The Effect of 2023 Wildfire Smoke on Ozone and Public Health in Chicago

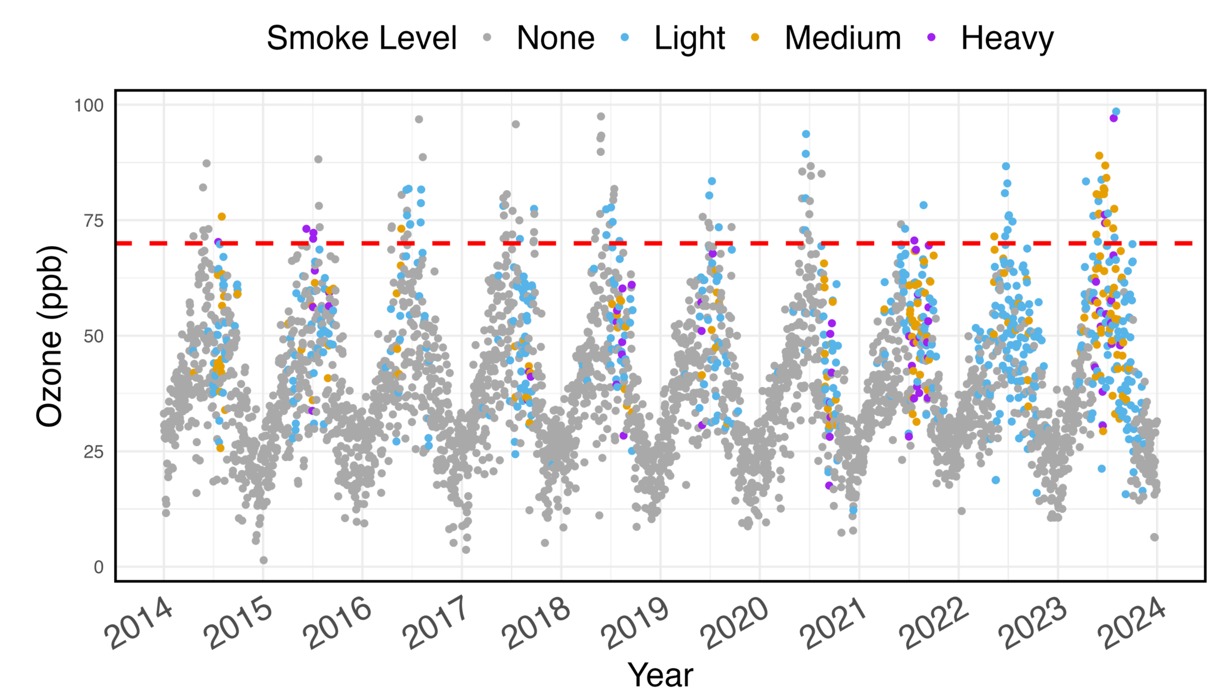
Ping Jing[1*], Weizhi Deng[2], Thomas Crabtree[1], Deborah Chen[3], Justin Harbison[3], Mena Whalen[4], Jun Wang[2]

(1) School of Environmental Sustainability, Loyola University Chicago, (2) Department of Chemical and Biochemical Engineering, University of Iowa, (3) Parkinson School of Health Sciences and Public Health, Loyola University Chicago, (4) Department of Mathematics and Statistics, Loyola University Chicago

*Contact: pjing@luc.edu

1. Motivation

- Chicago experienced unprecedented and prolonged wildfire smoke episodes during summer (May–September) 2023, and **only 5% of days were smoke-free.**
- Air quality deteriorated sharply. **On June 27, 2023**, Chicago recorded the worst air quality among major cities in the world (O'Kane, 2023).
- **There is an urgent need to understand how the wildfire smoke influenced ozone and public health in Chicago.**



