Multi-Day Wildfire Smoke Exposure Thresholds & Distributions for an Oregon Health Impacts Study

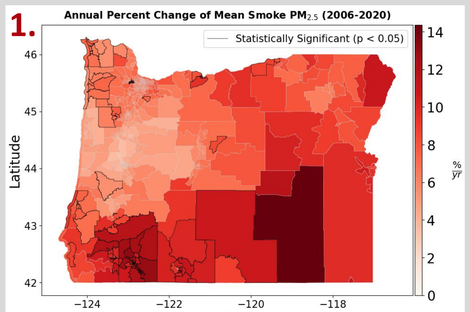
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Background & Motivation

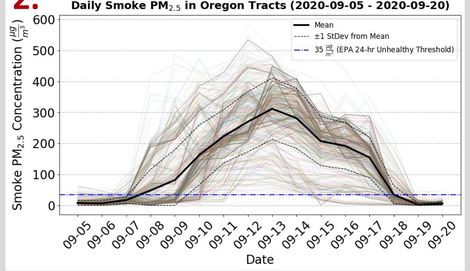
Wildfire smoke has drastically impacted air quality in Oregon[1]. Recent years saw the **most severe wildfire seasons in modern history**[1].

Fine particulate matter ($PM_{2.5}$) from wildfire smoke poses significant **respiratory and cardiovascular risks**, among other health impacts[2,3].

1.



2.



Few studies have focused on:

- Smoke health impacts on children and different demographic groups[4]
- **Duration of exposure**[5]

The goal of this project is to **determine thresholds**, **identify trends**, and **understand distributions** of Oregon smoke events in preparation for a health impacts case-crossover study.

Smoke Dataset Information

Data: Daily CONUS census tract-level wildfire-driven smoke $PM_{2.5}$ estimates

Date Range: 2006-01-01 ⟶ 2020-12-31

Focus Area: 834 Oregon census tracts

Source: Environmental Change and Human Outcomes (ECHO) Lab at Stanford University[6]

Smoke Event Thresholds & Justification

Medium Smoke Day: **9-15 µg/m³** | High Smoke Day: **15+ µg/m³**

Event: One or more consecutive days with smoke $PM_{2.5} \geq 9$ µg/m³ in a single census tract

The World Health Organization (WHO) states that 24-hour average exposures should not exceed 15 µg/m³ more than 3-4 days per year. This value encapsulates all 98th percentile smoke events in Oregon (Table 2).

The values of 9 and 15 µg/m³ are consistent with a similar case-crossover study conducted in Washington state from 2006-2017[7]:

- 15 µg/m³ was the 99th percentile of $PM_{2.5}$ concentrations during two relatively smoke free years in Washington state
- 9 µg/m³ was their lower threshold, which is also near the 98th percentile of all days in Oregon between 2012-2020 (Table 1)

Table 1 - Smoke $PM_{2.5}$ (µg/m³) percentiles for ALL Oregon census tract days, including days with zero smoke.

Percentile	2006-2020	2012-2020
95%	3.107	4.154
98%	6.918	9.467
99%	11.425	19.034

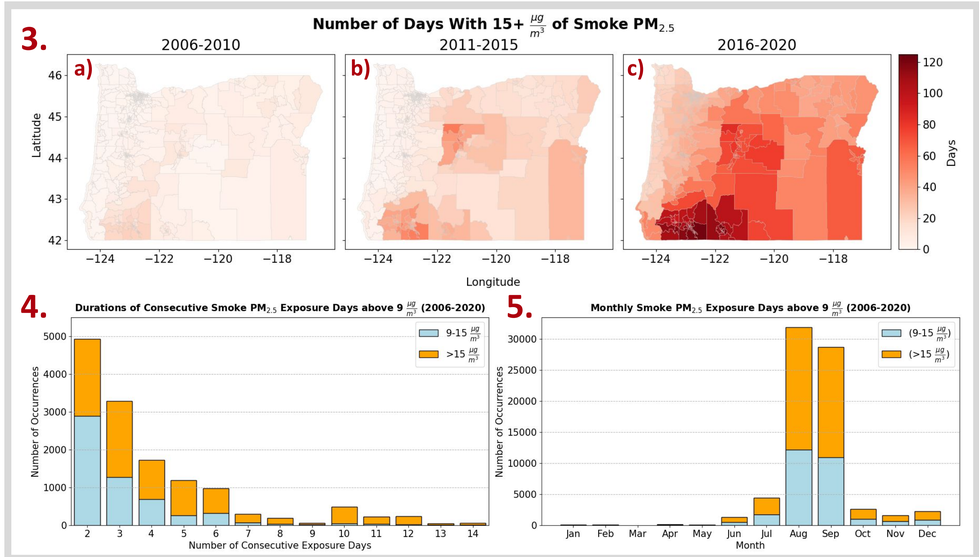
Table 2 - Smoke $PM_{2.5}$ (µg/m³) percentiles for ONLY Oregon census tract days with smoke.

