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2023 WILDFIRE SMOKE EXPOSURE AND PUBLIC HEALTH IN ONTARIO: TRIANGULATION OF EVIDENCE

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Research scientist

Health Canada & Public Health Ontario

May 23, 2024

YOUR HEALTH AND SAFETY... OUR PRIORITY.

Learning objectives

1. Discuss the acute impact of wildfire smoke exposure on human health, especially among Ontarians

2. Describe data sources and new findings in the area of wildfire-related health research

3. Describe the principles and the emerging methodologies in triangulating evidence in health research
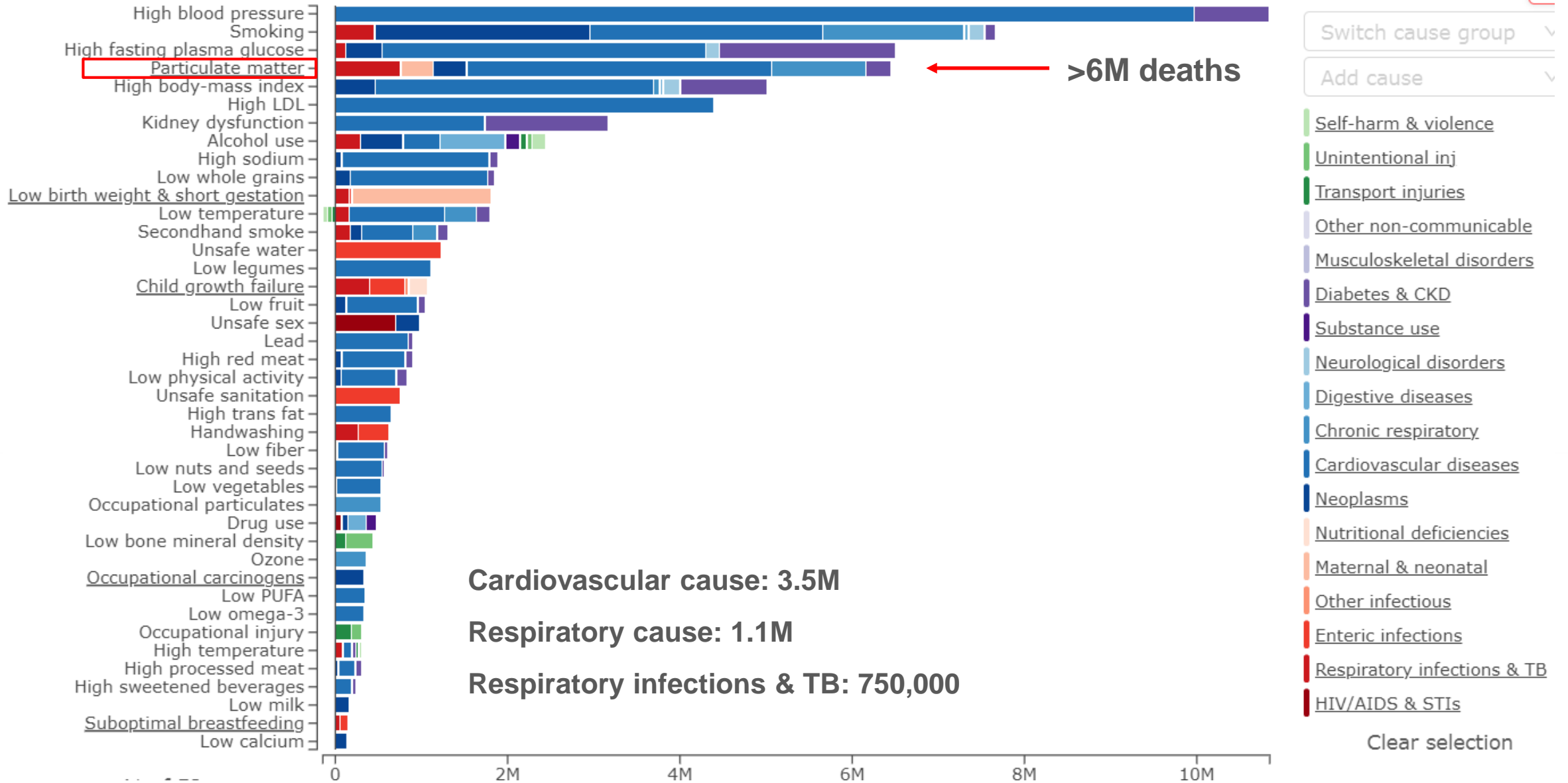
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Source: https://www.timeshighereducation.com/peer-review-way-validating-research-bunk

Global, Both sexes, All ages, 2019

>6M deaths

Cardiovascular cause: 3.5M

Respiratory cause: 1.1M

Respiratory infections & TB: 750,000

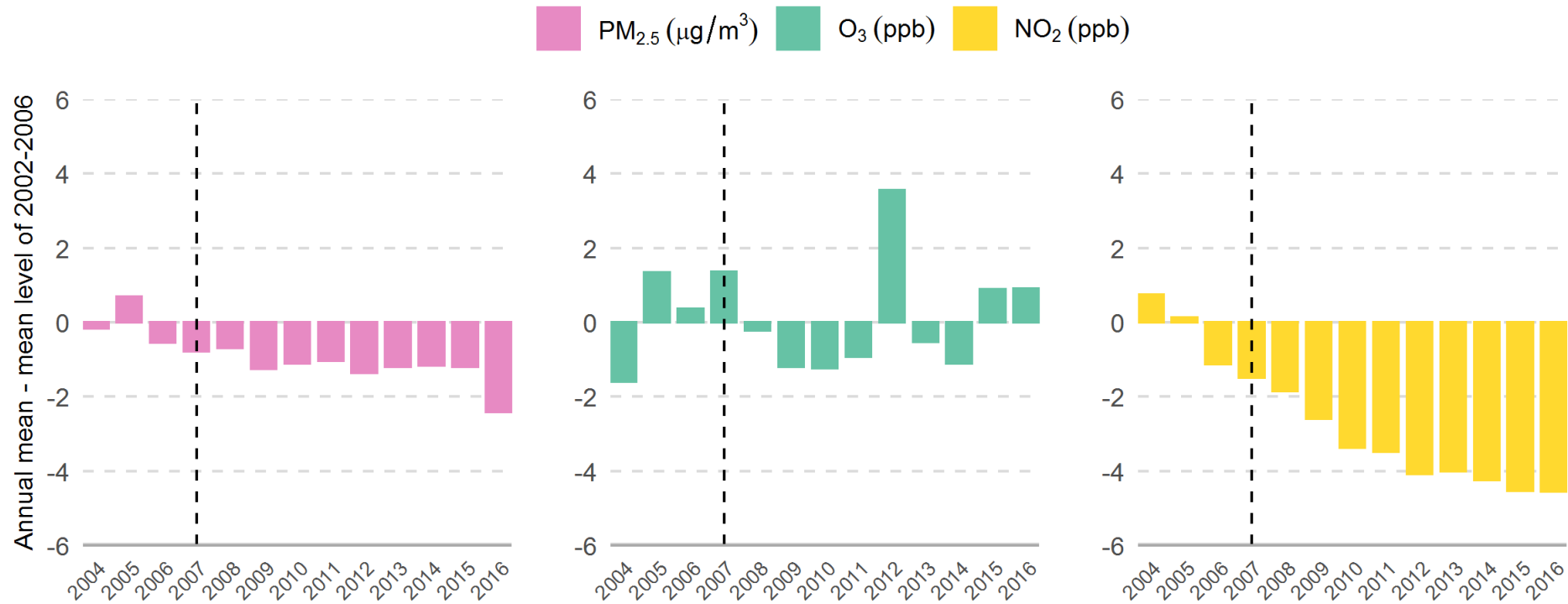*Source: https://vizhub.healthdata.org/gbd-compare/*

Air pollution is an ongoing public health concern in Canada

- PM$_{2.5}$ accounted for an estimated 10,000 premature deaths in 2016
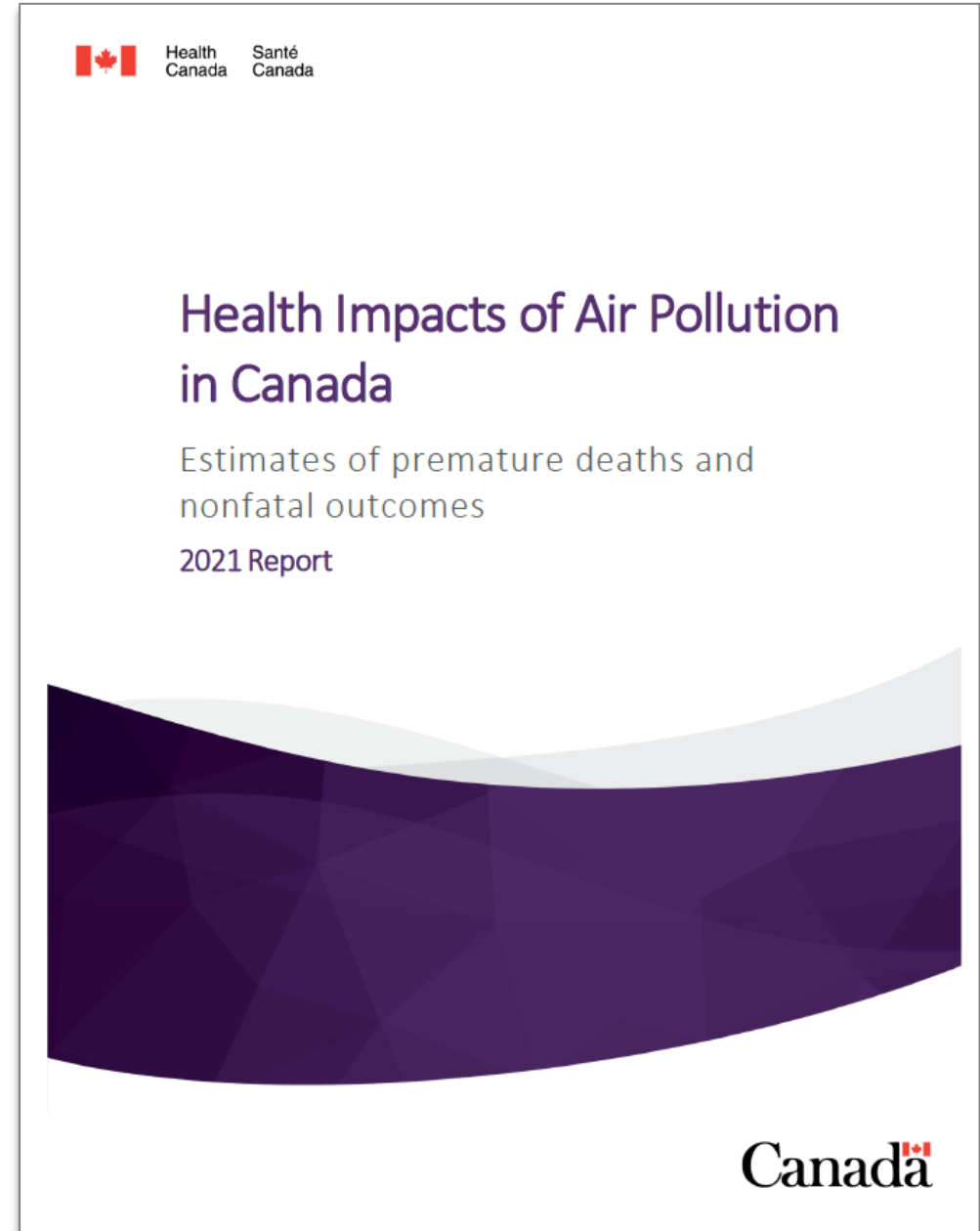
Any observable benefit from the past air quality improvements in Canada?

