

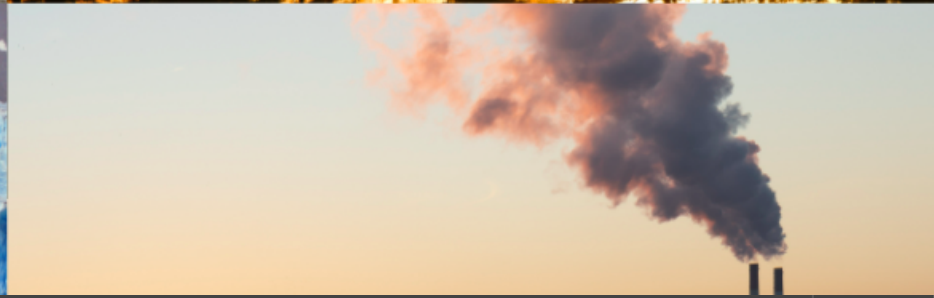

Climate and Human Health Responders Course for Health Professionals

Degraded Air Quality

Anthony Gerber, MD: Division of Pulmonary and Critical Care, National Jewish Hospital

Project ECHO
Columbia Mailman School of Public Health
Global Consortium on Climate and Health Education
NOAA
Santé Canada
Health Canada

Degraded Air Quality
Learning Objectives

- Describe the pathways through which climate change affects ozone, PM2.5, and other ambient respiratory irritants how these pollutants impact climate-sensitive respiratory diseases such as asthma, COPD, chronic lung disease, cardiovascular disease, cerebrovascular, and allergic diseases
- Describe how climate change might impact indoor air quality (e.g. mold from flooding)
- Analyze data related to hospital and ED usage for respiratory conditions as they relate to meteorological variables
- Describe how climate change makes air quality regulation more complex and difficult
- Identify populations that are vulnerable to degraded air quality. Describe how health professionals can protect these vulnerable patients.
- Explain how wildfires are impacted by climate change and the direct and indirect health implications
- Describe how climate change increases the risk of complex disasters due to combined and cascading events (heatwaves followed by wildfires)
- Identify particularly vulnerable patients and families and teach about risk mitigation, such as limiting outside work and recreation during poor air quality days.

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Disclosure Information

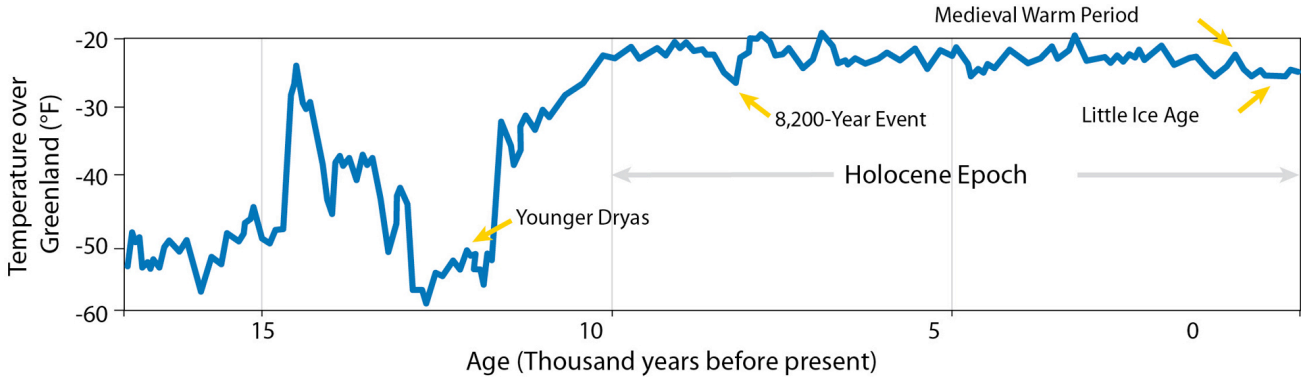
Consulting agreements last 3 years with:
Pliant Therapeutics
BeiGene
BioScience Pharma
Apellis Pharmaceuticals
Gala Therapeutics

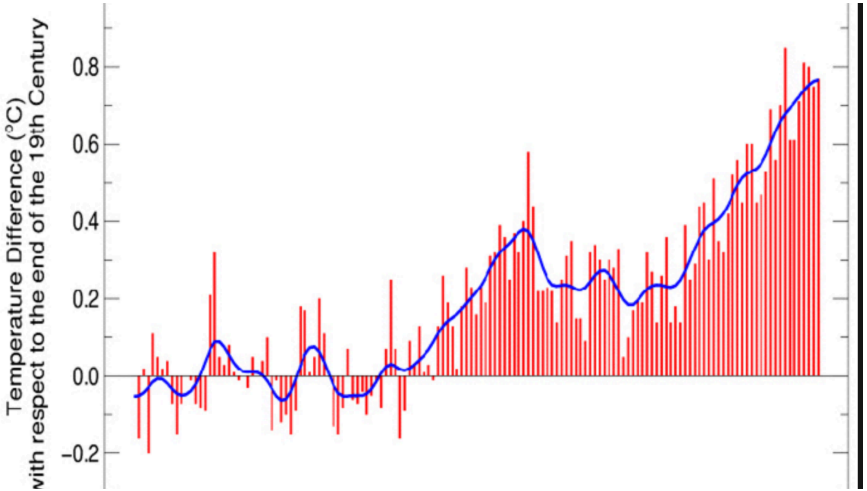
Founder, Psammiad Therapeutics

Chair, Colorado Air Quality Control Commission

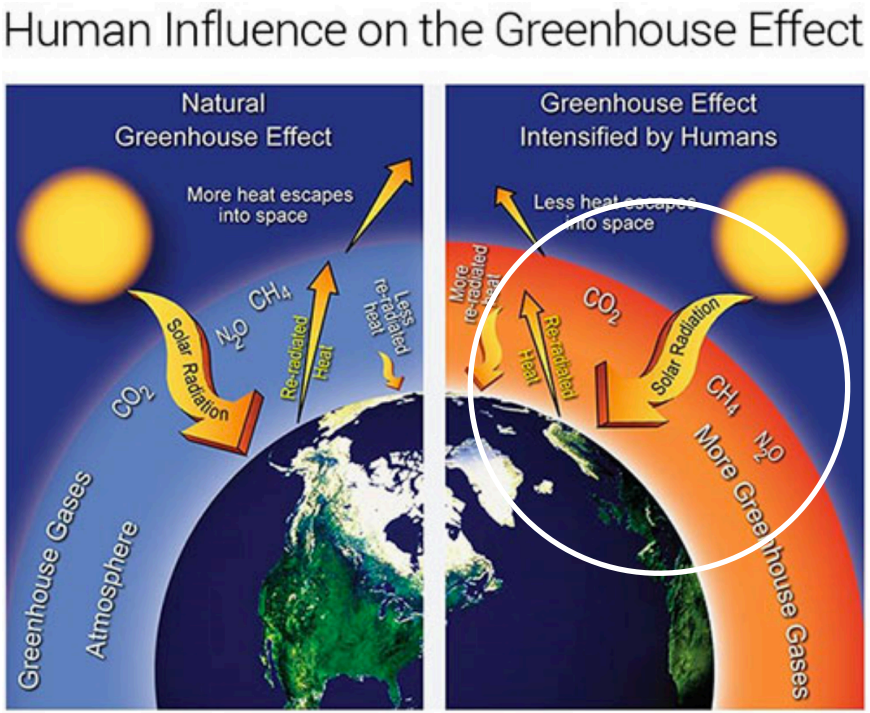
None of these relationships influence the content of this presentation

Poorly understood long-term climate variability does not reduce the validity of models predicting short-term impacts of GHGs on climate



