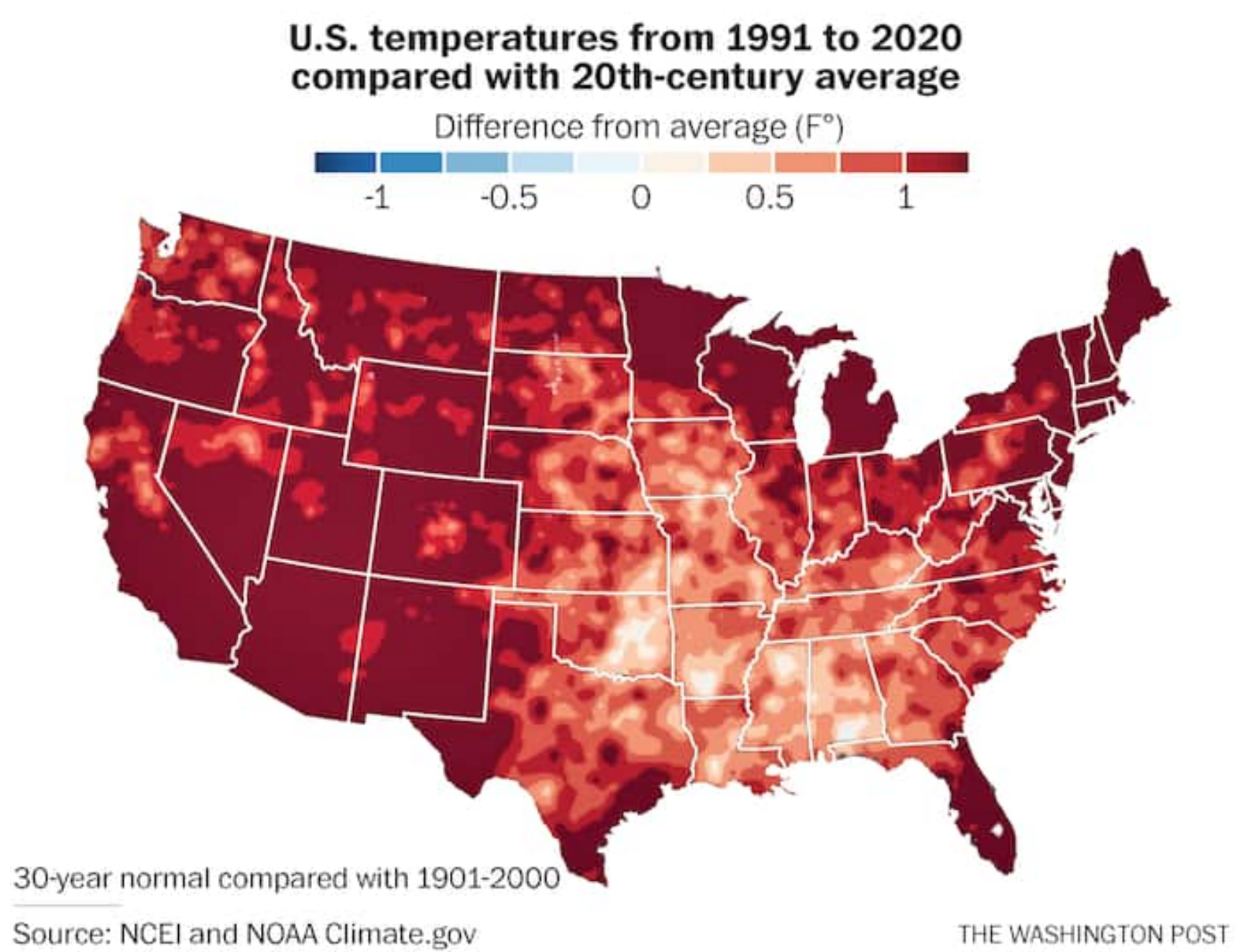
Climate Change, Environmental Exposure Effects, and Human Health

Mitchell Turker, Ph.D., J.D., Professor, Oregon Institute of Occupational Health Sciences, OHSU, Portland , OR

A lot of things are going to happen to the environment, a lot of populations are going to affected, and a lot of health effects are going to occur.

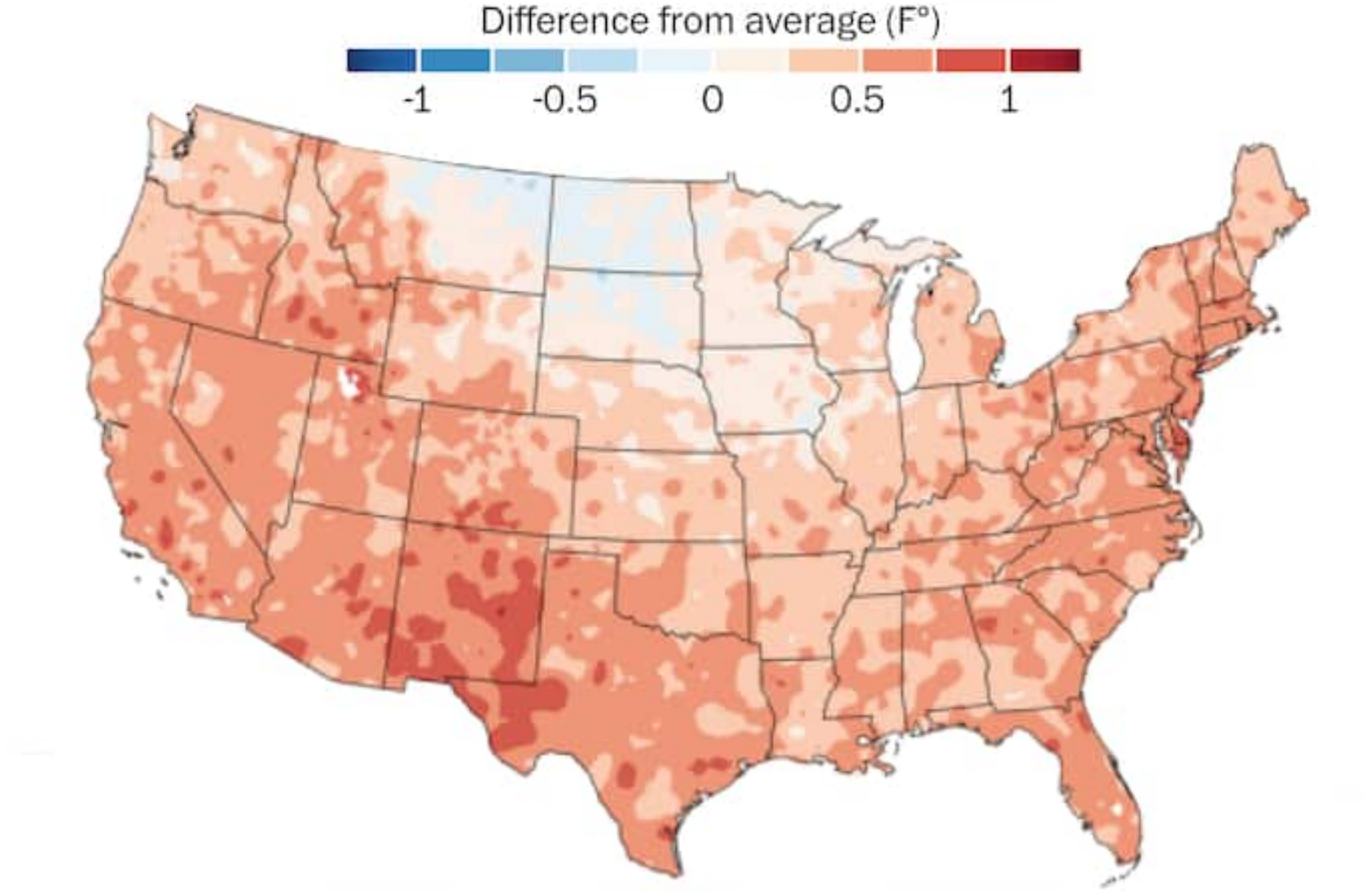
Topics

- Climate change basics
- Climate change and health effects-general
- Climate change and health effects-specific: smoke and wildfires
- Legal challenges: the kids are not alright.



The increase in temperature observed in Alaska reflected in the latest normals means that Fairbanks is “no longer a sub-Arctic climate in the widely used Köppen classification” for climate zones according to Rick Thoman, a climate specialist at the University of Alaska-Fairbanks. Instead, it resides within a “warm summer continental” zone.

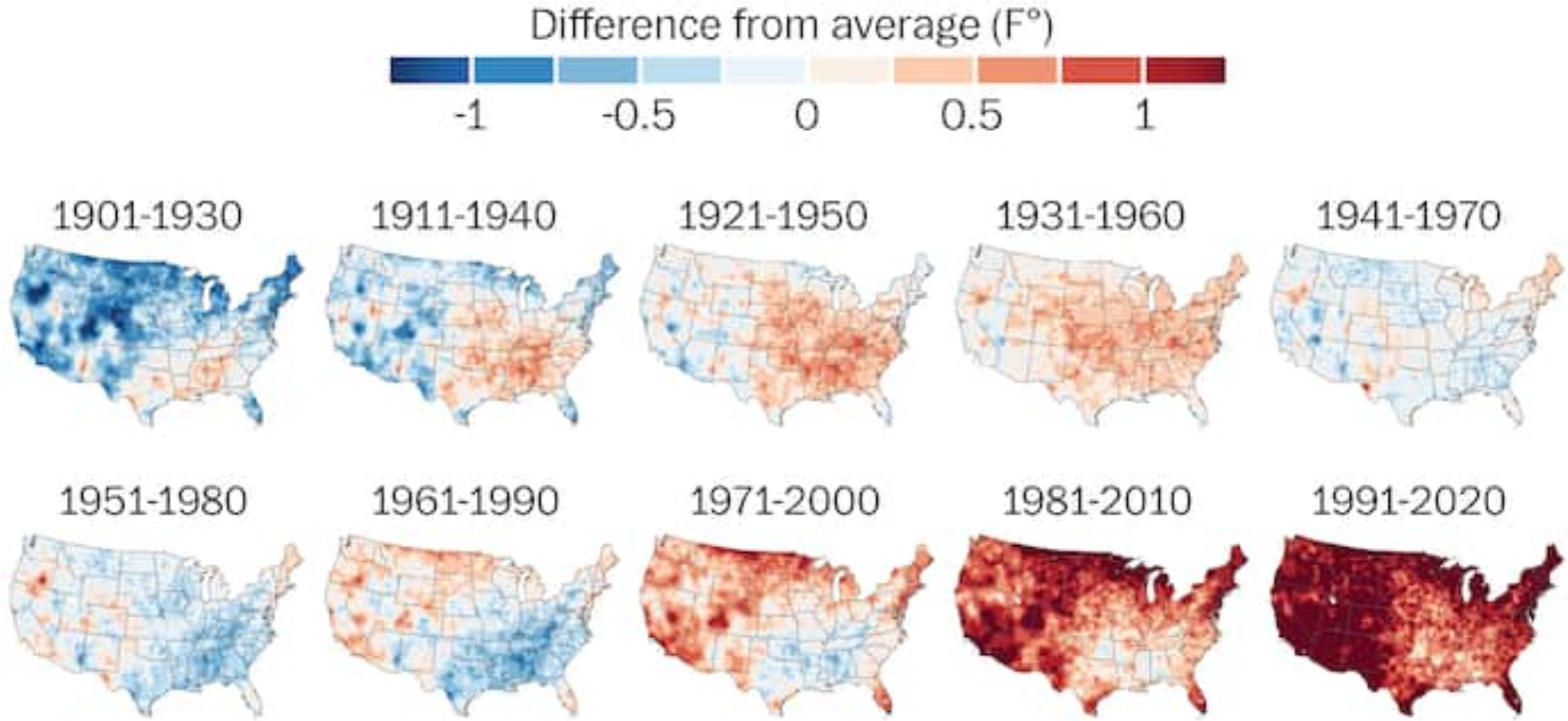
Change in normal temperatures between 1981-2010 and 1991-2020