From 2007 to 2016, joint change in exposures to 3 pollutants was found to prevent 609 deaths/M population and gain 2,652 years of life/M in Canada

Trend of PM$_{2.5}$ in North America, 1990-2020

Average Annual Population-Weighted PM$_{2.5}$

Canada

NPR
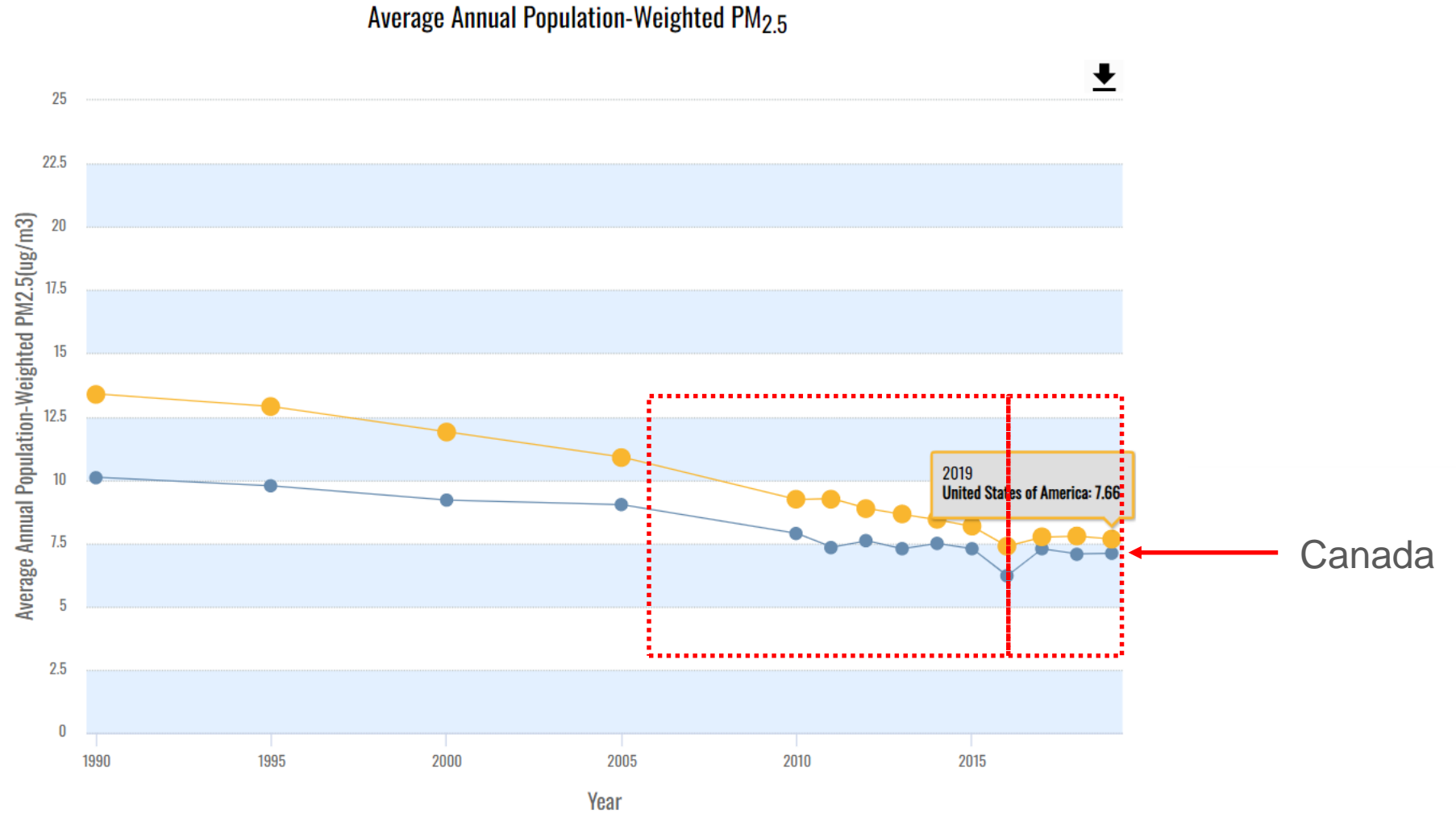
CLIMATE

How wildfire smoke is erasing years of progress toward cleaning up America's air

SEPTEMBER 20, 2023 · 11:00 AM ET

By Alejandra Borunda

The New York Times

The Reach of Wildfire Smoke Is Going Global and Undoing Progress on Clean Air

In the United States, smoke from wildfires is undoing progress from the Clean Air Act. In poorer countries, the situation is even worse.

Share full article

...urned the New York City sky dark yellow in June.

Los Angeles Times

CALIFORNIA

A single, devastating California fire season wiped out years of efforts to cut emissions

A firefighter battles the 2020 Creek Fire in Madera County, Calif. (Associated Press)

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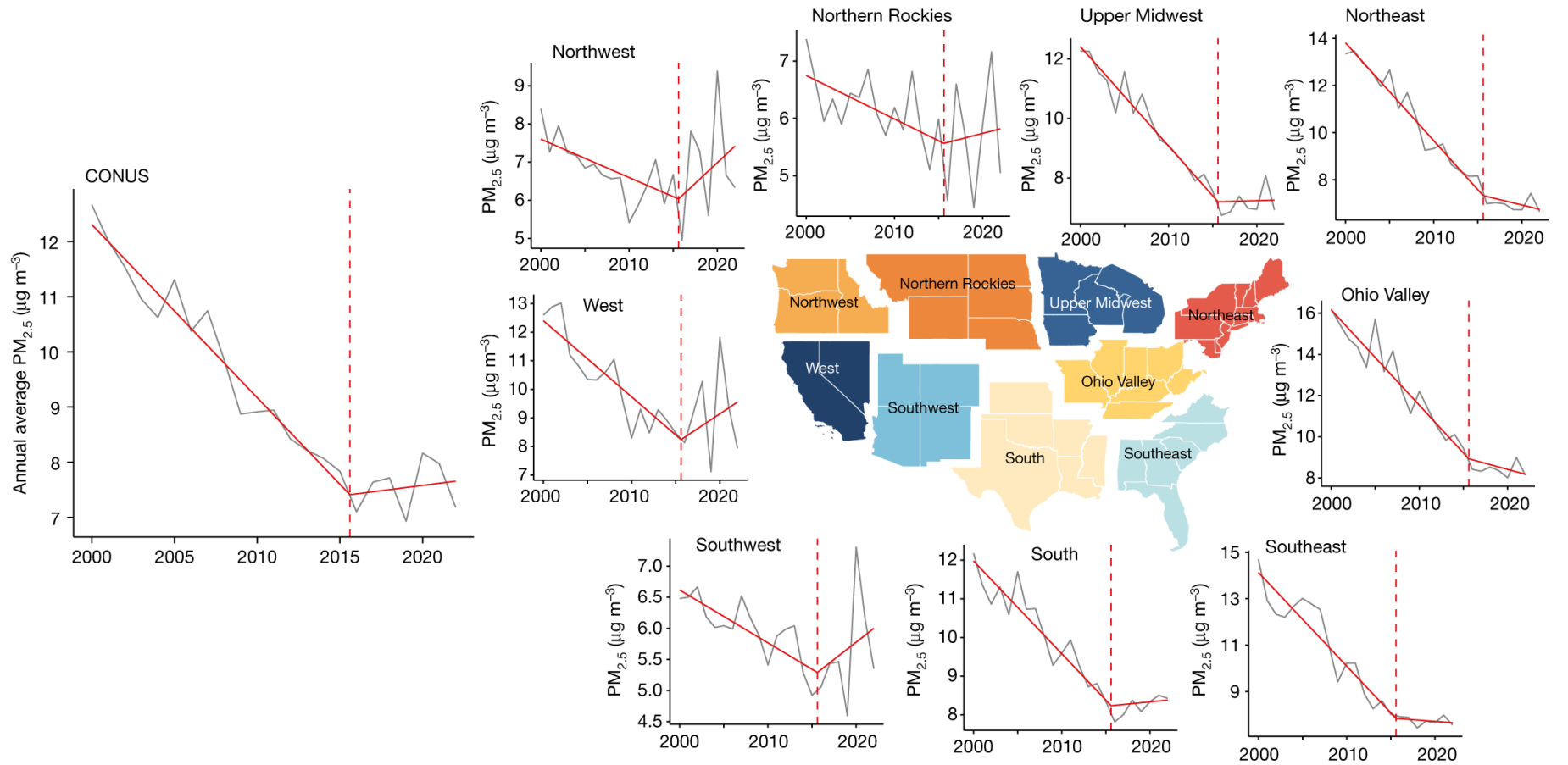
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Sources: https://www.latimes.com/; https://www.npr.org/; https://www.nytimes.com