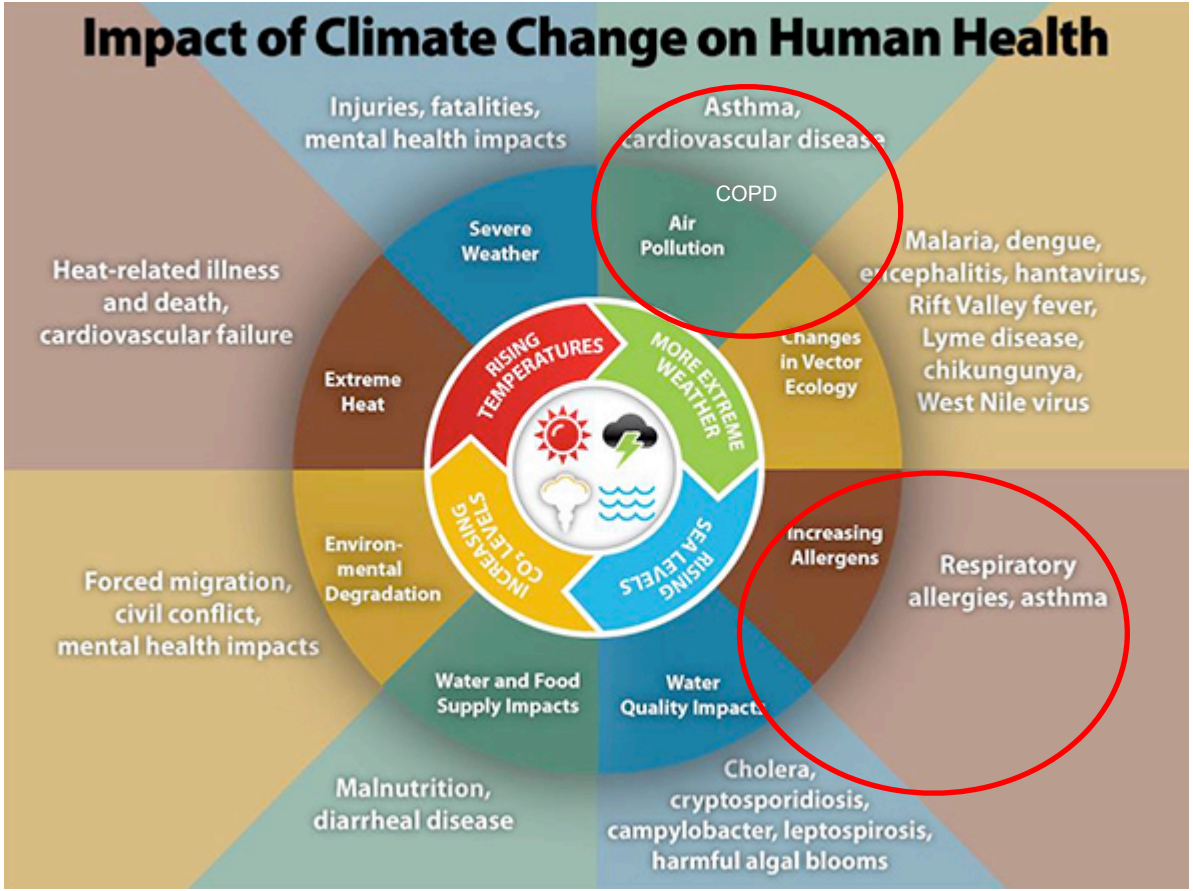


The well-established science of climate change and the central importance of the culprit gases in our economy and lives



- Transportation
- Electricity
- Heating/cooling
- Industrial processes (Steel production, Cement mills
- Fossil fuel extraction
- Specialty GHGs (CFCs)

Climate change and health



https://www.cdc.gov/climateandhealth/effects/

-> Ambient outdoor air pollution

I. Ozone
   a) Ozone forms best on hot days
   b) Frequent co-emission of ozone precursors and greenhouse gases

II. Particulates (wildfire)
   a) Wildfires worsened by climate change
   b) Urban encroachment increase impact
   c) Wildfire smoke can increase Ozone

III. GHGs themselves (e.g. CO2, methane) are NOT, however, typically classified as air pollutants based on traditional parameters.

Climate change and air quality: Multiple and complex direct and indirect interactions

-> Allergens - **Increased aeroallergens** from extended growing seasons, increased CO2, expanded plant ranges, intense dust-wind events, and pollutant chemistry

-> Increased flooding **degrading indoor air quality through mold growth**

Degraded air quality and climate change: Impact on allergens and allergic lung diseases (e.g. asthma)

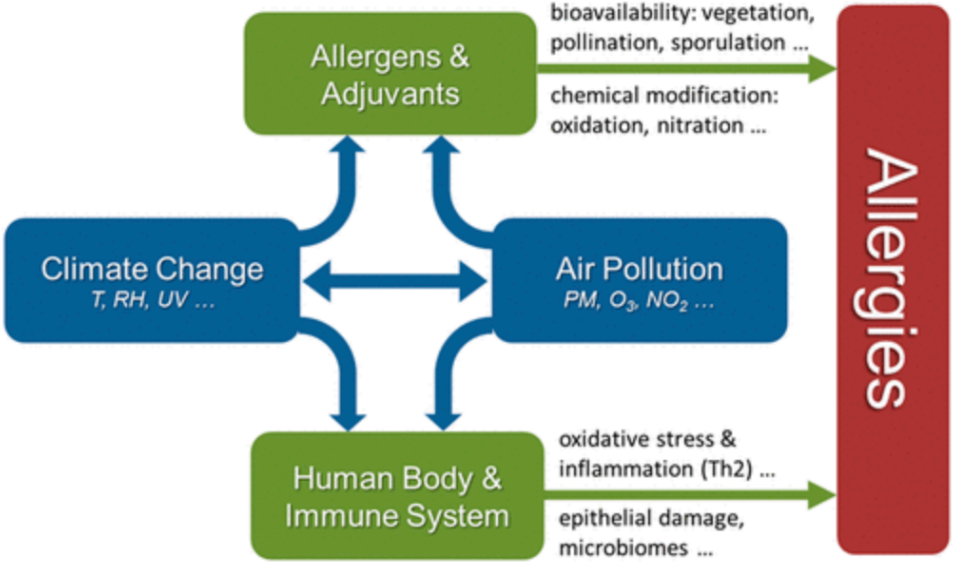
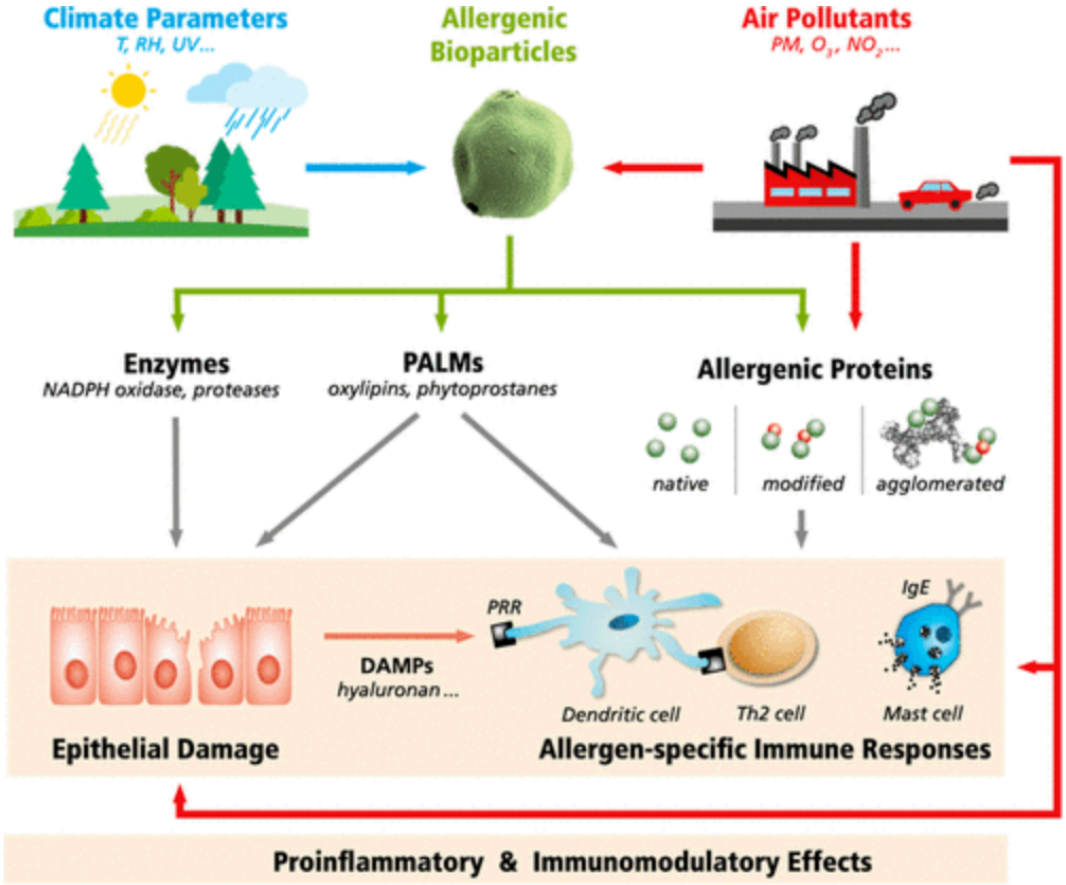


Figure 1. Interplay of air pollution and climate change can promote allergies by influencing the human body and immune system, as well as the abundance and potency of environmental allergens and adjuvants.