Source: NCEI and NOAA Climate.gov

THE WASHINGTON POST

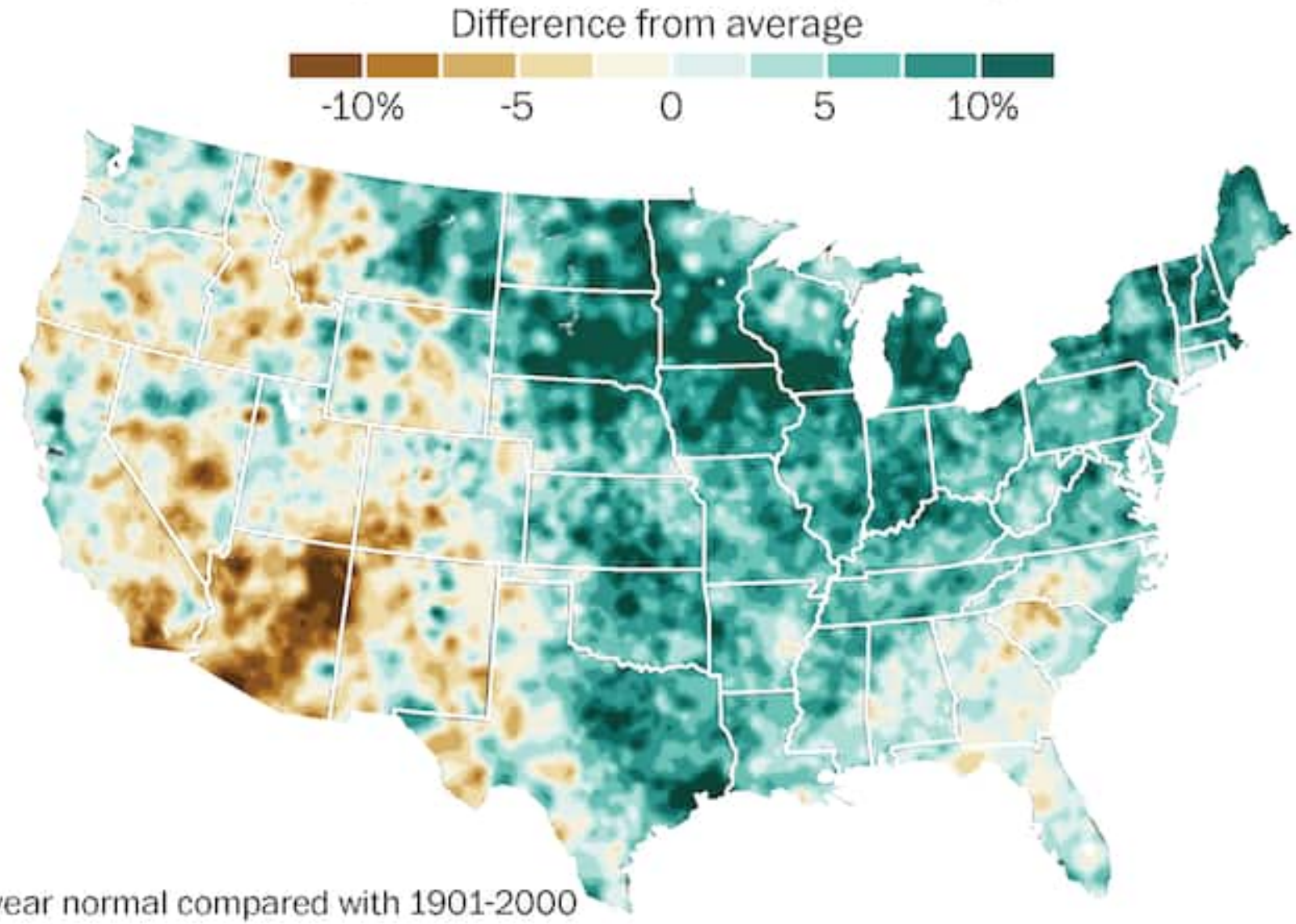
U.S. 30-year temperature compared with 20th-century average



Source: NCEI and NOAA Climate.gov

THE WASHINGTON POST

U.S. precipitation from 1991 to 2020 compared with 20th-century average

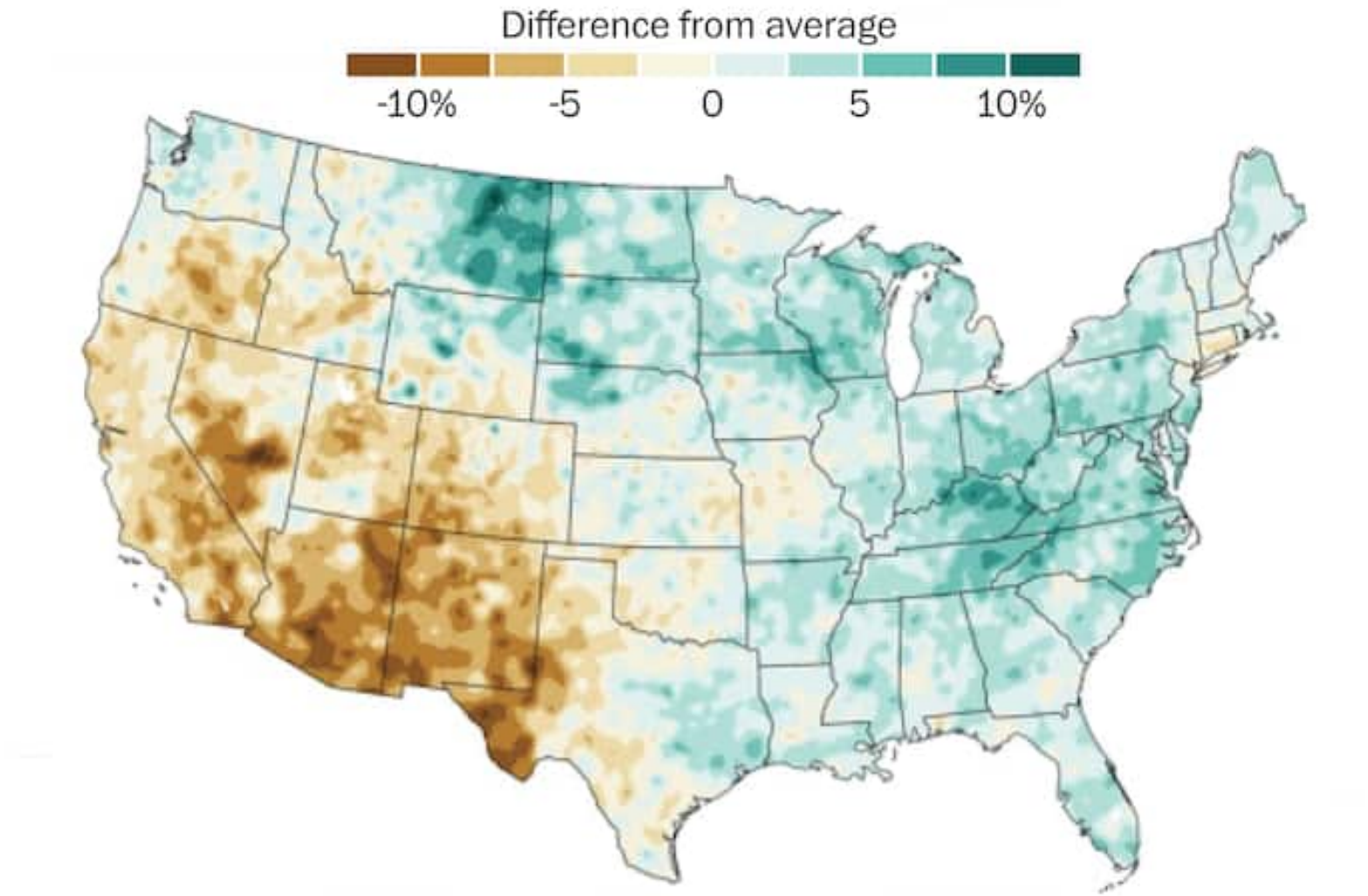


30-year normal compared with 1901-2000

Source: NCEI and NOAA Climate.gov

THE WASHINGTON POST

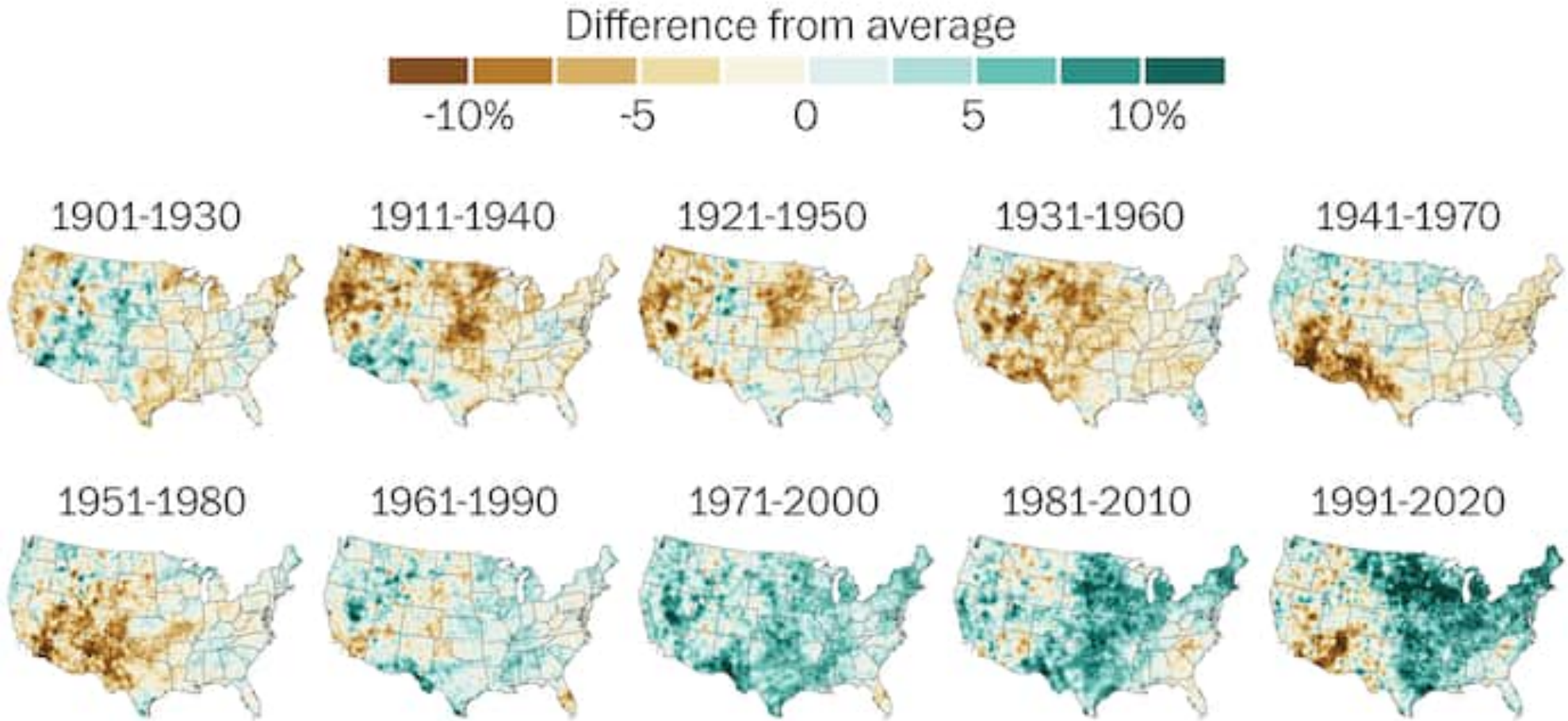
Change in normal precipitation between 1981-2010 and 1991-2020



