The World is on Wildfire

그런데.. 호흡기 질환을 곁들인..

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Wildfire

Uncontrolled fires that occur in a natural environment, such as forests, grasslands, or prairies.

Southern California Wildfires

Ignited on January 7, 2025, and were fully contained after 24 days, on January 31, 2025

Category	Palisades Fire	Eaton Fire	Total Impact
Total Area (km^2)	94.89	56.74	151.63 = 52.3Yeouido
Structures Destroyed	6,837	9,418	16,255
Fatalities	12	17	29
Estimated Cost	$28 - $275 billion	Included in total	$28 - $275 billion

Nearly three billion animals killed or displaced b Australia's fires

By Jack Guy, CNN

Updated 1232 GMT (2032 HKT) July 28, 2020

Greece faces 'disaster of unprecedented as wildfires ravage the country

By Chris Liakos, Elinda Labropoulou and Amy Woodyatt, CNN

Updated 2023 GMT (0423 HKT) August 10, 2021

Thousands more evacuated as California 24 times its size in 2 days

By Aya Elamroussi, CNN

Updated 1757 GMT (0157 HKT) August 19, 2021

The Caldor Fire burns through trees on Mormom Emigrant Trail east of Sly Park, California.

Maui blaze

Images from on the ground and from satellites show the devastation left by the wildfires, including buildings reduced to rubble and landscapes left charred.

Saturday 12 August 2023 05:20, UK

산불의 정의?

산림보호법 제2조 제7호에서 정하는 "산림이나 산림에 잇닿은 지역의 나무, 풀, 낙엽 등이 인위적으로나 자연적으로 발생한 풀에 타는 것"으로 정의

대형산불의 정의?

우리나라는 산불로 인한 피해면적이 100ha 이상, 산불 지속시간이 24시간 이상 이어질 때 대형산불로 분류

산불확산 3요소

연료

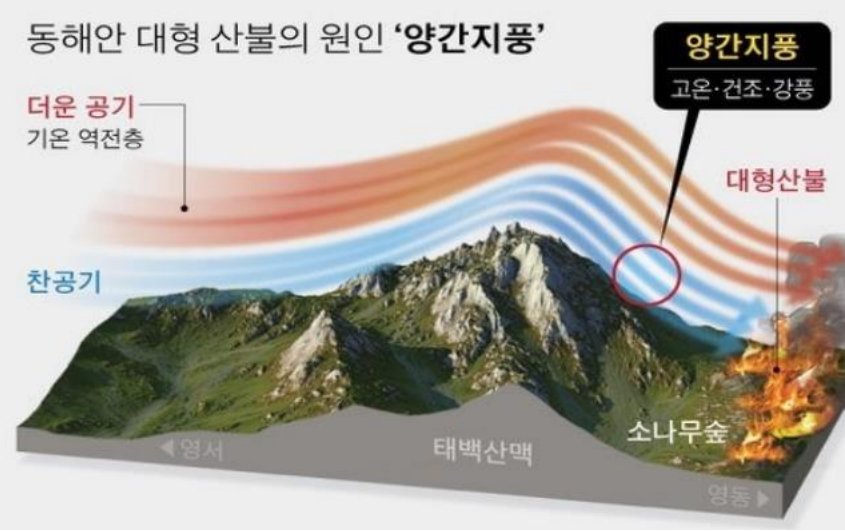
탈 수 있는 물질을 공급

지형

고도, 경사, 경사향, 지세 등

기상

바람, 습도, 온도, 강수 등



경남 산청 산불로 160명 대피...'산불 3단계' 발령

2025.03.21. 오후 9:49.

사천 산불 1단계 '진화율 85%'...경남도, 산불 대응 체계 점검

노컷뉴스 원문 | 기사전송 2025-03-20 20:17

0 0

AI챗으로 요약

최신뉴스

강원 평창서 산불…3시간여 만에 꺼져(종합)

송고 2025-03-13 17:57

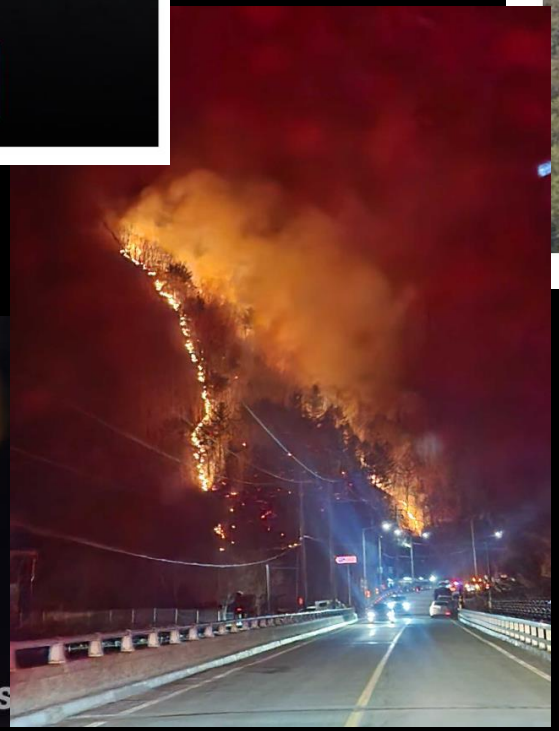
강태현 기자
+ 구독

평창 산불 현장

[동부지방산림청 제공. 재판매 및 DB 금지]

불티에 산림 '활활'...정선 산불 18시간 만에 진화

2025.02.22. 오후 10:02.

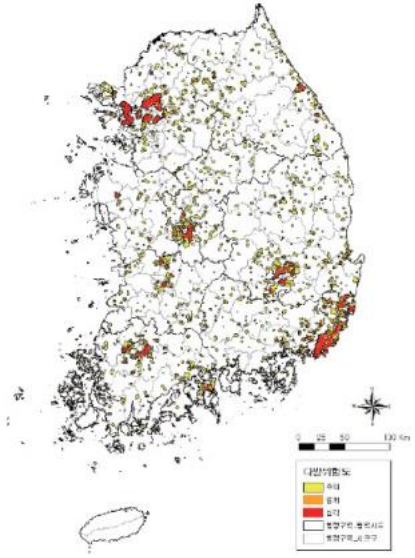


Wildfire of Korea

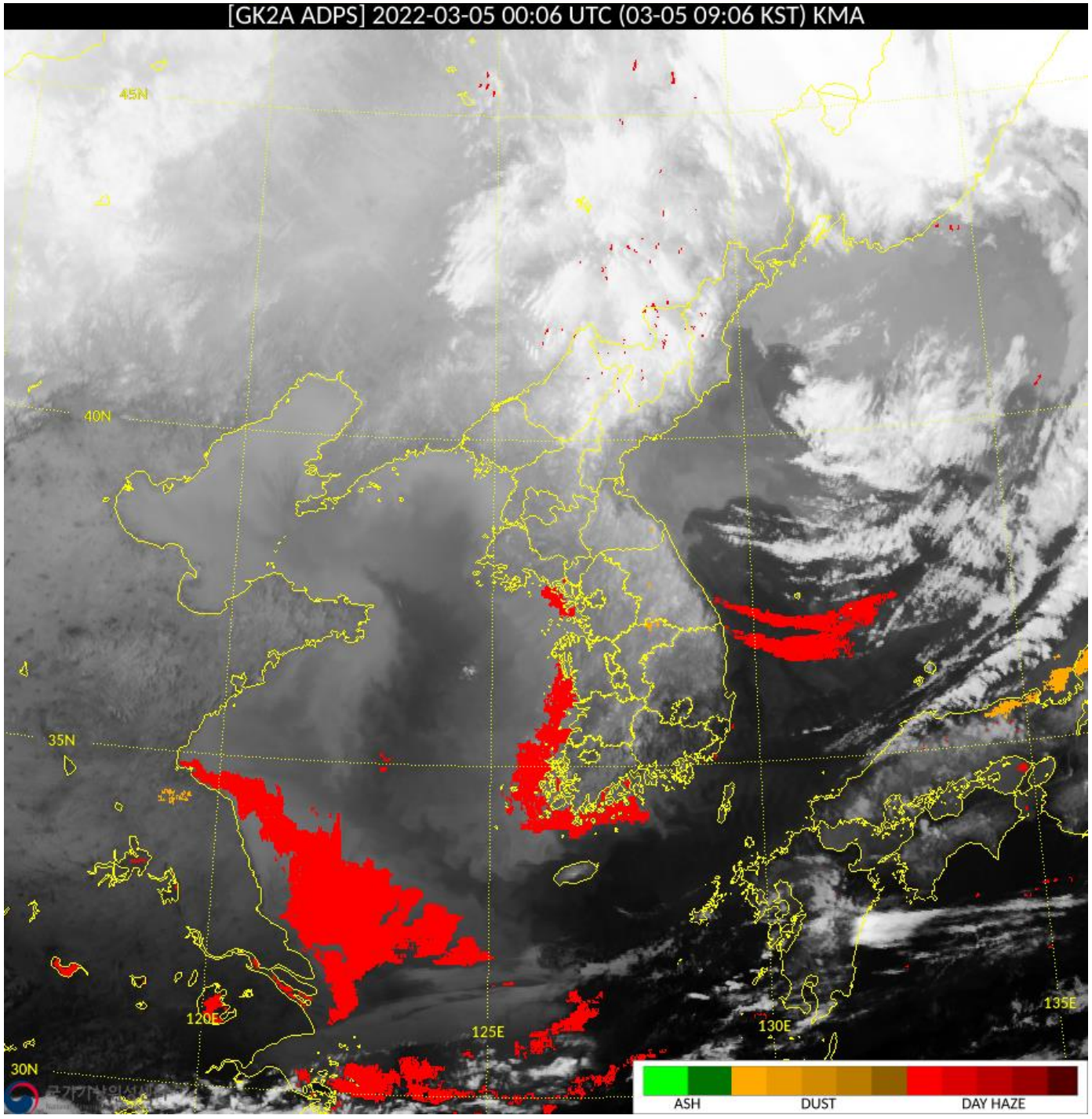
〈최근 10년 간 연도별 산불발생건수(건) 및 피해면적(ha)〉

연도	산불발생건수(건)	피해면적(ha)
2014년	492	137
2015년	623	418
2016년	391	378
2017년	692	1,480
2018년	496	894
2019년	653	3,255
2020년	620	2,920
2021년	349	766
2022년	756	24,797
2023년	596	4,992

※ 출처 : 산림청 산불통계



산불다발지역지도



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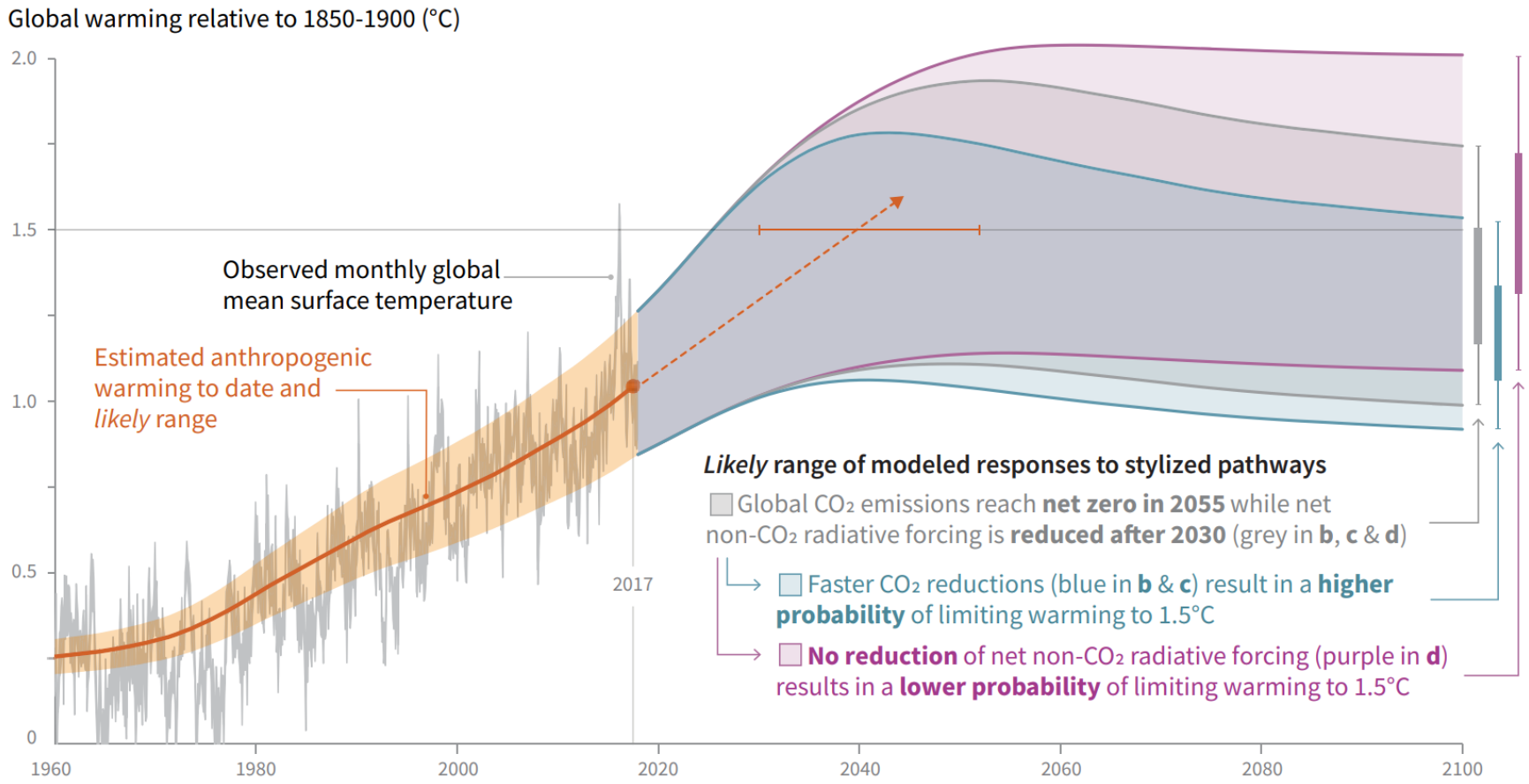
- Protecting health against Wildfires
- Mitigating Wildfire risks by limiting Global warming
- Insight of Research on the Respiratory Health Impacts of Wildfire smoke

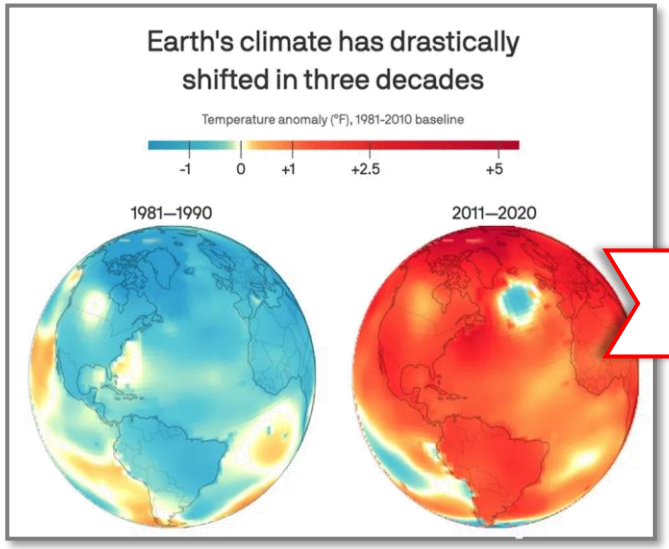
Climate Change and Wildfire

Climate change(Global Warming) & Wildfires

Devastating effects of human-induced climate change



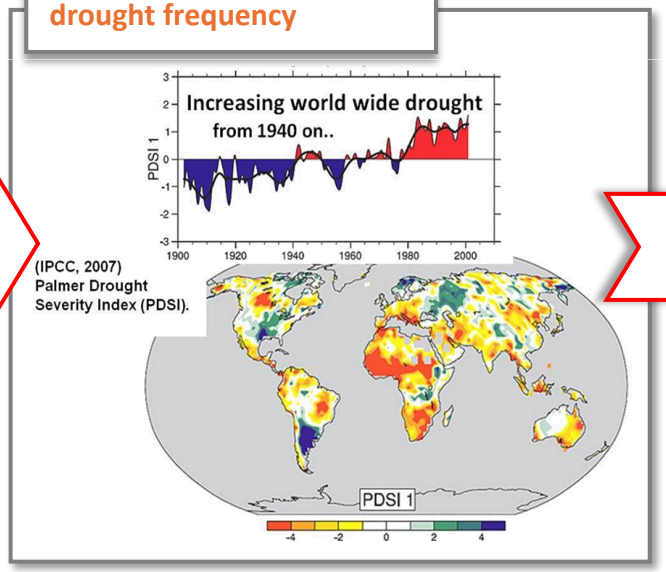
Global warming of 1.5°C: Geneva: Intergovernmental Panel on Climate Change, 2018.