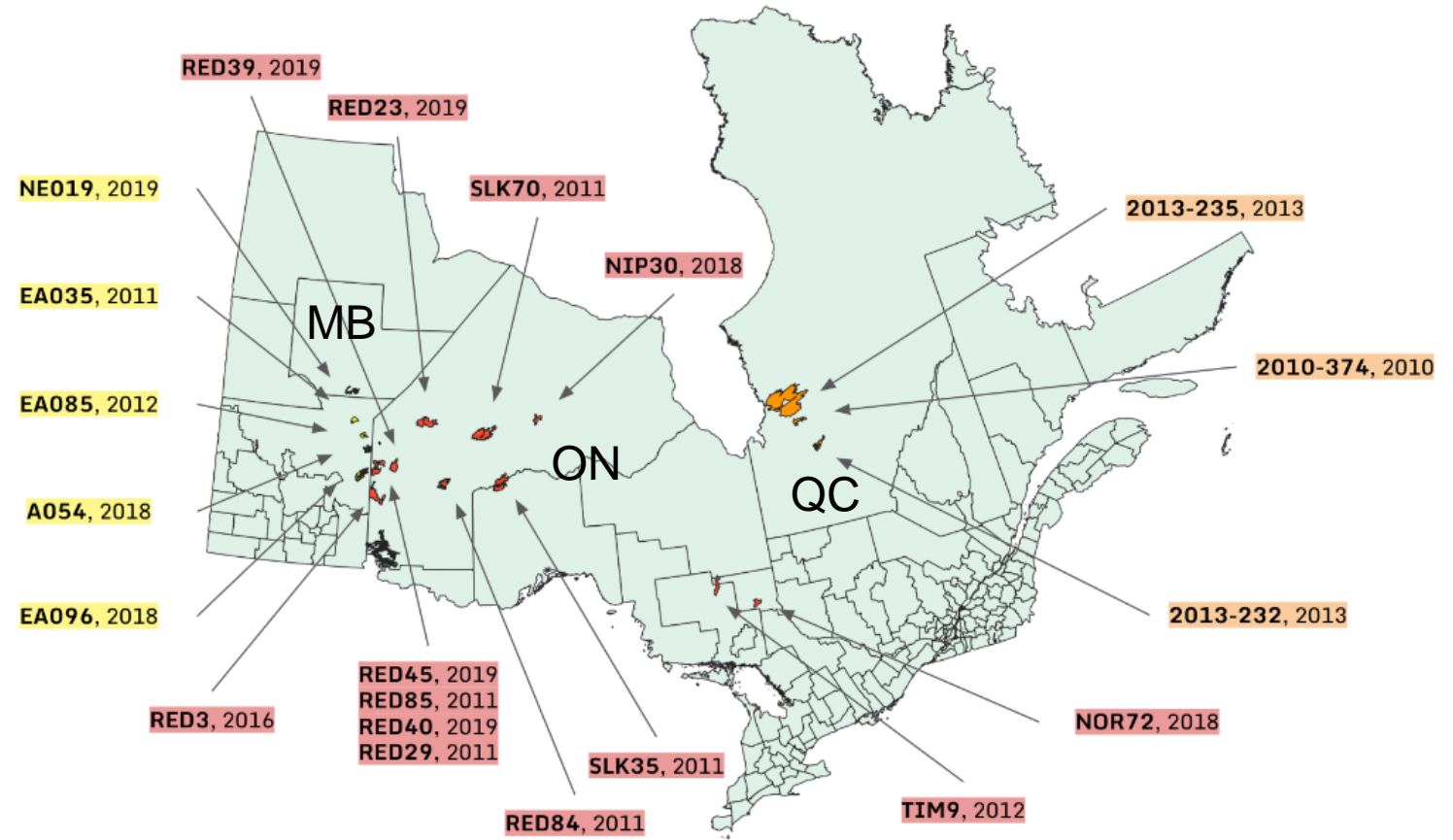# The contribution of wildfire to PM$_{2.5}$ trends in the USA

Marshall Burke ✉, Marissa L. Childs, Brandon de la Cuesta, Minghao Qiu, Jessica Li, Carlos F. Gould, Sam Heft-Neal & Michael Wara

Wildfires are a growing issue in and around Ontario

- While wildfires commonly occurred in western Canada, they have occurred in and around Ontario

RED39, 2019
RED23, 2019
NE019, 2019
SLK70, 2011
EA035, 2011
MB
2013-235, 2013
NIP30, 2018
EA085, 2012
2010-374, 2010
ON
A054, 2018
QC
2013-232, 2013
EA096, 2018
RED45, 2019
RED85, 2011
RED40, 2019
RED29, 2011
RED3, 2016
NOR72, 2018
SLK35, 2011
RED84, 2011
TIM9, 2012

Fire perimeters of selected large fires in Ontario, Manitoba, and Quebec (2010-2019)

Wildfires are a growing issue in and around Ontario

- Focusing on Ontario, most wildfires were in the Northwestern Ontario
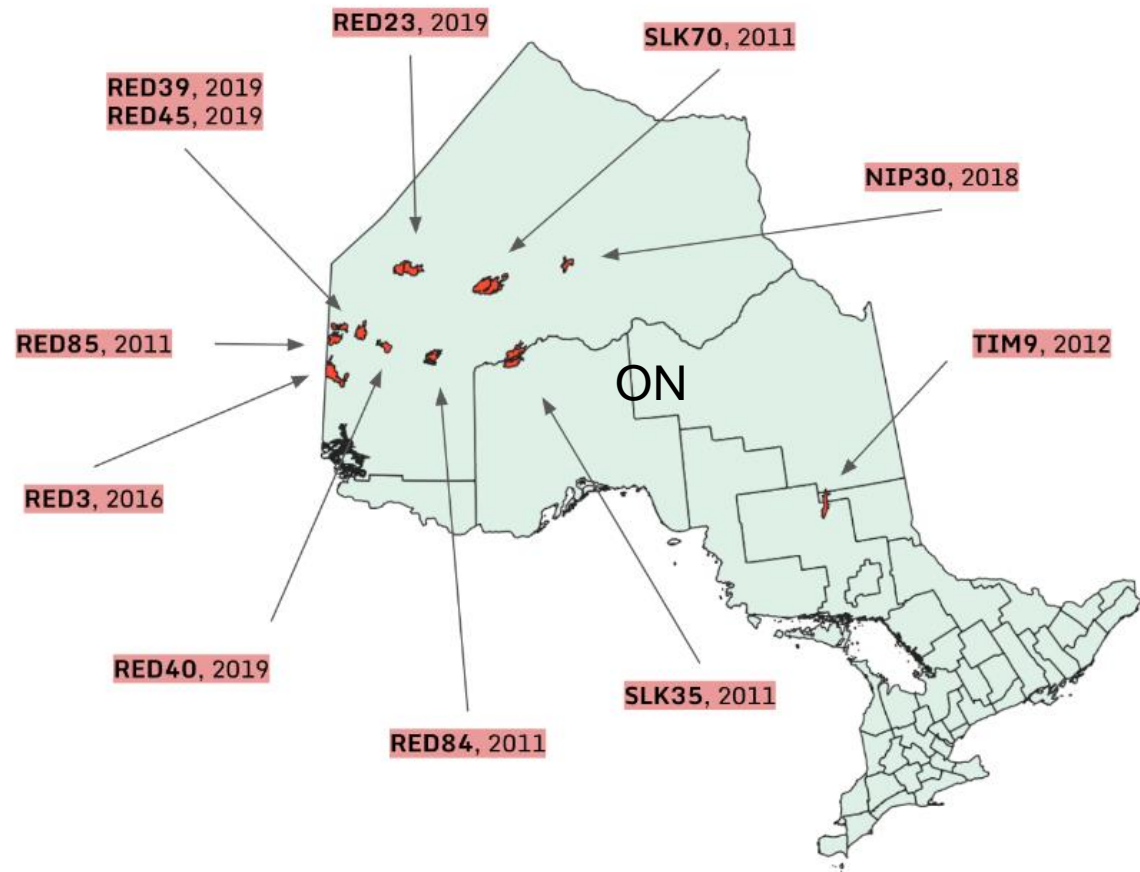
Fire perimeters of selected large fires in Ontario (2010-2019)

Wildfires are a growing issue in and around Ontario

- Focusing on Ontario, most wildfires were in the Northwestern Ontario

- Due to long distance and relatively modest intensity, the wildfire smoke has rarely substantially affect air quality in Ontario's large population centres

SLK 35

MB

ON   QC
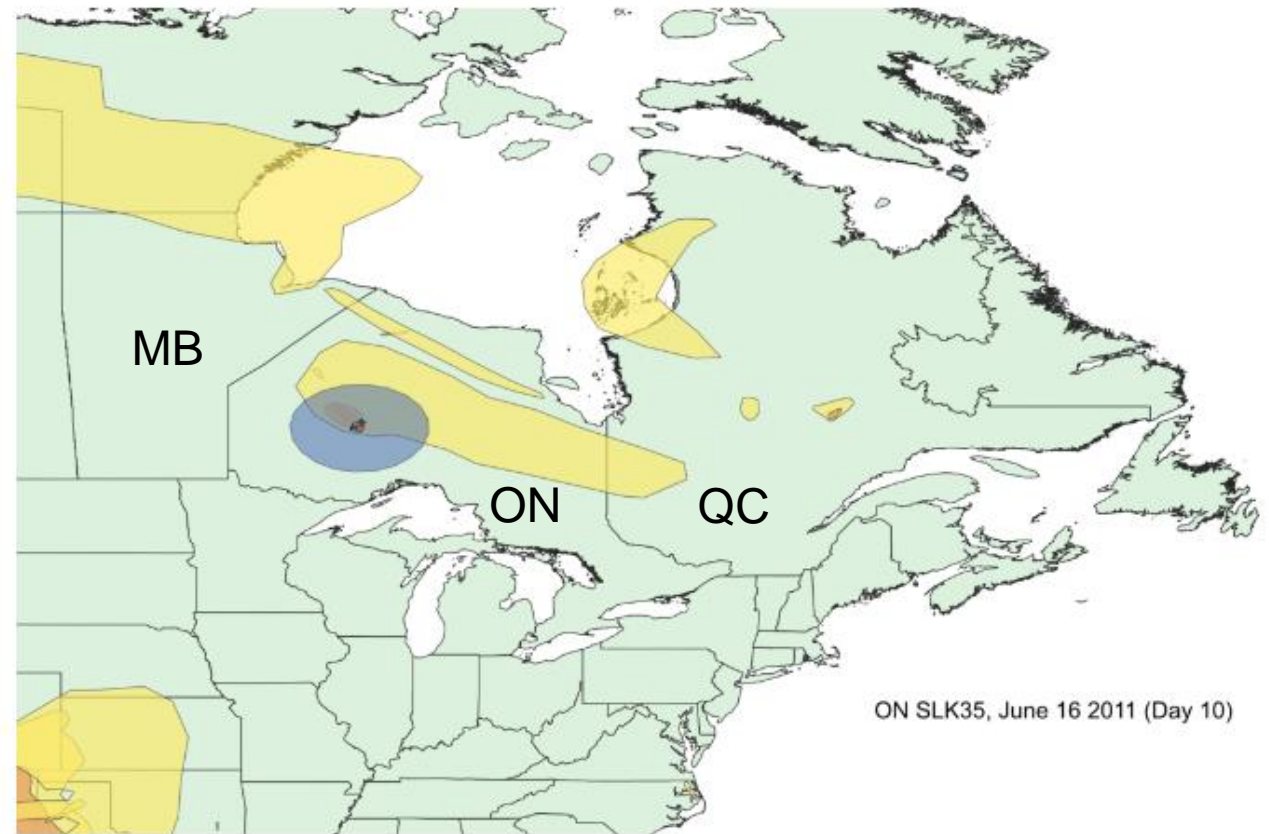
ON SLK35, June 16 2011 (Day 10)

ON SLK 35

The unprecedented 2023 Wildfires significantly worsened air quality in Ontario's population centres

June 7, 2023 Toronto (CP24)

Hazy skies seen as The Weather Network meteorologist Mark Robinson reported live from Canada's capital in June 2023.