Reinmuth-Selzle K, et al *Environ Sci Technol*. 2017;51(8):4119-4141. doi:10.1021/acs.est.6b04908

Degraded air quality and climate change: Impact on allergens and allergic lung diseases (e.g. asthma)

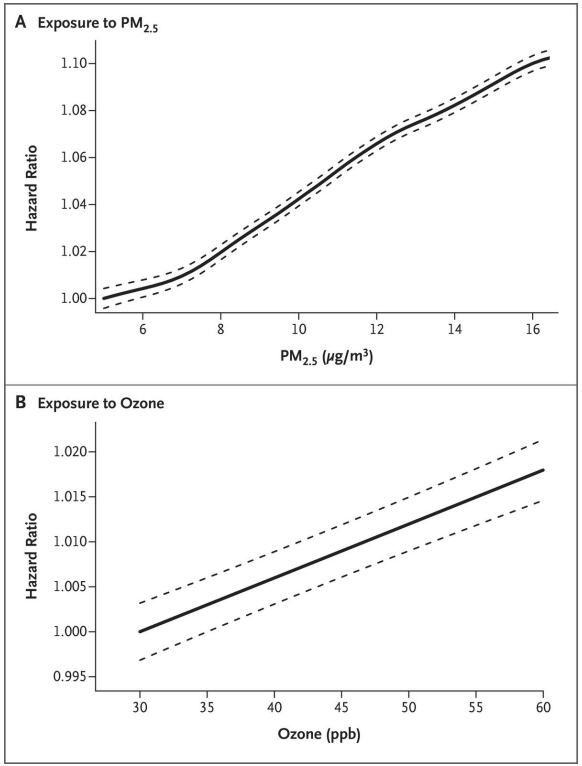


Reinmuth-Selzle K, et al *Environ Sci Technol*. 2017;51(8):4119-4141. doi:10.1021/acs.est.6b04908

A note on regulating air pollution in the USA…

1. The EPA, under the clean air act, adopts science-based standards for levels of so-called “Criteria pollutants” (and air toxics)
2. PM 2.5 and (especially) ozone are the major criteria pollutants where standards are both becoming more stringent and where there remain significant regions with non-attainment
3. States are tasked with implementing the federal standards through state-based regulations, often promulgated by volunteer commissions (e.g. California ARB, Colorado AQCC)
4. It is impossible for state-based regulations to solve climate change, however:
    a. As we will discuss, climate change is making attainment of EPA standards more difficult.
    b. Reduction of ozone and PM pollution frequently has a GHG co-benefit.
    c. If states don’t act on GHGs, who will?

Some of the underlying science: Exposure to PM 2.5 and Ozone and Increased All-Cause Mortality



Di Q et al. N Engl J Med 2017;376:2513-2522

Underlying science: Short-term associations between ambient air pollutants and pediatric asthma emergency department visits (Atlanta area)

Am J Respir Crit Care Med

	Overall RR (95% CI) (Jan–Dec)	Warm Season RR (95% CI) (May–Oct)
Ozone[†‡]	**1.062 (1.031–1.093)**	**1.082 (1.043–1.123)**
Nitrogen dioxide[†]	**1.036 (1.018–1.055)**	**1.066 (1.038–1.095)**
Carbon monoxide[†]	**1.023 (1.006–1.041)**	**1.068 (1.034–1.102)**
Sulfur dioxide[†]	1.012 (0.994–1.030)	**1.030 (1.002–1.058)**
PM_{10}[§]	**1.020 (1.003–1.038)**	**1.026 (1.001–1.051)**
$PM_{10-2.5}$[‖]	**1.034 (1.011–1.057)**	1.025 (0.991–1.059)
$PM_{2.5}$[‖]	**1.020 (1.002–1.039)**	**1.043 (1.016–1.070)**

Strickland et al. Am J Respir Crit Care Med. 2010 Aug 1;182(3):307-16.

Ozone levels are associated with increased disease-specific mortality

are Med — Am J Respir Crit Care !

HAZARD RATIO AND 95% CONFIDENCE INTERVALS FOR 5-ppb INCREASE IN 8-HOUR OZONE FOR THE YEAR OF FAILURE, ACROSS THE 105 CITIES

	Ozone Average May to September		Ozone Average Spring and Autumn	
	HR	95% CI	HR	95% CI
CHF	1.06	1.03–1.08	1.02	0.99–1.05
MI	1.09	1.06–1.12	1.04	1.00–1.08
Diabetes	1.07	1.05–1.10	1.03	1.00–1.07
COPD	1.07	1.04–1.09	1.03	1.00–1.06

Zanbetti et al Am J Respir Crit Care Med. Oct 1, 2011; 184(7): 836–841

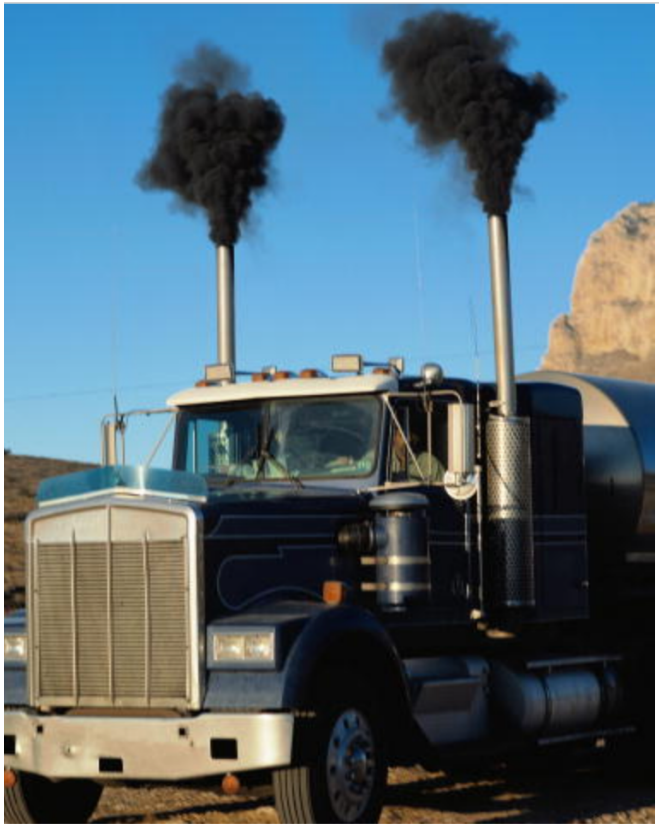
Ozone and PM2.5 in Metropolitan Areas and Asthma

O_3	18,746	1st (lowest)	Reference	Reference
		2nd	1.01 (0.88, 1.16)	0.99 (0.78, 1.26)
		3rd	1.09 (0.89, 1.34)	1.09 (0.85, 1.41)
		4th	1.19 (0.84, 1.68)	1.56 (1.15, 2.10)
PM2.5	27,462	1st (lowest)	Reference	Reference
		2nd	1.13 (0.97, 1.32)	1.04 (0.89, 1.22)
		3rd	1.03 (0.86, 1.24)	1.00 (0.83, 1.21)
		4th	1.13 (0.82, 1.56)	1.43 (0.98, 2.10)

Odds ratios by pollutant quartile for having asthma or at least one asthma attack in the previous year.

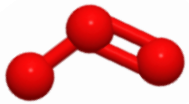
Akinbami et al Environ Res. 2010 Apr;110(3):294-301

Climate change and degraded air quality: GHG emissions, particulates and ozone formation



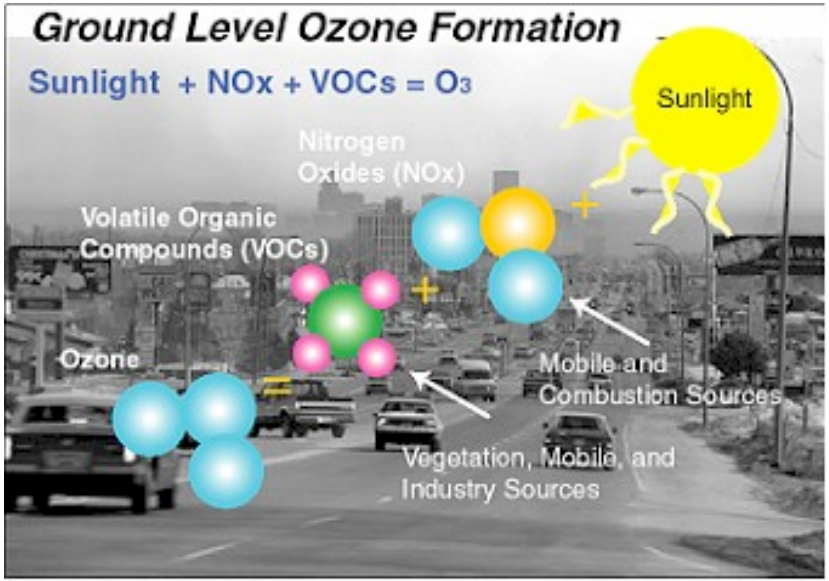
Carbon dioxide (minimal direct effect on health)
Particulate Matter
Air Toxics