Global Temperature Rises: Global Warming

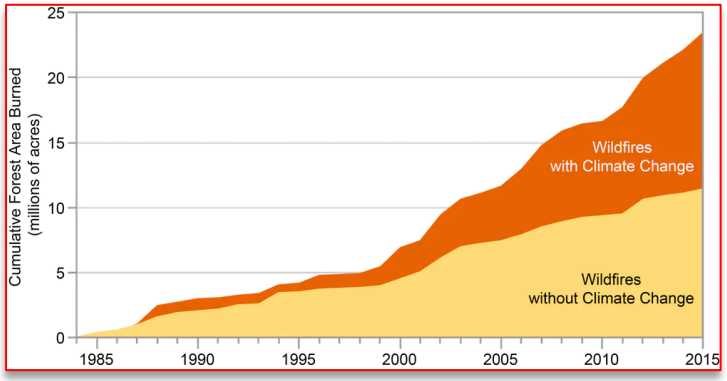
Climate Change

Increasing dry area and drought frequency



Climate Change

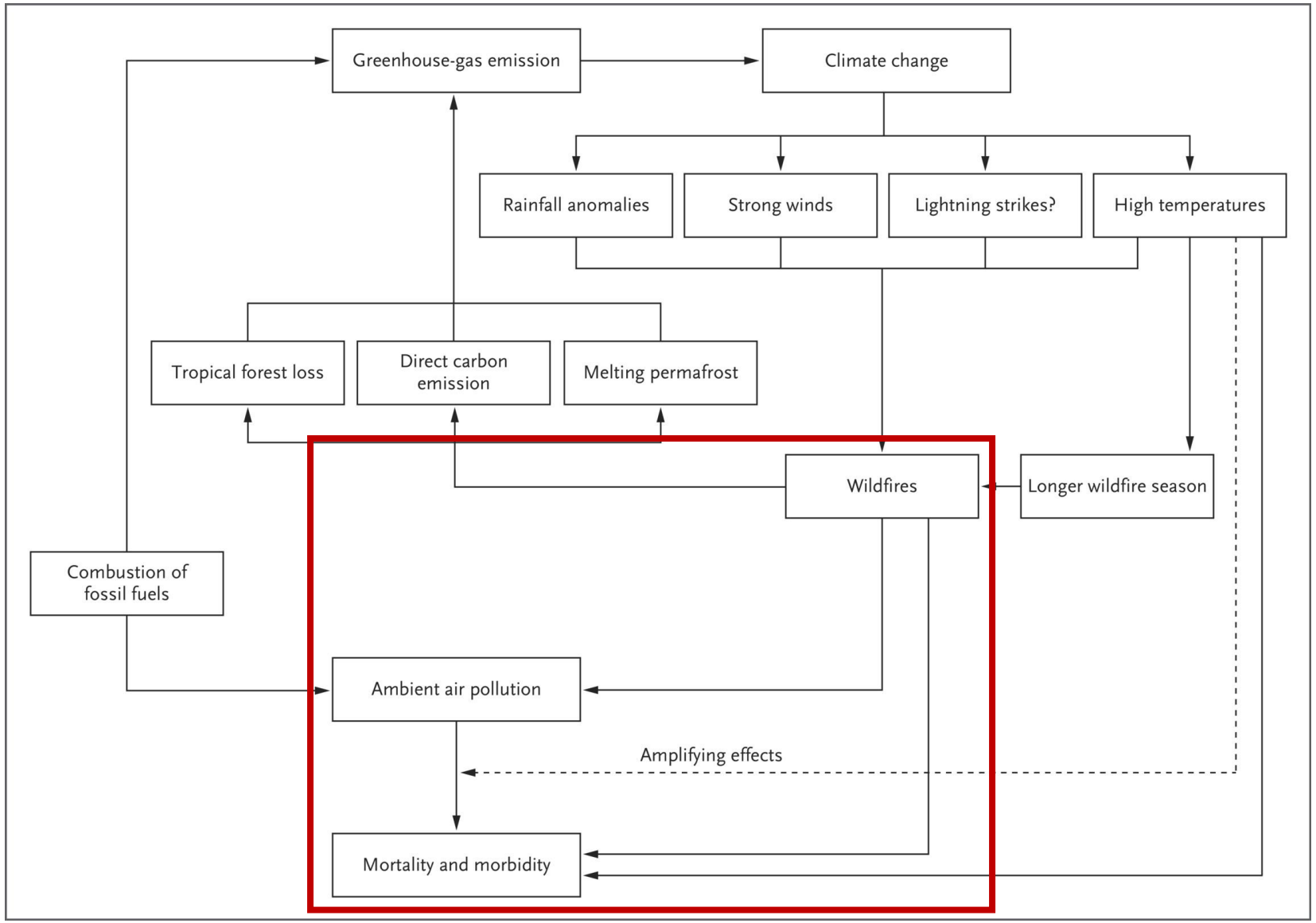
Increasing burned area from wildfire and length of fire season



Climate change factors leading to increase wildfires:

- Intensifying drought
- Increase in surface wind
- Increase in the frequnecy and intensity of heat waves
- Longer wildfire season because of a warming climate

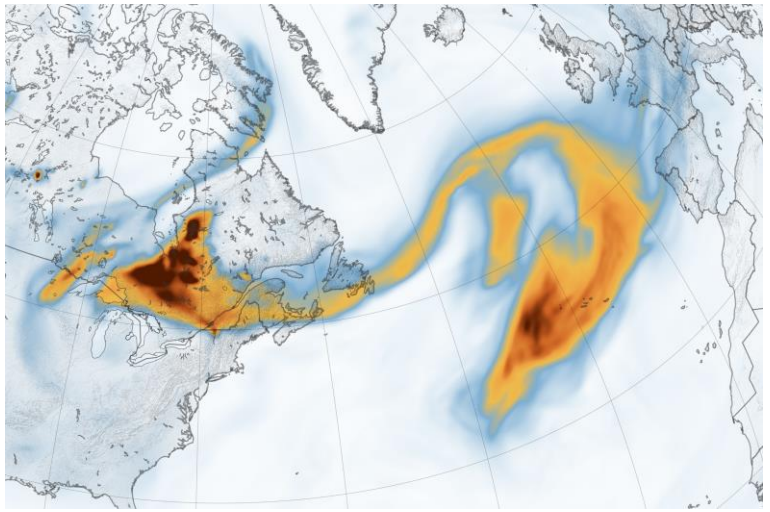
Potential Reinforcing Feedback Loop of Climate Change, Wildfires, and Health Risks.



N Engl J Med, 2020;383:2173-2181

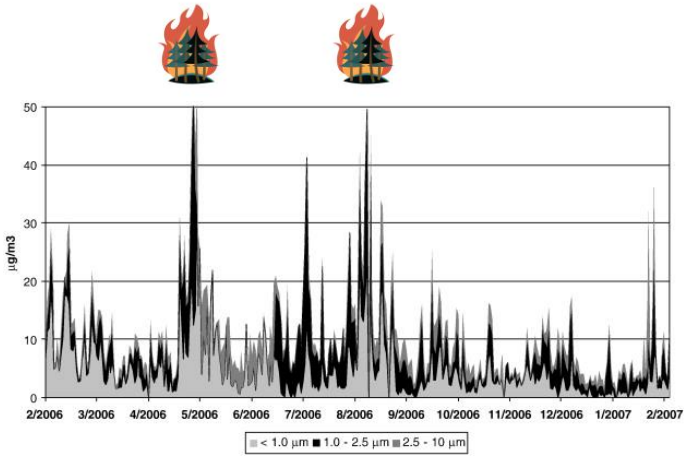
Air Pollutant from **Wildfire Smoke**

- **Composition** of Wildfire Smoke
  - Depending on the fire's size, temperature, materials burned, distance, and environmental conditions like wind speed, temperature, and humidity
  - **Extremely high level of Particulate Matter (Especially $PM_{2.5}$)**
    - Most studies focused on the health risks associated with wildfire $PM_{2.5}$
  - **Carbon monoxide, nitrogen oxides** (NO, NO_2)
  - **Volatile Organic Compounds and Gases**
    - Photochemical reaction between VOCs and NOx → **Ozone**
    - Toxic carcinogen – Benzene, Formaldehyde and hydrogen cyanide
    - Heavy metal – Hg, Pb..
      - O3, PMs → Spread farther
- **Wildfire smoke - Increasingly important source of ambient air pollution**
  - Industrial emissions of air pollutants are declining

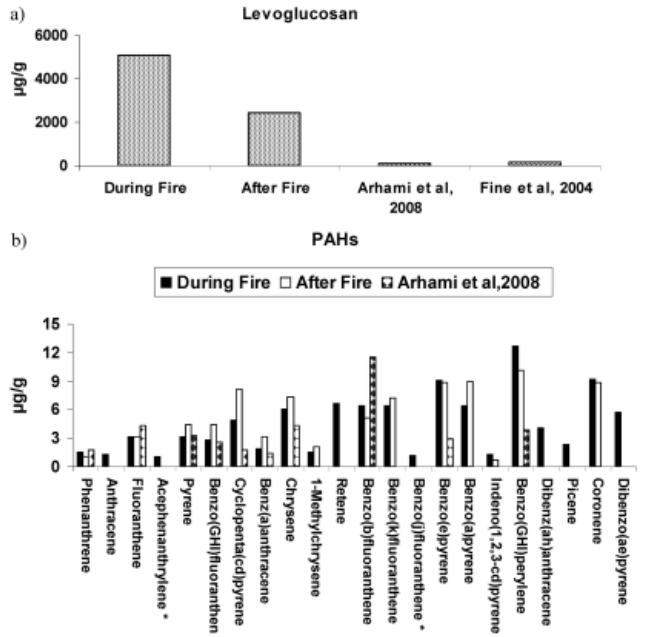


Characteristics of Wildfire PM

Source	Wildfire particulate matter results from **Combustion of biomass**
Particle size	**Smaller than PM from urban sources** **(i.e., with a higher proportion of $PM_{2.5}$ and PM_1 in PM_{10})**
Contribution to ambient PM	Contributing factor on **20% of the days that $PM_{2.5}$ level exceeded standard** (35 μg per cubic meter) During the 2019–2020 Australian wildfire, the daily **$PM_{2.5}$ level reached 600 μg per cubic meter**
Components and toxic effects	**More oxidative components** (oxygenated PAHs and quinones) **More proinflammatory components** (aldehydes and oxides of nitrogen) → **Greater oxidative potential** When **wildfire PM reaches urban areas, toxic effects on macrophage cells could be 5X than urban PM** **High temperatures and oxidant gases amplify health risks**



Sci Total Environ 2010;408:644-651.



Sci Total Environ 2010;408:644-651
Sci Total Environ 2017;603-604:268-278

Health risks associated with Wildfires

Direct health risks from Wildfire events

Direct Health Risks from Wildfire Events

- For Vulnerable people (Wildfire prone area)
  - Direct health effects include burns, injuries, mental health effects, and death
  - Due to exposure to flames or radiant heat

- PTSD (Psychiatric)
  - Firefighter
  - Children and Adolescents

Int J Environ Res Public Health 2019;16:1604-1604.

Aust N Z J Psychiatry 2018;52:542-551.

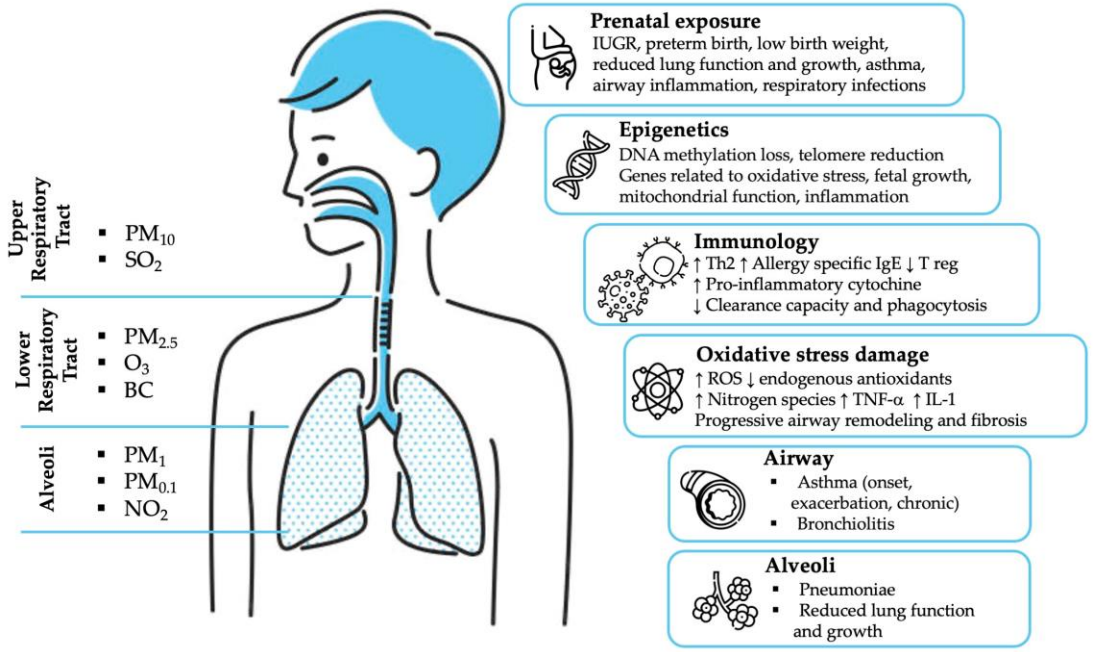
BMC Psychiatry 2019;19:18-18.