Source: NCEI and NOAA Climate.gov

THE WASHINGTON POST

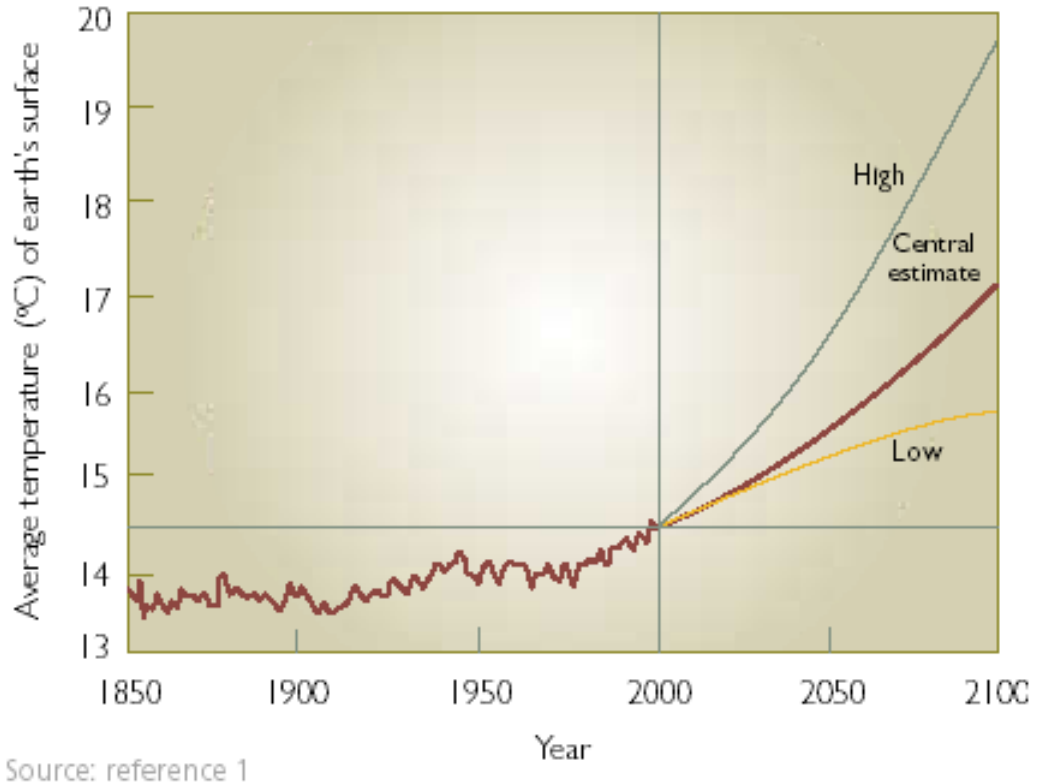
U.S. 30-year precipitation compared with 20th-century average



Source: NCEI and NOAA Climate.gov

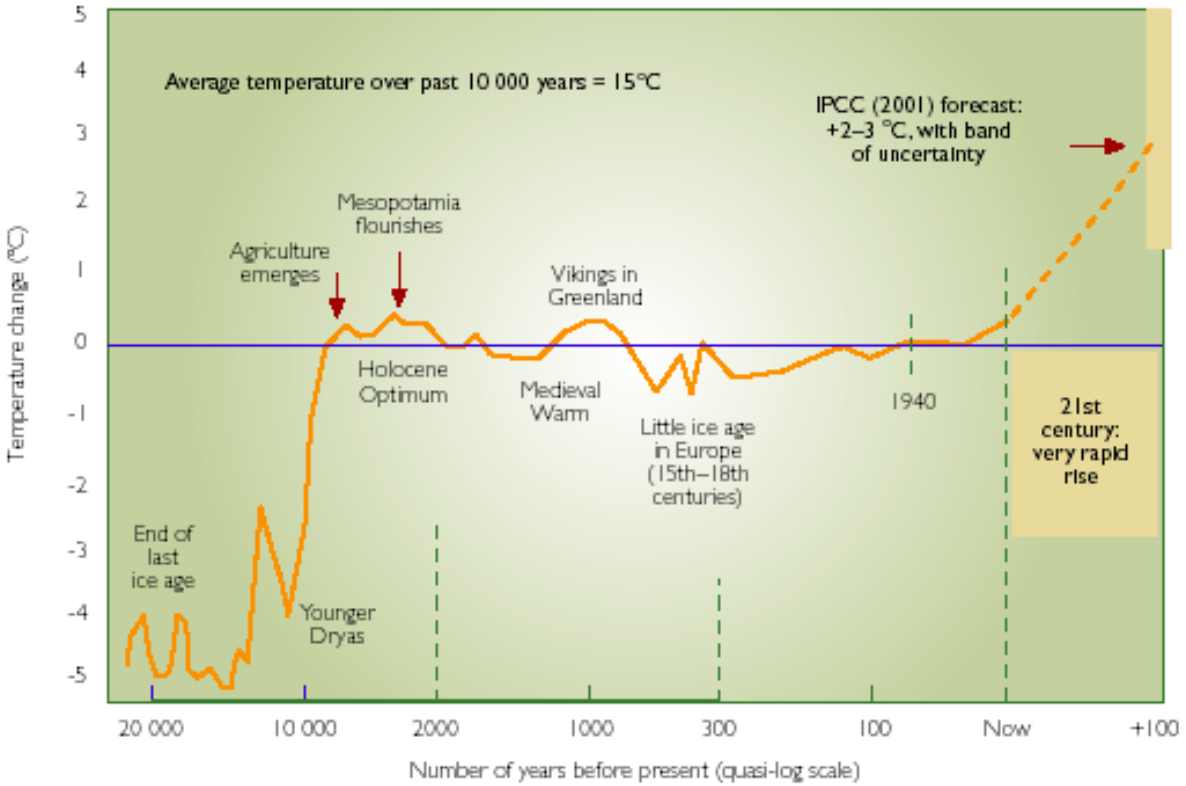
THE WASHINGTON POST

Figure 1.2 Global temperature record, since instrumental recording began in 1860, and projection to 2100, according to the IPCC



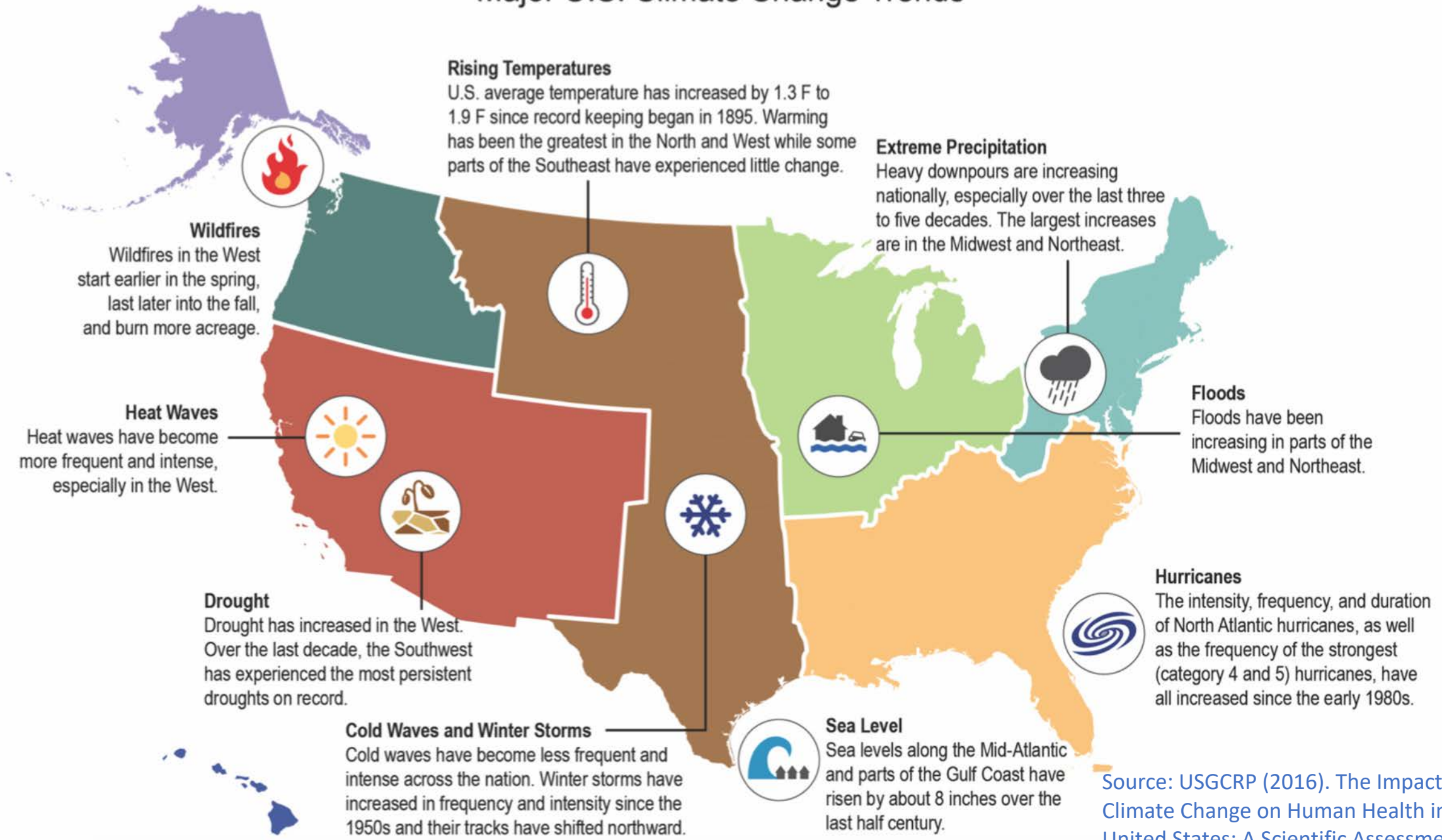
Source: reference 1

Figure 1.1. Variations in Earth's average surface temperature, over the past 20,000 years

