Climate Change and the Environment:

Respiratory Impacts, General Health Risks, and the IAQ Implications of Increased Flooding and Wildfires

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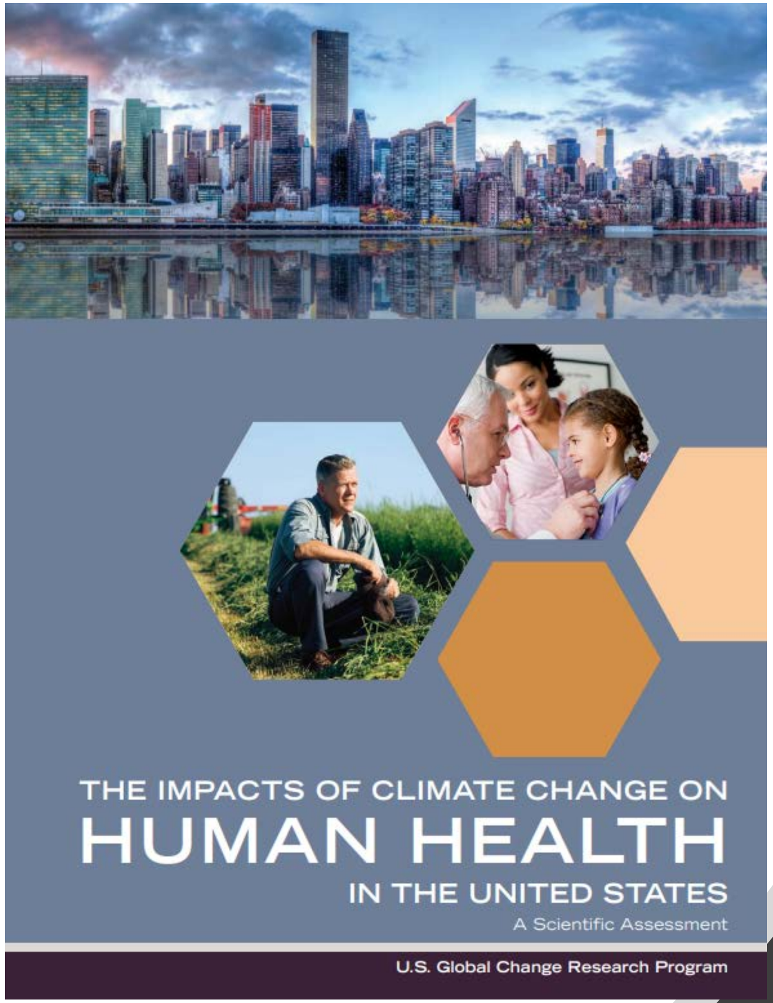
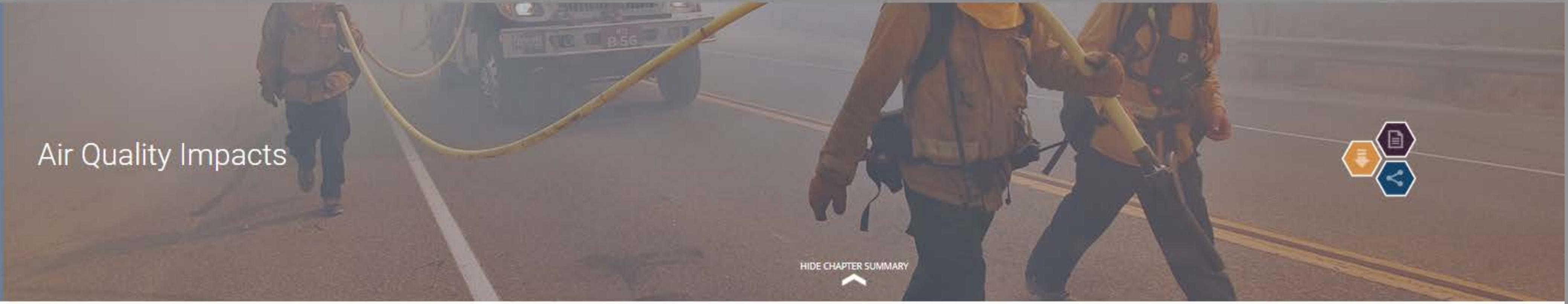


Climate Change and the Indoor Environment:

Scientific research on nature of impact (the "what"), but what about practitioner voice? (the "how")