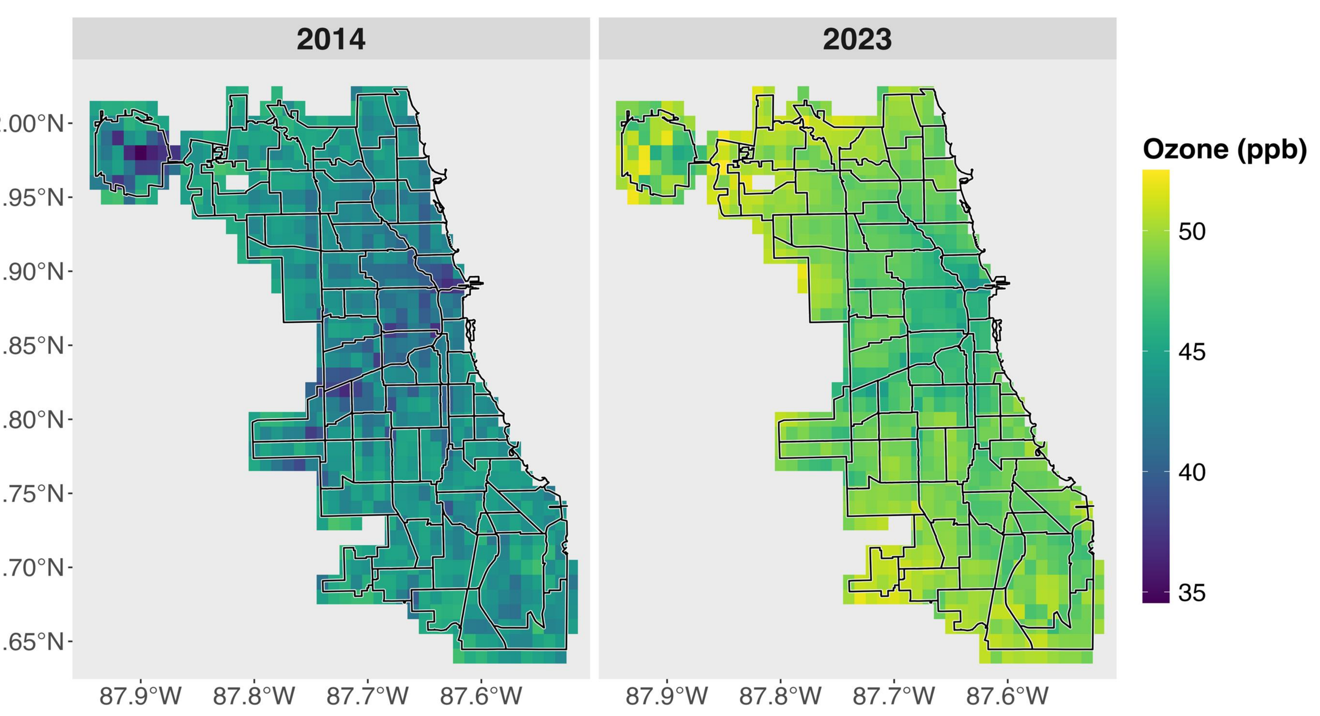
MDA8 O_3 concentrations among Chicago community areas from 2014 to 2023, colored by smoke level. The horizontal red dashed line marks the 2015 NAAQS of 70 ppb for O_3.

Objectives

1) Quantify the impact of wildfire smoke on ground-level O_3 levels in Chicago in 2023.
2) Estimate short-term daily health impacts associated with smoke-enhanced O_3 exposure.
3) Assess spatial disparities in exposure and health burdens across communities of different socioeconomic status.