Percentile	2006-2020	2012-2020
95%	10.236	12.614
98%	18.405	24.898
99%	33.627	43.616

Trends & Distributions of Smoke Events

- **25,317 total events** were identified between 2006-2020
- Several census tracts experienced **over 60 events and 300 days above 9 µg/m³** of smoke $PM_{2.5}$ individually, with over 60% of these days also exceeding 15 µg/m³ and occurring between 2016-2020
- Most event days occurred during **August and September**, but a significant portion also occurred during June-July and October-December

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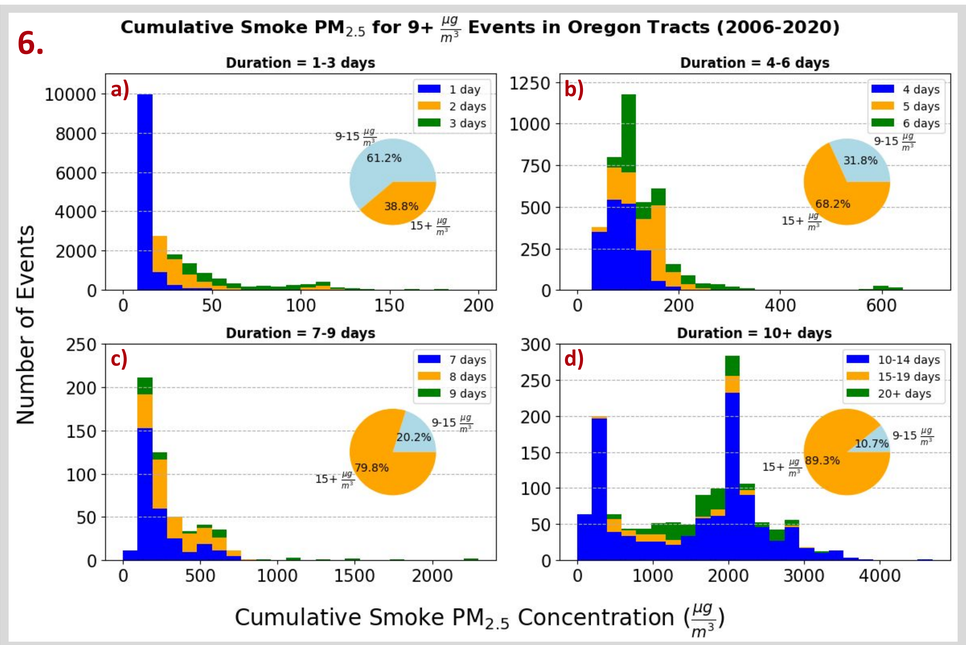
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Distributions of Smoke Event Durations

- In general, long-term events (7+ days) had a **greater fraction of high threshold days** (15+ µg/m³ of smoke $PM_{2.5}$) than short-term events (e.g. 1-3 days)
- There were over **1300 instances** of consecutive day events lasting at least 10 days within individual census tracts, where the longest event lasted **40 days**
- Over **900 instances** of consecutive day events exceeding a cumulative smoke $PM_{2.5}$ concentration of **1000 µg/m³** within individual census tracts were observed

6.



Ongoing & Future Work

Health Impacts Case-Crossover Study:

Focus: Examine the association between the duration and magnitude of exposure to smoke $PM_{2.5}$ and risk of hospitalization among different ages and demographic groups

Data: Oregon patient-level hospitalization records (2012-2022)

Health Impacts Studied:

- Respiratory
- Cardiovascular
- Pregnancy complications
- Acute mental health

Meteorological Reanalysis Data:

Data: Daily Oregon census-tract level temperature and heat index values

Purpose: Account for heat-related impacts on smoke days

Supplemental Information

Additional Oregon smoke $PM_{2.5}$ statistics, event analysis, short wildfire case studies, and more:

References & Acknowledgements

1. Rohlman et al., 2022, OHA's Climate and Health in Oregon 2021-2022 Report, Oregon Health Authority.
2. Chen, H., J.M. Samet, P.A. Bromberg, and H. Tong. 2021. Cardiovascular health impacts of wildfire smoke exposure. Particle and Fibre Toxicology 18:2. DOI: 10.1186/s12989-020-00394-8.
3. Jones, C.G., A.G. Rappold, J. Vargo, W.E. Cascio, M. Kharrazi, B. McNally, and S. Hoshiko. 2020. Out-of-hospital cardiac arrests and wildfire-related particulate matter during 2015–2017 California wildfires. Journal of the American Heart Association 9:e014125. DOI: 10.1161/JAHA.119.014125.
4. Künzli N, Avol E, Wu J, Gauderman WJ, Rappaport E, Millstein J, et al. Health effects of the 2003 Southern California wildfires on children. Am J Respir Crit Care Med. 2006;174(11):1221–8 Available from: https://www.ncbi.nlm.nih.gov/pubmed/16946126.
5. Ma, Y., Zang, E., Liu, Y., Wei, J., Lu, Y., Krumholz, H.M., Bell, M.L., Chen, K., 2024. Long-term exposure to wildland fire smoke $PM_{2.5}$ and mortality in the contiguous United States. medRxiv. DOI: 10.1101/2023.01.31.23285059
6. Marissa L. Childs, Jessica Li, Jeffrey Wen, Sam Heft-Neal, Anne Driscoll, Sherrie Wang, Carlos F. Gould, Minghao Qiu, Jennifer Burney, and Marshall Burke. 2022. Daily Local-Level Estimates of Ambient Wildfire Smoke $PM_{2.5}$ for the Contiguous US. Environmental Science & Technology 56 (19), 13607-13621. DOI: 10.1021/acs.est.2c02934
7. Doubleday, A., Schulte, J., Sheppard, L. et al. Mortality associated with wildfire smoke exposure in Washington state, 2006–2017: a case-crossover study. Environ Health 19, 4 (2020). https://doi.org/10.1186/s12940-020-0559-2

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