3 Air Quality Impacts

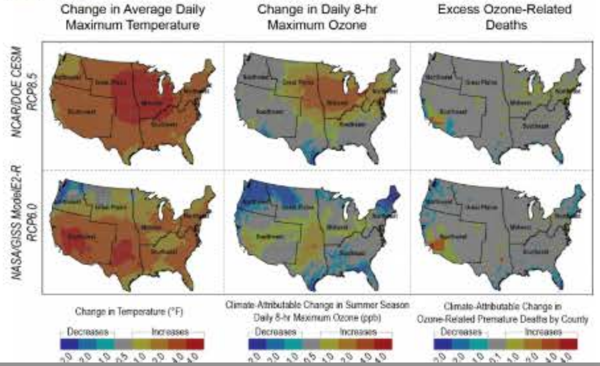
HIDE CHAPTER SUMMARY

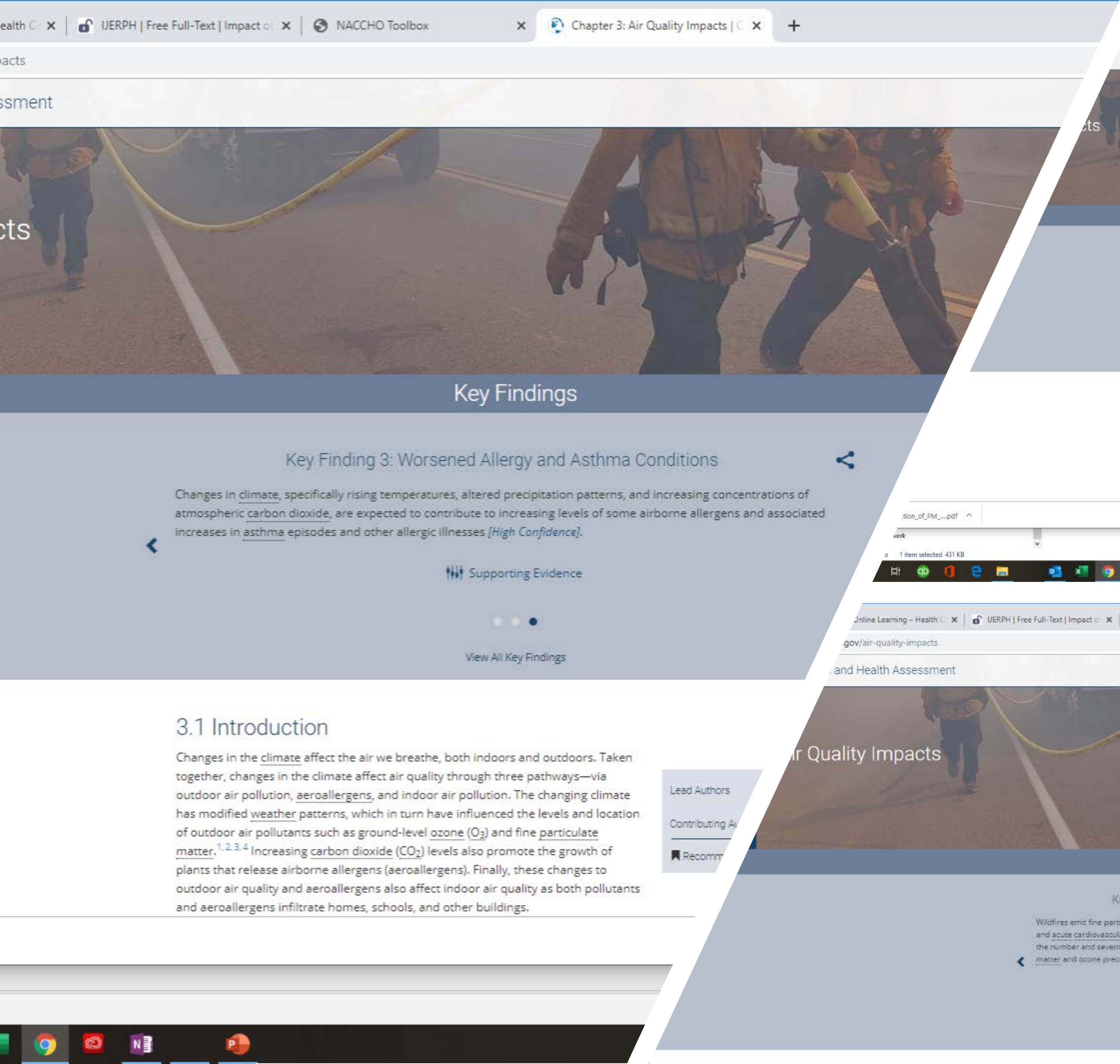
Summary

Air Quality Impacts

Changes in the climate affect the air we breathe, both indoors and outdoors. The changing climate has modified weather patterns, which in turn have influenced the levels and location of outdoor air pollutants such as ground-level ozone (O_3) (see Figure ES4) and fine particulate matter. Increasing carbon dioxide (CO_2) levels also promote the growth of plants that release airborne allergens (aeroallergens). Finally, these changes to outdoor air quality and aeroallergens also affect indoor air quality as both pollutants and aeroallergens infiltrate homes, schools, and other buildings. Poor air quality, whether outdoors or indoors, can negatively affect the human respiratory and cardiovascular systems. Higher pollen concentrations and longer pollen seasons can increase allergic sensitization and asthma episodes and thereby limit productivity at work and school.

Figure ES4: Projected Change in Temperature, Ozone, and Ozone-Related Premature Deaths in 2030





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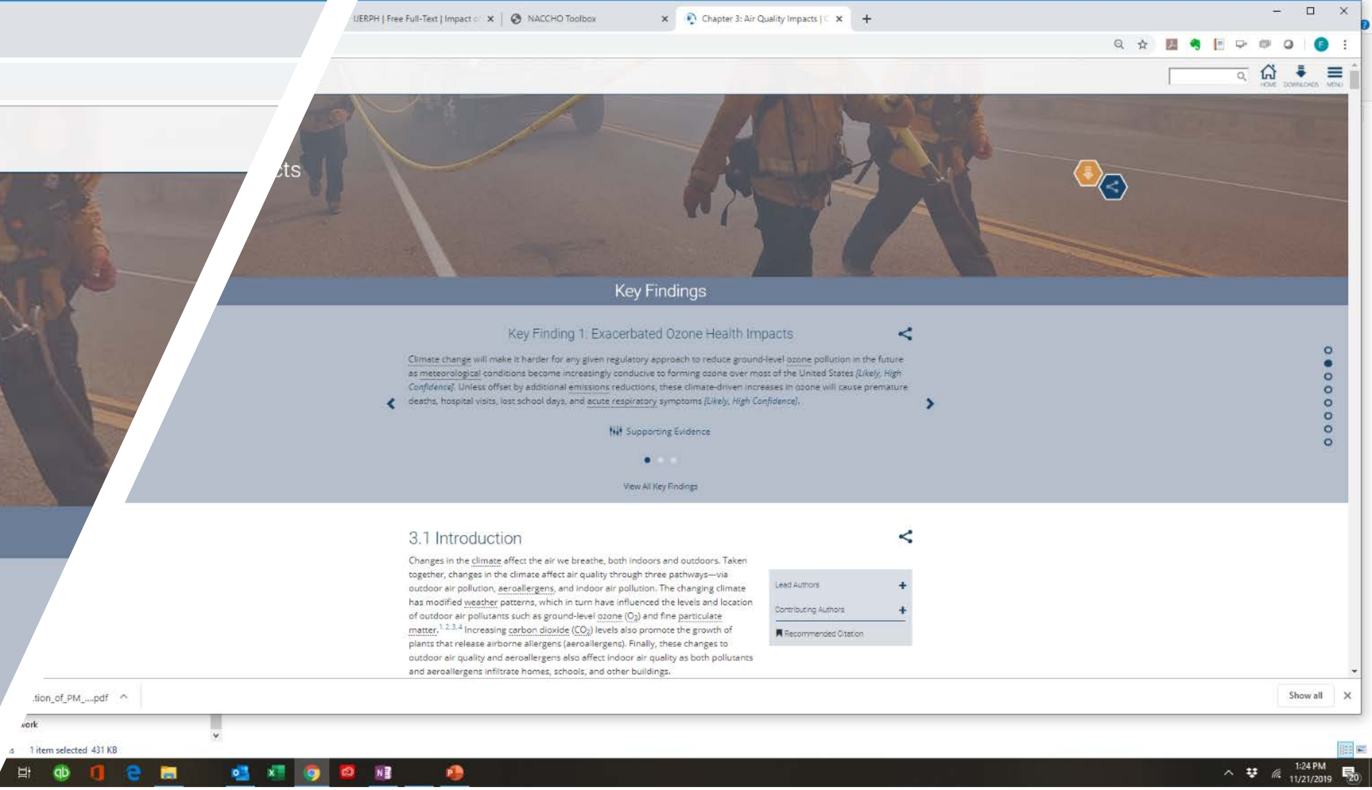
NACCHO Toolbox
Chapter 3: Air Quality Impacts
Key Findings
Key Finding 3: Worsened Allergy and Asthma Conditions
Changes in climate, specifically rising temperatures, altered precipitation patterns, and increasing concentrations of atmospheric carbon dioxide, are expected to contribute to increasing levels of some airborne allergens and associated increases in asthma episodes and other allergic illnesses [High Confidence].
Supporting Evidence
View All Key Findings
3.1 Introduction
Changes in the climate affect the air we breathe, both indoors and outdoors. Taken together, changes in the climate affect air quality through three pathways—via outdoor air pollution, aeroallergens, and indoor air pollution. The changing climate has modified weather patterns, which in turn have influenced the levels and location of outdoor air pollutants such as ground-level ozone (O3) and fine particulate matter.1,2,3,4 Increasing carbon dioxide (CO2) levels also promote the growth of plants that release airborne allergens (aeroallergens). Finally, these changes to outdoor air quality and aeroallergens also affect indoor air quality as both pollutants and aeroallergens infiltrate homes, schools, and other buildings.
Lead Authors