Nitrogen Dioxide and VOCs (+sun and heat)



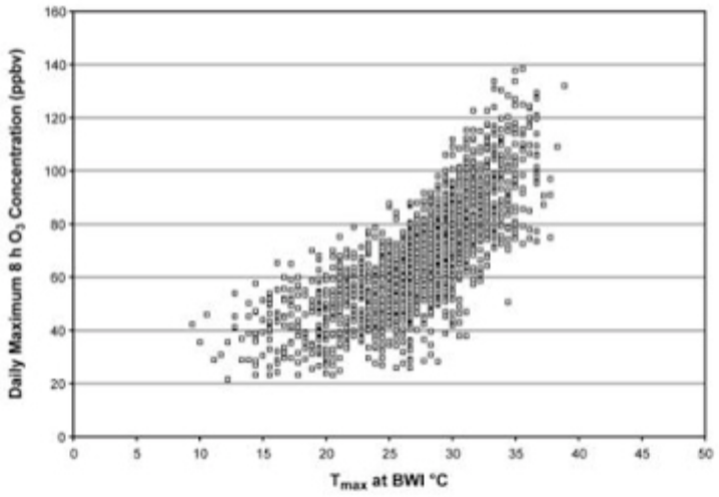
OZONE

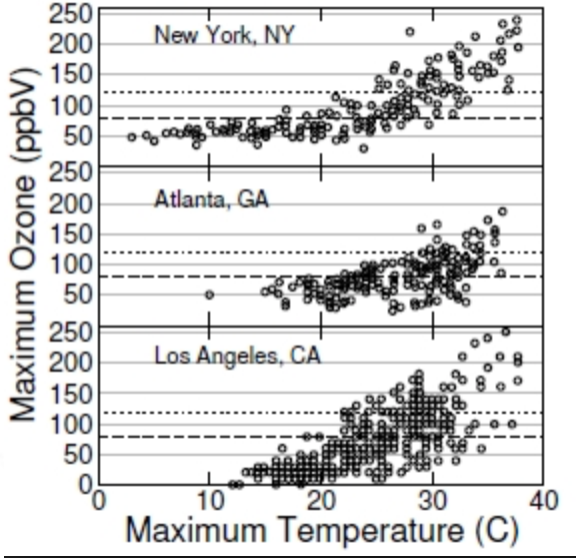
Ozone formation and climate change



- The underlying chemistry of ozone formation works best on hot days
- Ozone formation also requires sunlight
- Typically, the sites of highest ozone do not directly overlap with areas of production of ozone precursors
  - Chemical scavenging
  - Meteorology
- Extreme heat from climate change can directly impact achieving NAAQS levels
- Wildfire smoke can also provide ozone precursors
- Exceptional events or the new reality?

Climate change -> Hotter days → more ozone days





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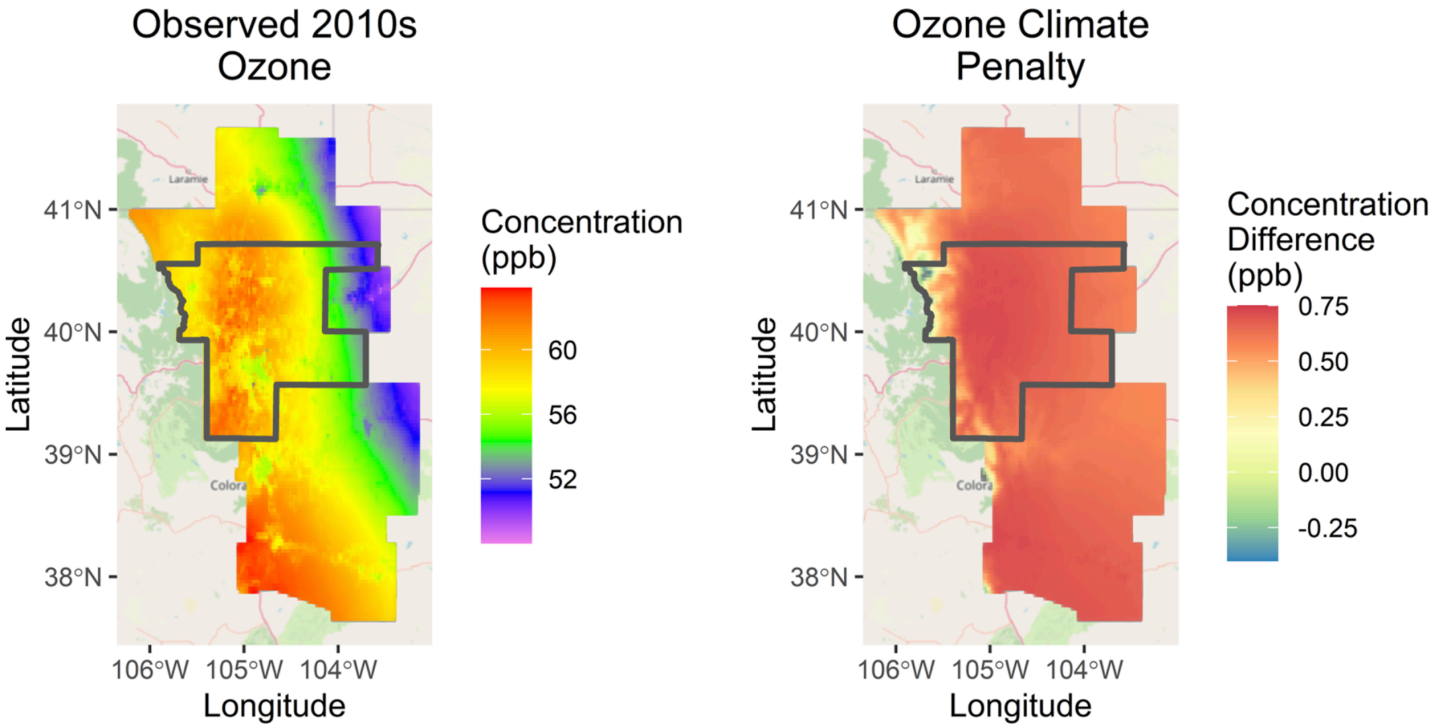
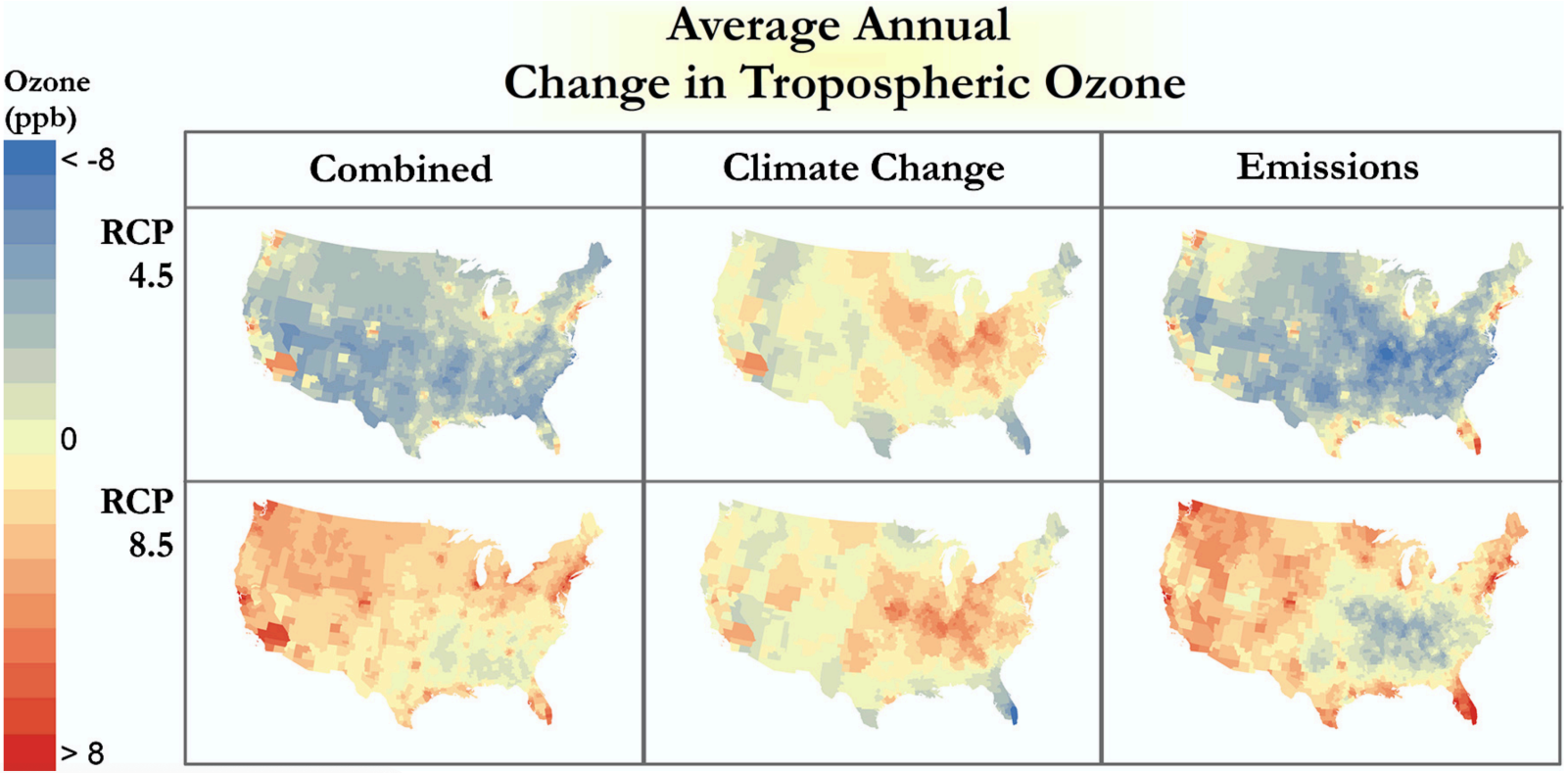