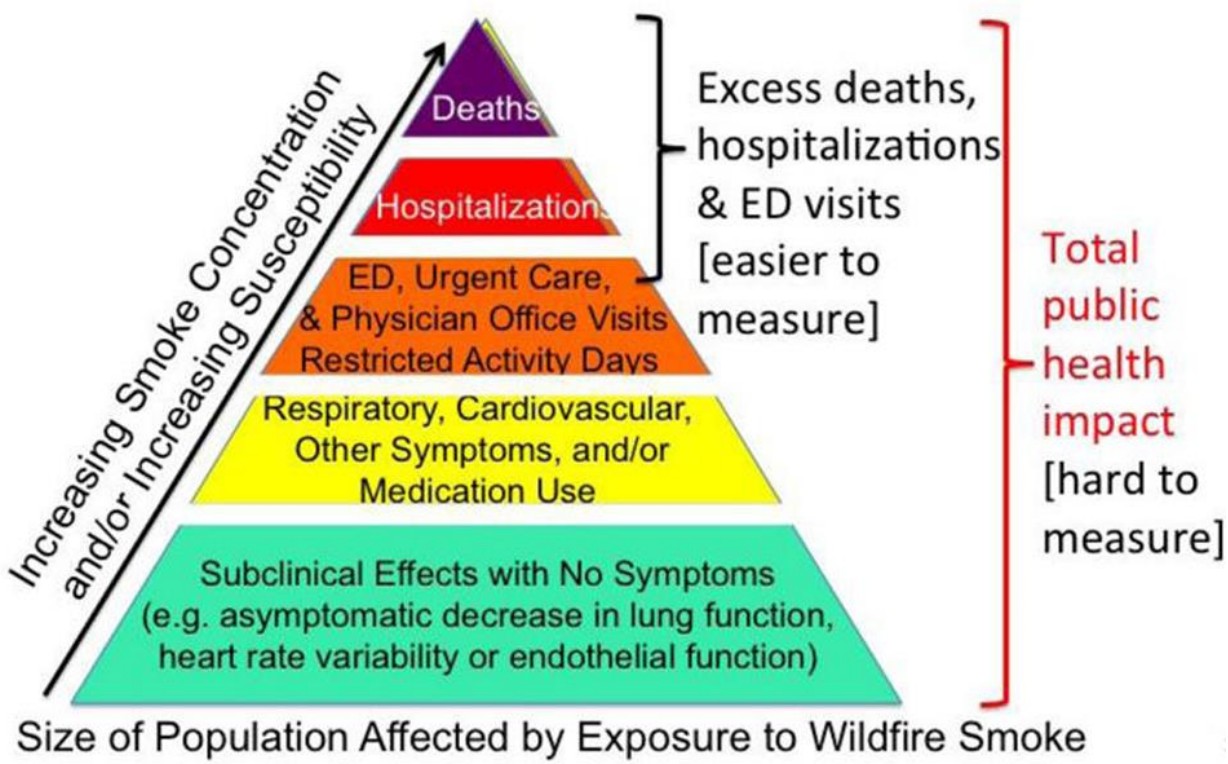
The 2009 “Black Saturday” wildfires in Australia
Killed 173 people directly; in the first 72 hours

Respiratory Health risks from Wildfire Smoke

Short-term & Long-term respiratory health effects of wildfire smoke

Health risks associated with Wildfire Smoke





Curr Opin Pulm Med. 2019 March ; 25(2): 179–187

Short-Term Health Effects of Wildfire Smoke

- **PM Levels During Wildfires**
  - (2020) 25 million in US were exposed to at least 1 day with wildfire $PM_{2.5}$ > 100 µg /m^3
  - Near fires: $PM_{2.5}$ levels reach **350–500 µg/m^3** (U.S. : 35 µg/m^3)
  - Up to 1000 km away: $PM_{2.5}$ levels **35–150 µg/m^3**

BBC News. September 18, 2020

- **Mortality Risks**

PM Level Increa	urce
$PM_{2.5}$ (Wil	e events
PM_{10} (Wil	e events
$PM_{2.5}$ (Urb	ban sources
PM_{10} (Urb	ban sources

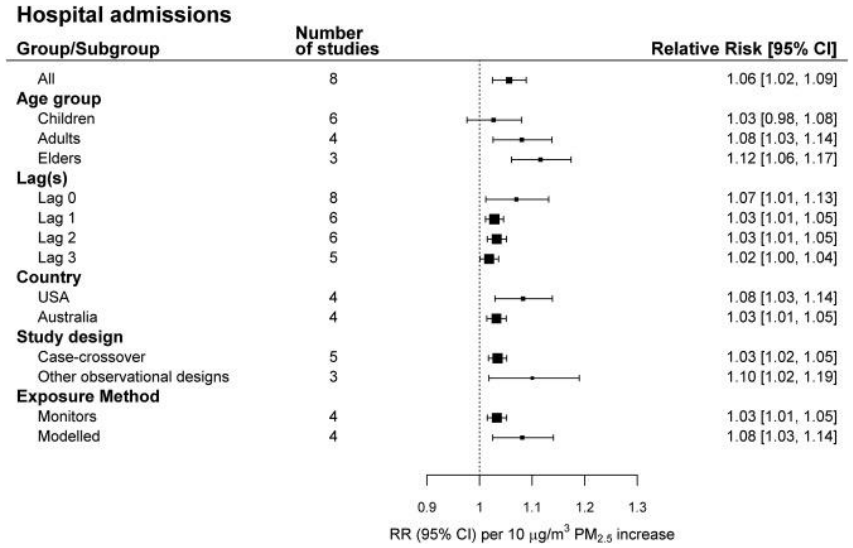
Perspect 2016;124:1334-1343
ol Pharmacol 2017;55:186-195
otal Environ 2018;624:586-595

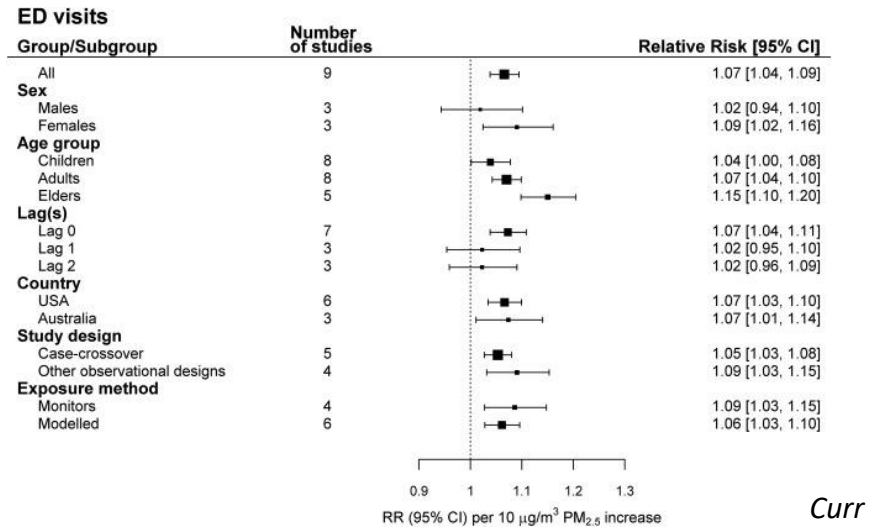
Short-Term Health Effects of Wildfire Smoke

- **Respiratory Effects of Wildfire Particulate Matter**
  - Strong and Consistent Associations
    - **Increased Healthcare utilization (hospitalizations, emergency visits, and physician visits)**
    - **High medication use for asthma, COPD, and respiratory infections**

Sci Total Environ 2018;624:586-595 / *Int J Epidemiol*. 2022 Feb 18;51(1):166-178/ *Environ Health Perspect* 2016;124:1334-43

  - **Asthma-Related Event**
    - Strongest association among all respiratory outcomes
    - Wildfire PM has greater effects than urban PM due to oxidative/proinflammatory properties → Asthma





Curr Opin Pulm Med 2019;25:179-87
Environ Res 2019;179:108777-108777

Peat Bog Wildfire Smoke Exposure in Rural North Carolina Is Associated with Cardiopulmonary Emergency Department Visits Assessed through Syndromic Surveillance

Ana G. Rappold,[1] Susan L. Stone,[1] Wayne E. Cascio,[1] Lucas M. Neas,[1] Vasu J. Kilaru,[2] Martha Sue Carraway,[1] James J. Szykman,[3] Amy Ising,[4] William E. Cleve,[5] John T. Meredith,[6] Heather Vaughan-Batten,[7] Lana Deyneka,[7] and Robert B. Devlin[1]

[1]Environmental Public Health Division, National Health and Environmental Effects Research Laboratory, and [2]National Exposure Research Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, USA; [3]Environmental Sciences Division, National Exposure Research Laboratory, U.S. Environmental Protection Agency, NASA Langley Research Center, Hampton, Virginia, USA; [4]Department of Emergency Medicine, School of Medicine, University of North Carolina, Chapel Hill, North Carolina, USA; [5]Pitt County Memorial Hospital, Greenville, North Carolina, USA; [6]Brody School of Medicine at East Carolina University, Department of Cardiovascular Sciences and the East Carolina Heart Institute, Greenville, North Carolina, USA; [7]North Carolina Division of Public Health, North Carolina Department of Health and Human Services, Raleigh, North Carolina, USA

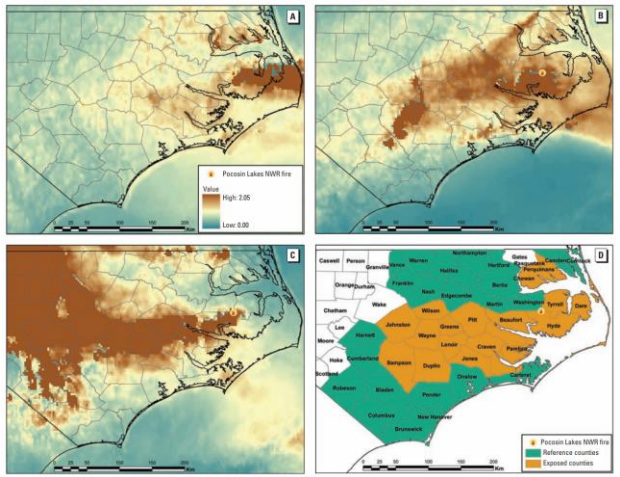


Figure 1. Aerial maps showing counties impacted by the Evans Road Fire at the Pocosin Lakes National Wildlife Refuge on 10, 11, and 12 June 2008 (*A*, *B*, and *C*, respectively) as measured by satellite AOD images. (*D*) Assignment of counties as exposed or referent.

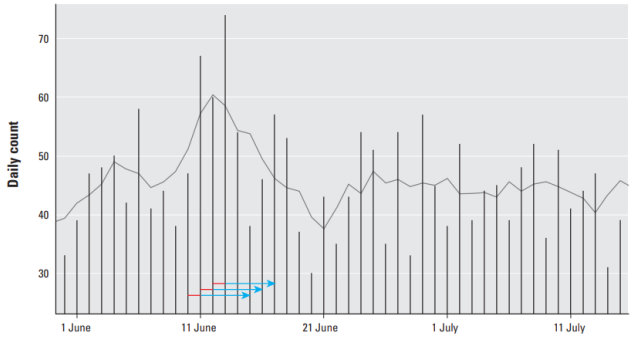
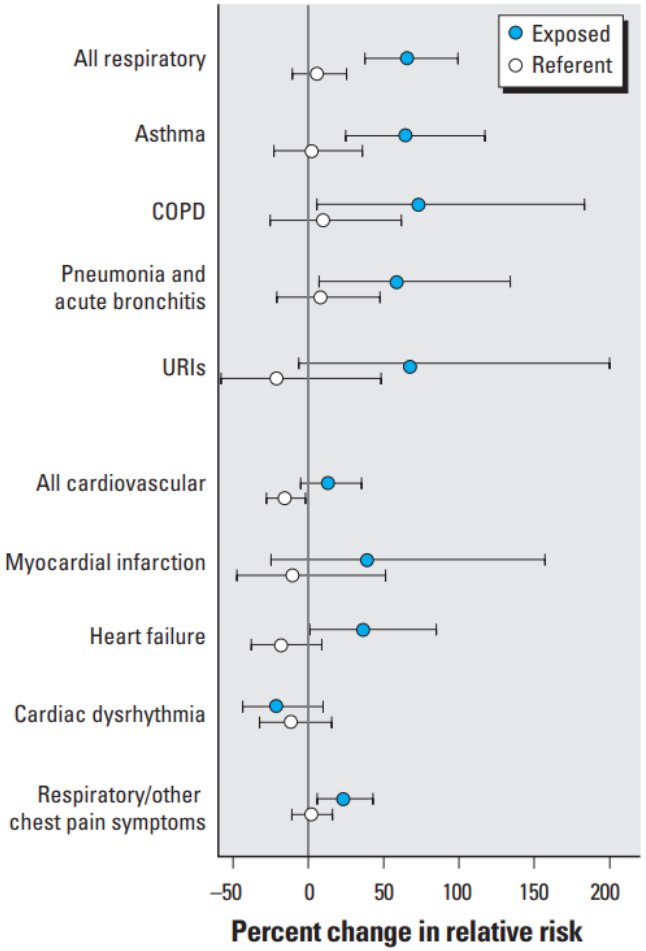


Figure 2. Daily counts of asthma-related ED visits in the exposed counties. Arrows represent the 3 days of high exposure (red) and the subsequent 5 lag days (blue).



- Daily ED visits 111 of 114 North Carolina Eds
  - Exposed counties vs. Reference counties
  - Study period - 1 June–14 July 2008
    - **10–12 June as a window of high exposure**
- **Exposed county**
  - RR : Days in which a county was exposed to wildfire smoke (and corresponding 5 lag days) was compared with other days in which that county was not exposed to smoke
- Result
  - Significant increases in cumulative RR for
  - **Asthma** [1.65 (95% confidence interval, 1.25-2.1)],
  - **COPD** [1.73 (1.06-2.83)
  - **Pneumonia and acute bronchitis** [1.59 (1.07-2.34)]
- **Satellite data and syndromic surveillance** were combined to assess the health impacts of wildfire smoke in rural counties with sparse air-quality monitoring.

