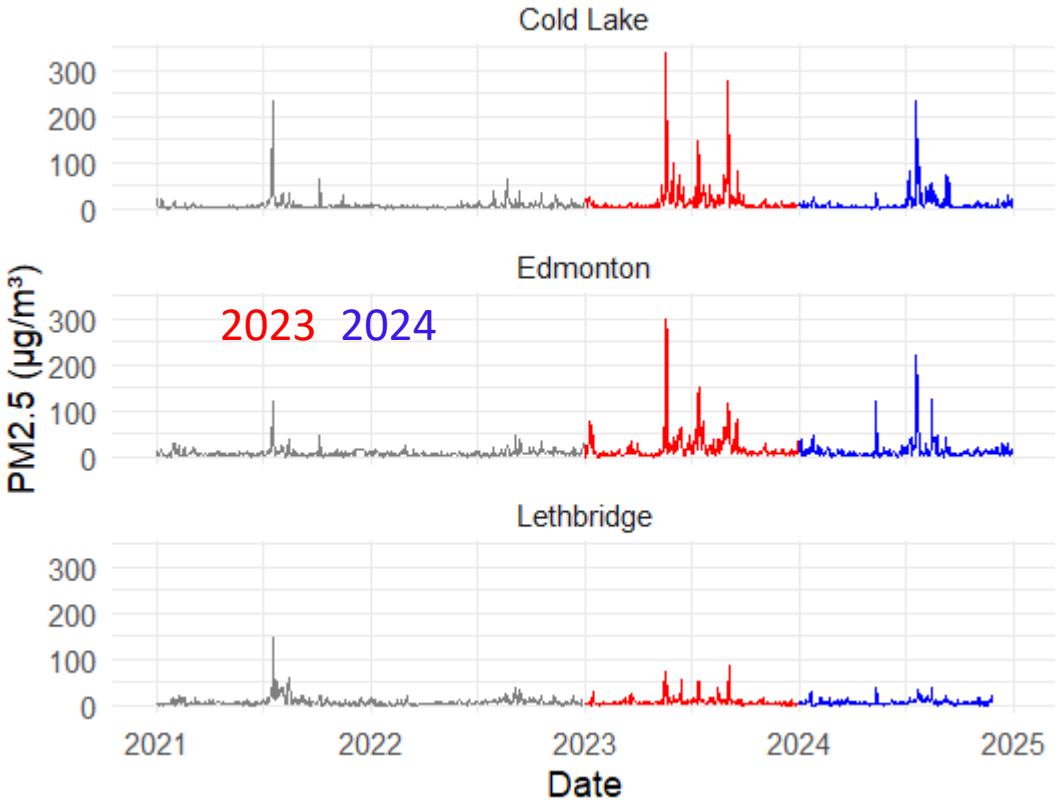
Edmonton

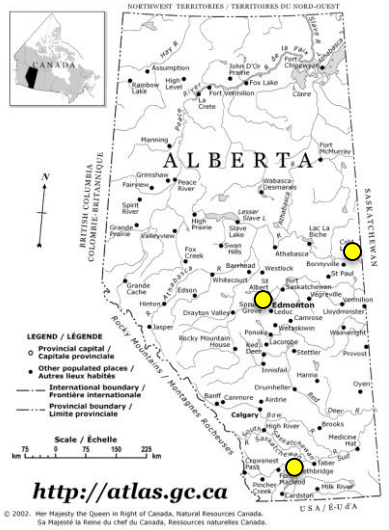
Lethbridge

Multiple weeks of elevated $PM_{2.5}$ were observed across several Alberta sites during the 2023 wildfire season, highlighting the widespread and prolonged impact of wildfire smoke exposure.