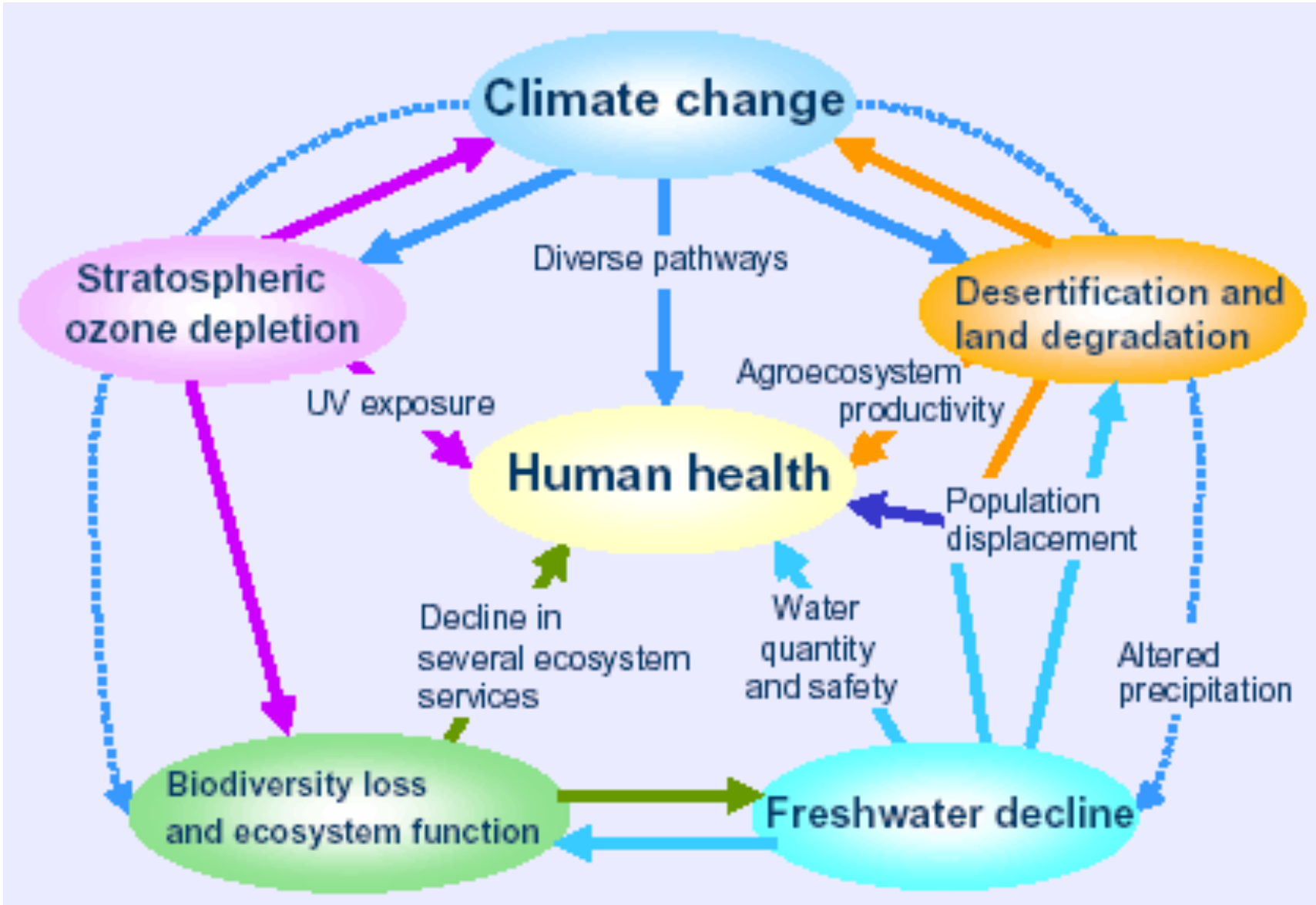


WHO

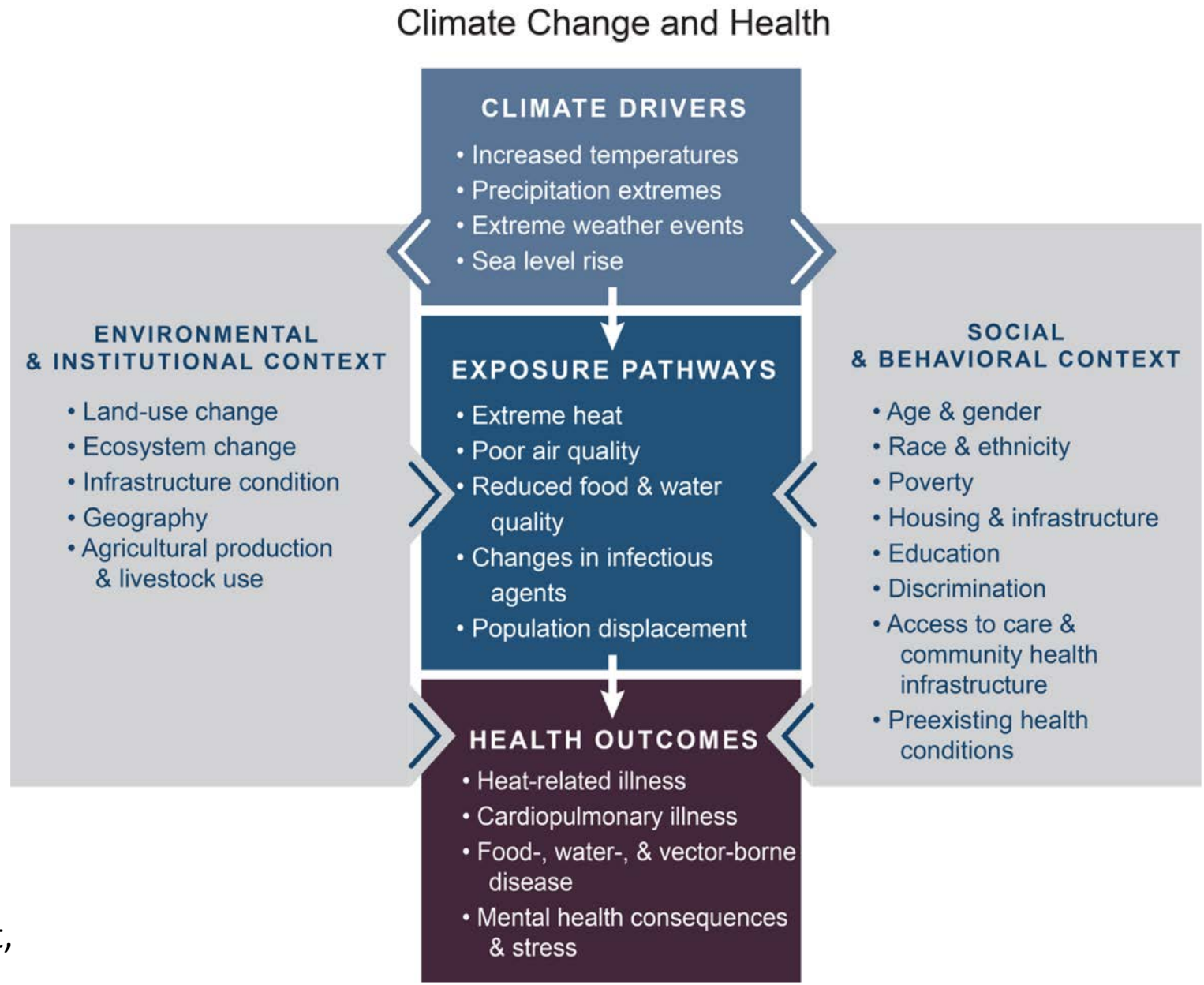
Major U.S. Climate Change Trends



Source: USGCRP (2016). The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment.


Climate change
Stratospheric ozone depletion
Diverse pathways
Desertification and land degradation
UV exposure
Agroecosystem productivity
Human health
Population displacement
Decline in several ecosystem services
Water quantity and safety
Altered precipitation
Biodiversity loss and ecosystem function
Freshwater decline

Source: WHO



Fourth National Climate Assessment, 2018

Figure 2. Connecting Climate Change Indicators to Health Pathways

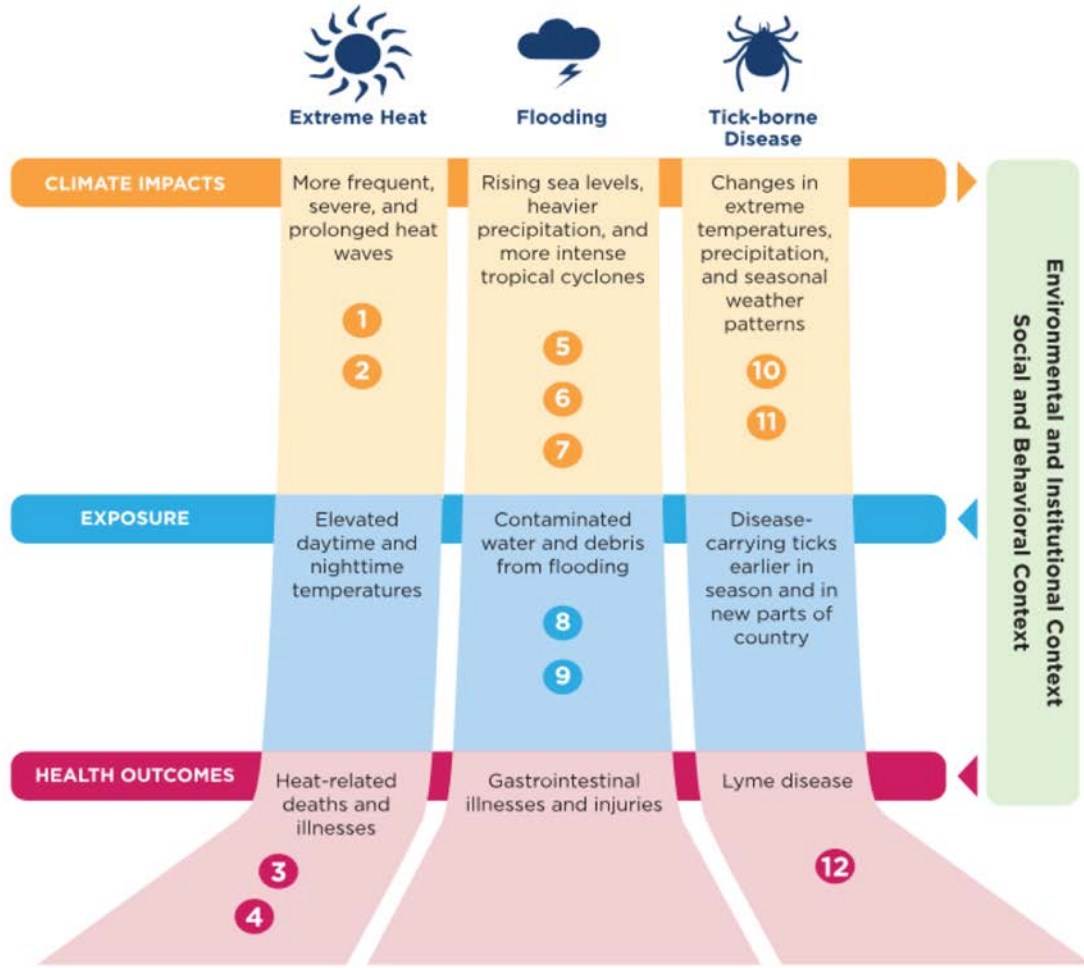
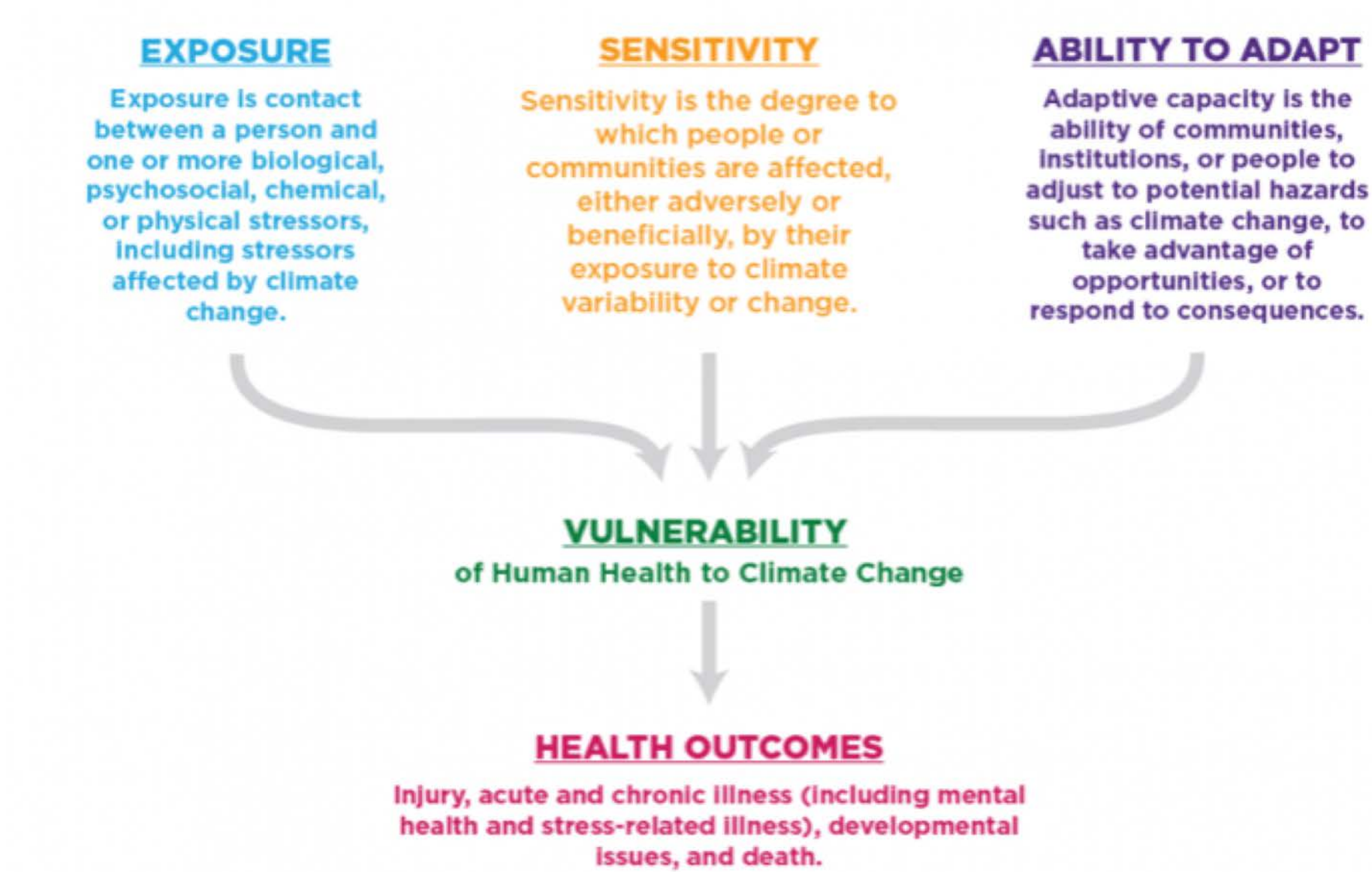