Also affected major cities in the U.S.

Canadian Wildfire Smoke and Asthma Syndrome Emergency Department Visits in New York City

Kai Chen, PhD[1]; Yiqun Ma, MPhil[1]; Michelle L. Bell, PhD[2]; et al
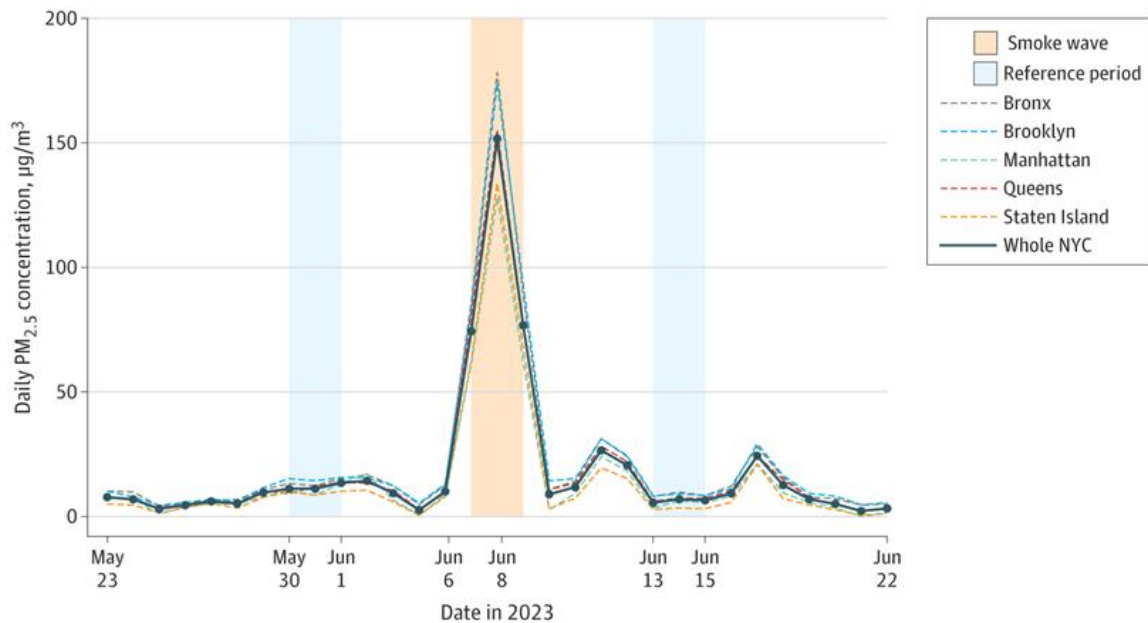

Table. Asthma Syndrome ED Visits by Age Groups and Boroughs in New York City Before, During, and After the Wildfire Smoke Wave in June 2023[a]

| | | No. of ED visits | | | |
	Population	Before smoke wave (May 30-June 1)	Smoke wave (June 6-8)	After smoke wave (June 13-15)	IRR (95% CI)
New York City					
All age groups	8 335 897	523	783	566	1.44 (1.31-1.58)
Age 0-4 y	516 826	19	28	31	1.12 (0.71-1.78)
Age 5-17 y	1 225 377	87	112	83	1.32 (1.04-1.67)
Age 18-64 y	5 334 974	344	562	394	1.52 (1.36-1.70)
Age ≥65 y	1 258 720	73	81	58	1.24 (0.94-1.63)
Borough					
Bronx	1 379 946	146	215	156	1.42 (1.20-1.70)
Brooklyn	2 590 516	173	247	192	1.35 (1.15-1.59)
Manhattan	1 596 273	97	138	93	1.45 (1.17-1.81)
Queens	2 278 029	69	128	89	1.62 (1.28-2.05)
Staten Island	491 133	13	25	6	2.63 (1.45-4.78)

Abbreviations: ED, emergency department; IRR, incidence rate ratio.

[a] The New York City (New York, New York) population in total and for each age group and each borough is assumed to have remained the same before, during, and after the smoke wave in June 2023. Borough-specific IRRs were not adjusted for age.

Source: Chen K et al JAMA 2023

Morbidity and Mortality Weekly Report (*MMWR*)

Asthma-Associated Emergency Department Visits During the Canadian Wildfire Smoke Episodes — United States, April– August 2023

Cristin E. McArdle, PhD[1,2]; Tia C. Dowling, MPhil[2,3]; Kelly Carey, MPH[4]; Jourdan DeVies, MS[4]; Dylan Johns, MS[4,5]; Abigail L. Gates, MSPH[4]; Zachary Stein, MPH[4]; Katharina L. van Santen, MSPH[4,5]; Lakshmi Radhakrishnan, MPH[4]; Aaron Kite-Powell, MS[4]; Karl Soetebier, MAPW[4]; Jason D. Sacks, MPH[6]; Kanta Sircar, PhD[2]; Kathleen P. Hartnett, PhD[4]; Maria C. Mirabelli, PhD[2] (VIEW AUTHOR AFFILIATIONS)
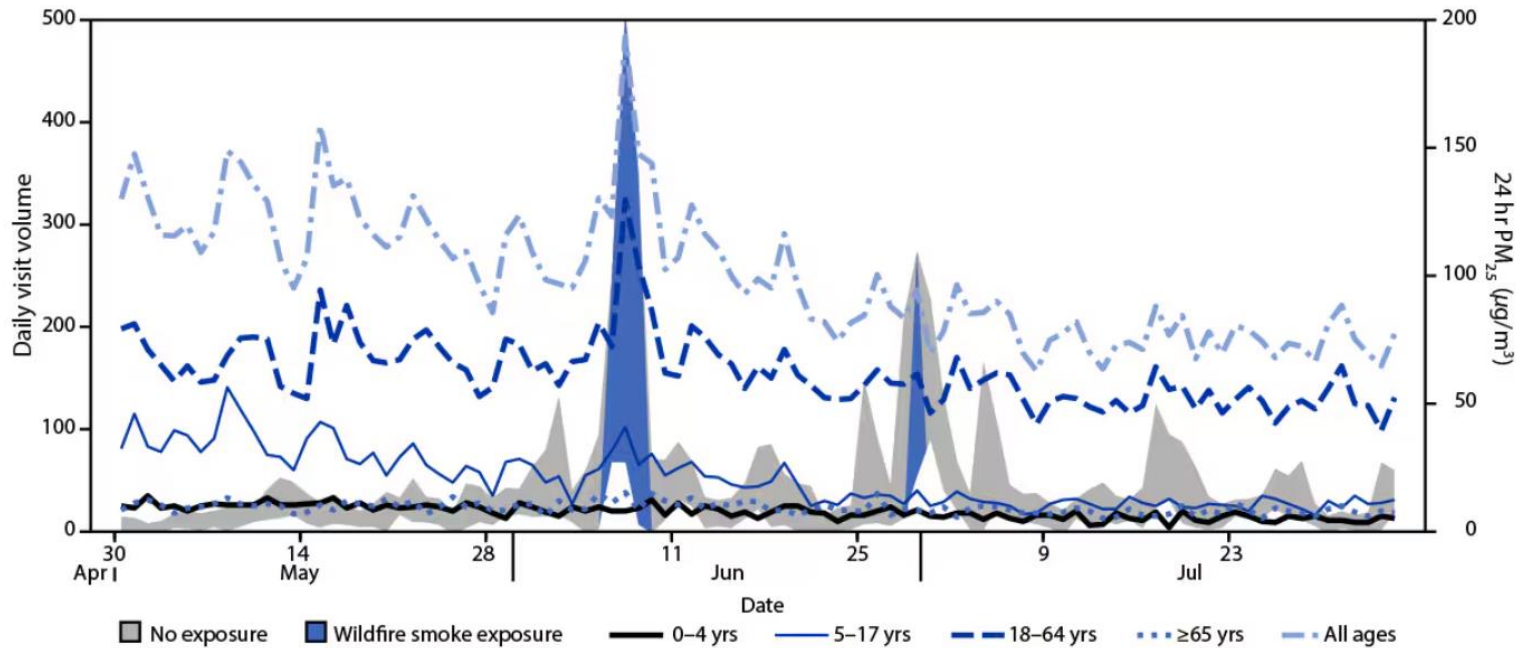
- In New Jersey and New York, 364 excess visits during June 6-8, 2023
- Overall an 17% increase in asthma ED visits than expected

Source: McArdle C et al 2023 MMWR

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Why studying the health impact of 2023 wildfire smoke exposure in Ontario?

- Given evidence on wildfire smoke exposure on asthma ED visits in the U.S., it is of great interest whether a similar impact occurred in Ontario

- It is also important to know whether other health outcomes (*esp.*, cardiovascular) were affected by high level of wildfire smoke exposure

- The 2023 wildfire season in Ontario comprised 2 unprecedented major wildfire episodes (~3 weeks apart), providing a unique opportunity to characterize difference (if any) in the health impacts

- Finally, we aimed to close the gap between association and causation (through epidemiological triangulation)

Epidemiological triangulation

- Seek different study designs, data sources, and analytical approaches
  - Examples: traditional cohort studies, natural experiments, randomized experiments
  - Involve different assumptions (hence, different sources of potential biases)
  - May yield different findings (align with the Bradford Hill criteria of 'consistency')
  - Goal is strengthen confidence in causal inference (qualitative assessment)
- In contrast, systematic review approach seeks similar studies
  - Expected to see similar findings
  - Goal is to obtain a more precise estimate of an exposure (quantitative assessment)

Study design: 5 complementary approaches used

- Interrupted time-series study (a quasi-experiment design for evaluating a well-defined public policy or intervention)

- Case crossover study (a self-matched study design)

- Daily time-series study (a regression-based approach)

- Falsification analysis: a negative outcome control (non-cardiorespiratory outcome) and a placebo test (year 2022)

- Visual analysis

Data sources: health outcome

- ACES (The Acute Care Enhanced Surveillance Application)
  - Ontario Syndromic Surveillance system developed by KFL&A Public Health
  - Timely (real-time monitoring triage registration records from EDs in Ontario)
  - Population representative (over 95% of Ontario's acute care hospitals)
  - A wide array of syndromes ascertained using validated algorithms