Ozone concentrations across the modeling domain during the high ozone period (June–August) under the observed 2010s climate and the difference between the observed and counterfactual climates.

Crooks JL, et al J Expo Sci Environ Epidemiol. 2021 Sep 10. doi: 10.1038/s41370-021-00375-9. Epub ahead of print. PMID: 34504294.

Climate change -> Hotter days → Higher ozone



Stowell JD, et al Environ Int. 2017 Nov;108:41-50

Regulating ozone levels and climate change (part 1)

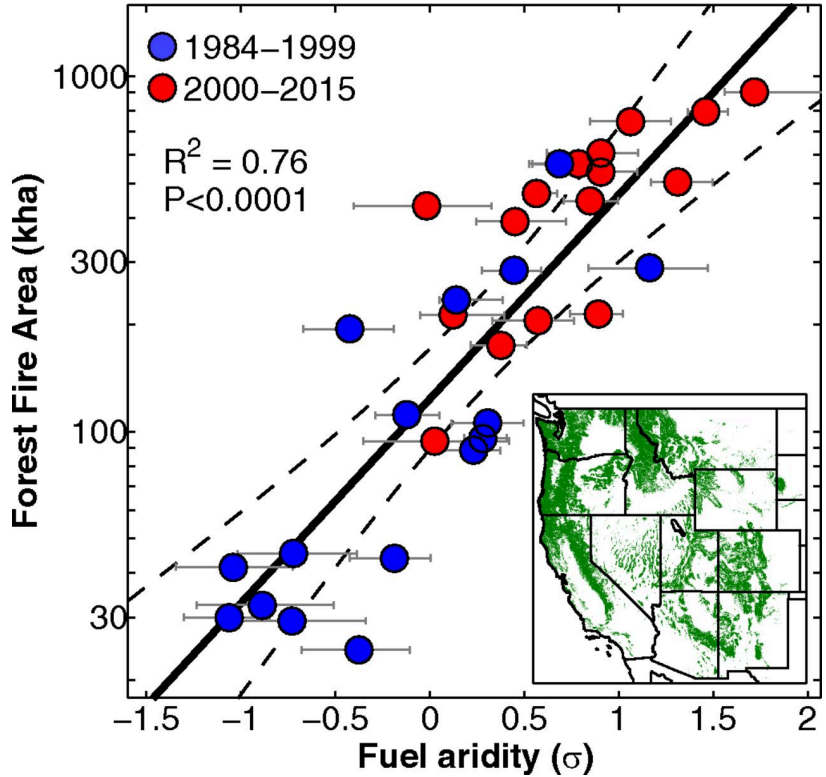
- Hotter temperatures increase risk of high ozone days
- Climate change is increasing the number of hot days
- This means deeper reductions in ozone precursors are required to achieve a similar impact on ozone levels in comparison to a stable climate where average summer temperatures are constant
- Example – oil and gas Leak Detection and Repair (LDAR) in Colorado
    - 2017 – LDAR only required for larger production facilities
    - 2021 – Annual LDAR for all facilities, monthly LDAR in areas of non-attainment for most facilities (note co-benefit GHG reductions)

Wildfires, degraded air quality and climate change: A growing particulate matter problem with profound health impact and grossly inadequate immediate solutions

Wildfires, degraded air quality and climate change: Dangerous combusted products

Climate change is driving wildfires

Annual western continental US forest fire area versus fuel aridity: 1984–2015.

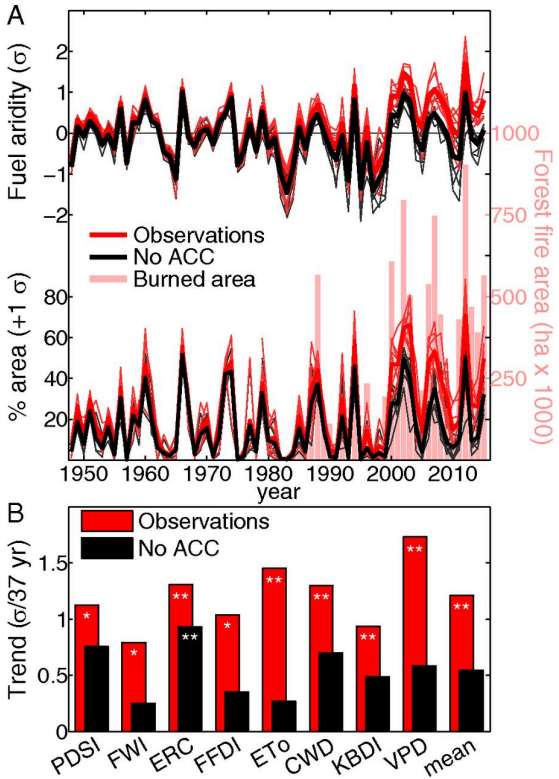


John T. Abatzoglou, and A. Park Williams PNAS doi:10.1073/pnas.1607171113

PNAS

Climate change is driving wildfires

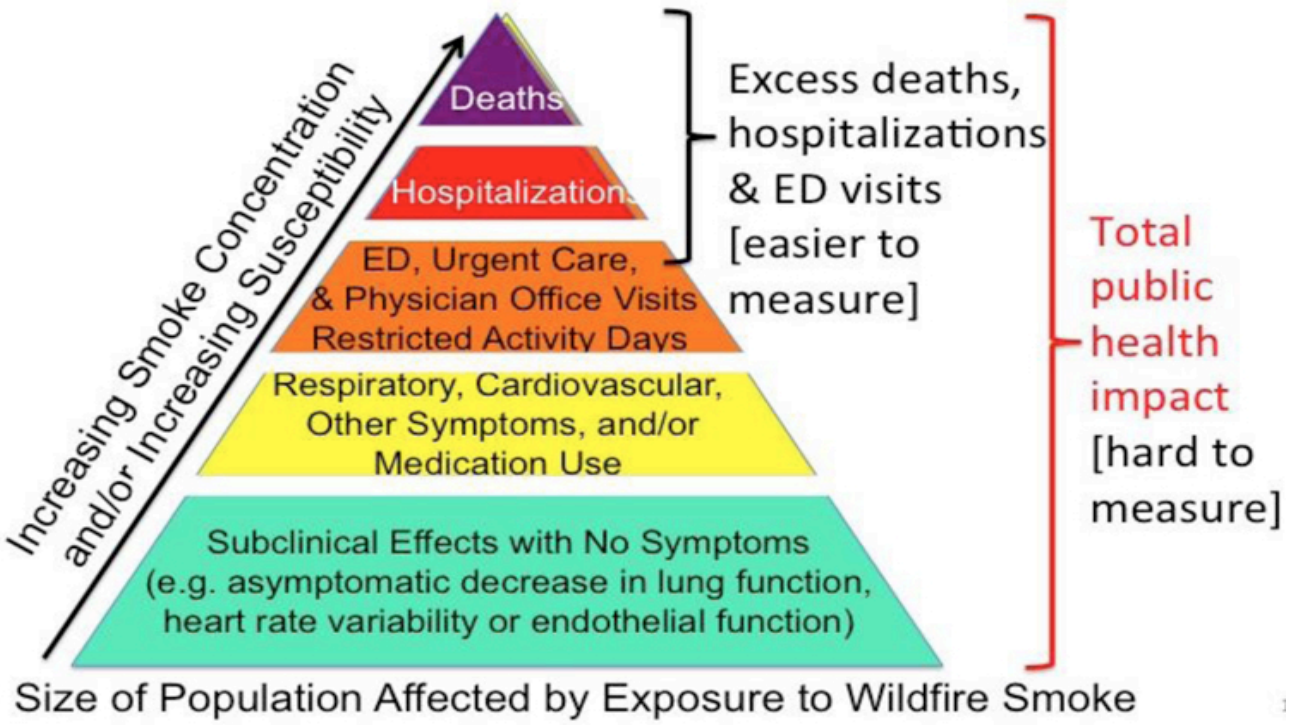
Evolution and trends in western US forest fuel aridity metrics over the past several decades.