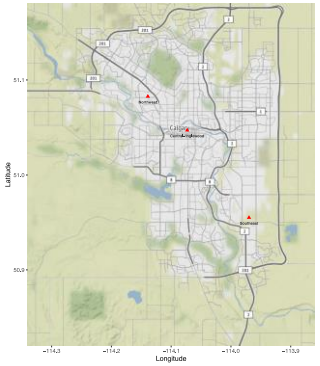
Environ Health Perspect. 2011 Oct;119(10):1415-20.

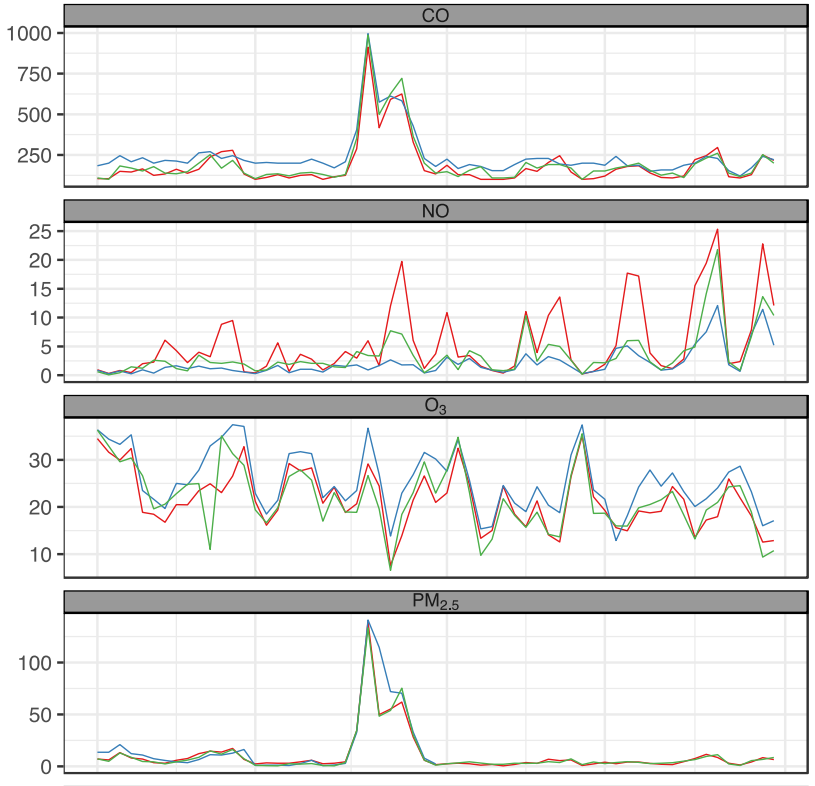
International Journal of Epidemiology, 2022, 166–178
doi: 10.1093/ije/dyab206
Advance Access Publication Date: 25 September 2021
Original article

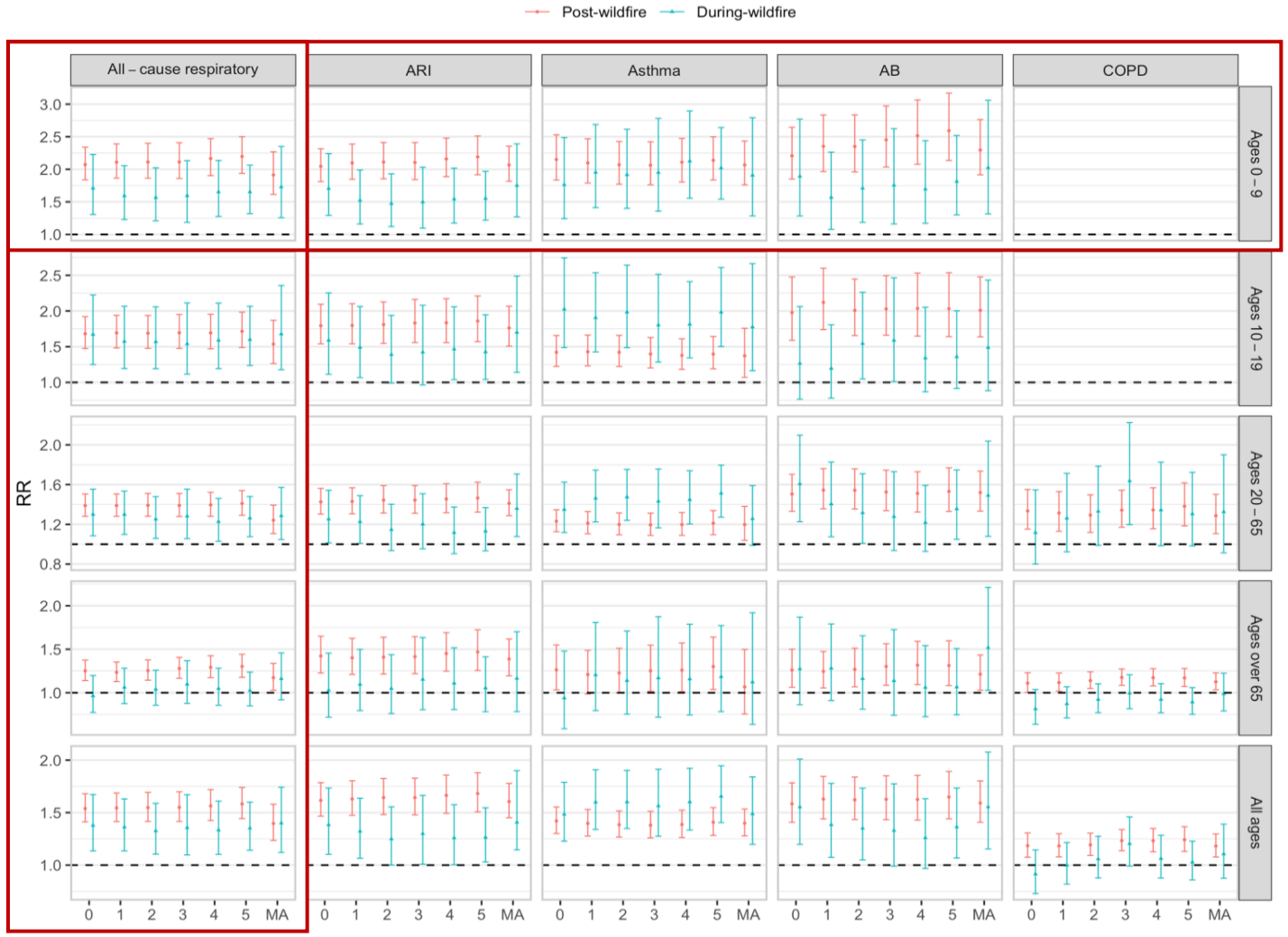
Fires and Smoke Exposure

Respiratory and cardiovascular condition-related physician visits associated with wildfire smoke exposure in Calgary, Canada, in 2015: a population-based study

MD Mahsin,[1] Jason Cabaj[2,3] and Vineet Saini[1,3]*



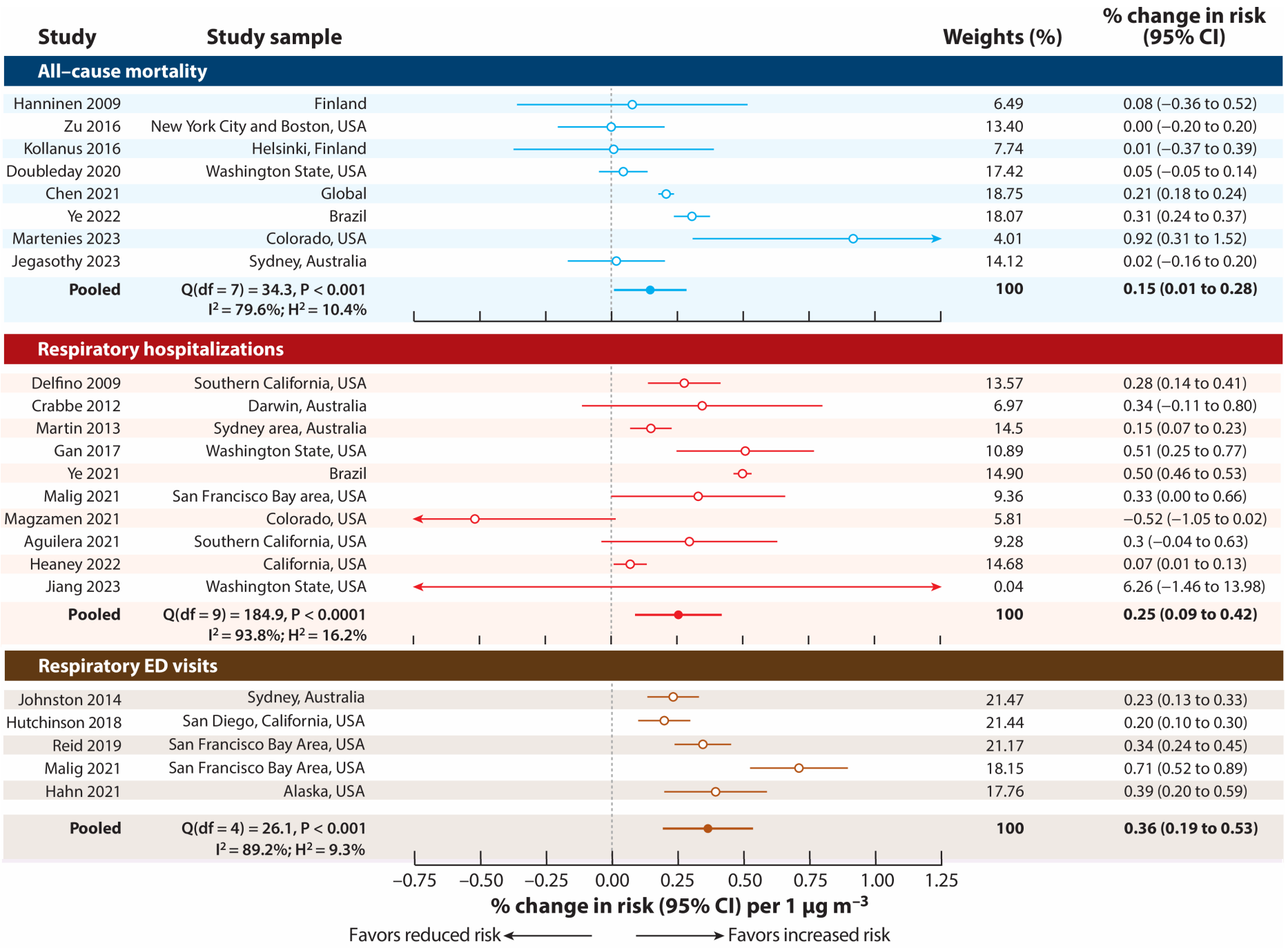




Impact of Wildfire $PM_{2.5}$ - Respiratory Disease Healthcare utilization:

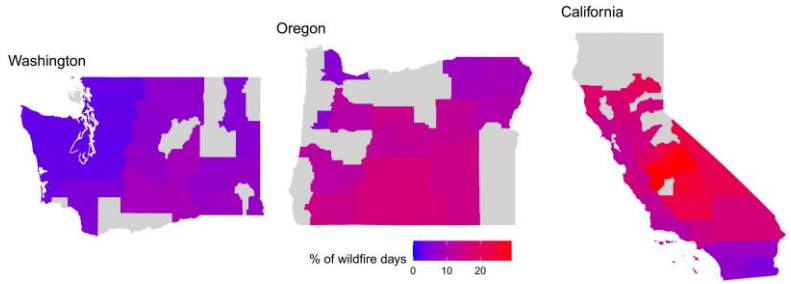
- **33% increase during wildfire / 55% increase post-wildfire** (RR: 1.55, 95% CI: 1.42–1.69)
- **OPD for asthma, acute respiratory infection and acute bronchitis conditions during and after the wildfires**
- **Children and adolescents have higher risk of physician visits due to wildfire smoke-related $PM_{2.5}$ exposure.**

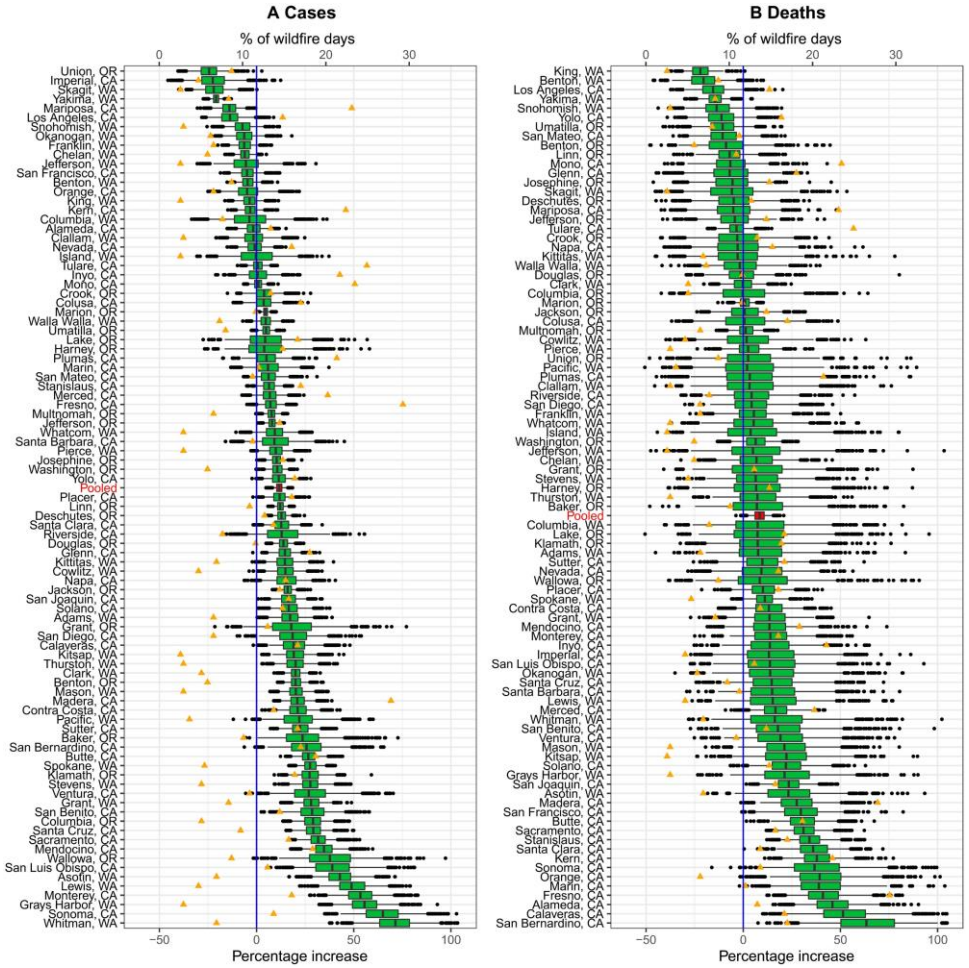
Int J Epidemiol. 2022 Feb 18;51(1):166-178.