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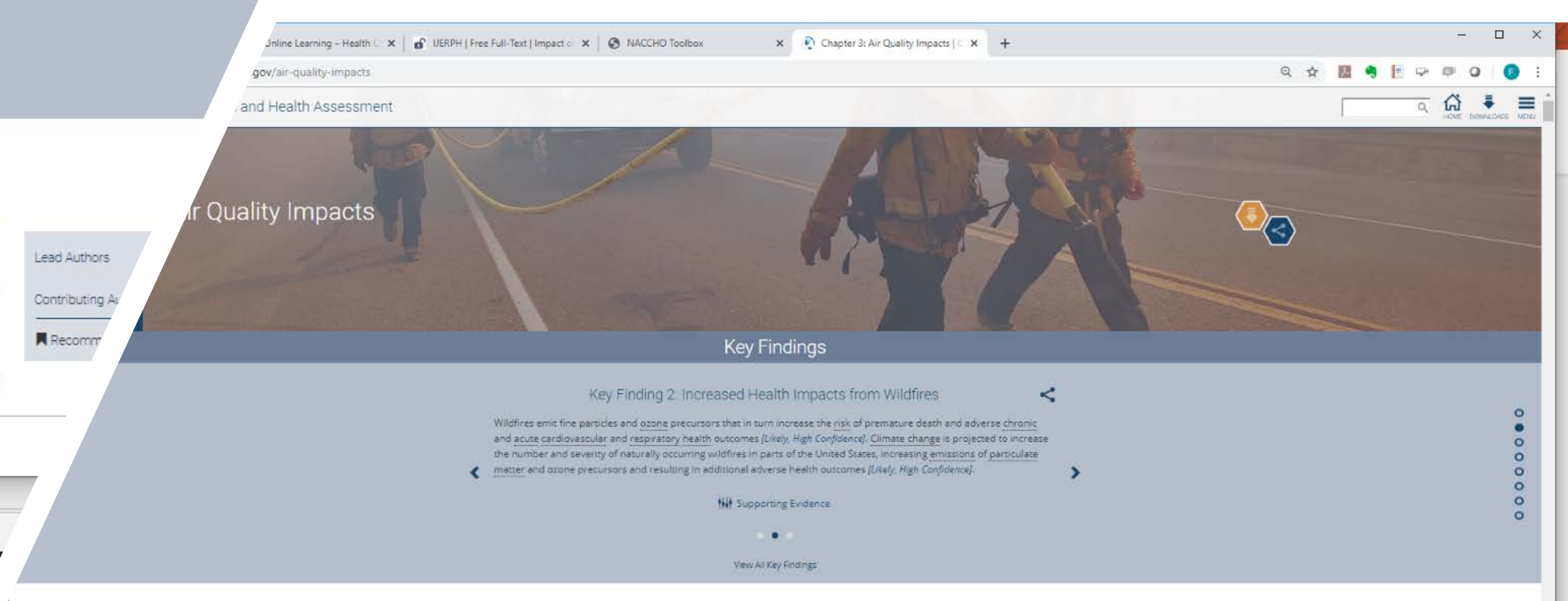
Chapter 3: Air Quality Impacts
Key Findings
Key Finding 1: Exacerbated Ozone Health Impacts
Climate change will make it harder for any given regulatory approach to reduce ground-level ozone pollution in the future as meteorological conditions become increasingly conducive to forming ozone over most of the United States [Likely, High Confidence]. Unless offset by additional emissions reductions, these climate-driven increases in ozone will cause premature deaths, hospital visits, lost school days, and acute respiratory symptoms [Likely, High Confidence].
Supporting Evidence
View All Key Findings
3.1 Introduction



Online Learning – Health
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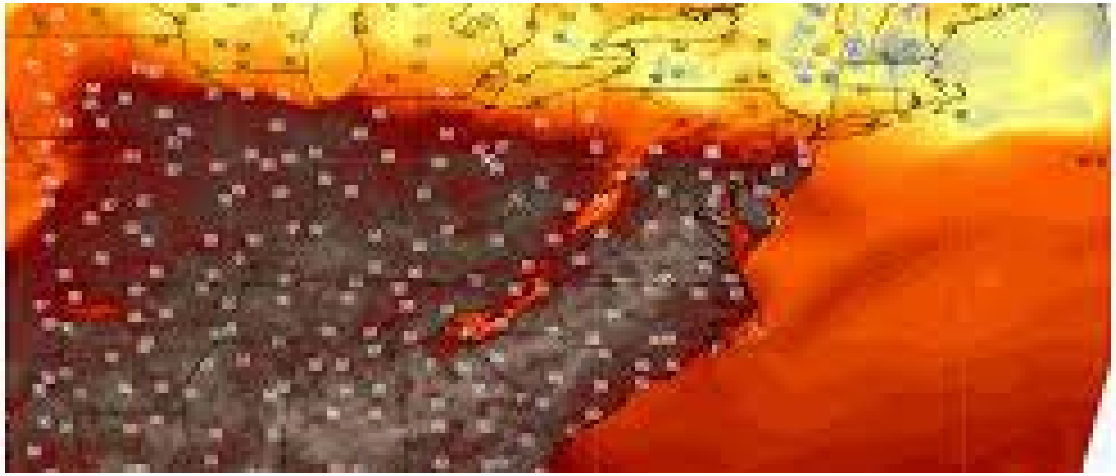
Chapter 3: Air Quality Impacts
gov/air-quality-impacts
and Health Assessment
Air Quality Impacts
Key Findings
Key Finding 2: Increased Health Impacts from Wildfires
Wildfires emit fine particles and ozone precursors that in turn increase the risk of premature death and adverse chronic and acute cardiovascular and respiratory health outcomes [Likely, High Confidence]. Climate change is projected to increase the number and severity of naturally occurring wildfires in parts of the United States, increasing emissions of particulate matter and ozone precursors and resulting in additional adverse health outcomes [Likely, High Confidence].
Supporting Evidence
View All Key Findings

Practitioner Knowledge

Healthy Homes and Indoor Air Quality professionals are *on the front line of impacts to the indoor environment.*

Data + field experience + first-hand knowledge of barriers and opportunities on building not just healthy homes but on programs and systems to mitigate lead, radon, mold, pests, smoke…

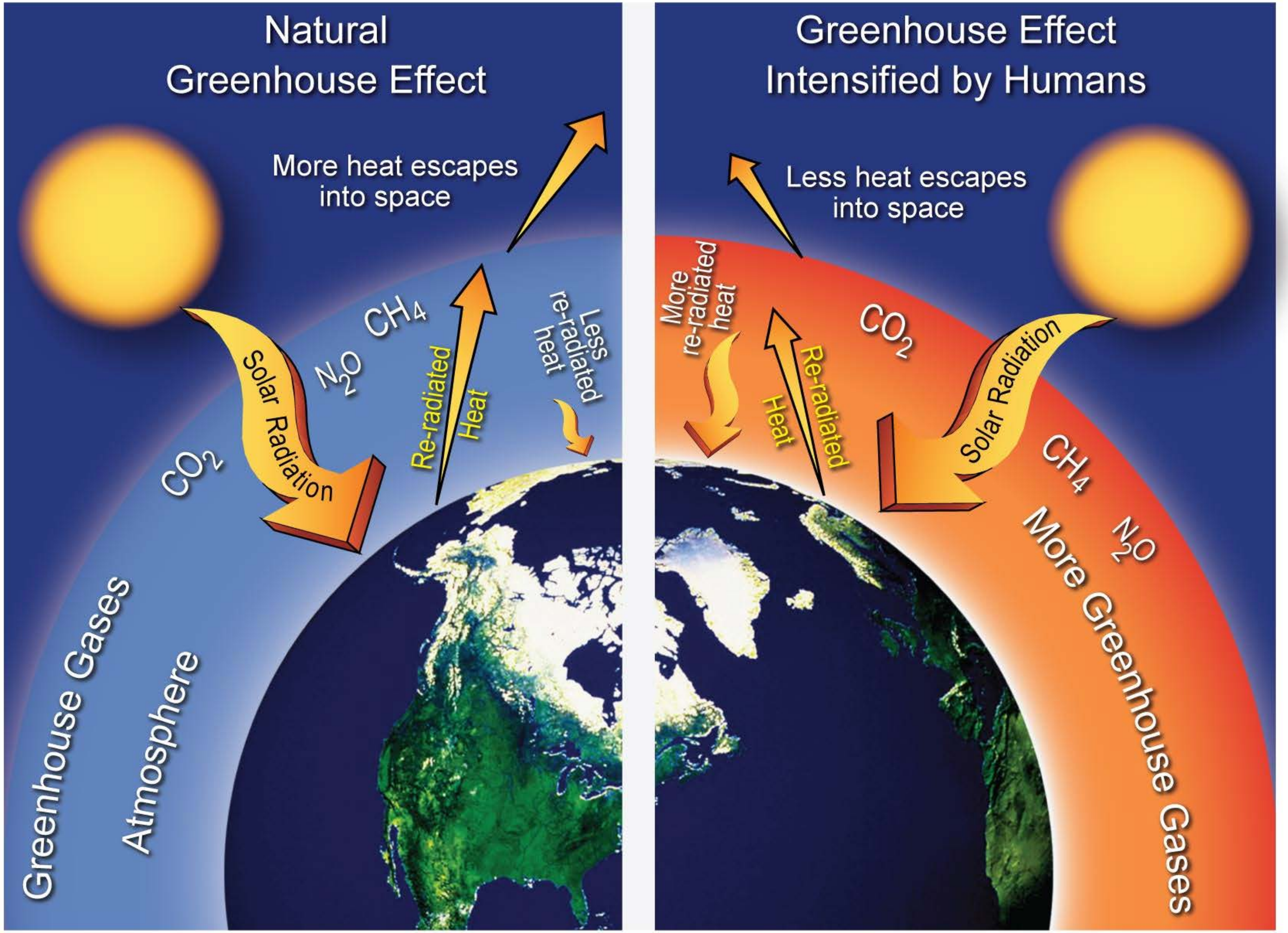
(The "How")