Figure 3. Determinants of Vulnerability



	Climate Driver	Exposure	Health Outcome	Impact
Extreme Heat	More frequent, severe, prolonged heat events	Elevated temperatures	Heat-related death and illness	Rising temperatures may lead to an increase in heat-related deaths and illnesses.
Outdoor Air Quality	Increasing temperatures and changing precipitation patterns	Worsened air quality (ozone, particulate matter, and higher pollen counts)	Premature death, acute and chronic cardiovascular and respiratory illnesses	Rising temperatures and wildfires and decreasing precipitation may lead to increases in ozone and particulate matter, elevating the risks of cardiovascular and respiratory illnesses and death.

Source: USGCRP (2016). The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment.

	Climate Driver	Exposure	Health Outcome	Impact
Flooding	Rising sea level and more frequent or intense extreme precipitation, hurricanes, and storm surge events	Contaminated water, debris, and disruptions to essential infrastructure	Drowning, injuries, mental health consequences, gastrointestinal and other illness	Increased coastal and inland flooding exposes populations to a range of negative health impacts before, during, and after events.
Vector-Borne Infection (Lyme disease)	Changes in temperature extremes and seasonal weather patterns	Earlier and geographically expanded tick activity	Lyme disease	Ticks may show earlier seasonal activity and a generally northward range expansion, increasing risk of human exposure to Lyme disease-causing bacteria.
Water-Related Infection (Vibrio vulnificus)	Rising sea surface temperature, changes in precipitation, and runoff affecting coastal salinity	Recreational water or shellfish contaminated with Vibrio vulnificus	Vibrio vulnificus-induced diarrhea and intestinal illness, wound and bloodstream infections, death	Increases in water temperatures may alter timing and location of Vibrio vulnificus growth, increasing exposure and risk of waterborne illness.

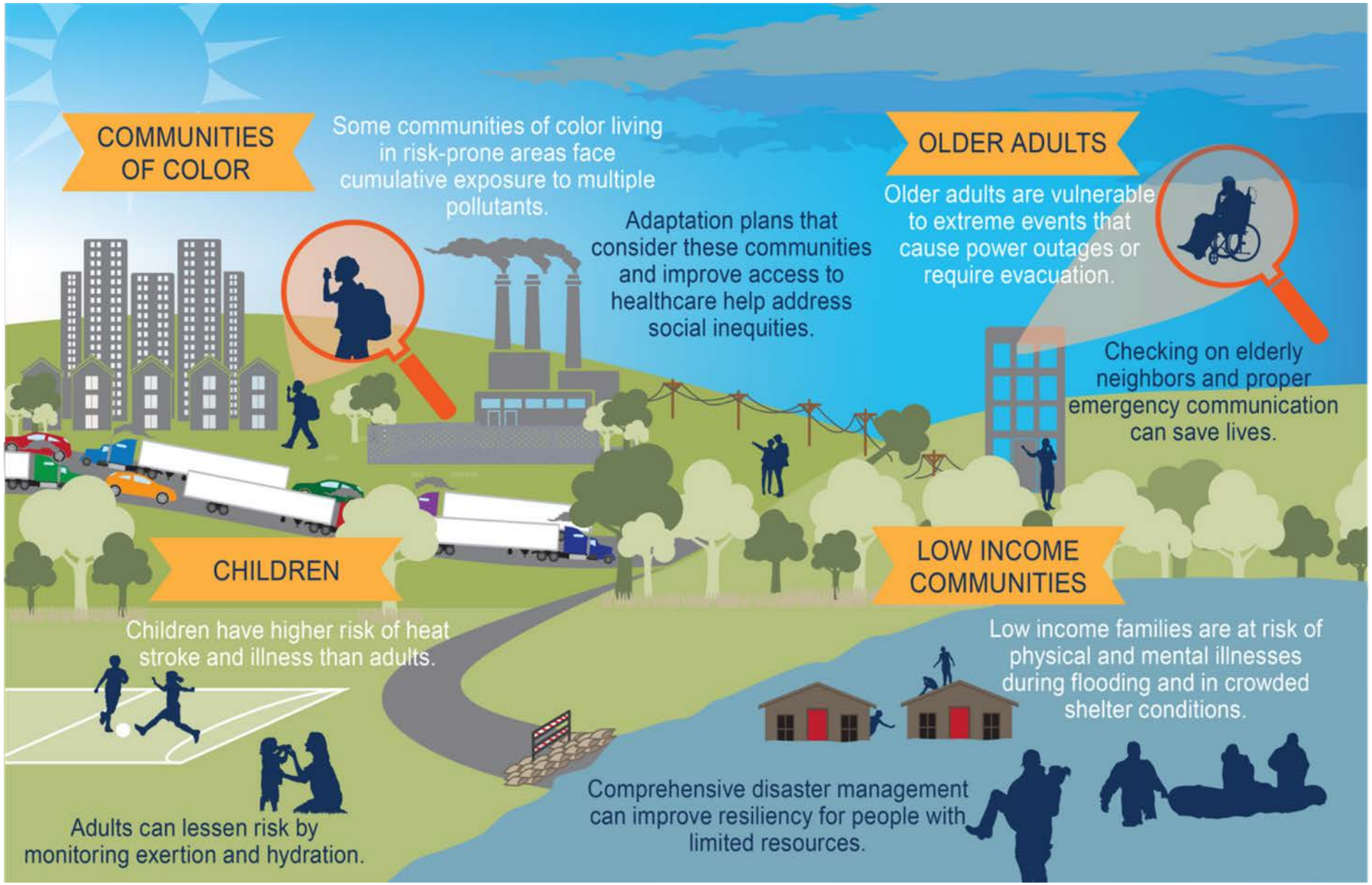
Source: USGCRP (2016). The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment.

	Climate Driver	Exposure	Health Outcome	Impact
Food-Related Infection (Salmonella)	Increases in temperature, humidity, and season length	Increased growth of pathogens, seasonal shifts in incidence of Salmonella exposure	Salmonella infection, gastrointestinal outbreaks	Rising temperatures increase Salmonella prevalence in food; longer seasons and warming winters increase risk of exposure and infection.
Mental Health and Well-Being	Climate impacts, especially extreme weather	Level of exposure to traumatic events, like disasters	Distress, grief, behavioral health disorders, social impacts, resilience	Changes in exposure to climate- or weather-related disasters may cause or exacerbate stress and mental health consequences.

Source: USGCRP (2016). The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment.

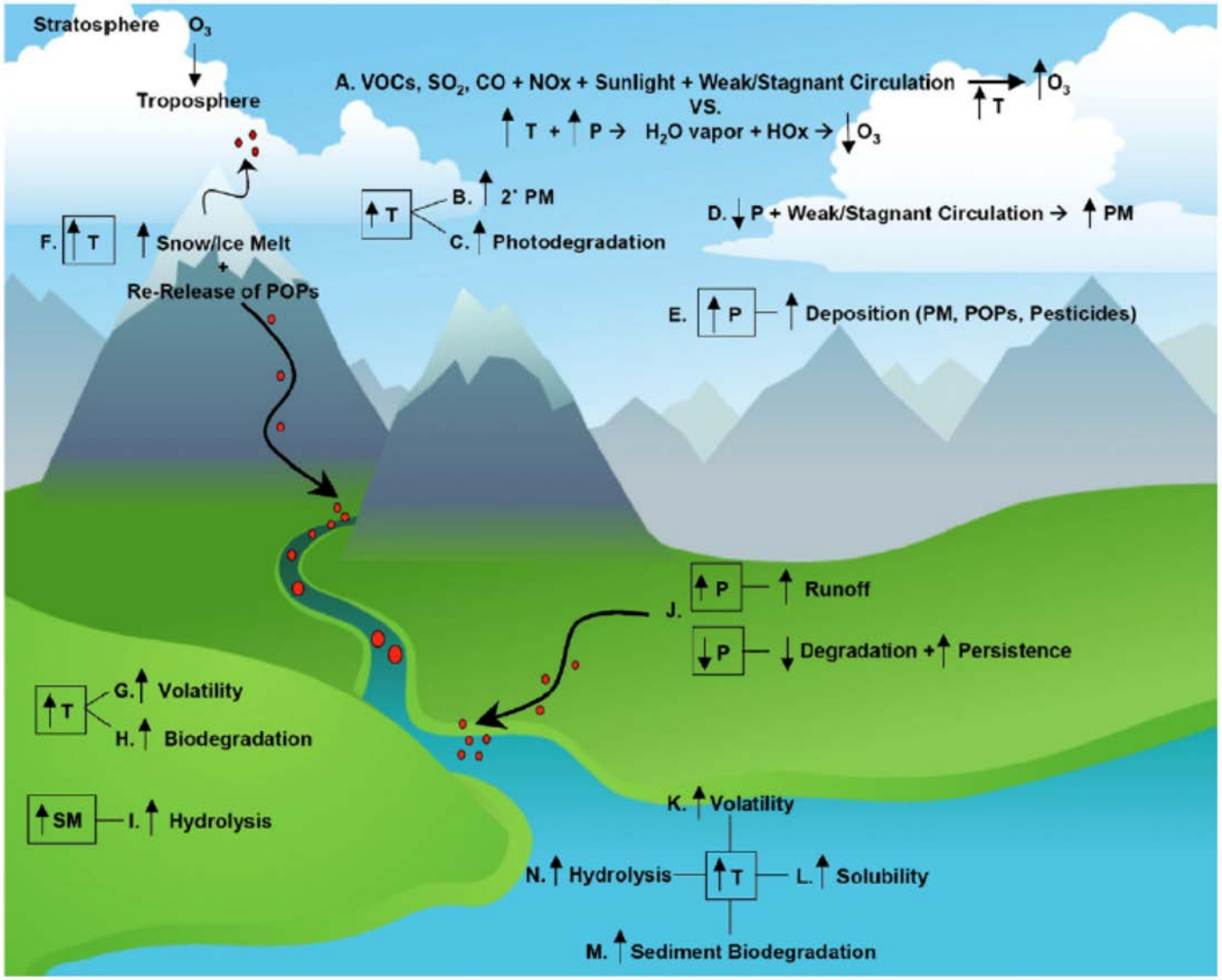
Climate change and health: more pieces of the big picture

- Extreme events: drought, wildfires, heavy rains, floods, storms, and storm surge. Can exacerbate medical conditions, increase stress, and disrupt public health systems.
  - Drought: Households in two drought-stricken CA counties (Tulare and Mariposa) reported a range of drought-related health impacts, including increased dust leading to allergies, asthma, and other respiratory issues.
- Food safety and nutrition: Food supplies will be threatened in a number of ways.
  - E.g., increased pathogen exposure, food chain disruptions, increased prices, rising CO2 can decrease nutrients in crops, seafood availability will decrease.