Annu Rev Med. 2024 Jan 29;75:277-292.

COVID-19 & $PM_{2.5}$ by wildfires??





- **Study Design - Multi-site time-series analysis**
  - **92 counties** (**March–December 2020**)
  - **Exposure:** Daily $PM_{2.5}$ levels (Wildfire vs Non-wildfire)
  - **Outcome:** COVID-19 cases and deaths
- **Analysis Approach**
  - **BH-ZINB-DL Model** adjusting for **weather, seasonality, and mobility**
- **Key Findings**
  - **Higher $PM_{2.5}$ levels led to increased COVID-19 cases and deaths.**
    - **10 μg/m³ $PM_{2.5}$ increase → 11.7% rise in COVID-19 cases, 8.4% rise in deaths**

Science Advance, 2021; 7 : eabi8789

(Unpublished) Impact of wildfire smoke on respiratory disease associated healthcare utilization in Gangwon province, South Korea, in 2017

Min-Taek Lee[1,2†], Hoyoung Cha[6†], Ju Won Lee[1,2], Jongjin Baik[7], Hae In Jung[3,4], Kyoung Min Moon[3,4] Changhyun Jun[7], Sun-Young Jung[1,2*] Kang-Mo Gu[3,4,5*]

[1]College of Pharmacy, Chung-Ang University, Seoul, Korea

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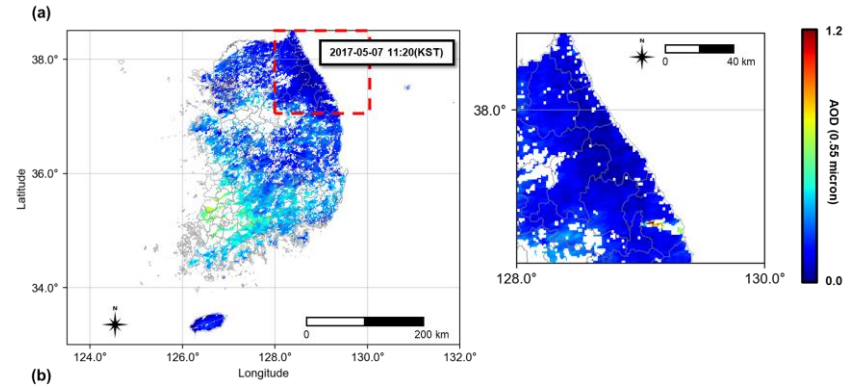
[6]Department of Civil, Environmental and Architectural Engineering, Korea University, Seoul, Korea

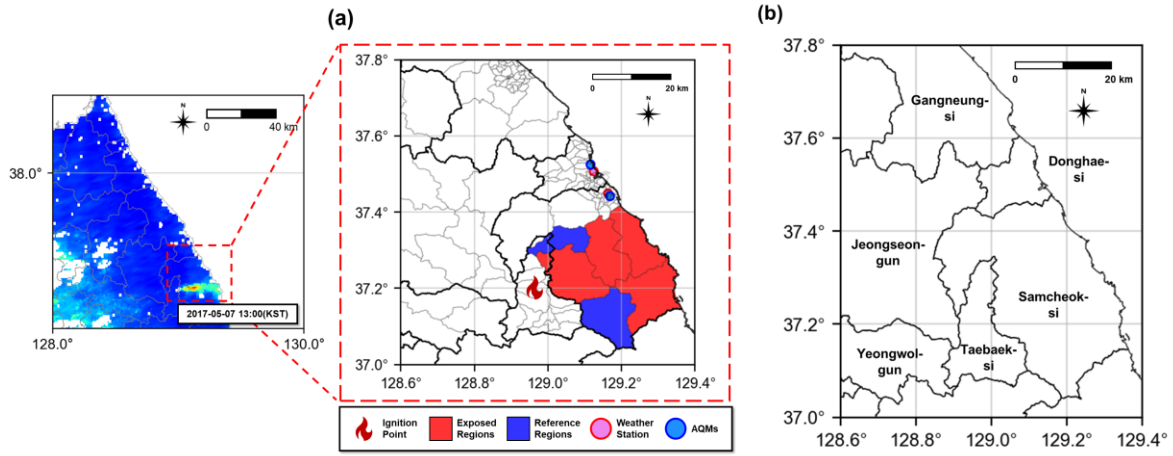
[7]School of Civil, Environmental and Architectural Engineering, Korea University, Seoul, Korea

Methods - Study Area & Period

- Gangwon Province Overview
  - 81.5% forest coverage
  - Structure vulnerable to wildfires
- Wildfire Incident area (A.O.D.)
  - May 6-9, 2017 in Samcheok and Donghae (764Ha)
- Study Period
  - Pre-wildfire: April 22 – May 5, 2017
  - Wildfire: May 6 – 9, 2017
  - Post-wildfire: Immediate and extended (2-week)

4.22.~5.5. (14 days)	5.6.~5.9	5.10.~5.23. (14 days)	5.24.~6.6. (14 days)
Pre-wildfire Period (Control)	**During Wildfire**	**Immediate Post-wildfire Period**	**Extended Post-wildfire Period**



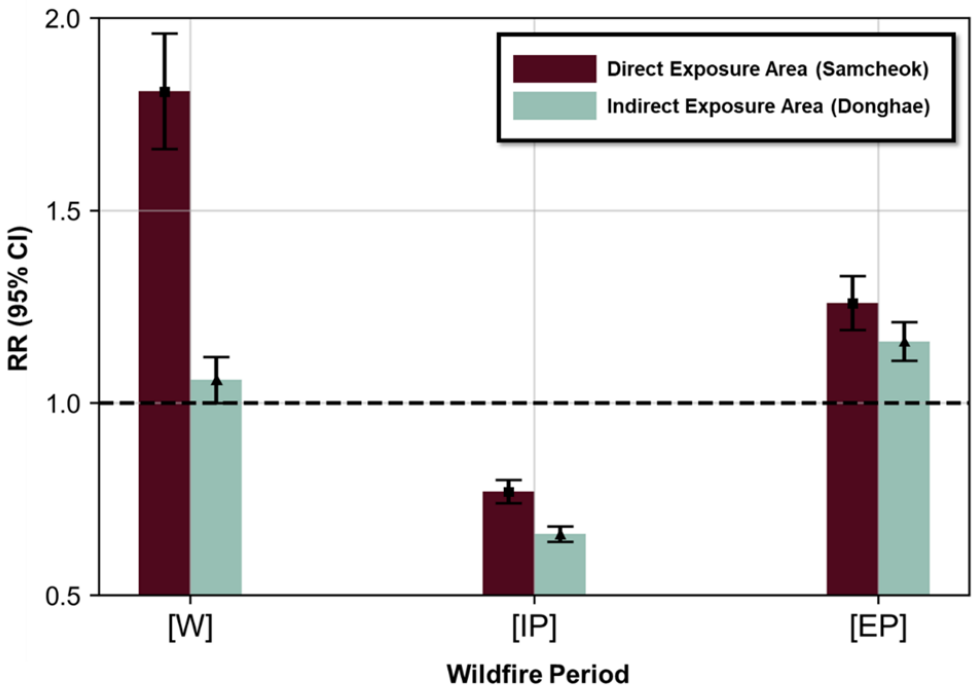


Wildfire-exposed areas
(a) Locations of ignition of AQMs, Weather Station, and Affected Areas from the May 6, 2017, wildfire
(b) Administrative divisions of Gangwon-do (Samcheok (directly-exposed area), Donghae (indirectly-exposed area)

Methods – Data Collection

- Air Pollutants Monitored
  - Data from Air Korea and satellite-based AOD (Aerosol Optical Depth)
  - $PM_{2.5}$, PM_{10} (μg/m^3), O_3 (ppm), NO_2 (ppm), CO (ppm), and SO_2 (ppm)
  - Normalization - Maximum-minimum normalization
- Healthcare Utilization
  - National Health Insurance Service (NHIS) - National Health Information Database
  - Respiratory disease healthcare utilization
    - Outpatient department visits
    - Emergency department visits
    - Hospitalizations
  - Respiratory diseases
    - Pneumonia (J13 and J15-18), acute bronchitis (J20), acute bronchiolitis (J21), unspecified lower respiratory tract infection (J22), COPD (J40-44), asthma (J45-46), and bronchiectasis (J47)

Relative Risk of Respiratory Disease healthcare utilization by Region



(a) Samcheok (Direct exposed area)

Age Group (year)	2017 [W] RR (95% CI)	2017 [IP] RR (95% CI)	2017 [EP] RR (95% CI)
All age	1.81(1.67–1.96)	0.77(0.75–0.80)	1.26(1.20–1.33)
≥ 20	1.83(1.68–1.98)	0.76(0.74–0.79)	1.23(1.17–1.29)
0-9	2.20(2.04–2.38)	0.83(0.80–0.86)	1.44(1.37–1.52)
10-19	1.23(1.13–1.33)	0.71(0.69–0.74)	1.09(1.03–1.15)
20-65	1.90(1.76–2.06)	0.80(0.77–0.82)	1.19(1.13–1.25)
>65	1.76(1.61–1.93)	0.71(0.68–0.73)	1.24(1.17–1.31)

(b) Donghae (Indirect exposed area)

Age Group (year)	2017 [W] RR (95% CI)	2017 [IP] RR (95% CI)	2017 [EP] RR (95% CI)
All age	1.06(1.01–1.12)	0.66(0.64–0.68)	1.16(1.11–1.21)
≥ 20	1.21(1.14–1.27)	0.64(0.62–0.66)	1.08(1.03–1.12)
0-9	0.71(0.67–0.75)	0.71(0.69–0.74)	1.57(1.51–1.64)
10-19	1.08(1.02–1.13)	0.66(0.64–0.68)	0.96(0.92–1.00)
20-65	1.13(1.08–1.19)	0.67(0.66–0.69)	1.07(1.03–1.11)
>65	1.40(1.31–1.49)	0.59(0.57–0.61)	1.07(1.02–1.12)

- **During the wildfire period - the direct-exposure area 81% increase RR (RR = 1.81, 95% CI 1.67–1.96) vs 6%**
- **During the extended post-wildfire period, the direct-exposure area an 26% increase in the RR vs. 16%**

Relative Risk Ratio of Respiratory Disease healthcare utilization by Region

(a) Samcheok (Direct exposed area)

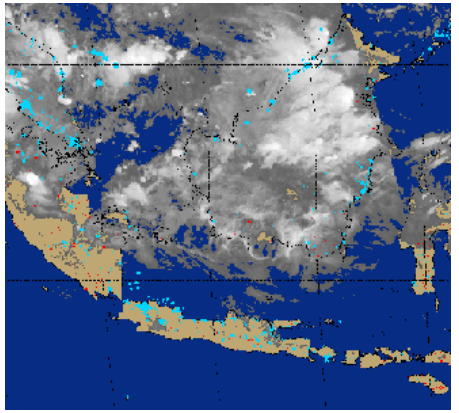
Age Group (year)	2017 [W] RR (95% CI)	2017 [IP] RR (95% CI)	2017 [EP] RR (95% CI)	2017/2018 [W] RRR (95% CI)	2017/2018 [IP] RRR (95% CI)	2017/2018 [EP] RRR (95% CI)
All age	1.81(1.67–1.96)	0.77(0.75–0.80)	1.26(1.20–1.33)	1.30(1.15–1.45)	0.97(0.91–1.04)	1.75(1.61–1.91)
≥ 20	1.83(1.68–1.98)	0.76(0.74–0.79)	1.23(1.17–1.29)	1.49(1.32–1.67)	1.04(0.97–1.11)	1.84(1.69–2.00)
0-9	2.20(2.04–2.38)	0.83(0.80–0.86)	1.44(1.37–1.52)	1.37(1.22–1.54)	0.94(0.87–1.00)	1.83(1.67–2.01)
10-19	1.23(1.13–1.33)	0.71(0.69–0.74)	1.09(1.03–1.15)	1.39(1.24–1.55)	1.20(1.12–1.28)	1.99(1.83–2.17)
20-65	1.90(1.76–2.06)	0.80(0.77–0.82)	1.19(1.13–1.25)	1.44(1.29–1.61)	0.98(0.92–1.04)	1.72(1.58–1.86)
>65	1.76(1.61–1.93)	0.71(0.68–0.73)	1.24(1.17–1.31)	1.22(1.07–1.39)	0.94(0.87–1.01)	1.67(1.52–1.83)

(b) Donghae (Indirect exposed area)

Age Group (year)	2017 [W] RR (95% CI)	2017 [IP] RR (95% CI)	2017 [EP] RR (95% CI)	2017/2018 [W] RRR (95% CI)	2017/2018 [IP] RRR (95% CI)	2017/2018 [EP] RRR (95% CI)
All age	1.06(1.01–1.12)	0.66(0.64–0.68)	1.16(1.11–1.21)	0.48(0.45–0.52)	0.51(0.48–0.53)	0.81(0.77–0.86)
≥ 20	1.21(1.14–1.27)	0.64(0.62–0.66)	1.08(1.03–1.12)	0.53(0.50–0.58)	0.48(0.45–0.50)	0.74(0.70–0.78)
0-9	0.71(0.67–0.75)	0.71(0.69–0.74)	1.57(1.51–1.64)	0.31(0.29–0.33)	0.55(0.52–0.58)	1.09(1.03–1.16)
10-19	1.08(1.02–1.13)	0.66(0.64–0.68)	0.96(0.92–1.00)	0.75(0.70–0.80)	0.59(0.57–0.62)	0.90(0.85–0.96)
20-65	1.13(1.08–1.19)	0.67(0.66–0.69)	1.07(1.03–1.11)	0.55(0.51–0.59)	0.53(0.50–0.55)	0.80(0.76–0.85)
>65	1.40(1.31–1.49)	0.59(0.57–0.61)	1.07(1.02–1.12)	0.52(0.48–0.57)	0.42(0.40–0.44)	0.63(0.59–0.68)

- In the **direct-exposure area**, the **RRRs during the wildfire (RRR = 1.30, 95% CI 1.15–1.45)** and **extended post-wildfire (RRR = 1.75, 95% CI 1.61–1.91) periods** were significantly elevated.

Long-Term Effects of Wildfire Smoke



- **1997 Indonesian Forest Fires** (12 million hectares burned)
  - **Indonesia Family Life Survey (IFLS)** (1997–2007)
  - **15,000+ individuals**
  - **Significant long-term negative effects** of wildfire smoke exposure on **Lung capacity / Self-reported general health /Physical functioning**

Table 1
Lung capacity regression results – full sample analysis (OLS estimation). Dependent variable: lung capacity (as measured in 2007).