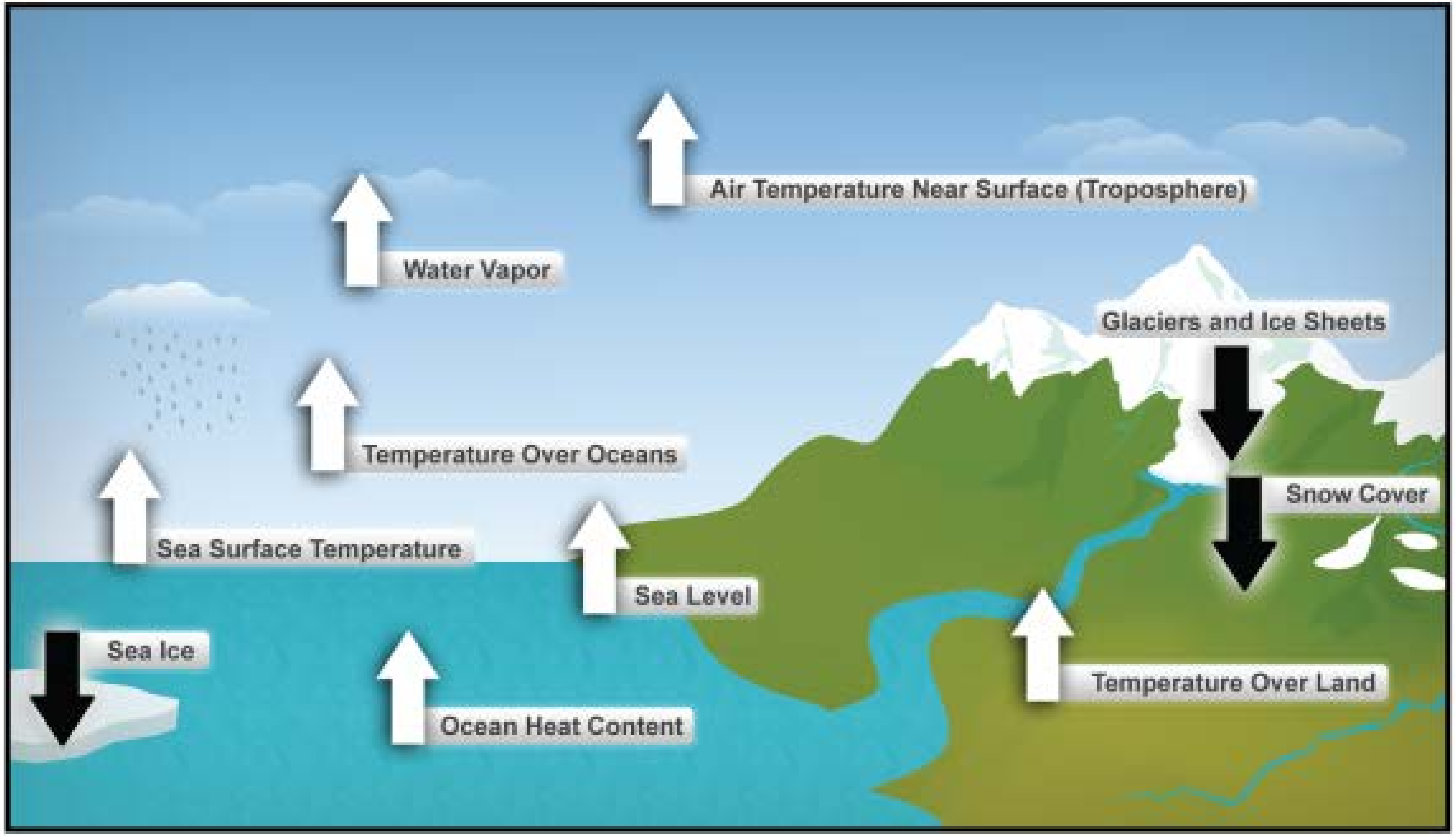
The American Public Health Association…

"The environments in which people live, work, learn and play have a tremendous impact on their health. Certain groups, like children, the elderly, the underserved and communities of color, are less climate-resilient and, therefore, more vulnerable to the negative health effects of climate change. "