2. Data Used

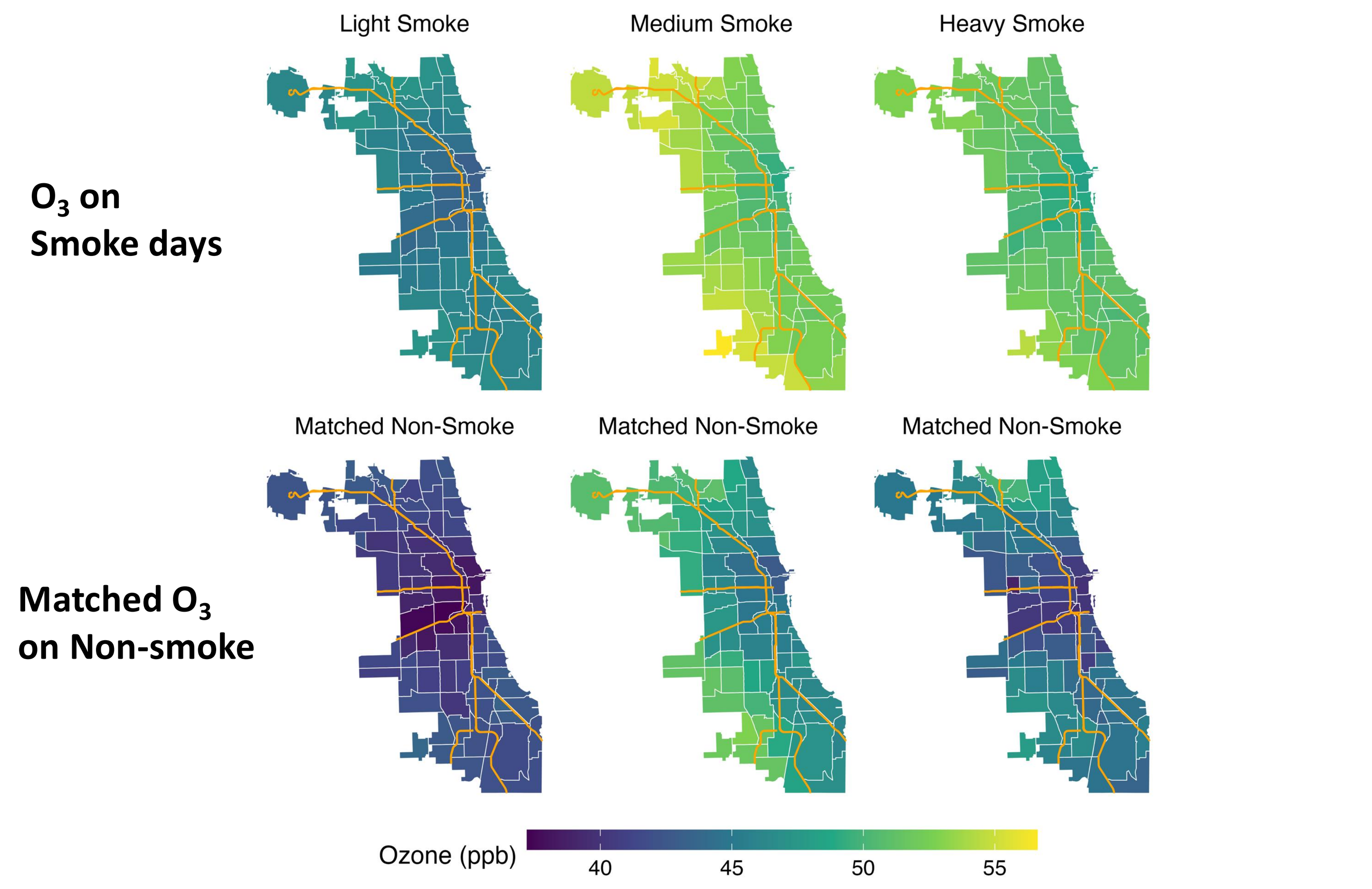
- **Smoke:**
  Satellite-derived smoke plume data from NOAA's Hazard Mapping System (HMS)
- **Ozone:**
  Downscaled (1 km × 1 km) maximum daily average 8-hr (MDA8) O_3 concentrations derived from a deep learning model trained on EPA AQS surface O3, meteorological fields from ERA5, and atmospheric composition from CAMS (Deng et al., 2025a and 2025b).
- **Chicago Community Data:**
  City of Chicago Data Portal
- **Meteorology:**
  GridMET daily data: maximum and minimum temperatures (Tmax, Tmin), surface shortwave solar radiation (Srad), wind speed (Vs) and direction (Th), and specific humidity (Sph).



Mean summertime (May–September) daily maximum 8-hour O_3 concentrations (ppb) at 1 km × 1 km resolution in Chicago community areas in 2014 and 2023.