Explanatory variables	Coefficient	Robust standard error
Pollution	−5.370***	1.052
Age	−4.646***	0.234
Age squared	0.0215***	0.00238
Education	1.904***	0.183
Log PCE	3.098***	1.075
Having outside kitchen	1.424	1.389
Having outside water	−3.029*	1.640
Lung capacity 97	0.577***	0.0075
Const.	245.1***	14.26

* Significant at 10% level.** Significant at 5% level.
*** Significant at 1% level.Sample size = 15,497, R^2 = 0.4288.

- **Results**
  - **Most affected groups**:
    - **Men** and **elderly individuals (Lung capacity ↓)**
    - **Children** showed **almost complete recovery**
  - **General population**:
    - A **one standard deviation increase** in pollution level raised the likelihood of poor general health by **3%**.

Conclusion:

- **Exposure to pollution caused by wildfires has a significant impact on lung capacity, even 10 years post-exposure**
- Factors such as age, education, and socioeconomic status also influence lung capacity, but **pollution remains a key determinant**

Econ Hum Biol. 2017 Aug;26:186-198.

Challenges in Assessing **Wildfire Smoke Health Effects**

- **Additional uncertainties exist…**
  - **Accurate measurement** of wildfire smoke pollution levels
  - **How well the chemical composition of wildfire smoke is reflected**
  - **Behavioral change - Differences between indoor exposure and ambient $PM_{2.5}$ concentrations**
  - **Synergistic health effects** of **extreme heat and wildfire smoke** occurring together
  - **Regional variations in wildfire risk perception and their effects on health outcomes**

Impact of Air Pollutant from Wildfire Smoke

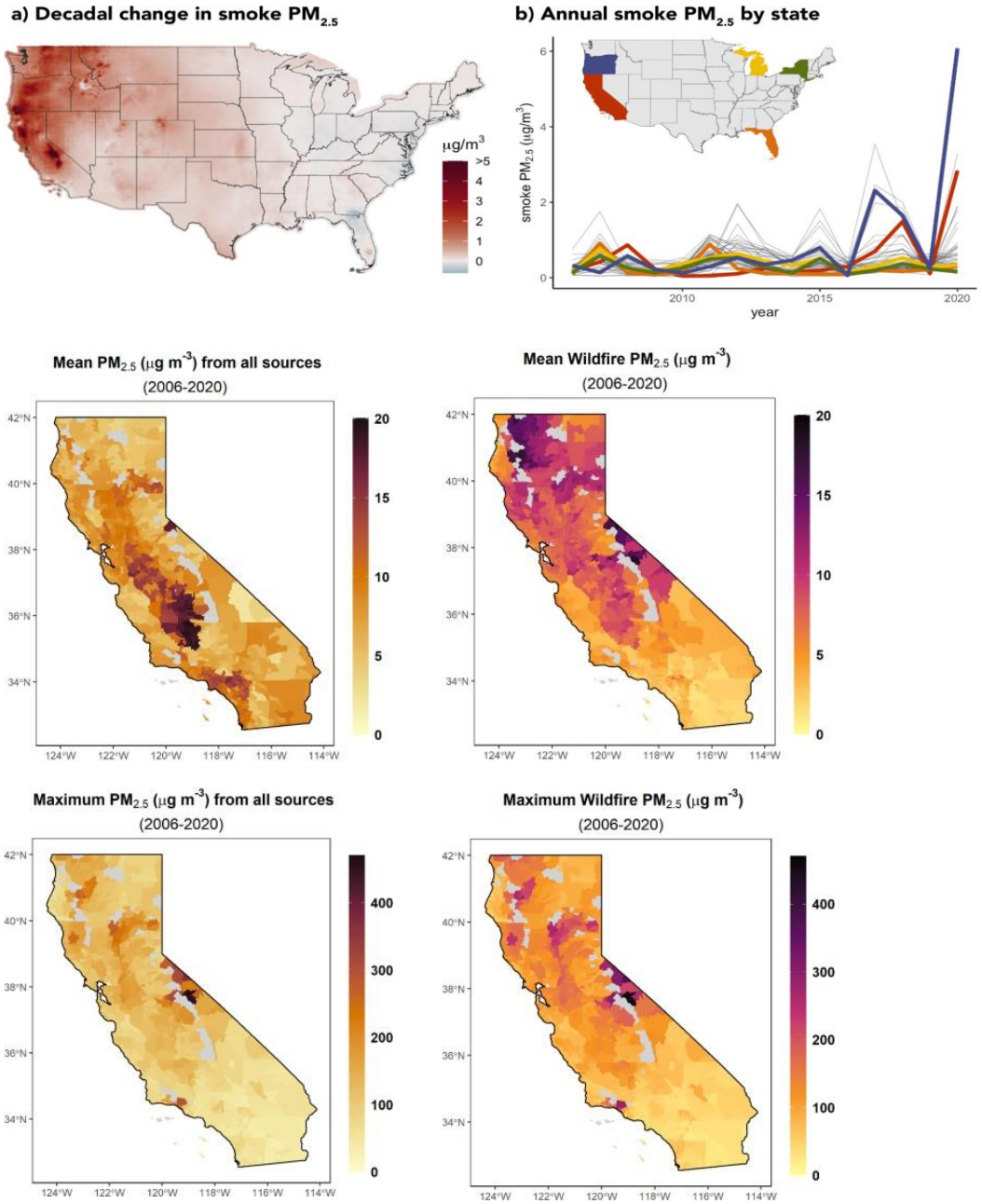
- **Unpredictable Nature of Wildfire Smoke**
  - Unlike transportation and industrial pollution, **wildfire emissions fluctuate across time and space**.
  - Limited research on **how different exposure patterns impact health outcomes**
    - **Scenario 1:** PM2.5 reaches **100 µg/m³ in a single day**.
    - **Scenario 2:** PM2.5 remains at **10 µg/m³ for 10 days**.
  - **Total exposure is the same (100µg/m³), but health effects may differ** (e.g., emergency visits).

- **Human Behavior & Health Outcomes**
  - Public health strategies assume **people take protective measures during high-smoke events**.
  - **Findings:**
    - **Limited behavioral change** on **moderate smoke days**.
    - **Stronger protective actions** (e.g., staying indoors) **during extreme smoke events.**
    - Studies may **mask real health impacts** by averaging exposure levels, leading to inconclusive results.

Measurement of Wildfire smoke

- Ground Monitors
  - Cannot distinguish wildfire-specific pollution
- Chemical Transport Models (CTMs)
  - Simulate atmospheric chemistry & fire emissions
- Dispersion Models
  - Use meteorology & physics to model pollution spread
- Statistical Models
  - Correlate wildfire smoke plumes with pollution data
  - Incorporate satellite data & meteorology

- **Hybrid Approaches**
  - **Combine CTMs, statistical models, and satellite data**
  - **Increasingly used for better accuracy**



Environment international 171 (2023): 107719.

Methodological Challenges in Assessing Wildfire Smoke Health Effects

Isolating Causal Effects – Many confounders → Regression adjustment

- **Case-crossover design (comparing individuals pre- and post-exposure)**
- **Time-series analysis (tracking exposure fluctuations over time)**

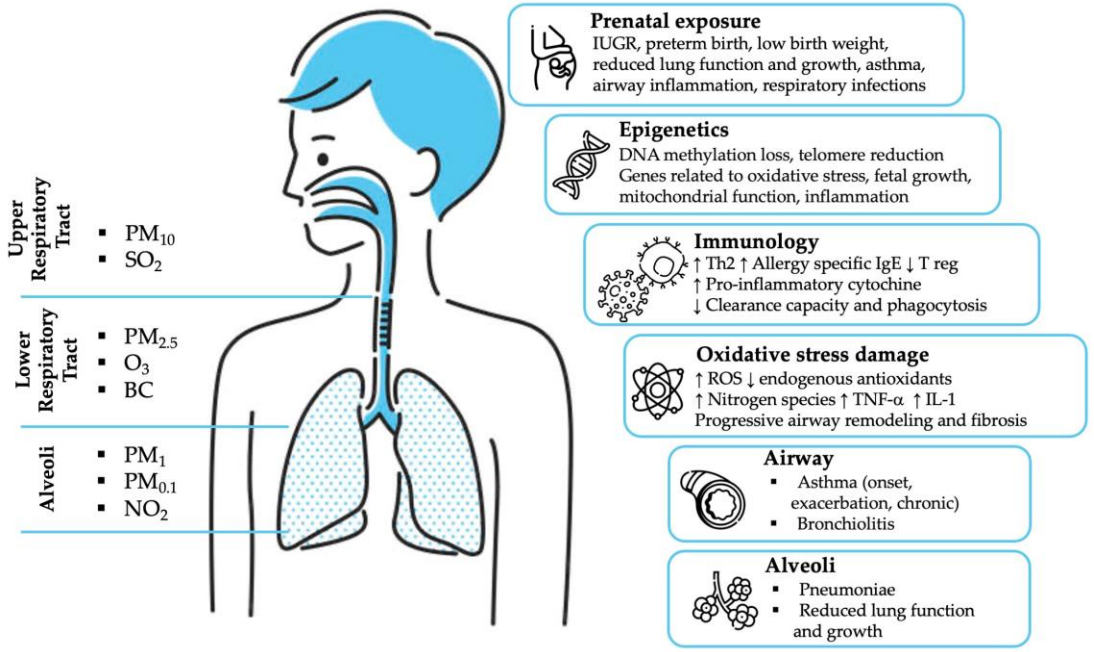
Accounting for Nonlinear Effects

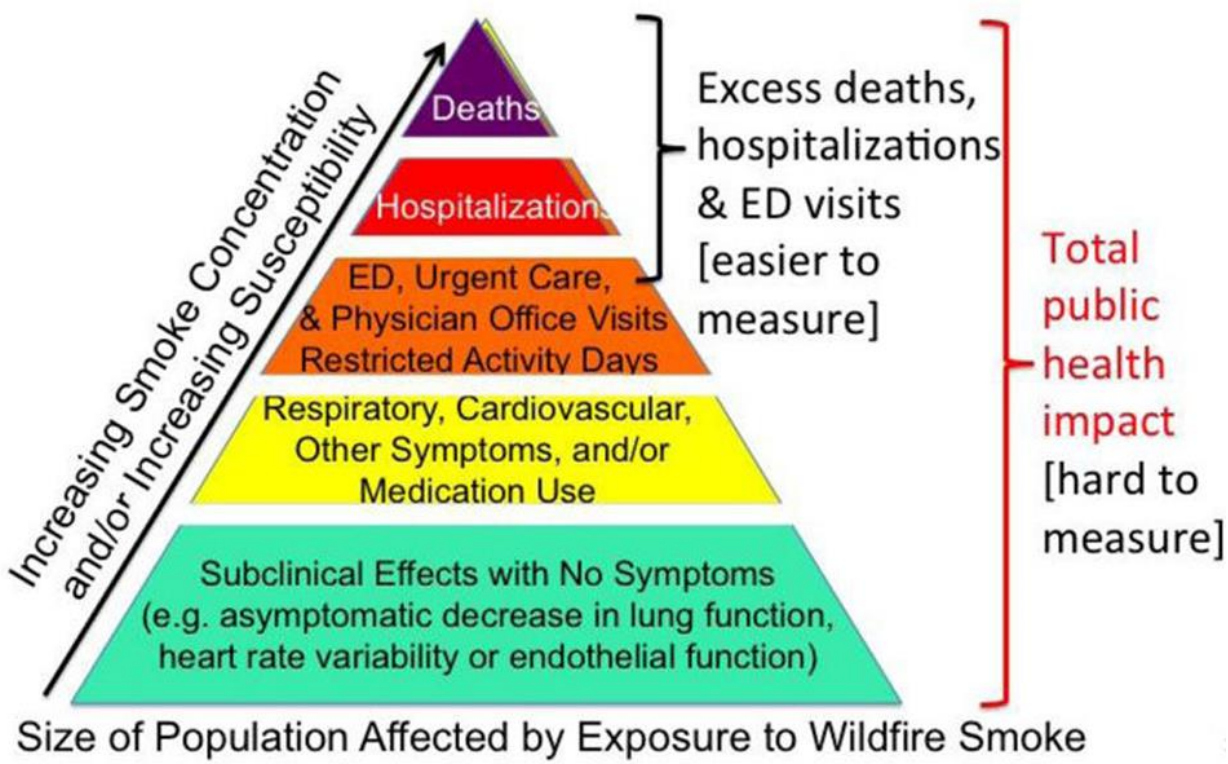
- Emergency visits **decrease at extreme levels of $PM_{2.5}$** due to behavior changes (e.g., reduced mobility)
- **Using a linear model underestimates true health impacts**
- Solution: **Implement flexible models to capture nonlinear relationships**

Considering Temporal Lag Effects

- Health impacts may not be immediate—**delayed effects can amplify risks**
- Solution: **Use distributed lag models** to measure cumulative effects over time.