Human Influence on the Greenhouse Effect



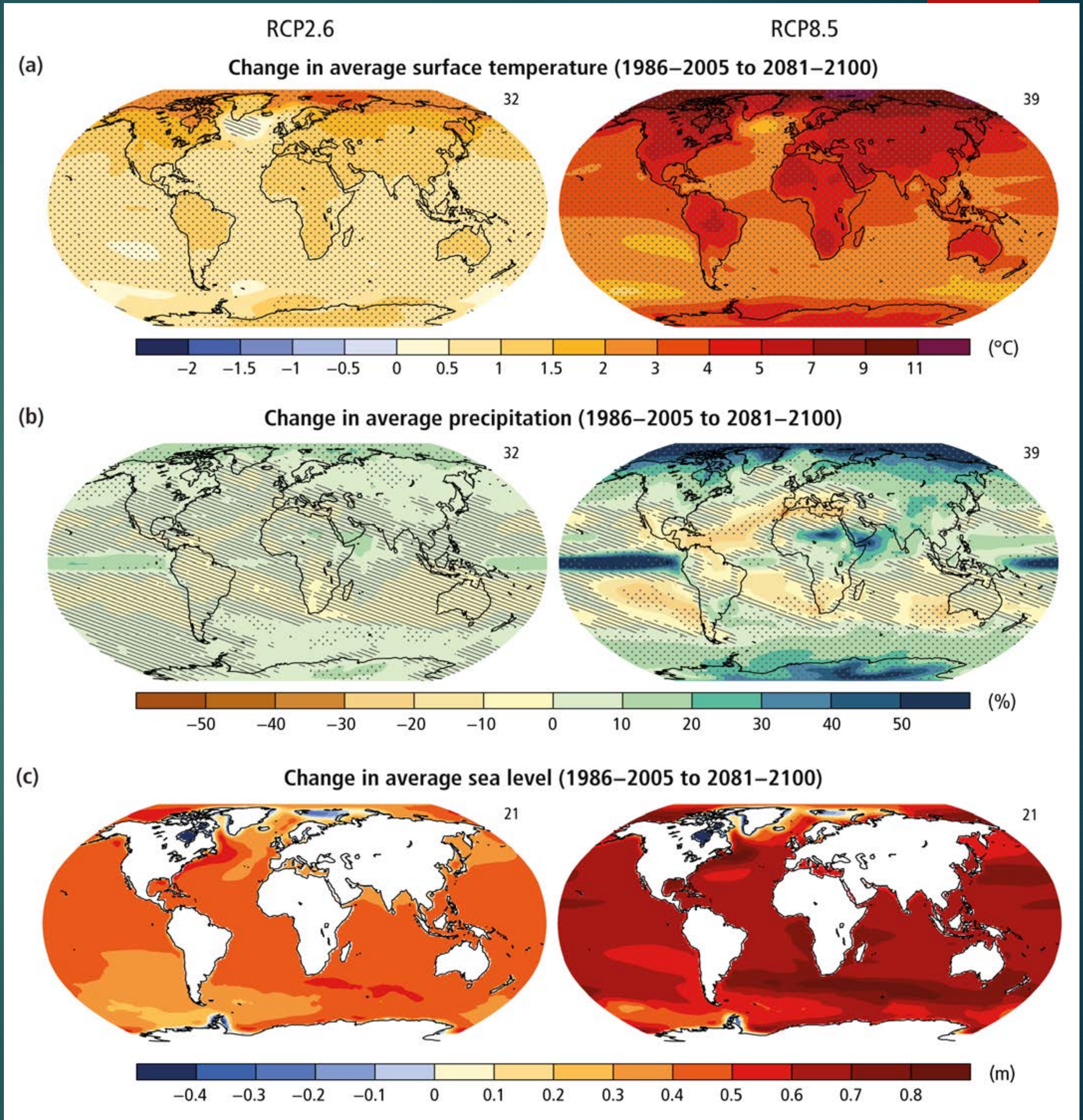
Ten Indicators of a Warming World



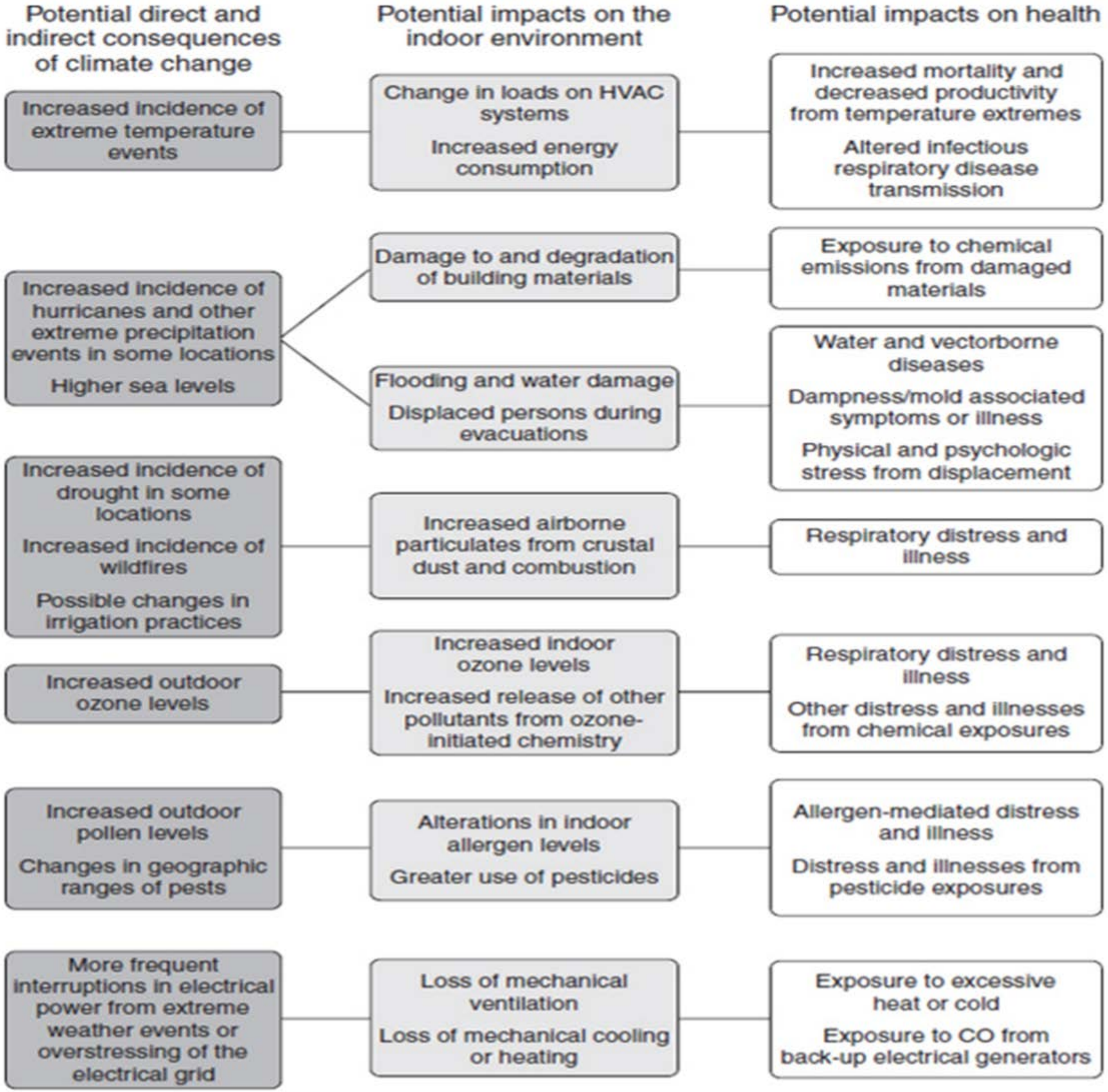
https://www.globalchange.gov/

IPCC

The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for assessing the science related to climate change

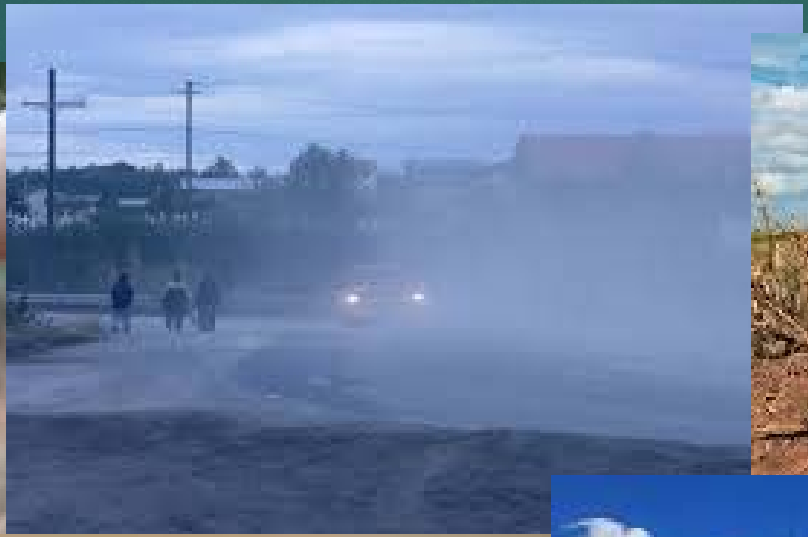


Climate change, potential impacts on the indoor environment, and the potential impacts on health