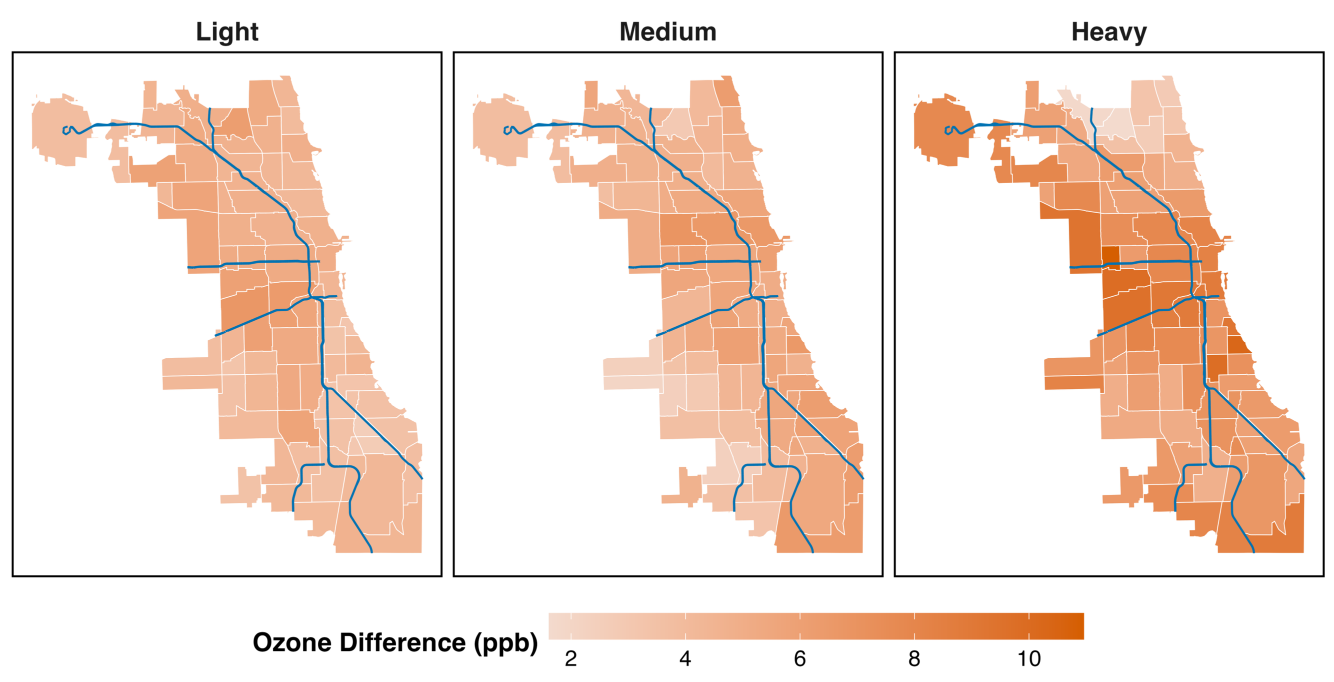
3. Assess Smoke-Enhanced O_3

Using MatchedIt Package in R, we compared O_3 levels on smoke-affected days in summer 2023 with those on non-smoke days under similar meteorological conditions from summer 2014–2022.