- NACRS (National Ambulatory Care Reporting System)
  - "Gold standard" acute care data (commonly used to study acute effects of many risk factors and healthcare utilizations)
  - However, a limitation is lag in data availability (delayed up to 6-12 months)

Data sources: exposure

- Air quality monitoring stations in ON (MOECP)

  o "Gold standard" air quality measurement data

  o Timely (real-time monitoring air quality in Ontario)

  o Not specific to wildfires and not all PHUs have a station

- Wildfire smoke plume (NOAA HMS)

  o Satellite-based remote sensing data covering entire NA

  o Available daily, with smog plume intensity score (0: no, 1: light, 2: medium, 3: heavy)

  o Possible missingness due to cloud cover and difficult to differentiate vertical height of plumes
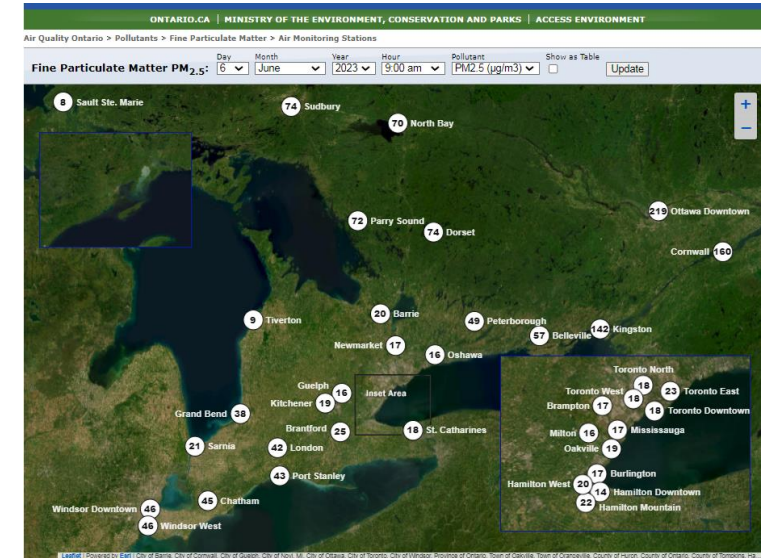
Hazard Mapping System Fire and Smoke Product
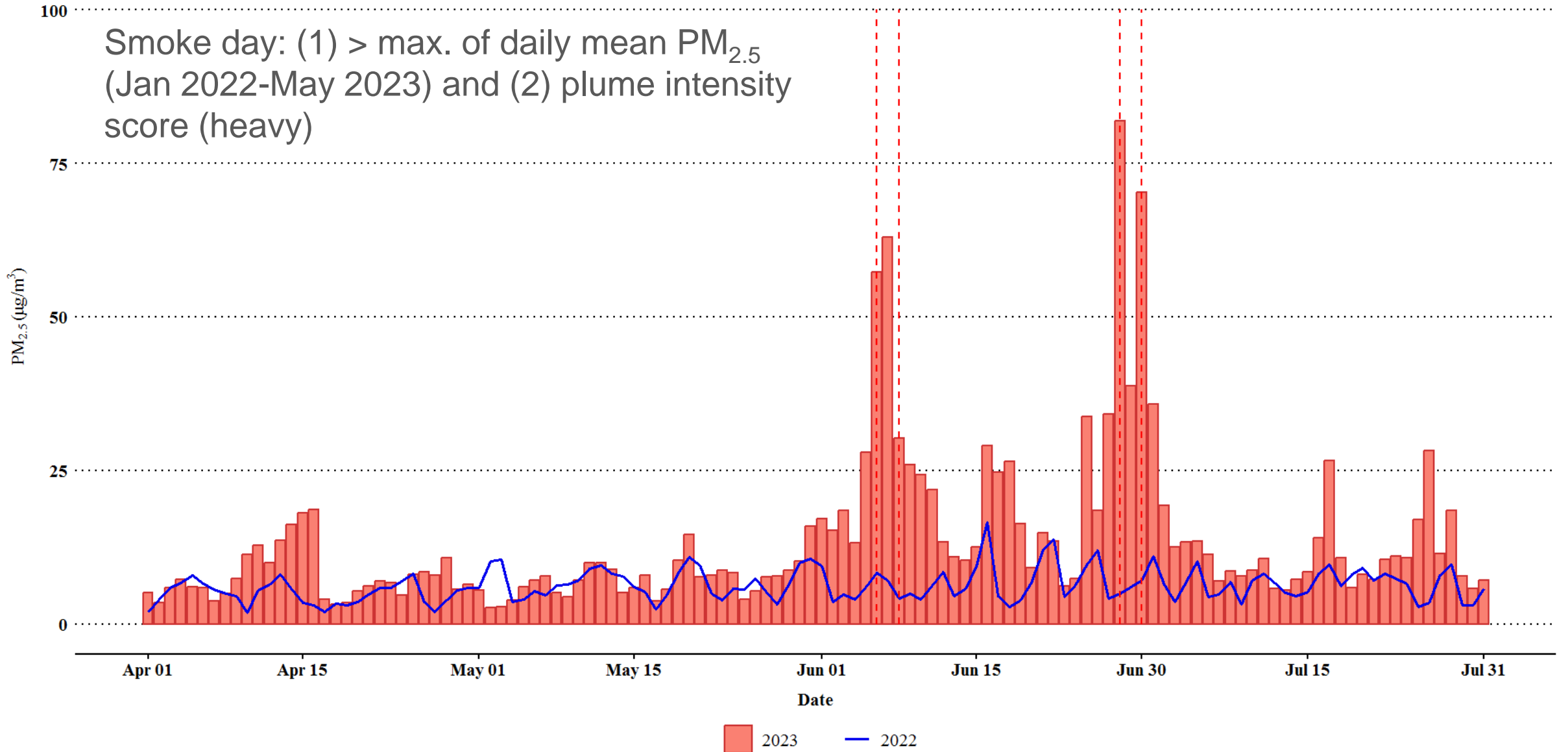
Current Analysis
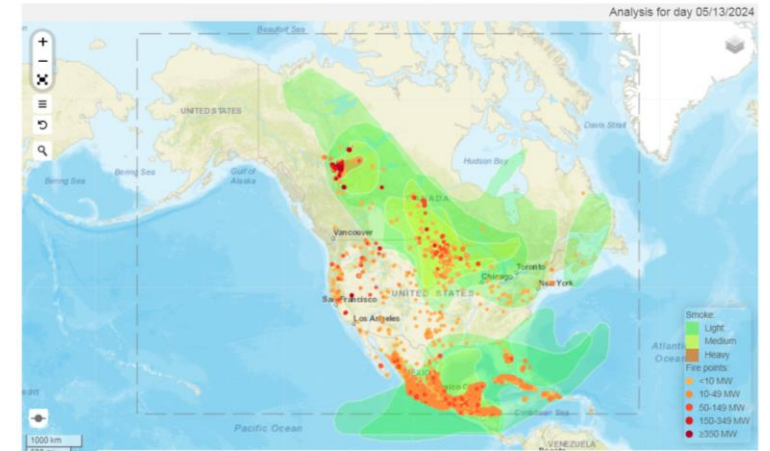
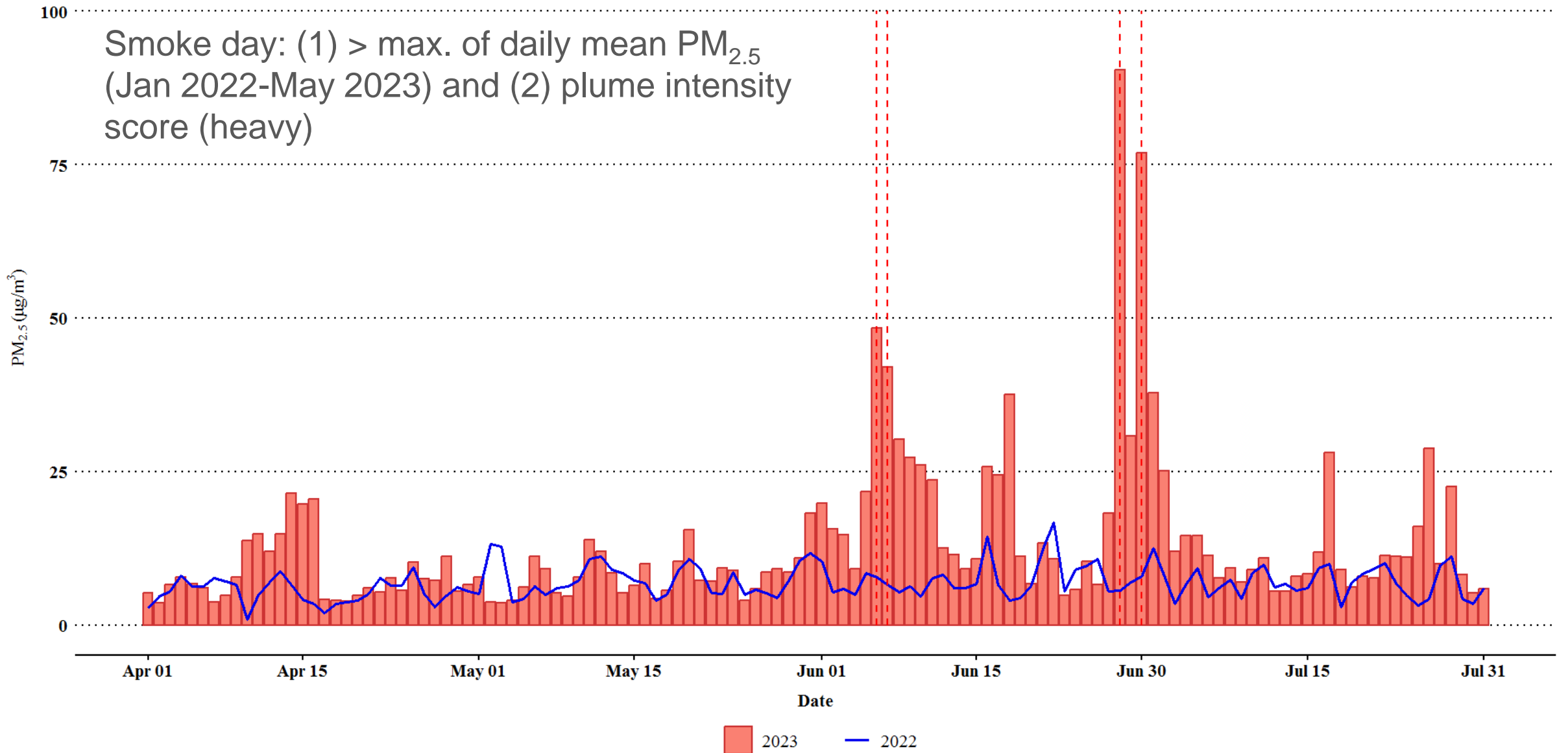# Study area: 29 Ontario Local Health Units
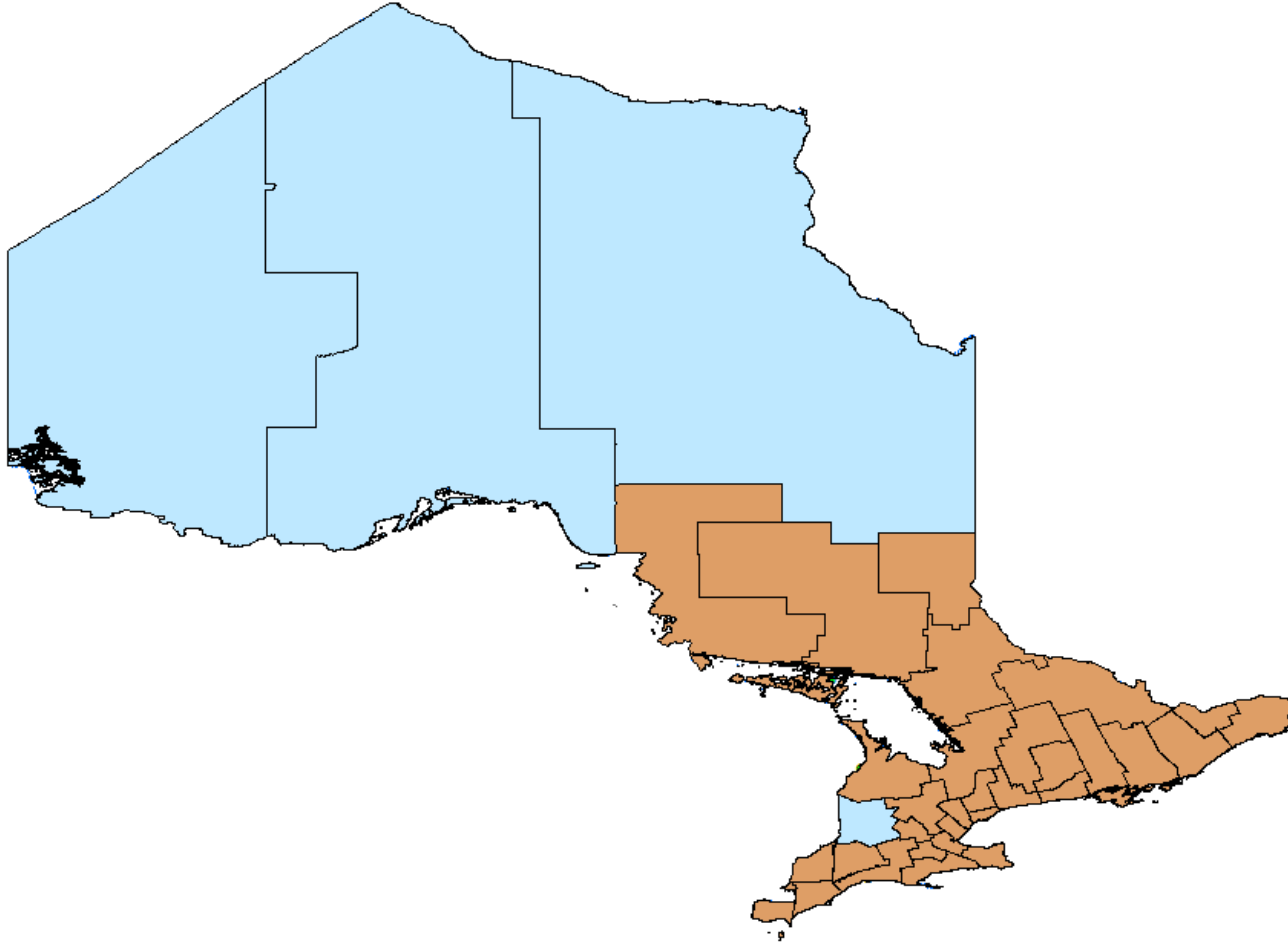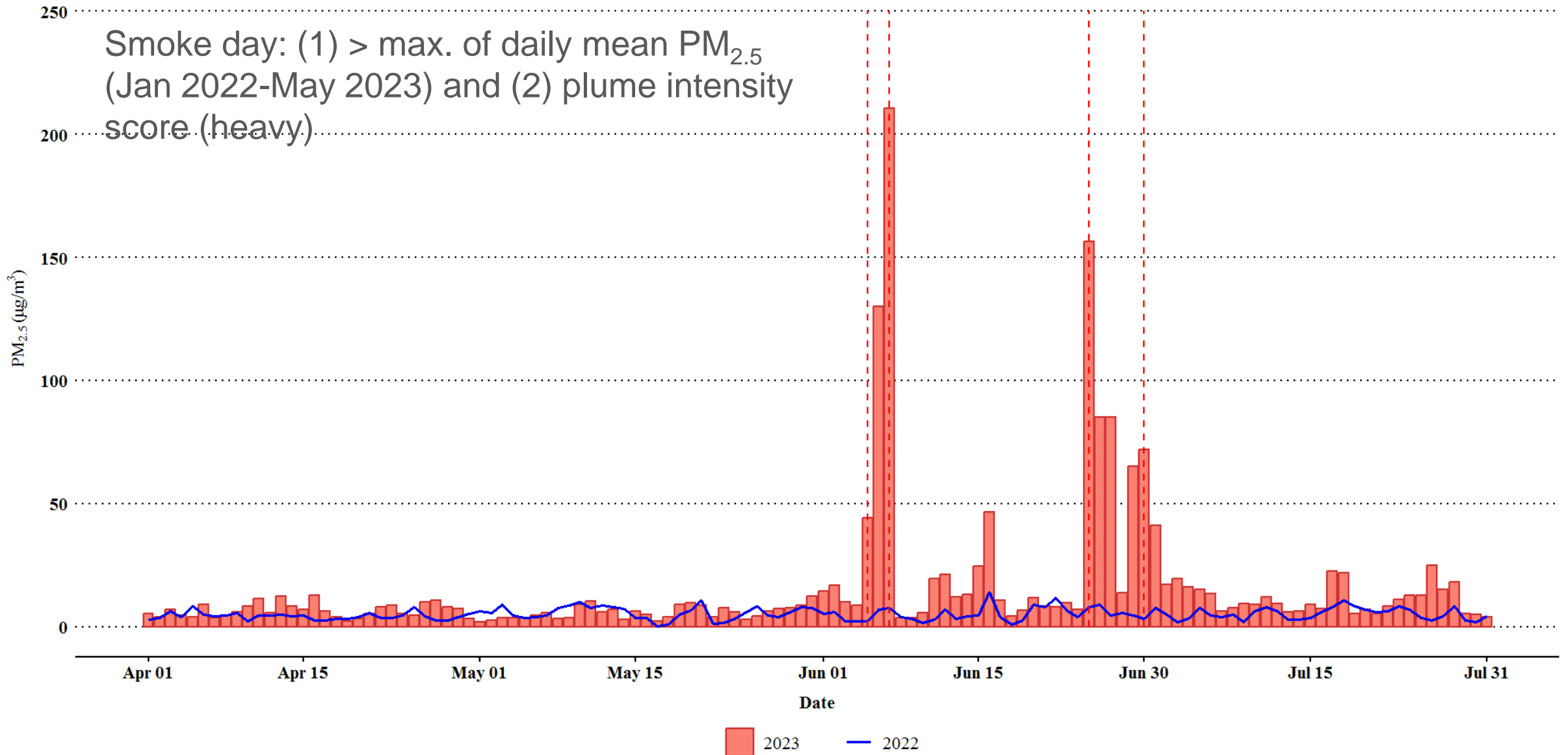