Changes in the environment: Wildfires

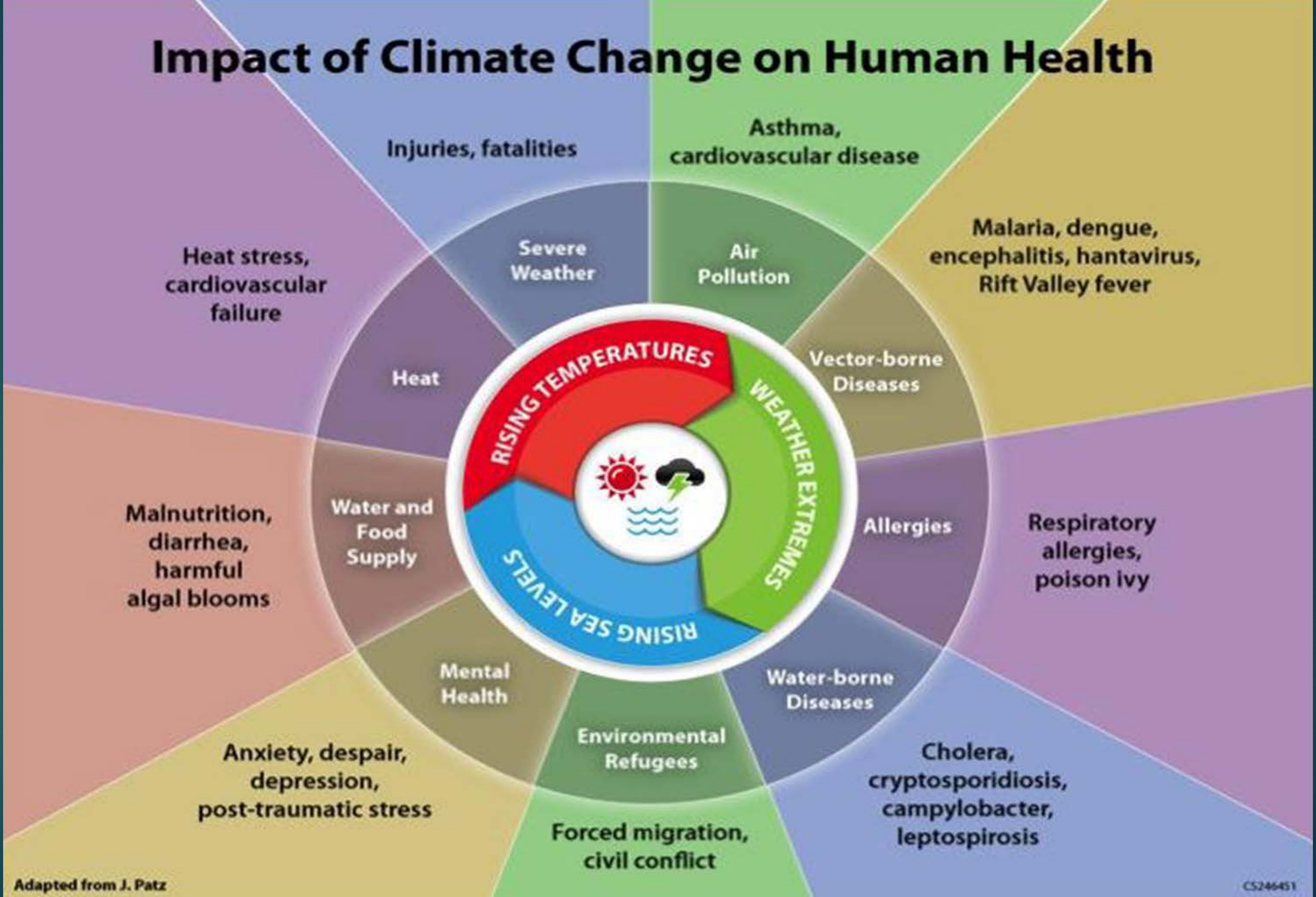
Changes in the environment: Thermal stress



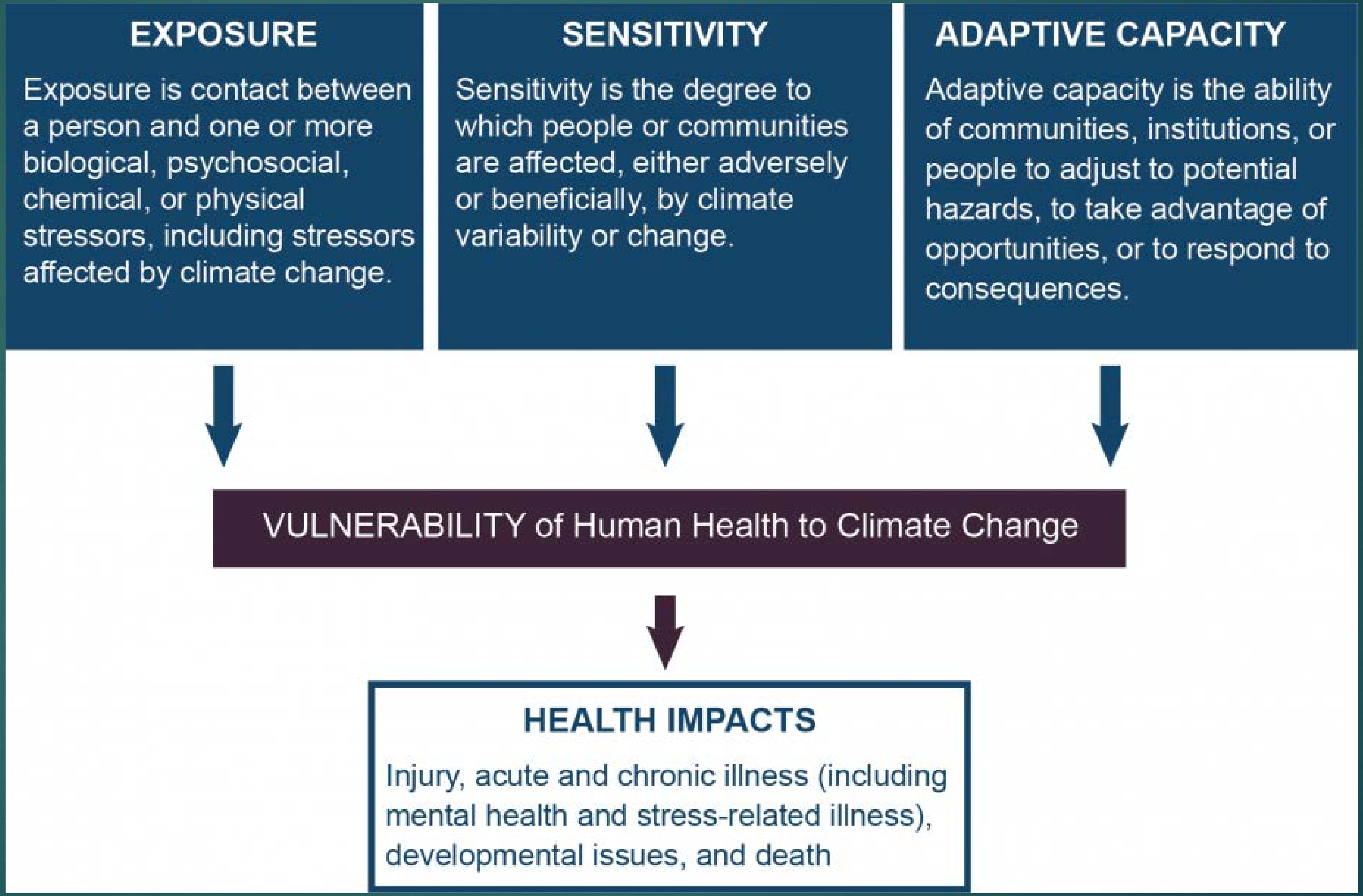

Changes in the environment: Flooding

“The sharp decline in summer Arctic sea ice has continued, is unprecedented, and is consistent with human-induced climate change. A new record for minimum area of Arctic sea ice was set in 2012.”

https://www.globalchange.gov/


Impact of Climate Change on Human Health
Injuries, fatalities
Asthma, cardiovascular disease
Heat stress, cardiovascular failure
Severe Weather
Air Pollution
Malaria, dengue, encephalitis, hantavirus, Rift Valley fever
Heat
Vector-borne Diseases
RISING TEMPERATURES
WEATHER EXTREMES
RISING SEA LEVELS
Malnutrition, diarrhea, harmful algal blooms
Water and Food Supply
Allergies
Respiratory allergies, poison ivy
Mental Health
Water-borne Diseases
Environmental Refugees
Anxiety, despair, depression, post-traumatic stress
Cholera, cryptosporidiosis, campylobacter, leptospirosis
Forced migration, civil conflict
Adapted from J. Patz

Climate change factors that can have critical importance on human health and quality of life



Defining the determinants of vulnerability to health impacts associated with climate change, including exposure, sensitivity, and adaptive capacity. (Figure source: adapted from Turner et al. 2003)

So why are we so concerned about climate change and housing?