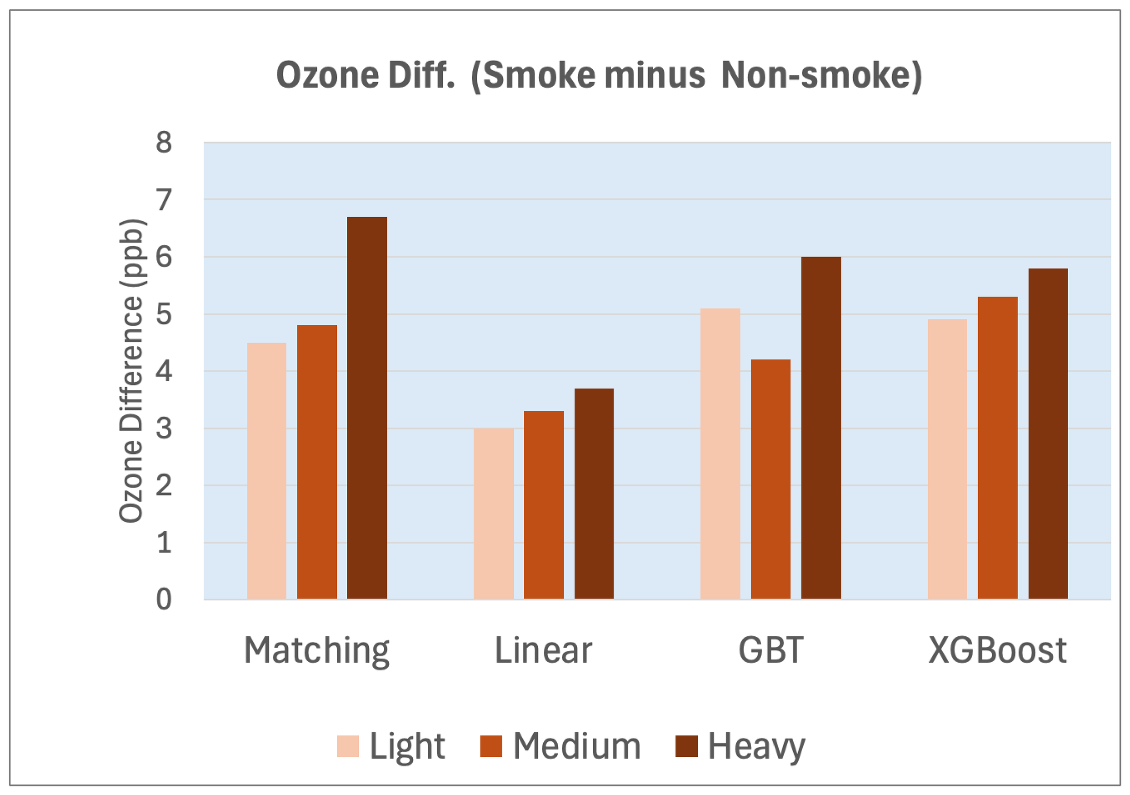


Community-level mean MDA8 O_3 concentrations in Chicago under light, medium, and heavy smoke conditions during summer 2023 (top row), compared with their respective matched non-smoke days from the summers of 2014–2022 (bottom row). Expressways are represented by the solid orange lines.

Ozone levels increased by up to 6.7 ppb in Chicago under heavy smoke conditions.



O_3 differences between smoke days during the summer of 2023 and matched non-smoke days by smoke level.