Source: Raw data from Alberta Air Data Warehouse

Wildfire-driven $PM_{2.5}$ exposure across Alberta (2023–2024)





Cold Lake

Edmonton

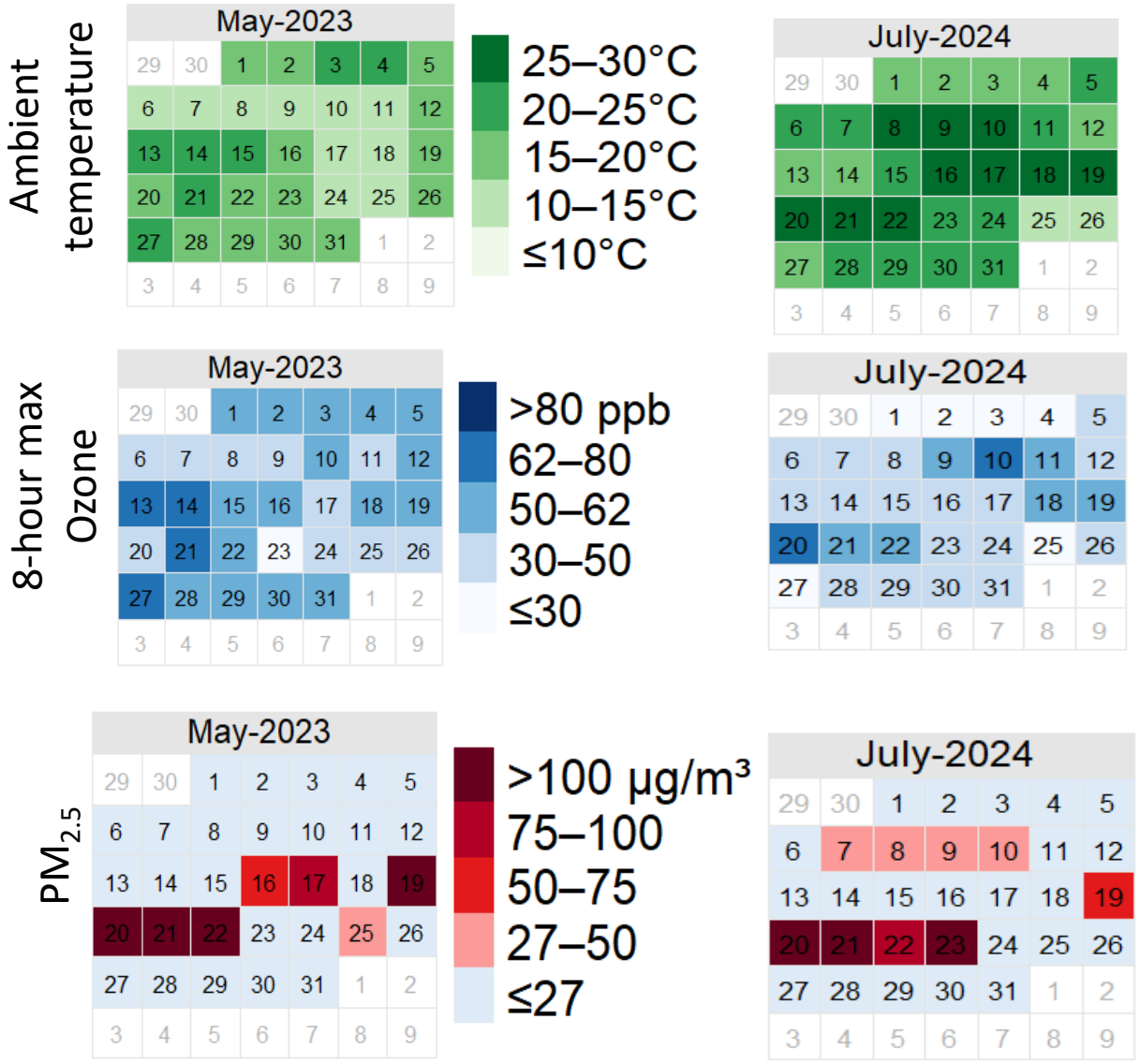
Lethbridge

$PM_{2.5}$ time series from Cold Lake, Edmonton, and Lethbridge highlight severe wildfire pollution in 2023, with recurring high-exposure episodes in 2024.

Although less area burned in 2024, multiple $PM_{2.5}$ spikes still occurred, reinforcing the persistent air quality threat across Alberta.