- ~97% of Ontario population

Statistical analysis

- Conditional Poisson regression (each of 29 PHUs as a stratum) with adjustment for confounding, overdispersion, and autocorrelation

- Key confounders included secular trend, seasonal effect, day-of-week effect, daily temperature, daily humidity, common co-pollutants (O_3 and NO_2), reported COVID-19 cases, and holidays

- Outcomes: asthma, other respiratory diseases, coronary heart disease, and non-respiratory and non-cardiovascular disease
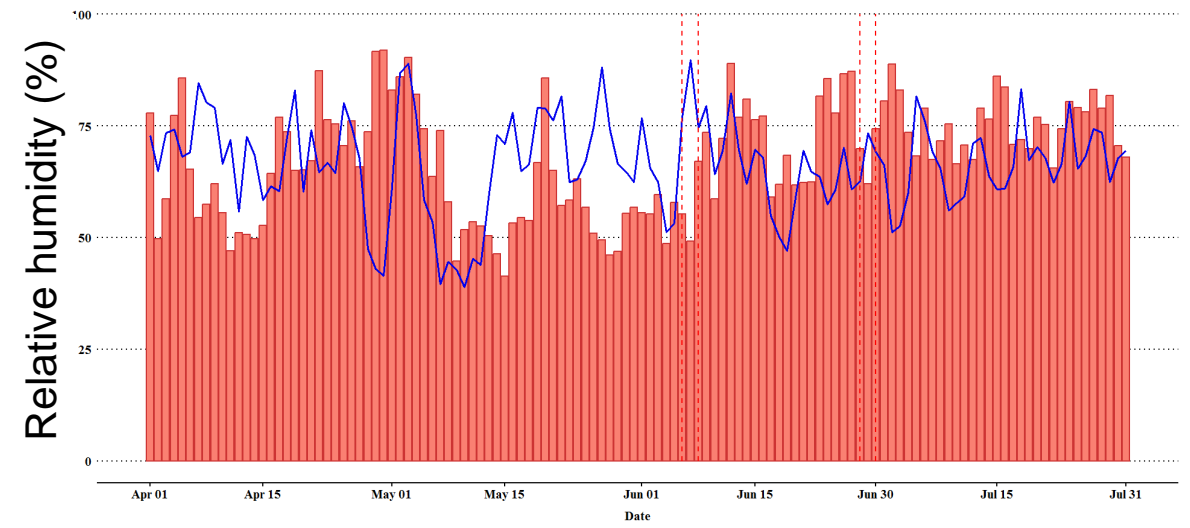
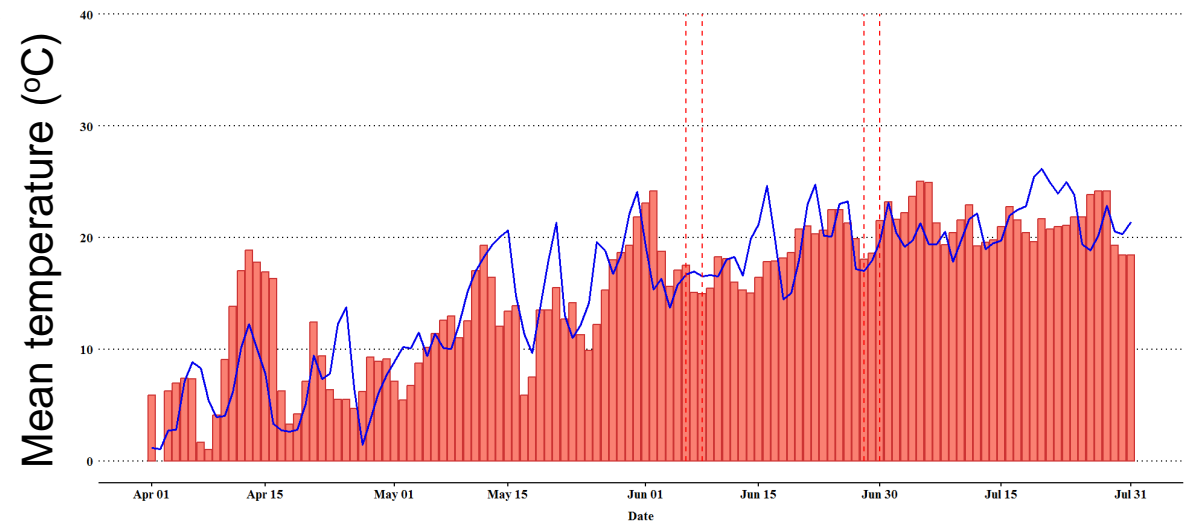Smoke day: (1) > max. of daily mean PM$_{2.5}$ (Jan 2022-May 2023) and (2) plume intensity score (heavy)