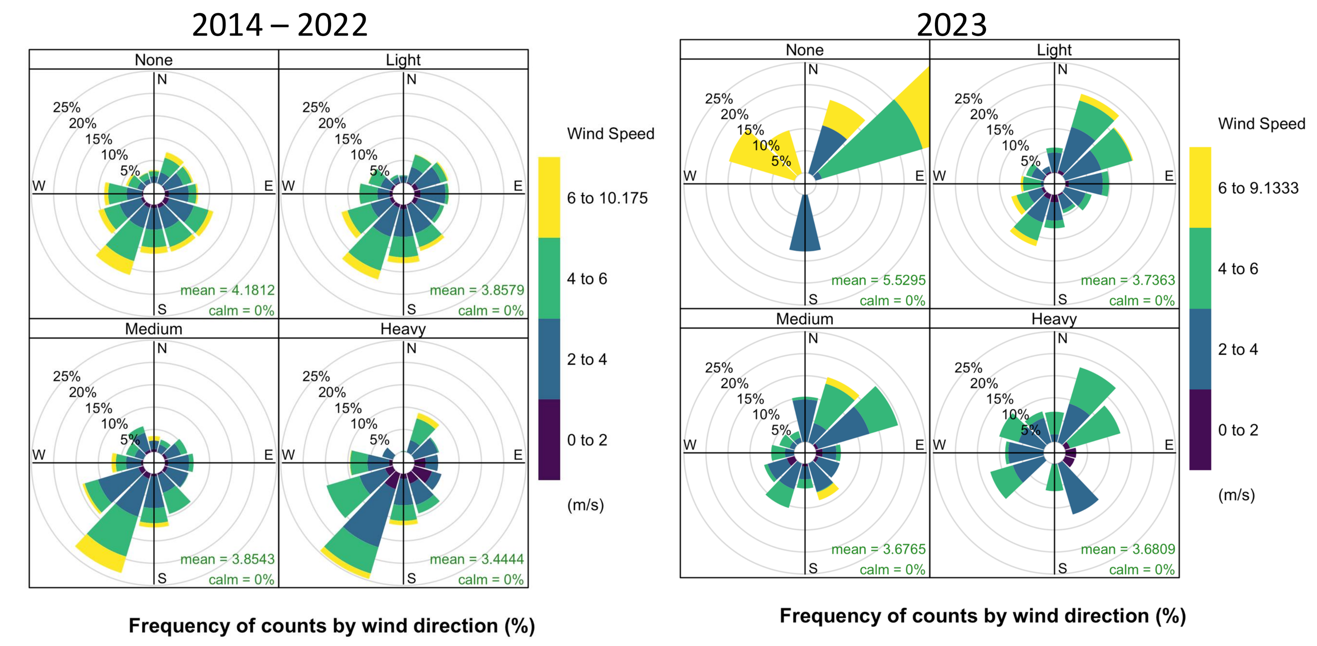


Comparison of median O_3 differences under light, medium, and heavy smoke levels during summer 2023, as estimated by four four methods: matching, linear regression, gradient-boosted trees (GBT), and extreme gradient boosting. (XGBoost).

Acknowledgements

The authors thank the National Oceanic and Atmospheric Administration, the Climatology Lab, and the City of Chicago for providing publicly accessible datasets used in this study. Ping Jing's research activity was made possible by release time granted through Loyola University Chicago's Faculty Development Leave program.

In summer 2023, smoke-affected days were primarily associated with winds from NE and SW.