John T. Abatzoglou, and A. Park Williams PNAS doi:10.1073/pnas.1607171113

PNAS

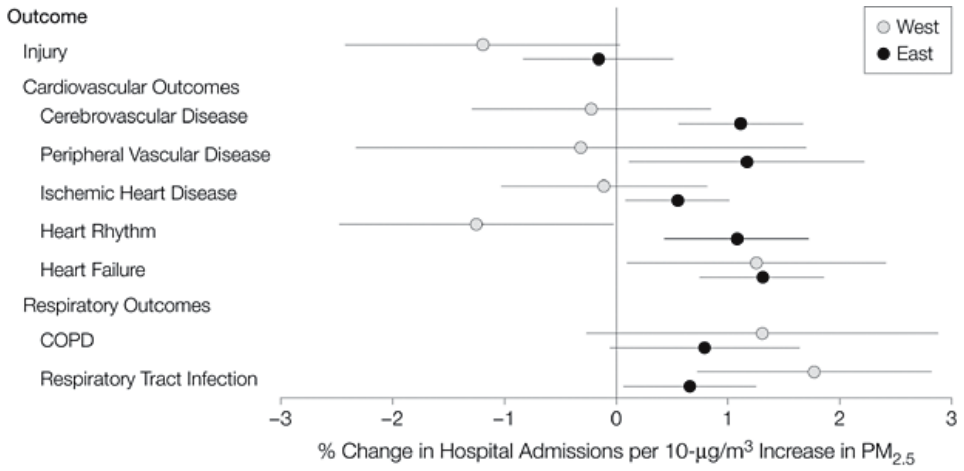
Health effects of wildfires



Cascio, Sci Total Environ. 2018 May 15; 624: 586–595.

Wildfires: a significant cause of mortality

Percentage Change in Hospitalization Rate by Cause per 10 ug/m3 Increase in PM2.5 for the US Eastern and Western Regions for all Outcomes



Dominici, F. et al. JAMA 2006;295:1127-1134.

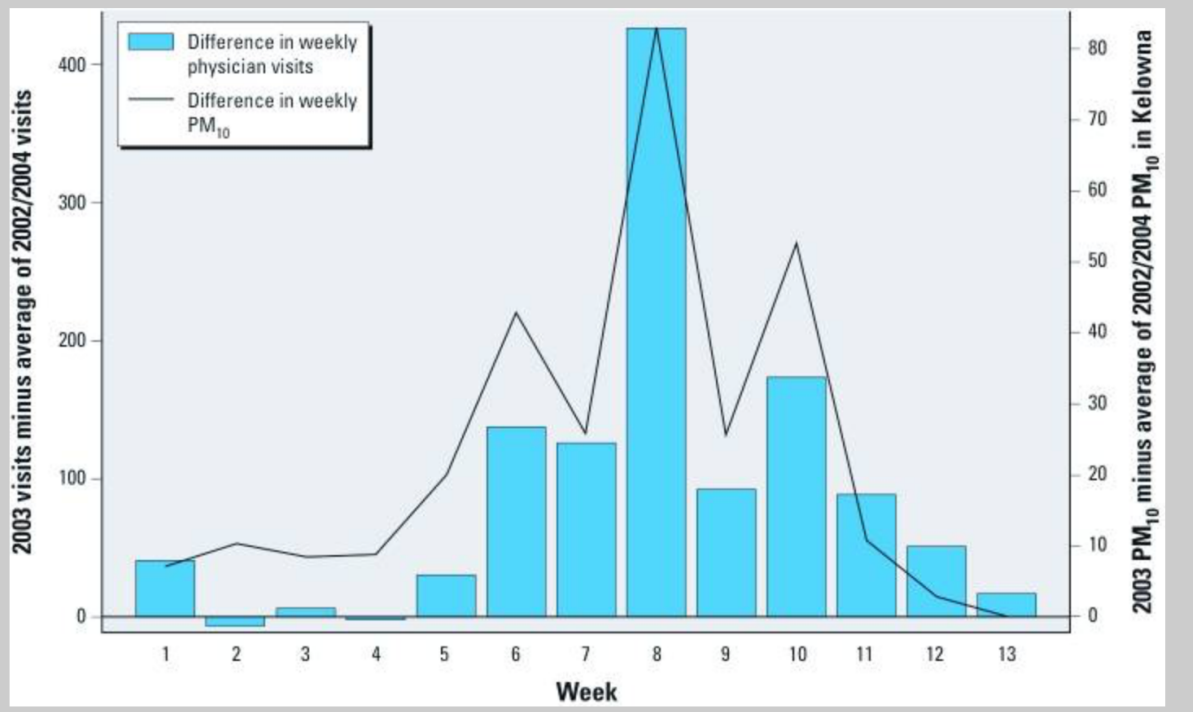
JAMA

Ample evidence associated wildfire smoke with adverse health outcomes: The science in this area would ordinarily lead to regulations

Association of wildfire smoke and morbidity: MULTIPLE LINES OF EVIDENCE

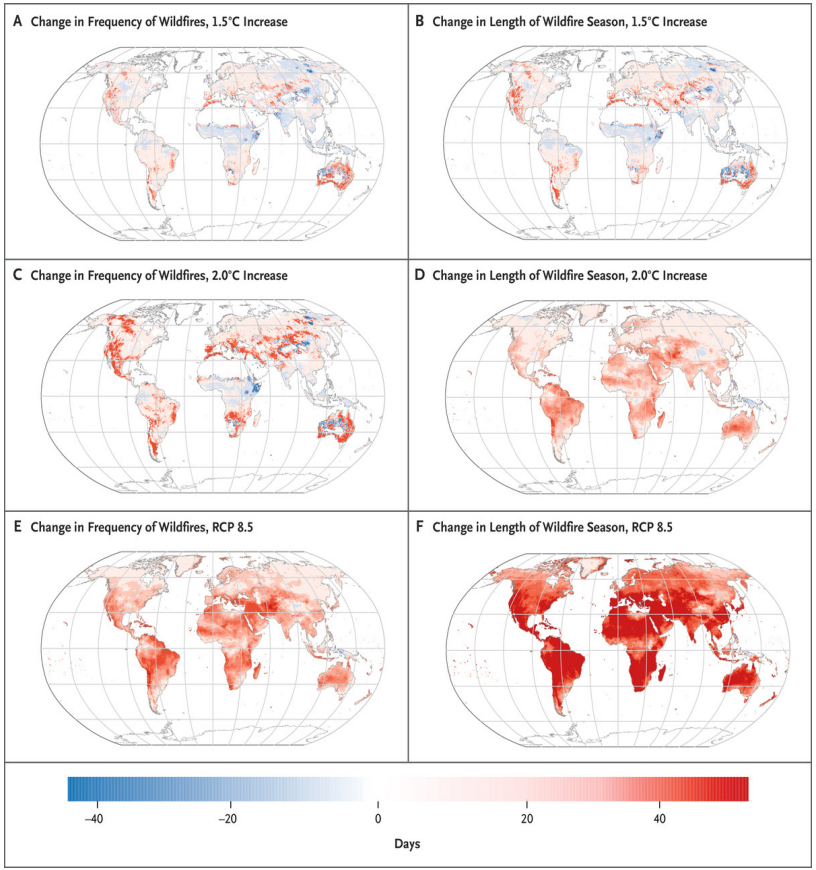
Morbidity					
	Respiratory		Increased	Very Strong	+ Liu et al., 2017a; Lui et al., 2017b; + Tinling et al., 2016; + Reid et al., 2016b; + Parthum et al., 2017; + Le et al., 2014*
		Asthma	Increased	Very Strong	+ Vicedo-Cabrera et al., 2016; + Reid et al., 2016b; + Alman et al., 2016; + Parthum et al., 2017, – Kollanus et al., 2016
		COPD	Increased	Very Strong	+ Reid et al., 2016b; Alman et al., 2016; + Parthum et al., 2017, – Kollanus et al., 2016; +Le et al., 2014*
		Infection	Increased	Strong	+ Tinling et al., 2016; + Parthum et al., 2017