Ontario

Smoke day: (1) > max. of daily mean PM$_{2.5}$ (Jan 2022-May 2023) and (2) plume intensity score (heavy)

Toronto Public Health

Smoke day: (1) > max. of daily mean $PM_{2.5}$ (Jan 2022-May 2023) and (2) plume intensity score (heavy)

Ottawa Public Health

Selected confounders: O$_3$, NO$_2$, temp, rel. humidity
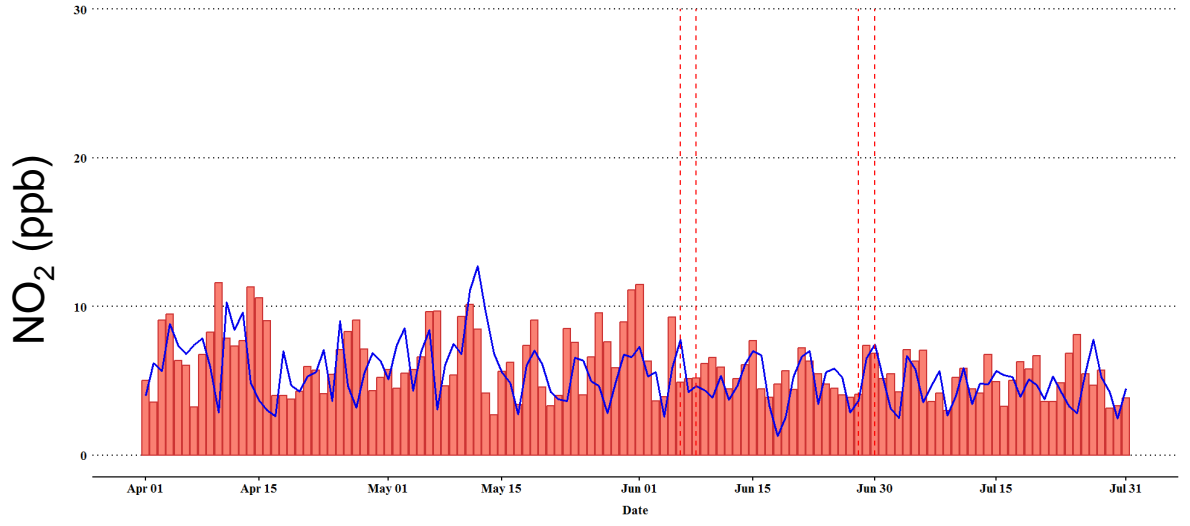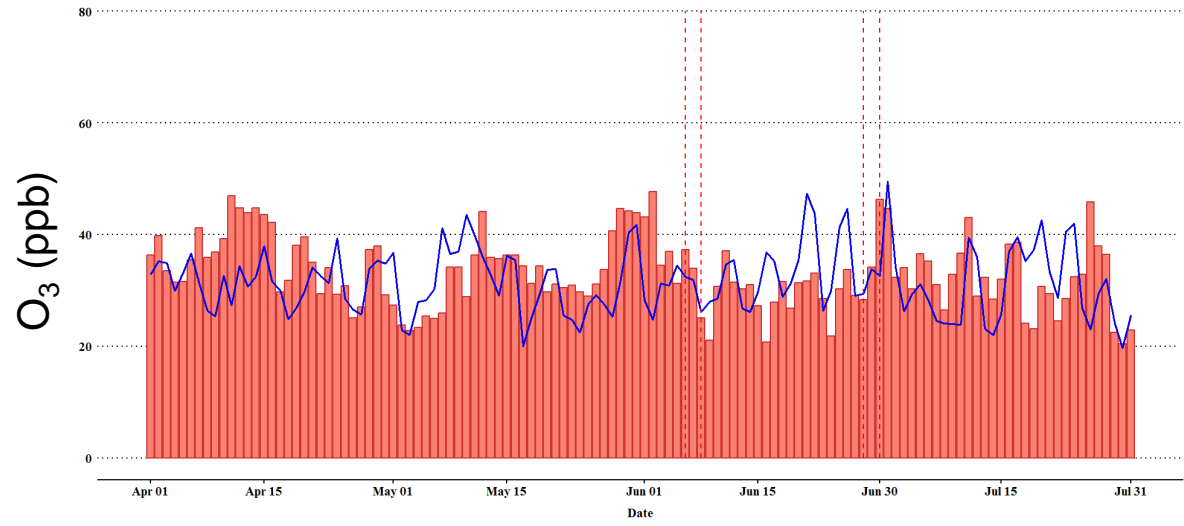
Ontario

2023 Wildfire events and syndrome ED visits

(A) First wave

Asthma

Change in daily visits (%)

Smoke days, Lagged 1 day, Lagged 2 days, Lagged 3 days, Lagged 4 days, Lagged 5 days, Lagged 6 days, Lagged 7 days
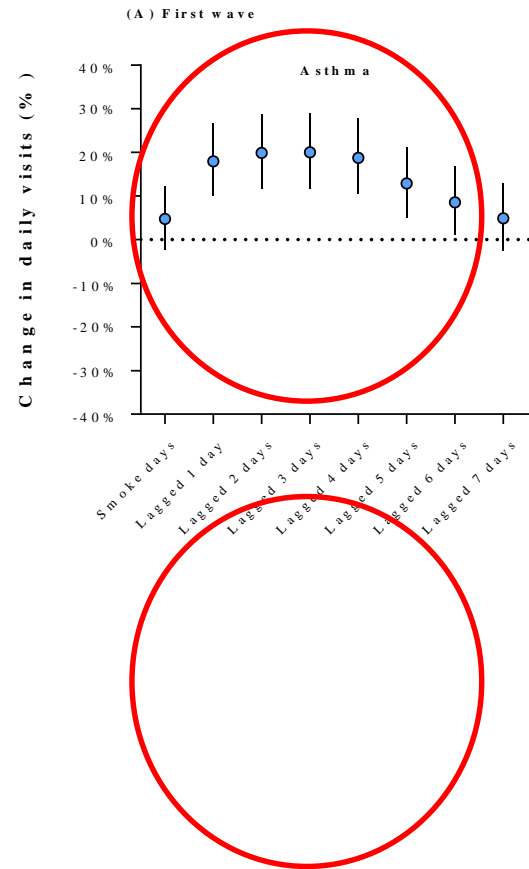
2023 Wildfire events and CIHIED visits