Fourth National Climate Assessment, 2018

Climate Change and Environmental Distribution of Contaminants



2°PM=Secondary PM; CO=Carbon monoxide; HOx=HO2+OH; NOx=Nitrogen oxides; O3=Ozone; P=Precipitation; PM=Particulate Matter; POP= Persistent Organic Pollutant; SM = Soil Moisture; T = Temperature; VOCs = Volatile organic compounds.

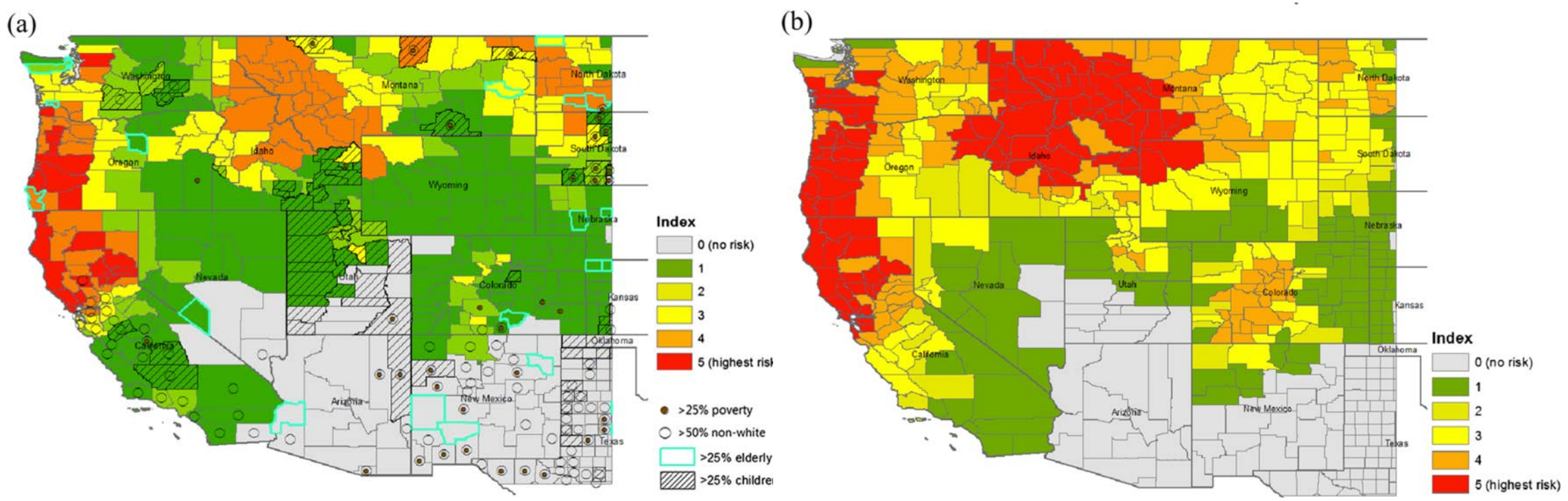
Climate Change and Toxic Agricultural Exposures

- Herbicides, insecticides, fungicides: Increased used due to increased abundance and activity of plant diseases. High
- Fertilizers and sewage sludge w/contaminants: Increased use due to decreased soil carbon and increased leaching. Medium
- Flooding: Will mobilize contaminants and move from soil. Medium
- Antibacterials and pesticides: Increased use from increased disease pressures for livestock. High
- Disease vectors-bacteria and viruses: range of diseases will spread leading to food insecurity High

Boxall et al, 2009, Environmental Health Perspectives

Fire Smoke Risk Index 2004-09 vs 2046-51

(overall wildfire risk based on duration, intensity, and frequency of smoke waves)



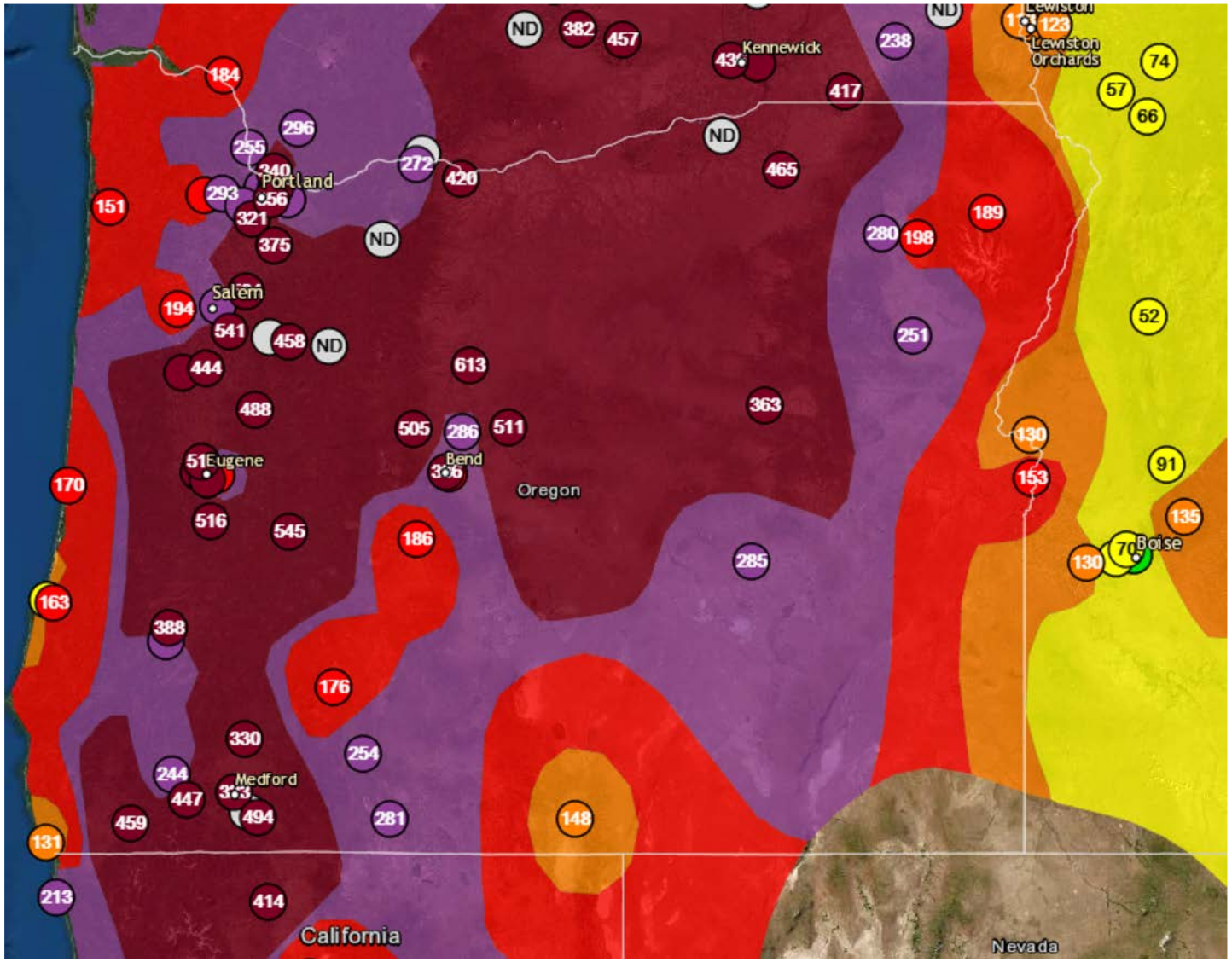
Liu et al, Climate Change, 2016

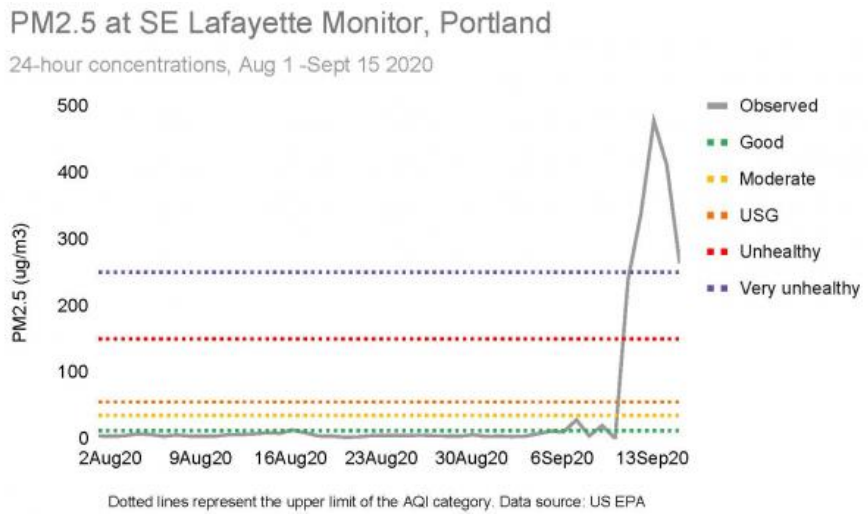
Air quality from wildfires

(want to be <50)

AQI tracks five major air pollutants:

*Ground level ozone
Carbon monoxide
Sulfur dioxide
Nitrogen dioxide
*Airborne particles, or aerosols