Kelowna, Australia: Impact of 2003 bush fires on PM10 and weekly MD visits



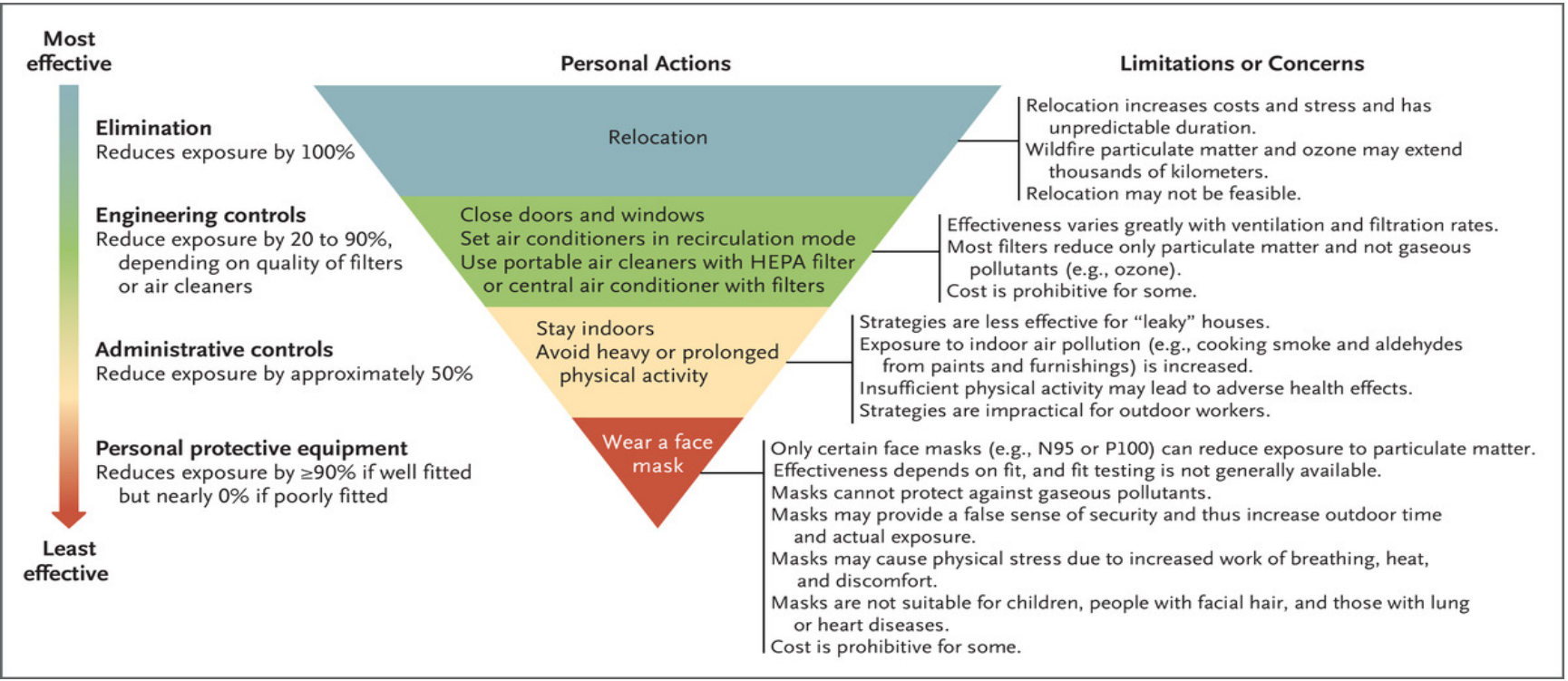
Henderson et al, Environ Health Perspect. 2011 Sep; 119(9): 1266–1271.

Projected Change from 1981–2000 to 2080–2099 in Frequency of Wildfires and Length of Wildfire Season, According to Global Mean Surface-Temperature Increase.



R Xu et al. N Engl J Med 2020;383:2173-2181.

Main Actions That Individual People Can Take to Reduce Exposure to Wildfire Smoke and Its Health Risks.

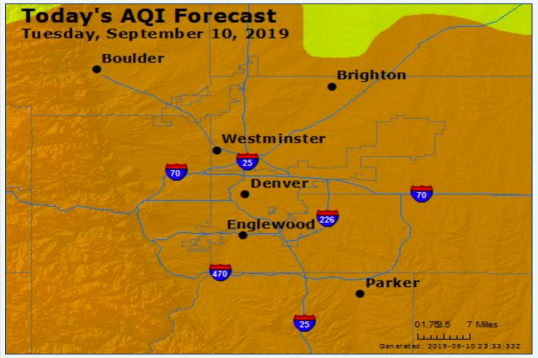


R Xu et al. N Engl J Med 2020;383:2173-2181.

The challenge of managing climate change driven degraded air quality and risks to individual and public health

AQI forecasts: Lack granularity to be useful

Current AQI | **Forecast** | AQI Loop | More Maps



Good | Moderate | USG | Unhealthy | Very Unhealthy | Hazardous | ! Action Day

Local Air Quality Resources

Air Quality Index (AQI) I CDPHE Advisories I Forecast I Regional Air Quality Council

State Air Quality Resources

American Lung Association (ALA) of Colorado
Colorado Air Quality Summary
Colorado DPHE - Air Pollution Control Division
Colorado DPHE - Contact Information
Colorado Department of Public Health & Environment (DPHE)

Data and Forecasts courtesy of:
Colorado Department of Public Health and Environment (DPHE), Southern Ute Indian Tribe

Current Conditions

Air Quality Index (AQI) observed at 17:00 MDT

115 **Unhealthy for Sensitive Groups**

Health Message: Active children and adults, and people with lung disease, such as asthma, should reduce prolonged or heavy exertion outdoors.

Note: Values above 500 are considered Beyond the AQI. Follow recommendations for the Hazardous category. Additional information on reducing exposure to extremely high levels of particle pollution is available here.

AQI - Pollutant Details

Ozone	115	Unhealthy for Sensitive Groups
Particles (PM10)	95	Moderate
Particles (PM2.5)	45	Good

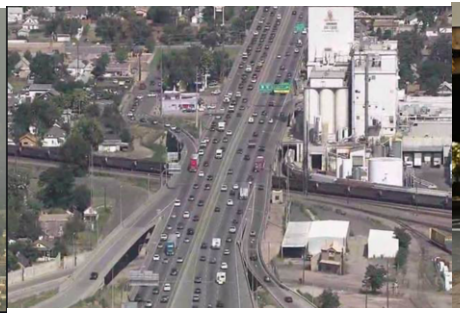
Air Quality Forecast

Today	Tomorrow
Air Quality Index (AQI)	**Air Quality Index (AQI)**
Unhealthy for Sensitive Groups	**Moderate**
Health Message: Active children and adults, and people with lung disease, such as asthma, should reduce prolonged or heavy exertion outdoors.	**Health Message:** Unusually sensitive people should consider reducing prolonged or heavy exertion outdoors.
! ACTION DAY	

AQI - Pollutant Details

Today		Tomorrow	
Ozone	! Unhealthy for Sensitive Groups	Ozone	Moderate
Particles (PM2.5)	Moderate	Particles (PM2.5)	Good

Regional and microscale air pollution during wildfires: What we see and how we are warned



Detailed Air Quality Summary for 09/26/20

Learn more about monitoring sites: **site descriptions** and **real-time monitoring map**

All data are collected real-time and have not been corrected nor validated.