(A) First wave

(B) Second wave

30
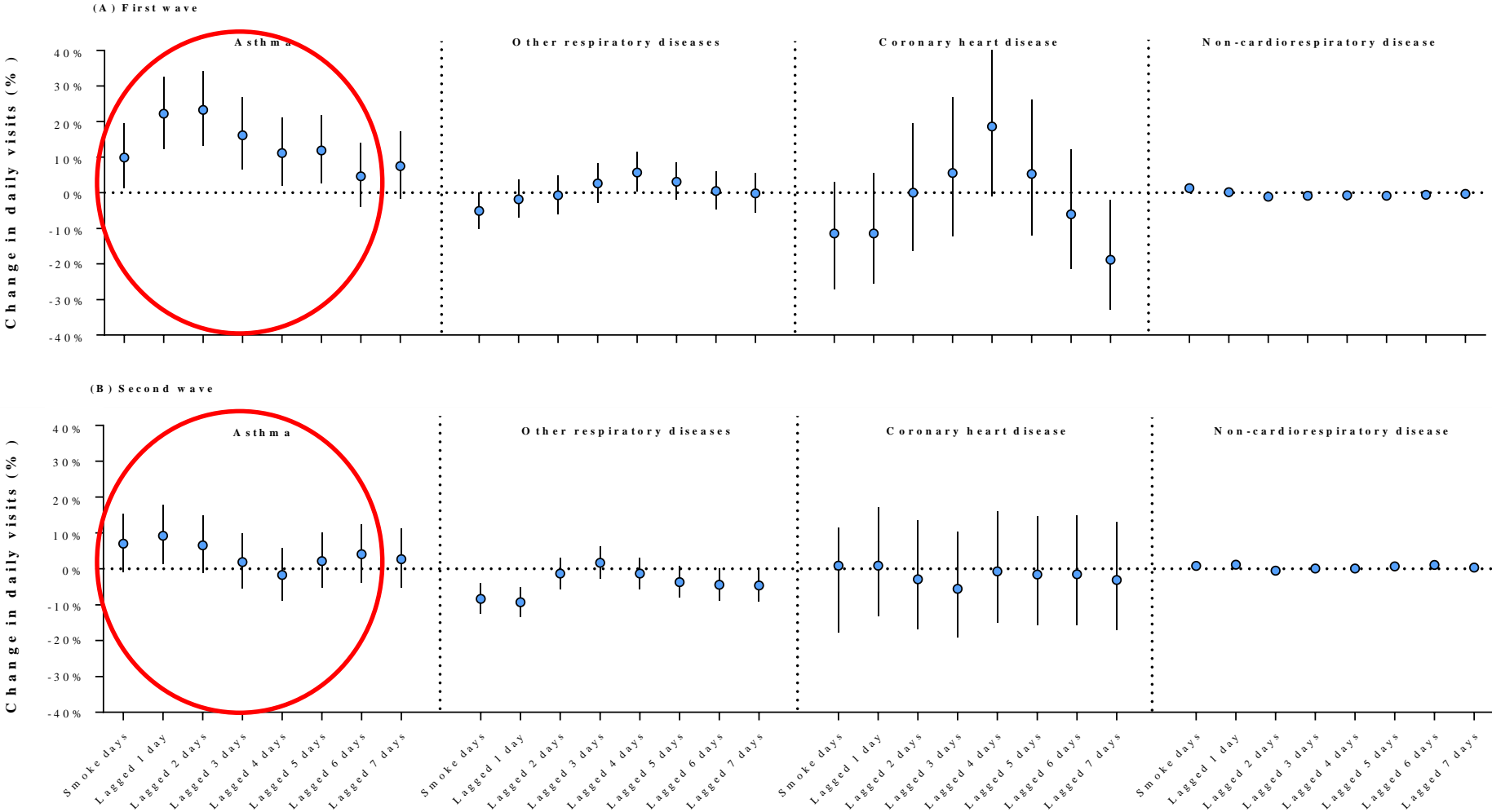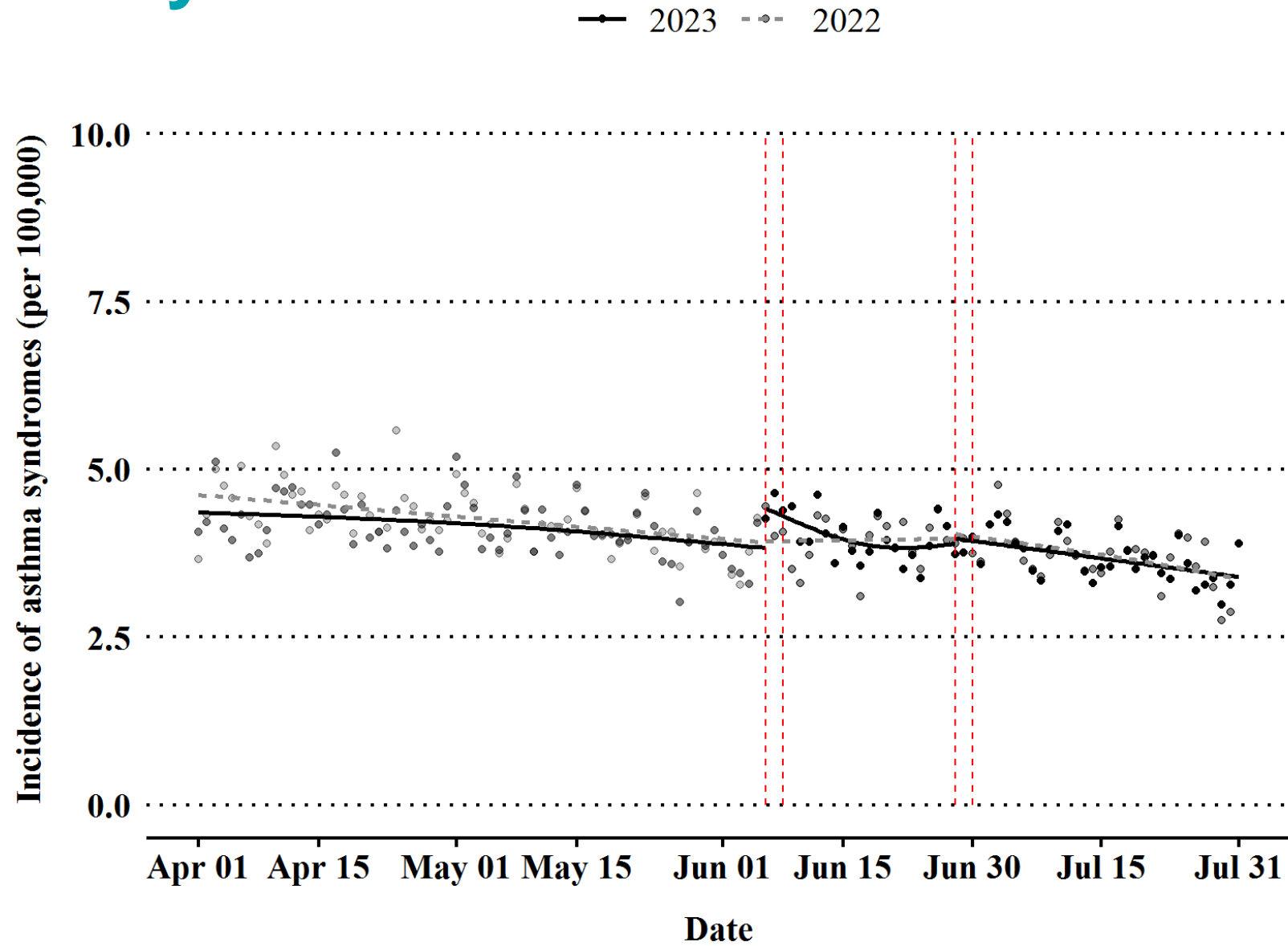
Visual analysis

Visual analysis
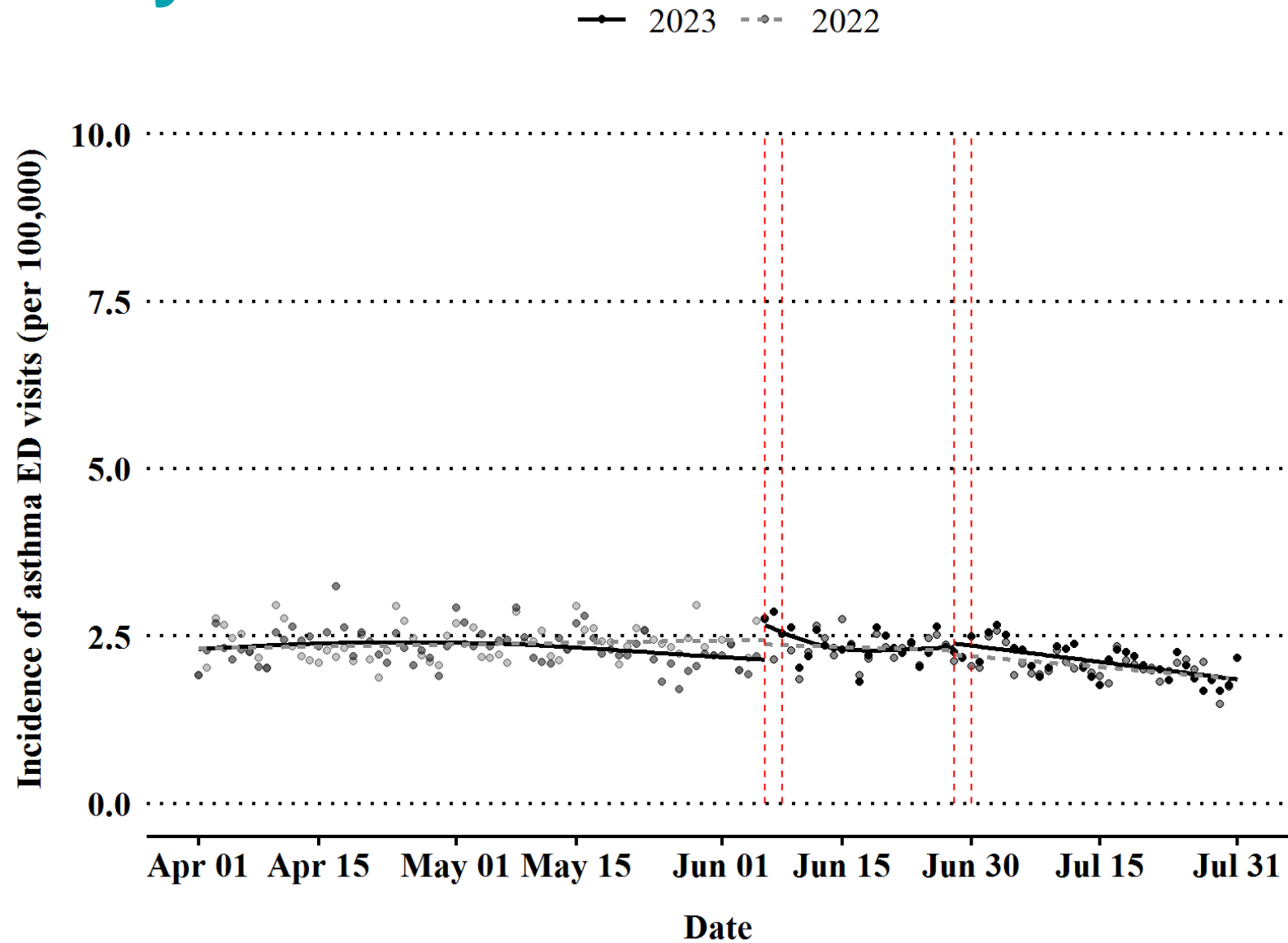
Triangulation of evidence

Interrupted time-series study	9% to 23% increase in daily asthma ED visits during the 1st wave (depending on lag and data source), but not in the 2nd wave. No association found for other outcomes
Case crossover study	8% to 20% increase in daily asthma ED visits during the 1st wave (depending on lag and data source), but not in the 2nd wave. No clear evidence found for other outcomes
Traditional time-series study	2% to 11% increase in asthma ED visits on days classified with "heavy" smoke plume compared to days with no plume (depending on lag and data source). No clear evidence for other outcomes
Falsification analysis	(1) non-cardiorespiratory-related ED visits: null effect and (2) placebo test (using year 2022): null effect on all outcomes
Visual analysis	Visual jump in daily incidence of asthma ED visits at the 1st wave, but not at the 2nd wave. No clear jump found for other outcomes

In summary

- Ambient air pollution is an ongoing public health issue in Canada; the 2023 wildfire season **exacerbated** this impact

- Exposure to the 2023 wildfire smoke was **causally** linked to a significant increase in asthma-related ED visits in Ontario

  - Daily visits jumped up to 23%, lagged by 1 day, and peaked on day 2 or 3

- There was a sharp increase in asthma ED visits following the **1st** wave of wildfires, but not with the 2nd wave

- Comparable findings between syndromic ED visits and CIHI ED visits, supporting the utility of syndromic data for (real-time) wildfire surveillance

Next steps

- Long-term effect of exposure to wildfire smoke
- Vulnerability and environmental justice

In the context of wildfires and public health

What additional research evidence are you seeking to support your work in protecting public health in Ontario?

Acknowledgements

- JinHee Kim, John Wang, and Elaina MacIntyre (Public Health Ontario)
- Allison Maier, Nancy Slipp, and Adam Van Dijk (KFL&A Public Health)
- Yushan Su (MOECP)
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Merci

Thank you