Source: Raw data from Alberta Air Data Warehouse

Co-occurrence of heat, ozone, and $PM_{2.5}$ in recent Alberta summers



Concurrent elevations in $PM_{2.5}$, O_3, and temperature were observed across multiple days in both 2023 and 2024.

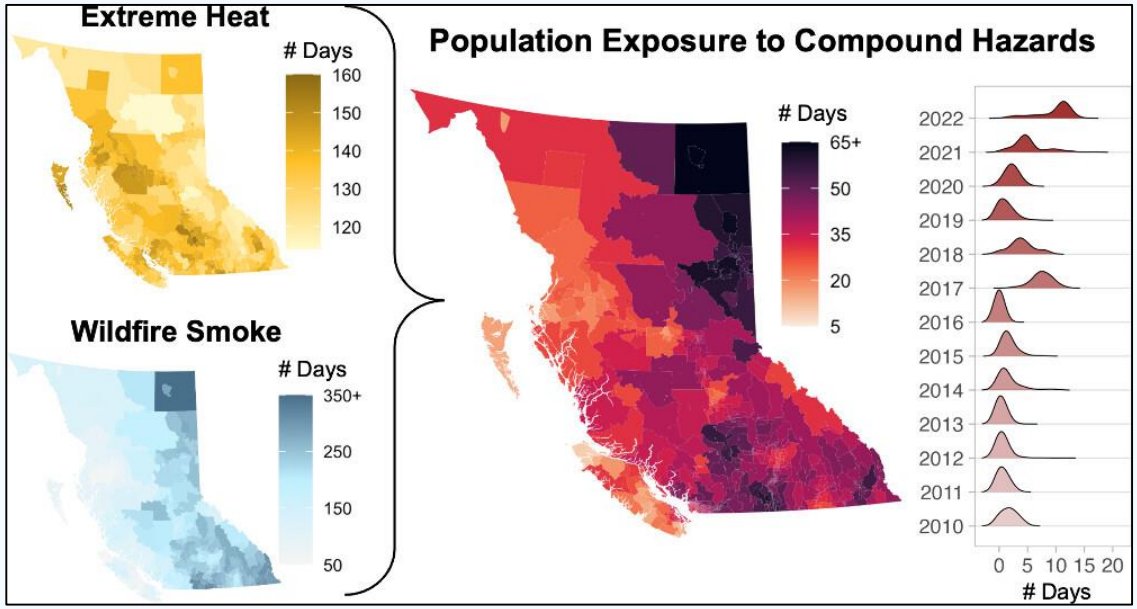
Need to quantify co-occurring atmospheric and thermal stressors as compound hazards in air quality and health risk assessments.

Source: Raw data from Alberta Air Data Warehouse

Quantifying co-exposure to wildfire smoke & extreme heat

- The extent to which wildfire smoke and extreme heat occur simultaneously has been largely unknown in Alberta.

- Identifying co-occurrence patterns is essential to support resilient communities.



Cleland et al. (2025) provide the first population-scale evidence that wildfire smoke and extreme heat frequently co-occur across BC, with events increasing sharply since 2017.

Source: *Cleland et al., 2025. ACS ES&T Air*

Building resilience to multi-stressor air quality risks

- Integrate wildfire smoke and heatwave co-occurrence into air quality risk assessments and health forecasting tools
- Expand monitoring and data linkage: pair meteorological data with $PM_{2.5}$, O_3, and population vulnerability indicators
- Support community-level early warning systems that account for compound events, not just single stressors
- Develop policy frameworks that bridge climate adaptation and air quality planning
- Encourage local research and spatially resolved analyses to identify high-burden, underserved regions

Acknowledgements

- Canadian Prairies and Northern Section (CPANS)
- CPANS 2025 Organizing Committee
- Air & Waste Management Association
- Environment and Climate Change Canada
- Alberta Air Data Warehouse, Alberta Environmental Science Program
- Government of Alberta – Ministry of Environment and Protected Areas
- David Carslaw for developing the openair R package

Thank you

7 Oct 2024