Daily Highs:

Area	Site	Air Quality	Max AQI	Pollutant	Conc.	Period	Time * (MST)
Denver METRO [expand +]	NJH	Unhealthy for Sensitive Groups	106	Particulate < 2.5 micrometers	38 µg/m^3	24-hour	8 PM
Ft. Collins - Greeley [expand +]	GREH	Moderate	97	Particulate < 2.5 micrometers	34 µg/m^3	24-hour	6 PM
Colorado Springs [expand +]	CCOL	Moderate	67	Particulate < 2.5 micrometers	20 µg/m^3	24-hour	12 AM
Grand Junction [expand +]	GJPB	Good	48	Particulate < 2.5 micrometers	11 µg/m^3	24-hour	1 AM
Colorado River Valley [expand +]	RIFLO3	Good	45	Ozone	49 PPB	8-hour	7 PM
Four Corners [expand +]	CTZ	Good	49	Ozone	53 PPB	8-hour	6 PM
Other [expand +]	ASPN2	Good	48	Particulate < 2.5 micrometers	11 µg/m^3	24-hour	10 PM

Area	Site	Visibility	Max VSI	4-hour Average (1/km)	Beta Extinction (1/km)	Time * (MST)
Denver	DES	Poor	126	0.095	0.092	3 PM

	CASA	Moderate	60	Particulate < 10 micrometers	74 µg/m^3	24-hour	11 PM
	CASA	Moderate	99	Particulate < 2.5 micrometers	35 µg/m^3	24-hour	8 PM
	CHAT	Good	45	Ozone	49 PPB	8-hour	3 PM
	CHAT	Moderate	56	Particulate < 10 micrometers	66 µg/m^3	24-hour	12 AM
	CHAT	Moderate	96	Particulate < 2.5 micrometers	33 µg/m^3	24-hour	12 AM
	HLD	Good	45	Ozone	49 PPB	8-hour	6 PM
	I25DEN	Good	7	Carbon Monoxide	0.6 PPM	8-hour	2 AM
	I25DEN	Good	32	Nitrogen Dioxide	34 PPB	1-hour	8 AM
	I25DEN	Moderate	55	Particulate < 10 micrometers	64 µg/m^3	24-hour	2 AM
	I25DEN	Moderate	71	Particulate < 2.5 micrometers	21 µg/m^3	24-hour	8 PM
	I25GLO	Good	41	Nitrogen Dioxide	43 PPB	1-hour	7 AM
	I25GLO	Moderate	57	Particulate < 10 micrometers	67 µg/m^3	24-hour	8 PM
	I25GLO	Moderate	95	Particulate < 2.5 micrometers	33 µg/m^3	24-hour	8 PM
	LNGM	Moderate	62	Particulate < 10 micrometers	77 µg/m^3	24-hour	8 PM
	LNGM	Moderate	91	Particulate < 2.5 micrometers	31 µg/m^3	24-hour	8 PM
	NJH	Moderate	61	Particulate < 10 micrometers	75 µg/m^3	24-hour	12 AM
	NJH	Unhealthy for Sensitive Groups	106	Particulate < 2.5 micrometers	38 µg/m^3	24-hour	8 PM
	NREL	Moderate	51	Ozone	55 PPB	8-hour	1 AM
	RFN	Good	3	Nitrogen Dioxide	3 PPB	1-hour	7 PM
	RFN	Moderate	54	Ozone	56 PPB	8-hour	1 AM
	SWAN	Good	9	Carbon Monoxide	0.8 PPM	8-hour	1 AM
	SWAN	Good	50	Nitrogen Dioxide	53 PPB	1-hour	8 AM
	SWAN	Moderate	93	Particulate < 2.5 micrometers	32 µg/m^3	24-hour	8 PM

Current health warnings for smoke

Public health recommendations for areas affected by smoke:
If smoke is thick or becomes thick in your neighborhood you may want to remain indoors. This is especially true for those with heart disease, respiratory illnesses, the very young, and the elderly. Consider limiting outdoor activity when moderate to heavy smoke is present. Consider relocating temporarily if smoke is present indoors and is making you ill. IF VISIBILITY IS LESS THAN 5 MILES IN SMOKE IN YOUR NEIGHBORHOOD, SMOKE HAS REACHED LEVELS THAT ARE UNHEALTHY.

The problem of degraded air quality from climate change: The patient perspective

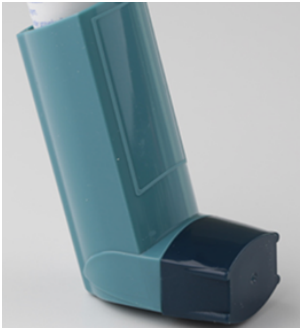
- 66 year-old man with chronic obstructive lung disease
- Exercise is known to improved COPD outcomes, so patient was encouraged by his MD to exercise daily
- Due to wildfires to the West, PM levels are in the unsafe range in Denver metro, and predicted to stay that way for at least a week
- Should patient be told to stay inside and not go for walks?

Blister versus bunion: A key concern for parents in relationship to air pollution

Do acute symptoms from wildfire pollution portend long term damage to the lungs, especially in kids?

How does wildfire smoke that causes “at risk” AQI levels impact health and activity?

- 15 year-old male with body mass index of 28 and asthma
- Family and primary care provider are trying to encourage more physical activity
- Summer of 2020 – patient needed rescue inhaler 4 times during a moderate wildfire AQI event after walking family dog



- *Should patient always avoid exercise/outdoors when AQI is bad?*
- *How does he know AQI in real time where he lives?*
- *Preventive use of inhalers prevent his symptoms= Is it OK for him to exercise after using albuterol?*

How does wildfire smoke that causes “at risk” AQI levels impact health and activity?

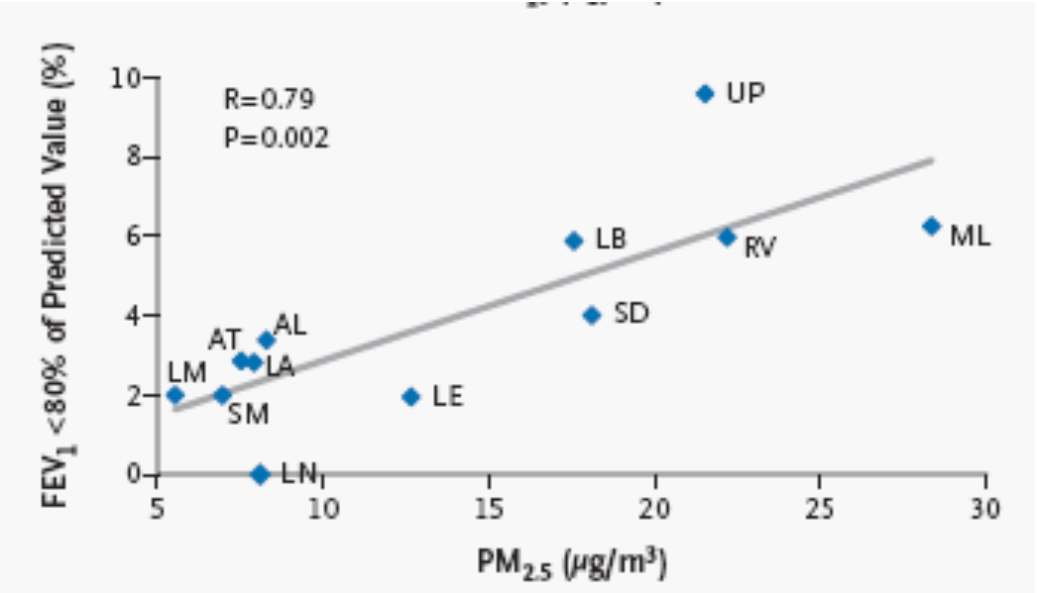
- 8-year old female on soccer team
- History of intermittent asthma symptoms after upper respiratory tract infections treated with sporadic albuterol

1. Should she skip soccer practice?
2. What if poor AQI event lasts for 4 weeks?
3. **Could exercise during poor AQI events cause her asthma to get worse in the long-term?**

Current “best” recommendations

- Education for parents and families about potential risks
- Children, adolescents, the elderly and those with lung disease are more susceptible to the effects of air pollution than healthy adults
- Individual sensitivity to pollution should be primary guide for activity recommendations (outside of known very high-risk groups)
  - History of symptom flares requiring step-up in therapy
  - Fairness issues (held inside for recess?).
  - Miss practices?
- No clear data to support blanket activity limitations during short term moderately poor AQI events
- **Prolonged and recurrent wildfire-driven AQI events are an increasing concern that require more research to enable evidence-based recommendations**

Community-Specific Proportion of 18-Year-Olds with a FEV_1 below 80 Percent of the Predicted Value Plotted against the Average Levels of Pollutants from 1994 through 2000



Gauderman et al: **The Effect of Air Pollution on Lung Development from 10 to 18 Years of Age**

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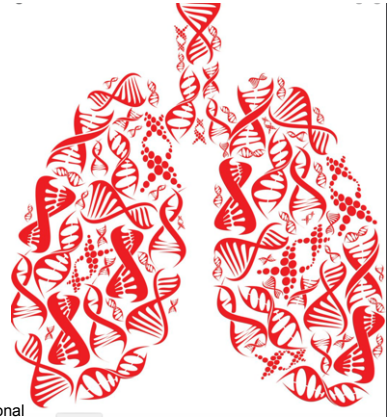
Public Health Goal: Developing personalized and granular health and activity recommendations



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