Health risks associated with Wildfire Smoke





Curr Opin Pulm Med. 2019 March ; 25(2): 179–187

New aspect

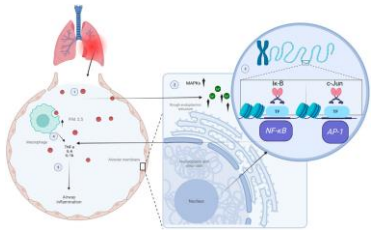
Molecular Epidemiology & Wildfire exposure effect

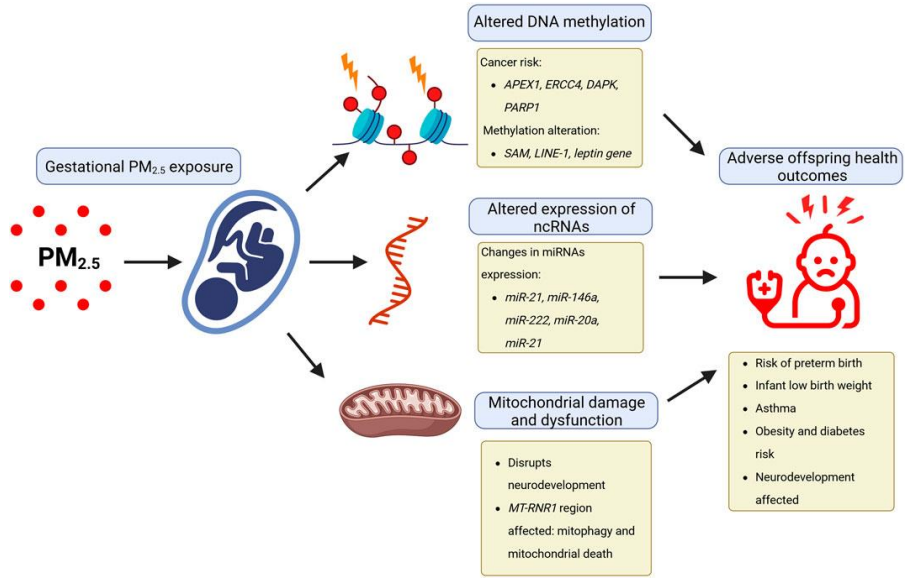
Molecular epidemiology

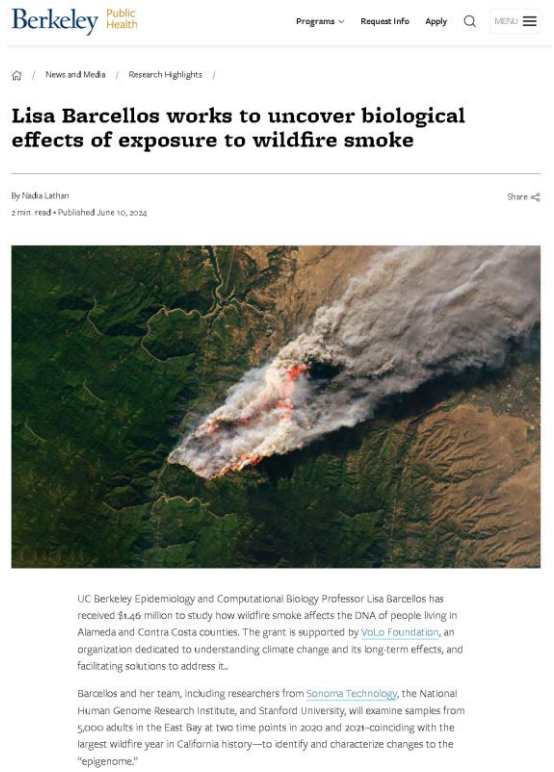
- (Epi)Genetic differences modify disease progression

Controlled Human Exposure Study

- (Epi)Genetic differences modify responses to environmental exposure







Epigenomics and Epigenetics, Volume 14 - 2023

nature medicine

Article

https://doi.org/10.1038/s41591-023-02424-2

The airway microbiome mediates the interaction between environmental exposure and respiratory health in humans

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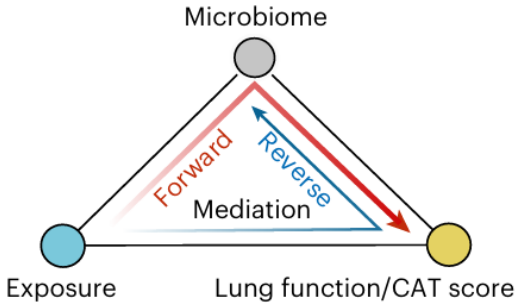
Published online: 22 June 2023

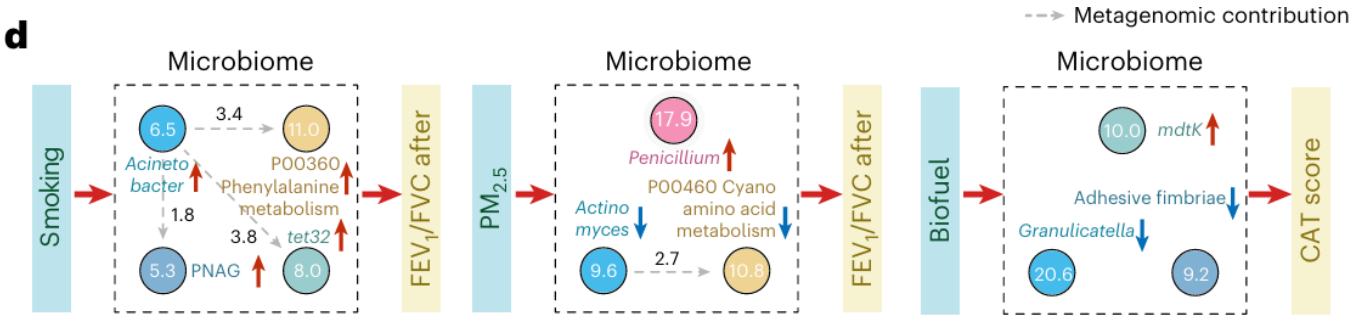
Check for updates

Lifeng Lin[1,9], Xinzhu Yi[2,9], Haiyue Liu[3,9], Ruilin Meng[1,9], Saiqiang Li[4], Xiaomin Liu[2], Junhao Yang[2], Yanjun Xu[1], Chuan Li[1], Ye Wang[1], Ni Xiao[1], Huimin Li[5], Zuheng Liu[6], Zhiming Xiang[7], Wensheng Shu[2], Wei-jie Guan[5,8], Xue-yan Zheng[1], Jiufeng Sun[1] & Zhang Wang[2]

GLM *P* value	FEV_1/FVC post-BD	FEV_1 pred post-BD	CAT score
Biofuel	0.052	0.478	3.4×10^{-5}***
Occupation	0.092	0.052	0.042*
$PM_{2.5}$	0.044*	0.175	0.165
Smoking	0.004**	0.945	0.435
Secondhand smoking	0.163	0.367	0.001**

***$P < 0.001$, **$P < 0.01$, *$P < 0.05$



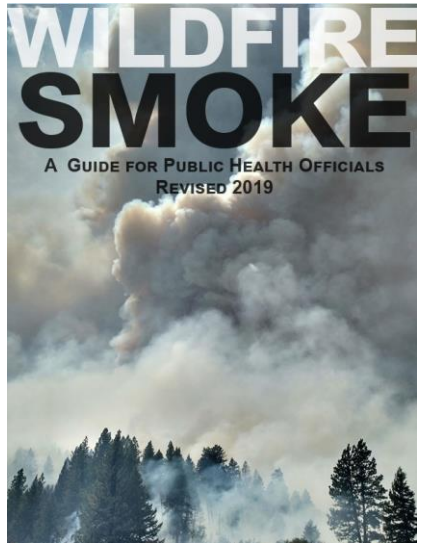


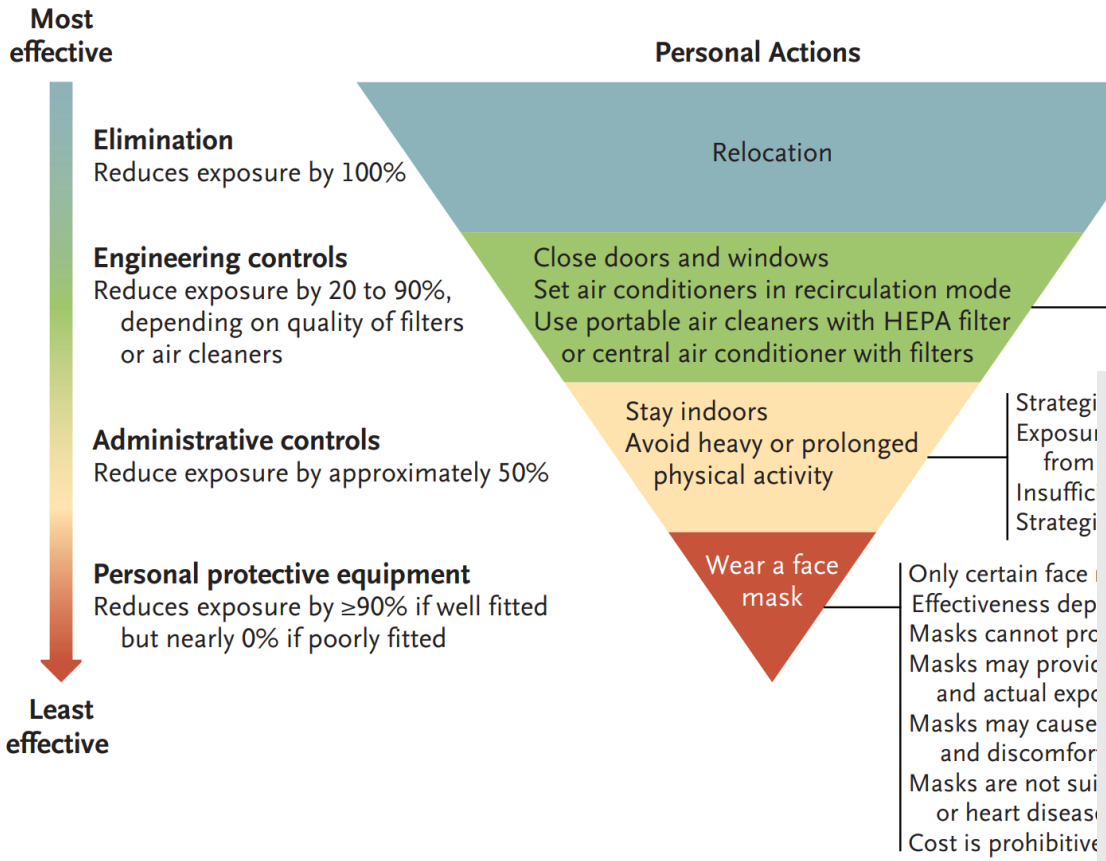
- **Background**
  - **Environmental pollutants (smoking, $PM_{2.5}$) → Airway microbiome → Lung function**
  - A large-scale study in Guangdong, China
  - Analyzed bacterial and fungal microbiomes from induced sputum **(n=1,651)**

- **Key Result**
  - **Smoking and $PM_{2.5}$ exposure are associated with reduced lung function (FEV1/FVC decline).**
  - Smoking alters bacterial composition, increasing Atopobium, Actinomyces, and Prevotella.
  - $PM_{2.5}$ exposure influences fungal taxa, increasing Cladosporium and Penicillium.
  - **$PM_{2.5}$ affects fungal metabolism, impacting lung health.**
  - **The microbiome mediates the relationship between exposure and lung function.**

Nature Medicine volume 29, 1750–1759 (2023)

Protecting Health against Wildfires





- Residents in wildfire-prone area
  - Emergency supplies (before wildfire)
    - **Food, water, medication, and N95 or P100 face masks**
    - **Fresh Water (Ash)**
    - **Heat-related illness protection**
  - **Psychological support (Children)**
- To reduce Exposure
  - **Relocation**
  - Limitation - Mask, HEPA filter (Cost effectiveness)
  - **Rescue medication – Children with asthma**

Wildfire Smoke: a guide for public health officials: revised 2019

GeoHealth

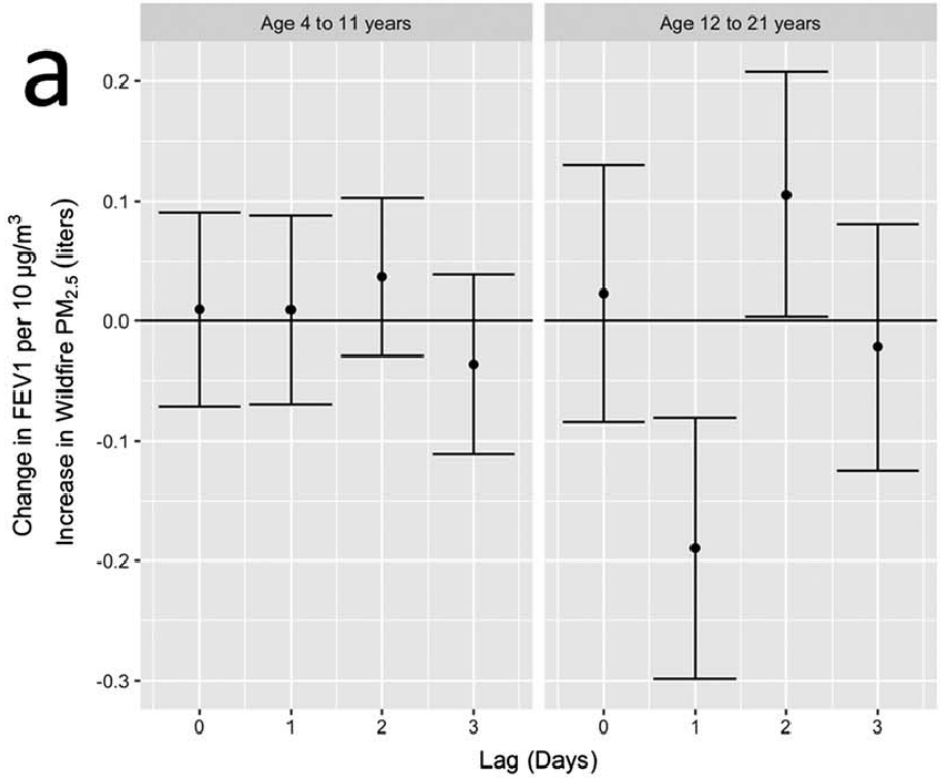
RESEARCH ARTICLE
10.1029/2018GH000142

Key Points:
- We found that lung function in older asthmatic children first decreased then increased following wildfire $PM_{2.5}$ exposure
- We found no associations between wildfire $PM_{2.5}$ and self-reported asthma control over the prior 30 days

The Associations Between Clinical Respiratory Outcomes and Ambient Wildfire Smoke Exposure Among Pediatric Asthma Patients at National Jewish Health, 2012–2015

Ettie M. Lipner[1,2], Katelyn O'Dell[3], Steven J. Brey[3], Bonne Ford[3], Jeffrey R. Pierce[3], Emily V. Fischer[3], and James L. Crooks[1,2]

[1]Department of Biomedical Research, National Jewish Health, Denver, Colorado, USA, [2]Department of Epidemiology, Colorado School of Public Health, Aurora, Colorado, USA, [3]Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado, USA



Pediatric asthma patients (ages 4–21, *n* = 1,404 for FEV1, *n* = 395 for ACT/CACT) from National Jewish Health, Denver, Colorado.

- Satellite-derived data (NOAA's Hazard Mapping System).
- Analysis using mixed-effect models
- **Key Findings:**
  - **Older Children (12–21 years):**
    - **Lower FEV_1** observed the next day after wildfire $PM_{2.5}$ exposure.
    - **Higher FEV_1** observed on the day after.
    - **Likely due to rescue medication use mitigating symptoms.**

GeoHealth 3.6 (2019): 146-159.