September 12, 2020

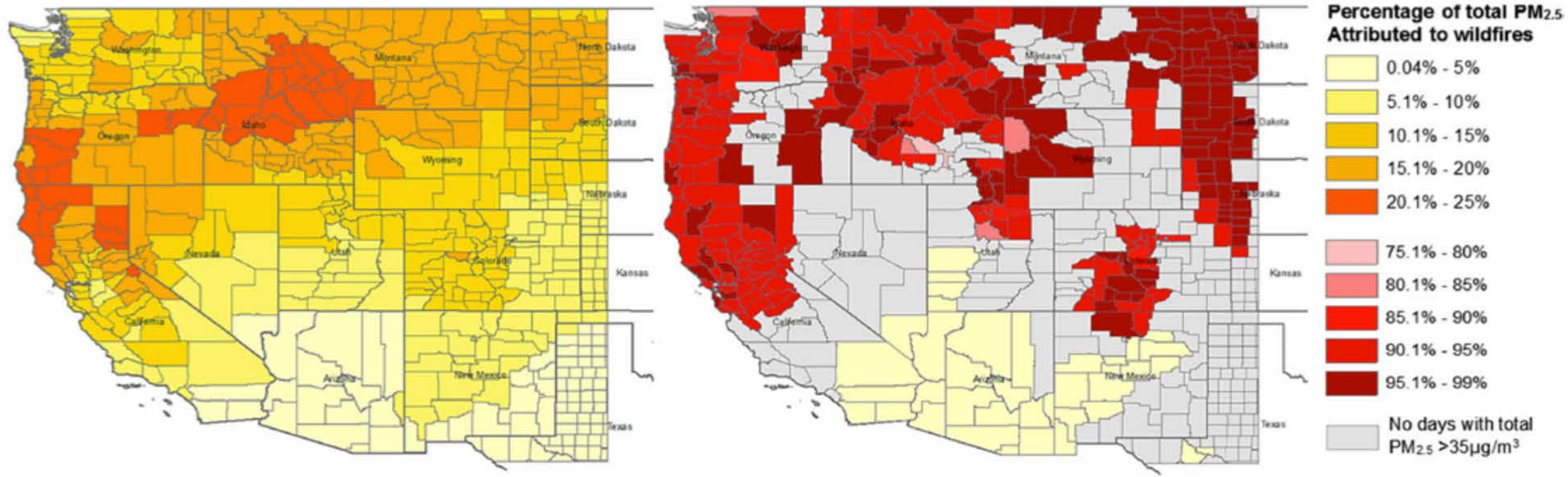


Fig. 1 Fraction of $PM_{2.5}$ attributable to wildfires by county during fire seasons (May-October) in the present day (2004–2009), on all days (left panel), and on the subset of days that had total $PM_{2.5} > 35$ $\mu g/m^3$ (The National Ambient Air Quality Standards (NAAQS) threshold; right panel)

Liu et al, Climate Change, 2016

The NEW ENGLAND JOURNAL of MEDICINE

SPECIAL REPORT

Wildfires, Global Climate Change, and Human Health

Rongbin Xu, M.B., B.S., Pei Yu, M.B., B.S., Michael J. Abramson, M.B., B.S., Ph.D., Fay H. Johnston, B.M., B.S., Ph.D., Jonathan M. Samet, M.D., Michelle L. Bell, Ph.D., Andy Haines, M.B., B.S., M.D., Kristie L. Ebi, Ph.D., M.P.H., Shanshan Li, M.D., Ph.D., and Yuming Guo, M.D., Ph.D.

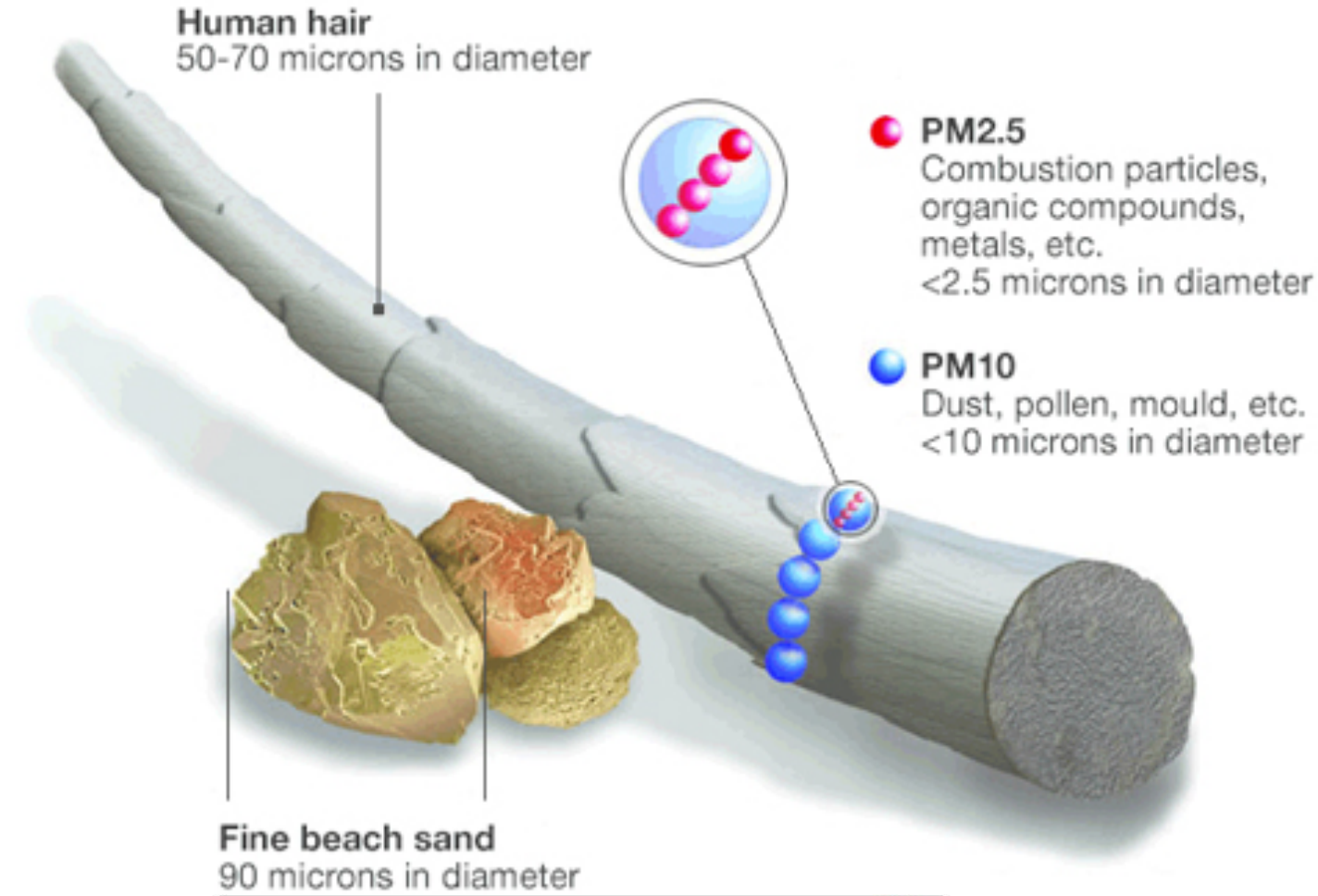
n engl j med 383;22 nejm.org November 26, 2020

- Wildfires in Australia in 2019 to 2020
- the Amazon rainforest in Brazil in 2019 and 2020
- the western United States in 2018 and 2020,
- British Columbia, Canada, in 2017 and 2018.
- Since August of this year, record-breaking wildfires have burned 2.7 million hectares (as of September 18, 2020) along the West Coast of the United States, killing more than 30 people.
- Robust projections indicate that the risk of wildfires will continue to increase in most areas of the world as climate change worsens and that the fires will increase excess mortality and morbidity from burns, wildfire smoke, and mental health effects.

Adopted from n engl j med 383;22 nejm.org November 26, 2020

Proximal vs. distal effects for fires

- Proximal effects are due to continued building at the wildland urban interface.
  - Fires are a normal and often required part of forest health, and in some regions occur every ~5-75 years.
  - Yet we build houses in the paths of these fires.
  - Forest fire released carbon emission (~20%) is not equivalent to that from fossil fuels (80%); however deforestation.
  - Burns and intense smoke inhalation.
- Distal effects are due to the smoke the fires create, which can spread great distances.
  - Portland has had smoke from California, Washington, British Columbia and Oregon forests west and east of Portland.
  - Fine particles, PM <2.5.