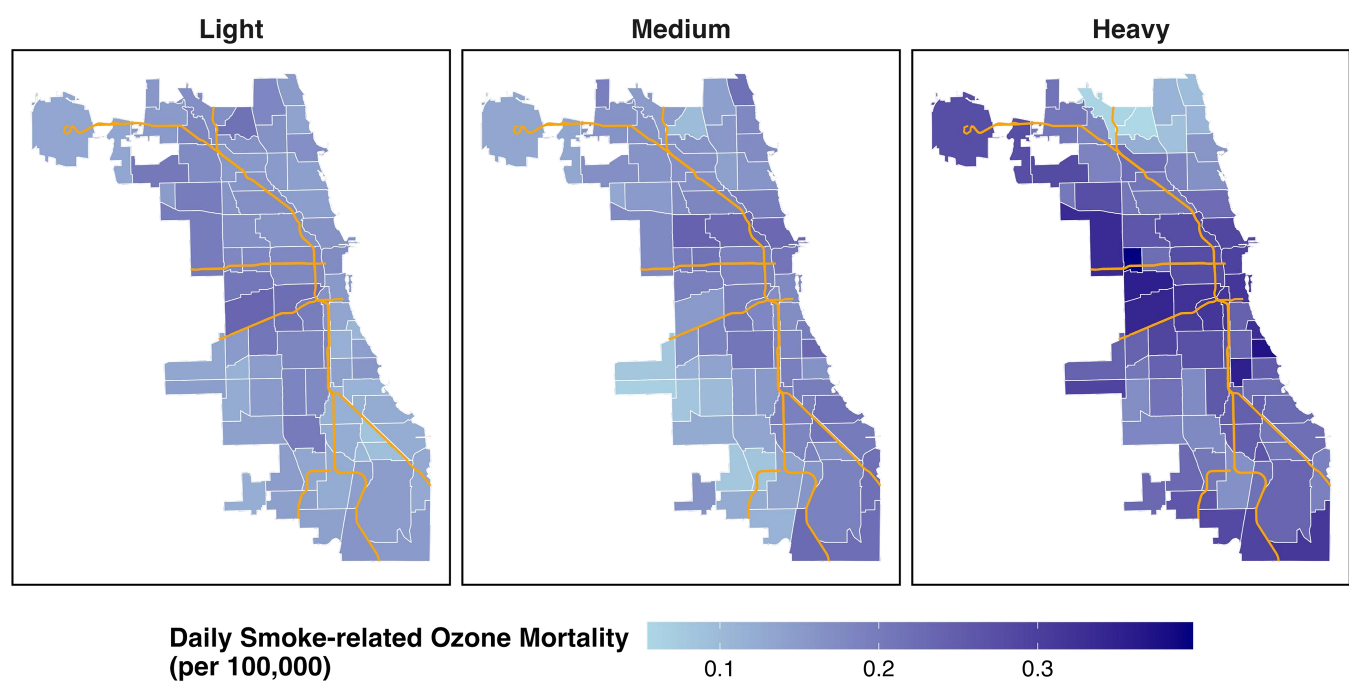


Wind rose plots showing the distribution of near-surface wind direction and wind speed during summers 2014–2022 (left) and 2023 (right) in Chicago by smoke level.

Smoke-related O_3 increases led to an estimated 0.24 additional deaths per 100,000 population in affected areas.

$$Attributable\ Cases = y_0 \times Pop \times (e^{\beta \cdot \Delta C} - 1)$$

- ***Baseline mortality rate (y0):*** 2.082×10^{-5} per person per day, derived from the annual all-cause mortality rate in Chicago 2010 – 2014 (Chicago Health Atlas).
- ***Population (Pop):*** Community –level population size from the 2020 U.S. Census (City of Chicago Data Portal).
- ***Exposure-response coefficient (β):*** 0.01595 per ppb, the daily increase in all-cause mortality associated with wildfire-related O_3 exposure (Chen et al., 2024).



Estimated daily all-cause mortality rates (per 100,000 population) attributable to smoke-related increase in daily O_3 concentrations across Chicago community areas under three categories of wildfire smoke exposure: light, medium, and heavy.

Future Directions

1. Future research should investigate disparities in smoke-related O_3 exposure and associated health effects across race, ethnicity, and socioeconomic groups in Chicago communities.
2. Future study should assess the combined effects of elevated O_3 and wildfire-derived $PM_{2.5}$ during smoke events in Chicago, as they together pose a substantial public health concern (Reid, et al., 2019).

References

- Chen, G., Guo, Y., Yue, X., Xu, R., Yu, W., Ye, T., ... & Zeka, A. (2024). All-cause, cardiovascular, and respiratory mortality and wildfire-related ozone: a multicountry two-stage time series analysis. The Lancet Planetary Health, 8(7), e452–e462
- City of Chicago (2025) Healthy Chicago 2025 Data Compendium. Retrieved May 12, 2025 from https://www.chicago.gov/content/dam/city/depts/cdph/CDPH/Healthy_Chicago_2025_Data-Compendium_10222019.pdf
- Deng, W., Wang, J., Zhou, M., Rouil, L. (2025a) Downscaled MDA8 ozone dataset over the contiguous USA (2003–2023) (Version v0) [Dataset]. Zenodo. https://doi.org/10.5281/zenodo.15178097
- Deng, W., Wang, J., Zhou, M., Chen, X., Wu, X., Zhang, H., Cohen, J. B., Wei, J., da Silva, A., Brasseur, G., Granier, C., Rouil, L. (2025b). Fire-Driven Trend Reversal in U.S. Ozone Exposure and Air Quality Progress. Under Review. Preprint doi:https://doi.org/10.21203/rs.3.rs-7024362/v1
- O'Kane, C. (2023, June 27) Chicago has the worst air quality in the world due to Canadian wildfire smoke. CBS News.
- Reid, C. E., Considine, E. M., Watson, G. L., Telesca, D., Pfister, G. G., & Jerrett, M. (2019). Associations between respiratory health and ozone and fine particulate matter during a wildfire event. Environ Int 129, 291–298.