Reducing Wildfire Occurrence

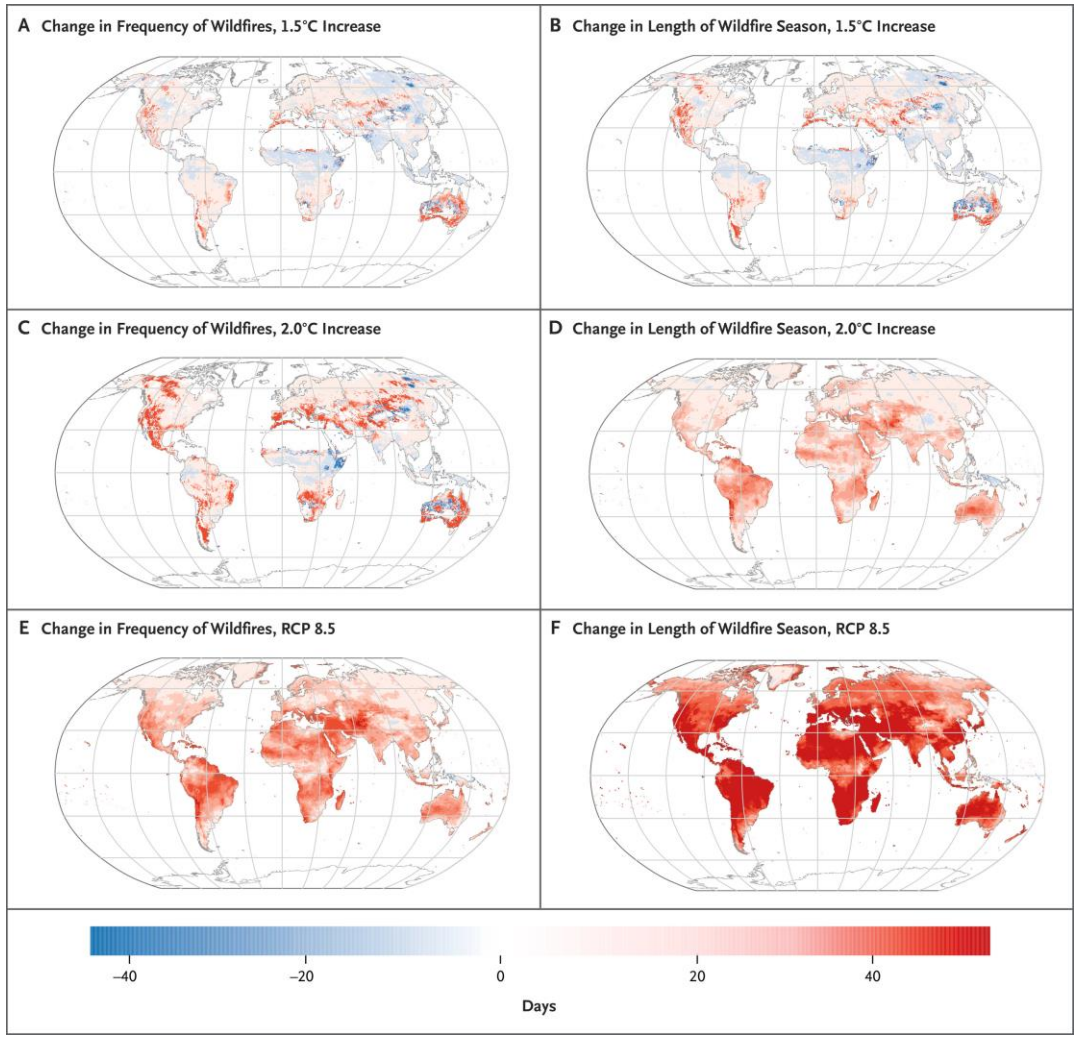
Strategies to Reduce Future Wildfire Risk

- **Mitigate and reverse climate change** to reduce fire-prone conditions.
- **Restrict development** in the wildland-urban interface.
- **Implement fuel management techniques** to clear accumulated vegetation.

Long-Term Challenge:

- These measures require **decades or longer** to take full effect.

The Urgency of Carbon Emission Reductions



- **High-Emission Scenarios (Worst Scenarios)**
  - **Representative Concentration Pathway, RCP) 8.5**
- **To decrease Wildfire - Global Emission Reduction Goals**
  - Cut net CO_2 emissions by **45% by 2030** → Achieve **"net zero" by 2050.**
  - **1.5°C Target**
    - Requires a **7.6% annual decline** in emissions from 2020 to 2030
- **Benefits of Cutting Emissions:**
  - **Cost Savings**
    - Estimated at **1.40 to 2.45 times** the cost of emission reductions
    - Avoiding health and climate risks, including those linked to wildfires

Environ Int 2019;128:125-136.

Prescribed Fire: A Strategic Wildfire Management Approach

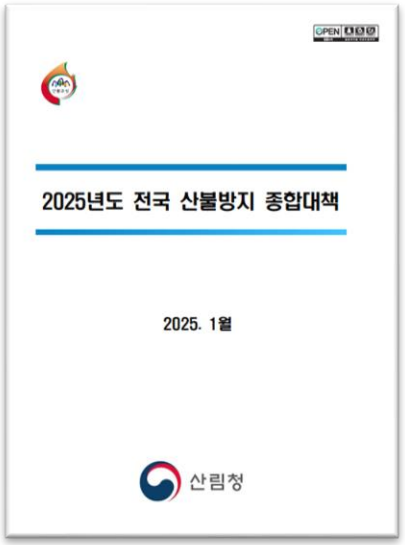
- **Definition**
  - **Intentional application of fire under specific environmental conditions to reduce fuel loads and manage ecosystems.**
- **Objectives:**
  - Reduce wildfire risk by eliminating excess vegetation.
  - Improve forest and grassland health.
  - Restore natural fire regimes to ecosystems.
- **Key Benefits:**
  - Lowers the intensity and spread of uncontrolled wildfires.
  - Reduces air pollution compared to extreme wildfires.
  - Maintains healthy soil and vegetation cycles.

Minimizing Health Impacts of Wildfire Smoke

- **Early Warning & Public Protection**
  - **Develop wildfire and smoke forecasting systems**
  - **Encourage protective behaviors** (e.g., air purifiers, masks, relocation)
  - **Expand research** on the effectiveness of risk mitigation strategies

- **Policy Interventions**
  - **Subsidies or rental programs** for air purifiers.
  - **Clean air shelters** for high-risk individuals.
  - **Targeted support** for vulnerable groups (e.g., pregnant individuals, children with asthma, elderly with lung disease, outdoor workers)

- **Role of Healthcare Providers**
  - **Encourage at-risk patients** to take preventive actions
  - **Pre-fill prescriptions** for respiratory medications
  - **Expand telemedicine services** to maintain healthcare access



산림청, 2025년 전국 산불방지 종합대책

잠언 시집

지금 알고 있는 걸 그때도 알았더라면

류시화 엮음

열림원

Take Home message

- Wildfires are not just fires. They cause severe air pollution with $PM_{2.5}$ and toxic chemicals.
- Wildfire smoke worsens respiratory diseases like asthma, COPD, and infections — with both immediate and delayed effects.
- Wildfire smoke “maybe” alters the airway microbiome, which can mediate lung function decline and respiratory symptoms.
- Reducing CO_2 is essential to prevent wildfires.
- Public health and medical responses are critical.
- Long-term solutions need ecosystem management.

Kang-Mo Gu

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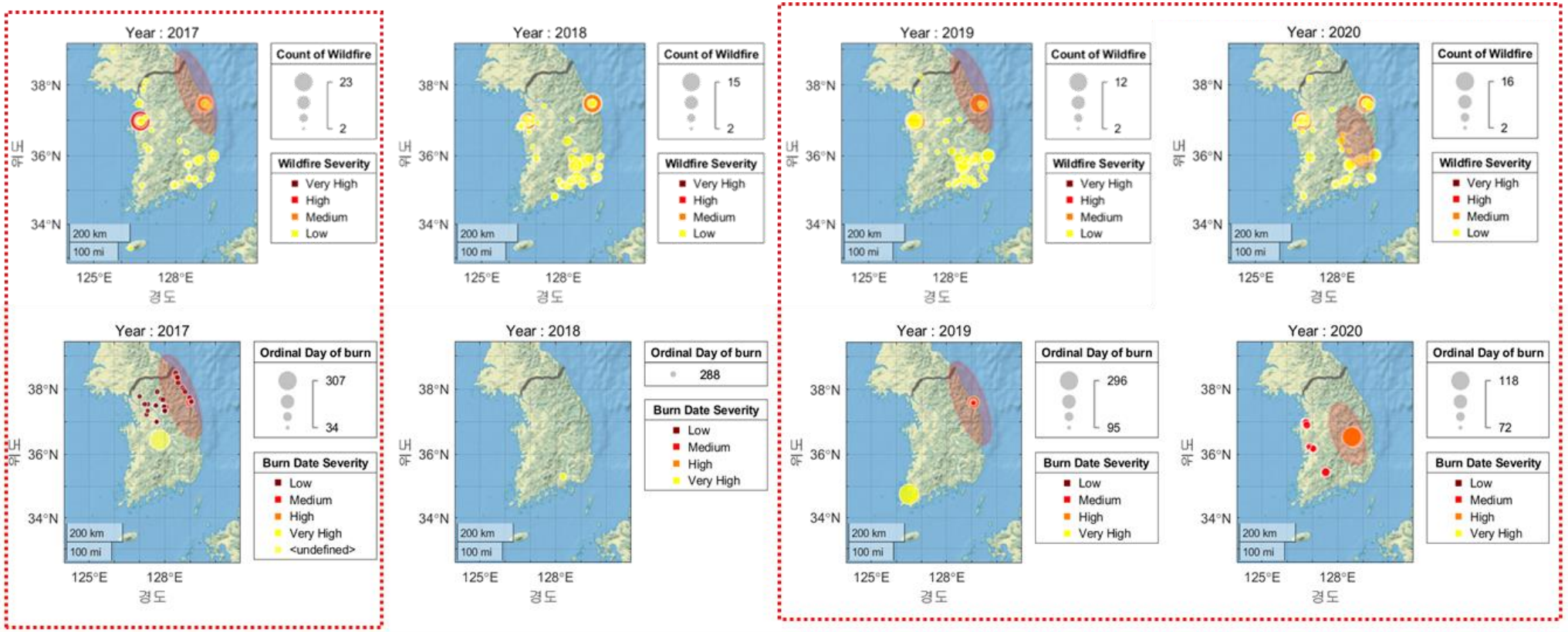
MOD14A2 (1 km)

- Fire
- Temporal Resolution : 8-day

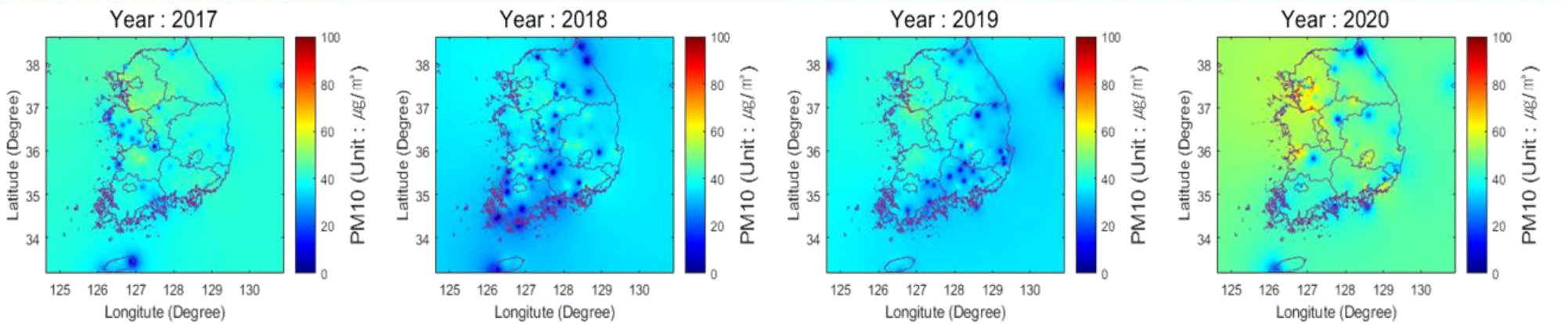


MCD64A1 (500 m)

- Burned Area
- Temporal Resolution : Monthly

Air Korea PM 10 (1km)

- Use of IDW method
- Unit : ㎍/㎥
- Temporal Resolution : Hourly



ARTICLE

https://doi.org/10.1038/s41467-021-21708-0 OPEN

Wildfire smoke impacts respiratory health more than fine particles from other sources: observational evidence from Southern California

Rosana Aguilera[1,3✉], Thomas Corringham[1,3], Alexander Gershunov[1] & Tarik Benmarhnia[1,2]

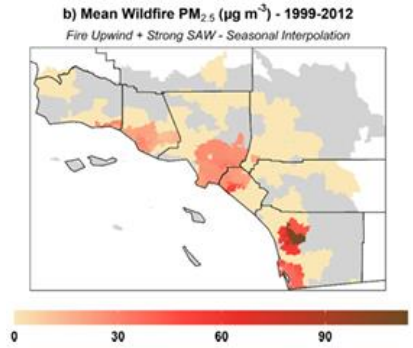


Table 1 Effect of (wildfire and non-wildfire) $PM_{2.5}$ on respiratory hospital admissions.

Fire upwind + strong SAW (1999–2012)	Regression model for respiratory admissions (rate per 100,000 people)							
	Aggregated sources (smoke and non-smoke)	Approach used to isolate wildfire-specific $PM_{2.5}$						
		Instrumental Variable	Imputation		Interaction		Seasonal Interpolation	
		Wildfire-specific	Non-smoke	Wildfire-specific	Non-smoke	Wildfire-specific	Non-smoke	Wildfire-specific
$PM_{2.5}$ coefficient	0.0014	0.0071	0.0013	0.018	1.00068	1.00061	0.0024	0.0055
(95% CI)	(0.00077-0.0021)	(−0.0022 to 0.017)	(0.00068-0.0020)	(0.0064-0.030)	(1.00049-1.00087)	(0.10-1.0015)	(0.0018-0.0030)	(−0.00068 to 0.012)
% change with 10 µg m^{-3} $PM_{2.5}$	0.76	3.8	0.72	10	0.67	1.28	1.3	3.0
(95% CI)	(0.42-1.1)	(−1.2 to 8.9)	(0.36-1.1)	(3.5-16.5)	(0.48-0.86)	(0.37-2.19)	(0.97-1.7)	(−0.37 to 6.3)

All regressions include controls:flu admissions, weather covariates, day-of-week effects, month-of-year effects, zip code fixed effects, and a time trend.
Summer months (June, July, August) are excluded.
Mean $PM_{2.5}$ = 15.6 µg m^{-3} (IQR = 9.2 µg m^{-3}).
Mean rate of respiratory admissions per 100,000 people = 1.85.

- Respiratory diseases
  - ICD 9 code – 460:519
  - Discharge data (California OSHPD)
  - Daily-zip-code based admission rate
- Duration 1999-2012
  - Zip code based $PM_{2.5}$
- **Rates of respiratory admissions are regressed on the wildfire-specific $PM_{2.5}$ concentrations**

- Multiple Spatio-temporal analysis
- Respiratory hospitalization per 10 µg/m^3 increase $PM_{2.5}$
  - **Wildfire-specific $PM_{2.5}$ caused a significant increase in respiratory hospitalizations, ranging from 1.3% to 10%, compared with a 0.67–1.3% increase associated with non-wildfire $PM_{2.5}$ in California, US.**

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