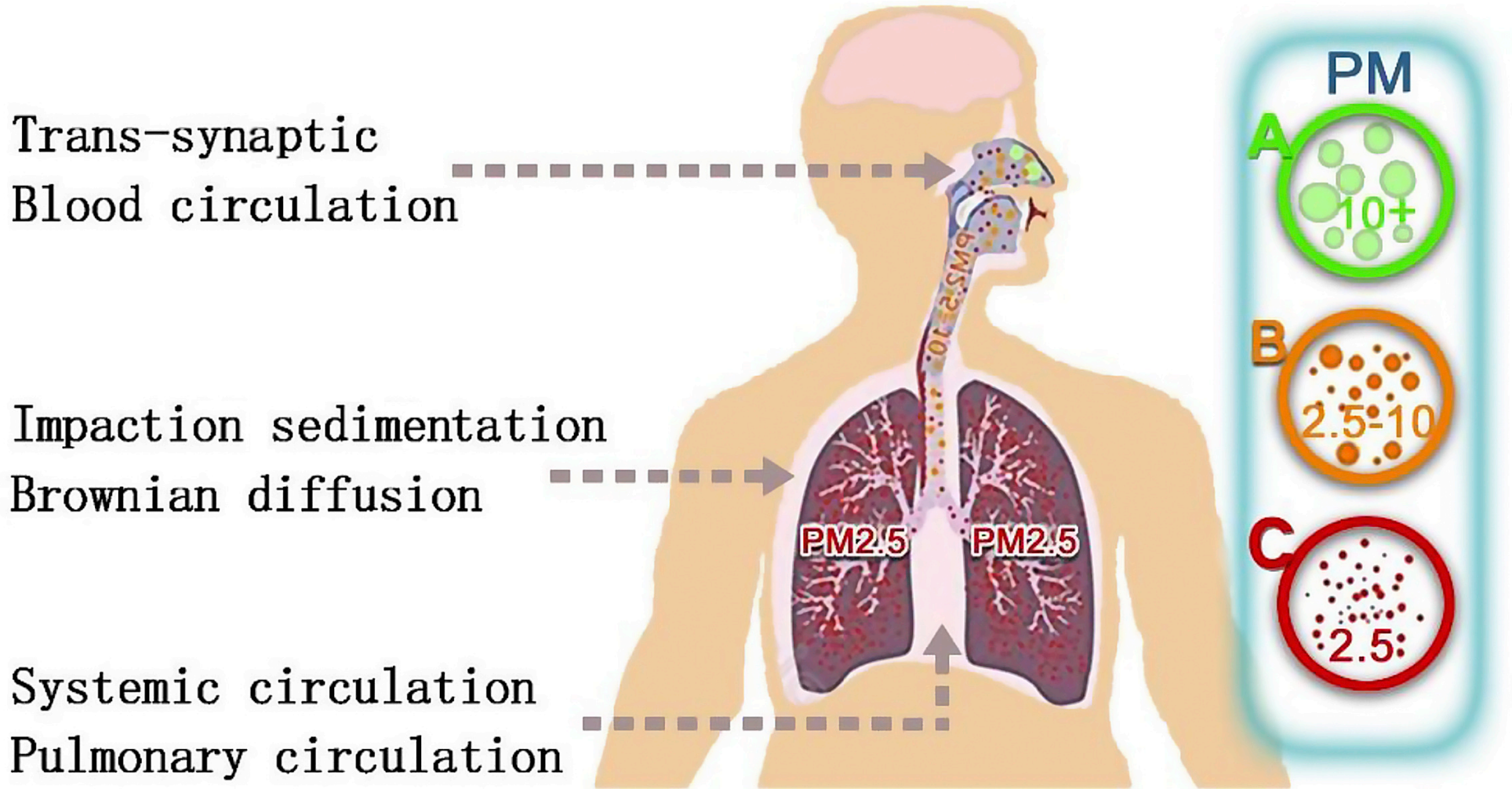


Source: US EPA

Foodthesis

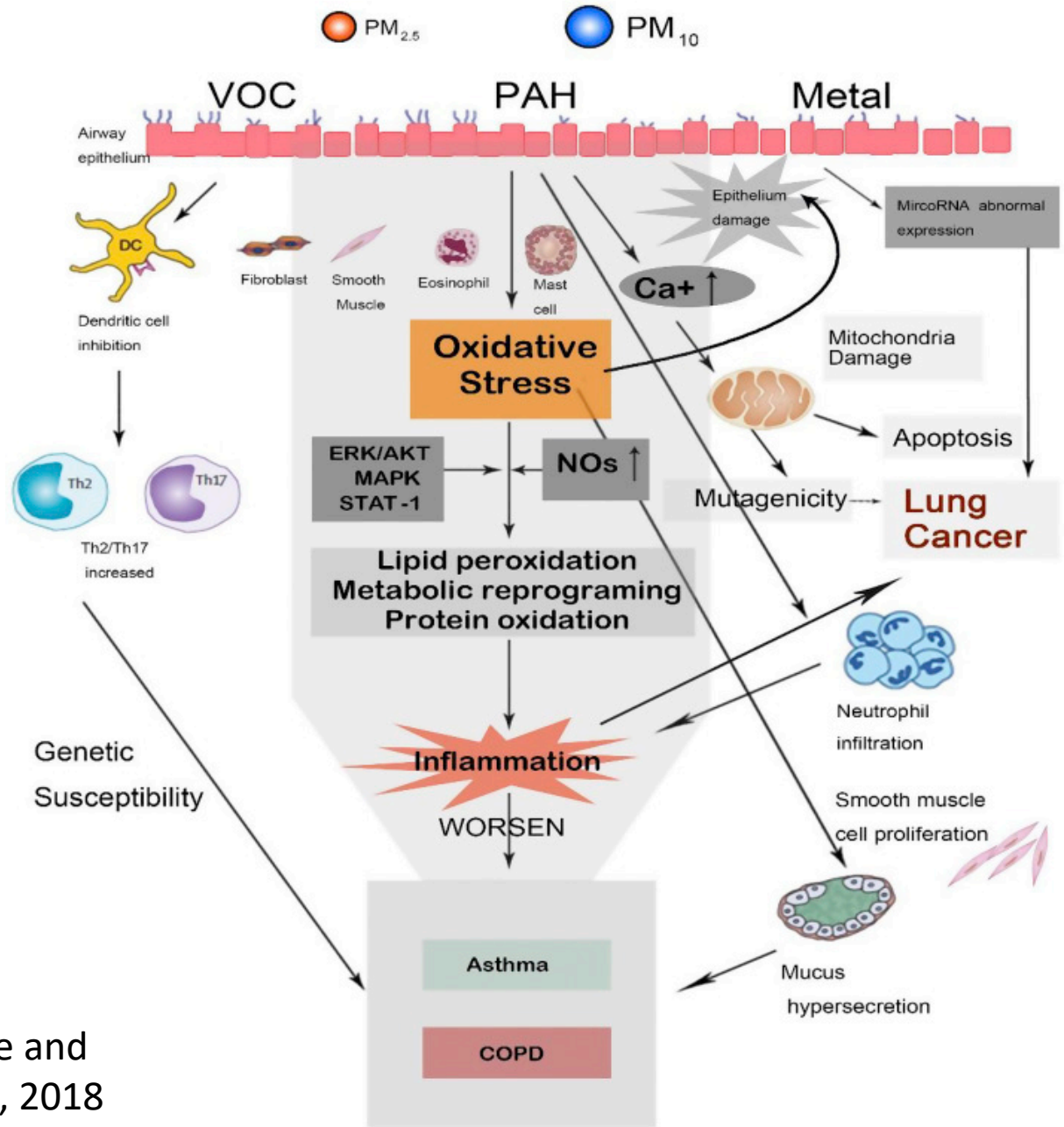
AIR QUALITY & PM 2.5 LEVELS

Air Quality Index	PM 2.5
GOOD (0-50)	0-30
MODERATE (51-100)	31-60
UNHEALTHY FOR SENSITIVE GROUP (101-150)	61-90
UNHEALTHY (151-200)	91-120
VERY UNHEALTHY (201-300)	121-180
HAZARDOUS (301-500)	181-300



Li et al, Chronic Disease and Translational Medicine, 2018

Exposure to PMs



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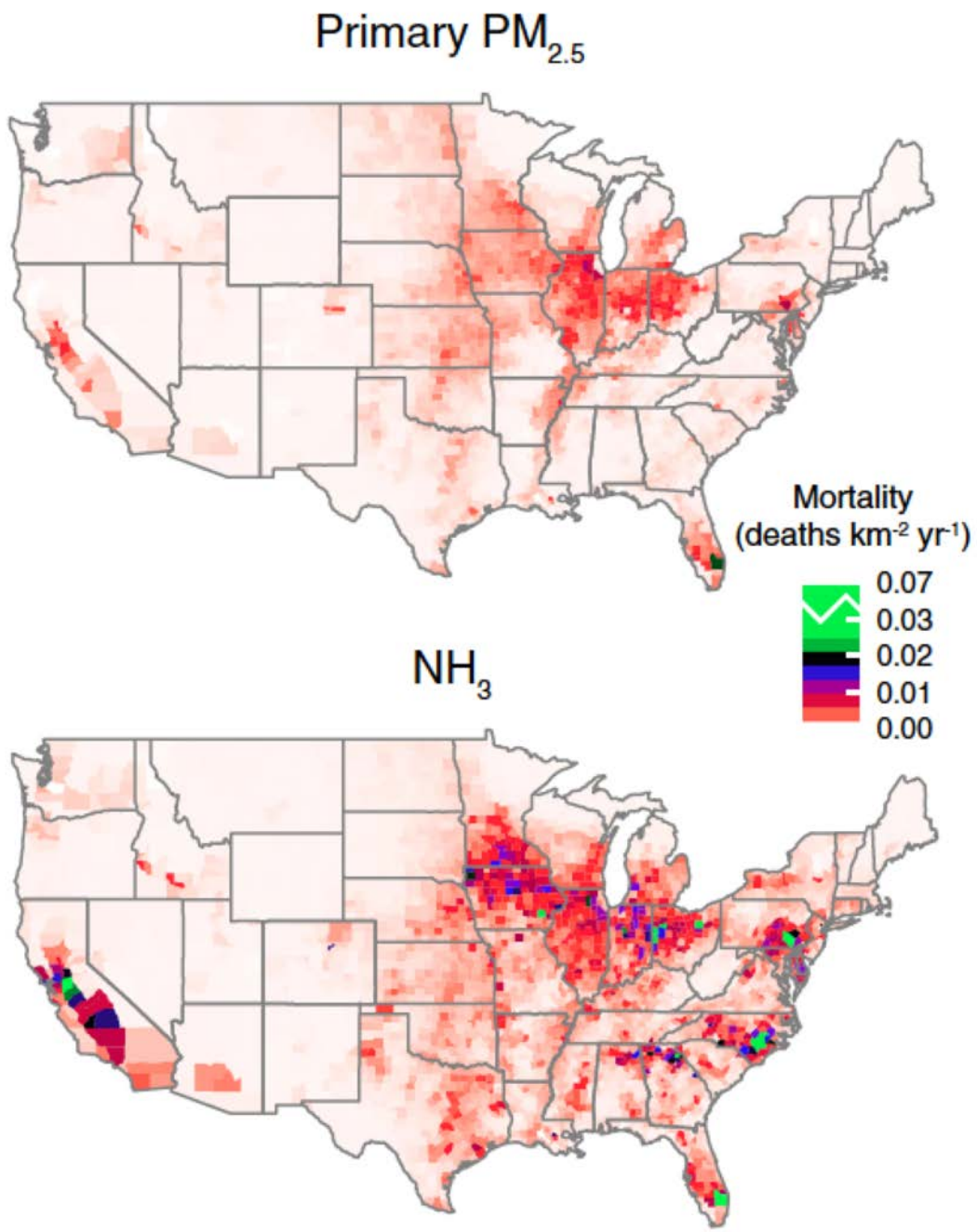

Spatial distribution of PM2.5-related mortality attributed to US agricultural production

Domigo et al PNAS 2021 Vol. 118 No. 20 e2013637118

Characteristics and Health Risks of Wildfire Particulate Matter

- Source: Particles from biomass combustion
- Particle size: a higher proportion of PM2.5
- Contribution: In US, wildfires contributed to 20% of days that PM2.5 exceeded 24-hour standard (35µg per cubic meter).
- Toxic Effects: As compared with urban background particulate matter, wildfire particulate matter that reaches urban areas may contain more oxidative components (e.g., oxygenated PAHs and quinones) and proinflammatory components (e.g., aldehydes and oxides of nitrogen) and may have greater oxidative potential.
  - Oxidative effect increases as smoke ages
  - ~ 5 times toxic effect on macrophages as urban particles.

Adopted from n engl j med 383;22 nejm.org November 26, 2020

Characteristics and Health Risks of Wildfire Particulate Matter

- Short term health effects
  - Mortality: Increased deaths, but specific causes unknown
    - Likely related to oxidative stress and pro-inflammatory characteristics of small particles.
  - Morbidity: Increased respiratory events (asthma, COPD, infections)-ER and hospitalizations
    - Again, wildfire particles are worse than common urban
  - Other: Low birth weight, diabetes complications.
- Long term health effects:
  - Still not clearly defined. Presumed increase in impaired lung capacity, heart problems
- Vulnerable populations
  - Older adults, children, pregnant women
  - People with pre-existing cardiac or respiratory conditions
  - People living in low income areas
  - Outdoor workers
  - People commuting on bikes

Adopted from n engl j med 383;22 nejm.org
November 26, 2020

Juliana, et al. v. United States of America, et al. 2016 *(public trust doctrine)*

Juliana, et al. v. United States of America, et al. 2016 (public trust doctrine)

- “Plaintiffs in this civil rights action are a group of young people between the ages of eight and nineteen”
- Plaintiffs allege defendants have known for more than fifty years that the carbon dioxide ("CO_2") produced by burning fossil fuels was destabilizing the climate system in a way that would "significantly endanger plaintiffs, with the damage persisting for millennia.”
- Defendants “permitted, encouraged, and otherwise enabled continued exploitation, production, and combustion of fossil fuels, ... deliberately allow[ing] atmospheric CO2 concentrations to escalate to levels unprecedented in human history[.]"
- Defendants moved to dismiss this action for lack of subject matter jurisdiction and failure to state a claim.

- Plaintiffs argue defendants' actions violate their substantive due process rights to life, liberty, and property,
- Plaintiffs seek (1) a declaration their constitutional and public trust rights have been violated and (2) an order enjoining defendants from violating those rights and directing defendants to develop a plan to reduce CO2 emissions.
- This is no ordinary lawsuit. Plaintiffs challenge the policies, acts, and omissions of the President of the United States, the Council on Environmental Quality ……
- Plaintiffs assert defendants' decisions on these topics have substantially caused the planet to warm and the oceans to rise. They draw a direct causal line between defendants' policy choices and floods, food shortages, destruction of property, species extinction, and a host of other harms.
- “The government's motion to strike is denied.”
- (In 2020, the Ninth Circuit held that ordering the federal government to adopt “a comprehensive scheme to decrease fossil fuel emissions and combat climate change” would exceed a federal court’s remedial authority.)

Chernaik v. Brown, 2020 (OR SC)

- Plaintiffs contended that the state was required to act as a trustee under the public trust doctrine to protect various natural resources in Oregon from substantial impairment due to greenhouse gas emissions and resultant climate change and ocean acidification.
- Plaintiffs asked for state to (1) prepare an annual accounting of Oregon's carbon dioxide emissions and (2) implement a carbon reduction plan protecting the natural resources.
- Majority opinion rule against plaintiffs and would not extend public trust doctrine to encompass climate change.
- Dissent: This court can and should issue a declaration that the state has an affirmative fiduciary duty to act reasonably to prevent substantial impairment of public trust resources ……Courts must not shrink from their obligation to enforce the rights of all persons to use and enjoy our invaluable public trust resources.