- We spend 90 - 92% of our time indoors, and our indoor air can be up to 5 times as polluted as our outdoor air
- The quality of our indoor environment is a key determinant the quality of life and health
- With climate change, attention to building quality increases as the indoors becomes more and more of a refuge against heat and other climate events
- We are going to have to adapt to the multifactorial challenges of global warming!

The external environment and agents of concern for the indoor environment:

- Temperature
- Biological contaminants
- Combustion-formed gases
- Formaldehyde
- Ozone
- Particulate matter (PM)
- Volatile organic compounds (VOCs)

Impacts of Climate change on indoor air quality

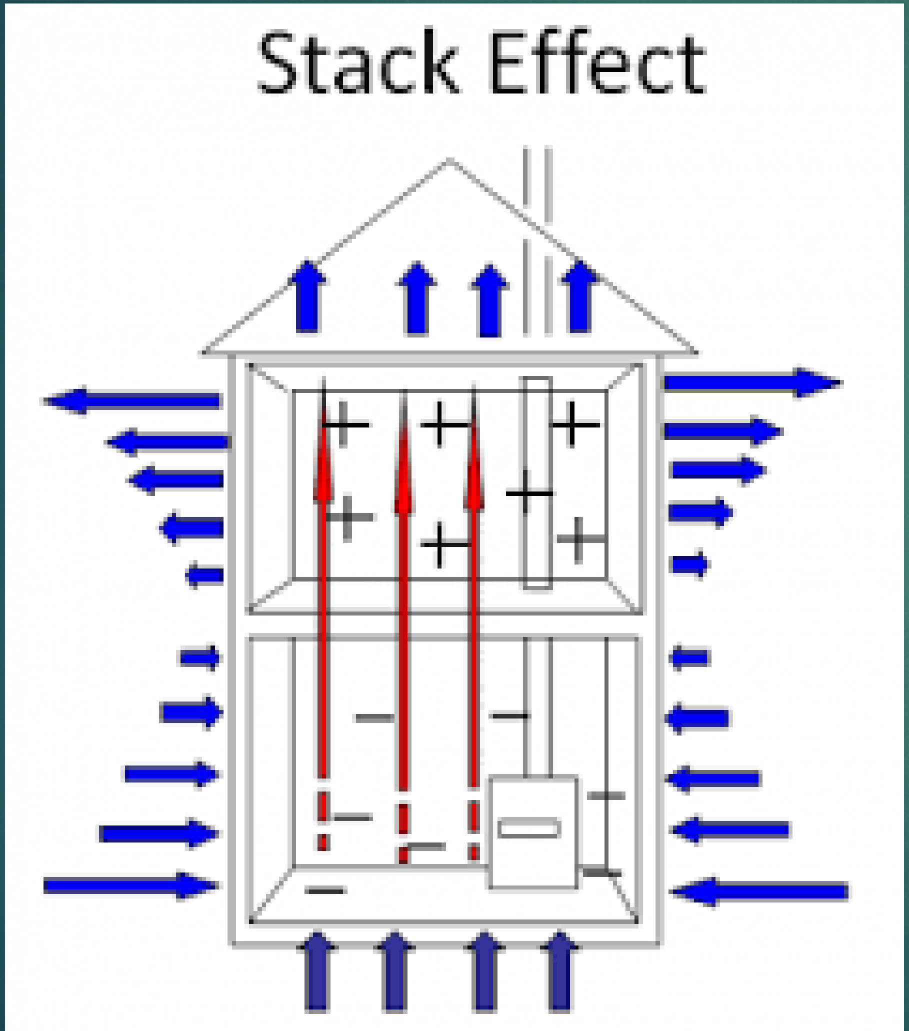
Changes in climate are likely to alter existing patterns of air pollution concentrations:

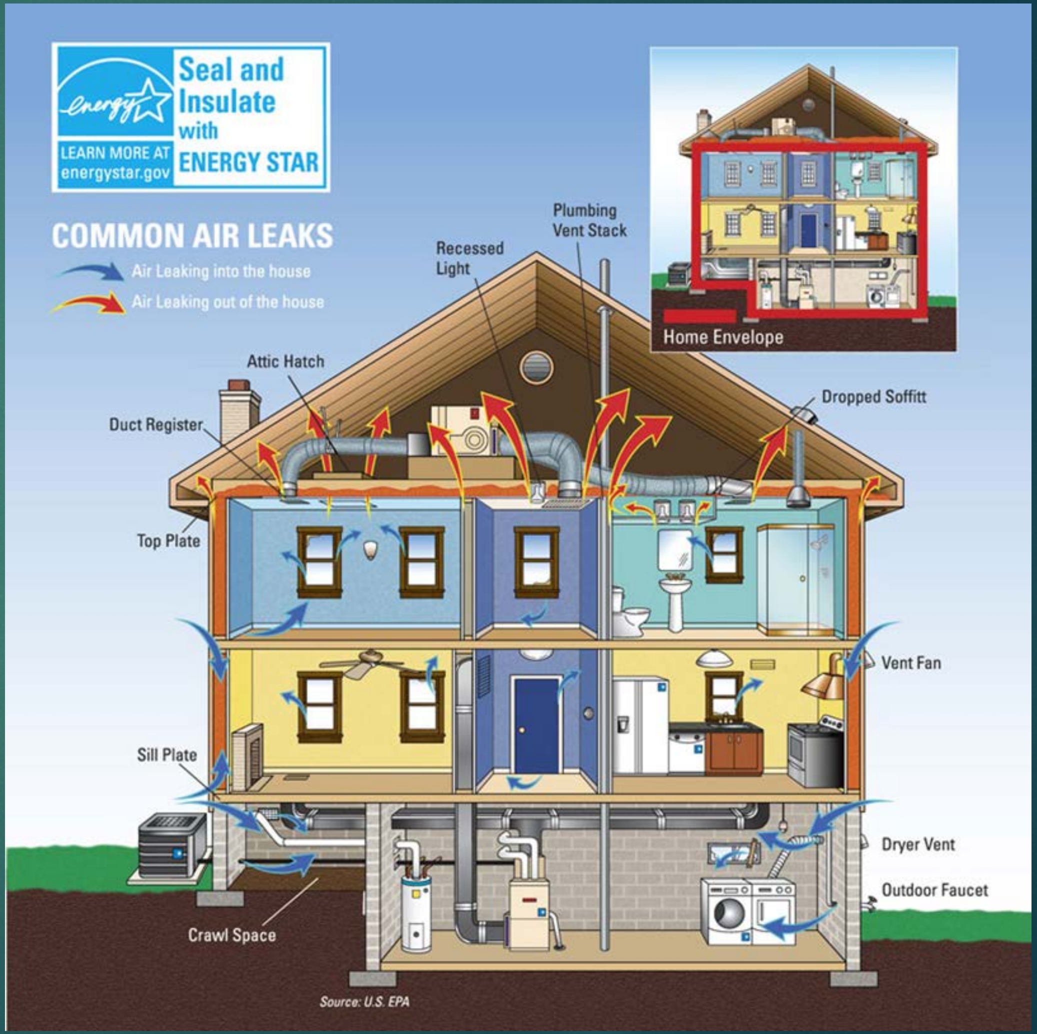
- Winds, vertical mixing, and rainfall

Higher temperatures will lead to:

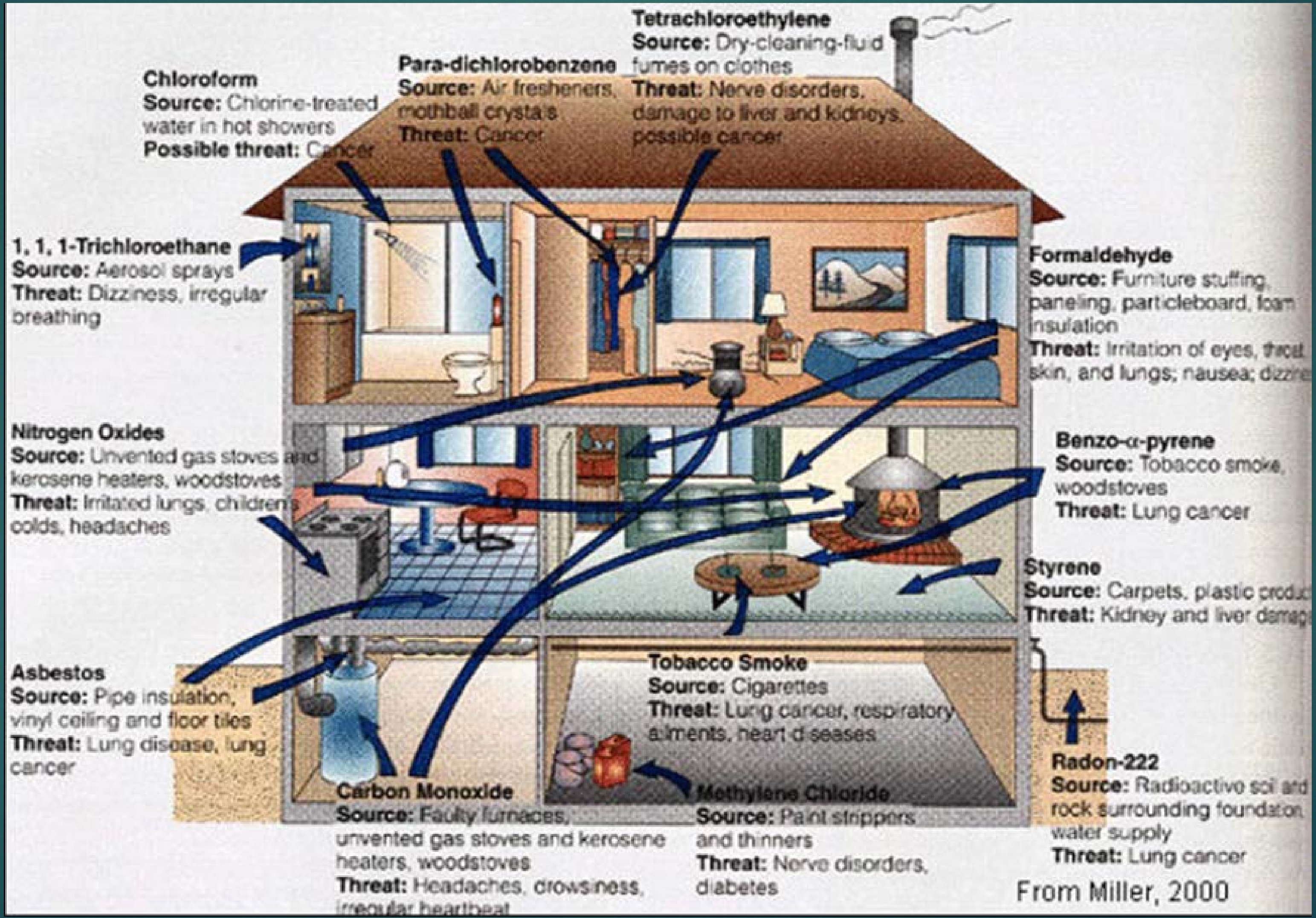
- Increased ozone pollution and fine particle formation
- Wildfires (frequency, duration, and spread) are increased by higher temperatures, drier winters, decreased soil moisture, and extended periods of drought

How air (and exterior pollution) moves into and through a building





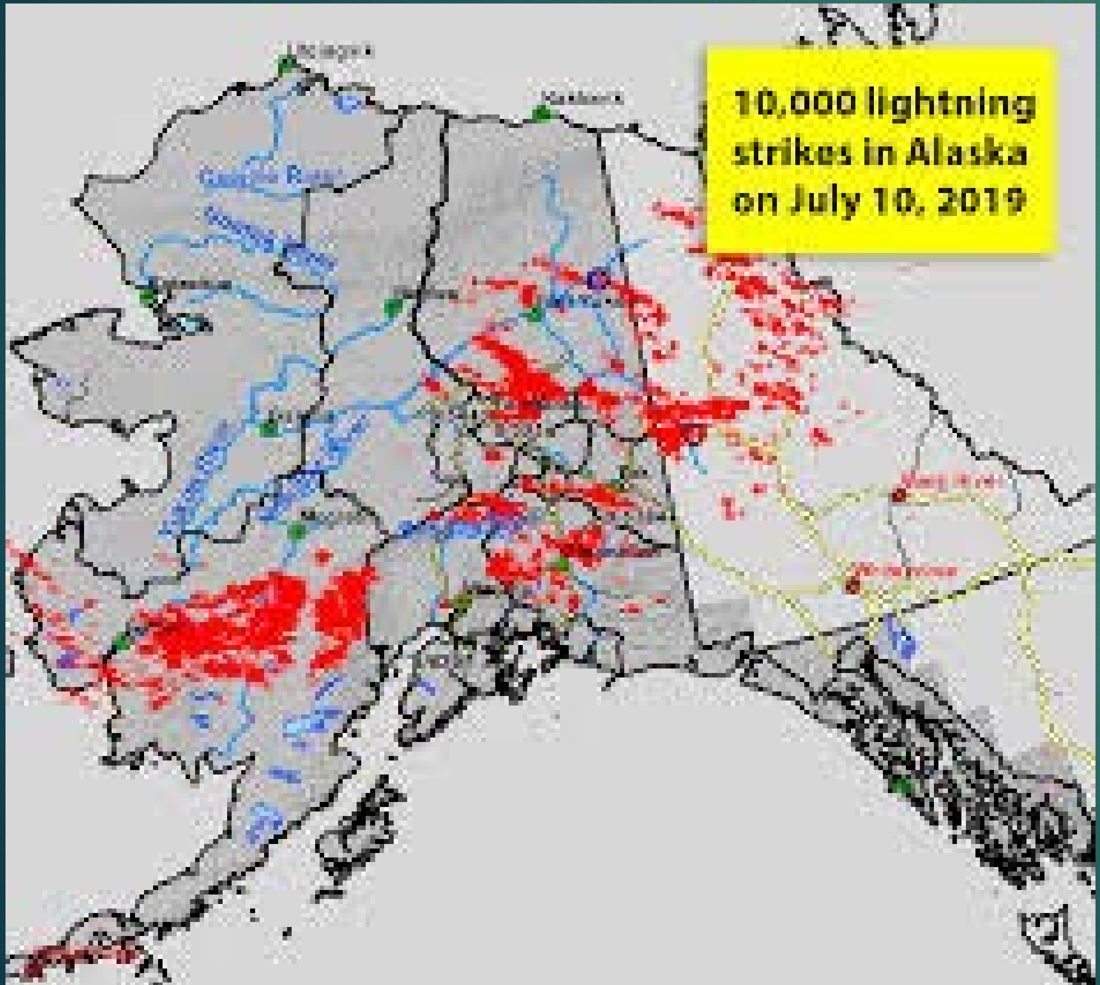
Exterior and Interior pollutant sources

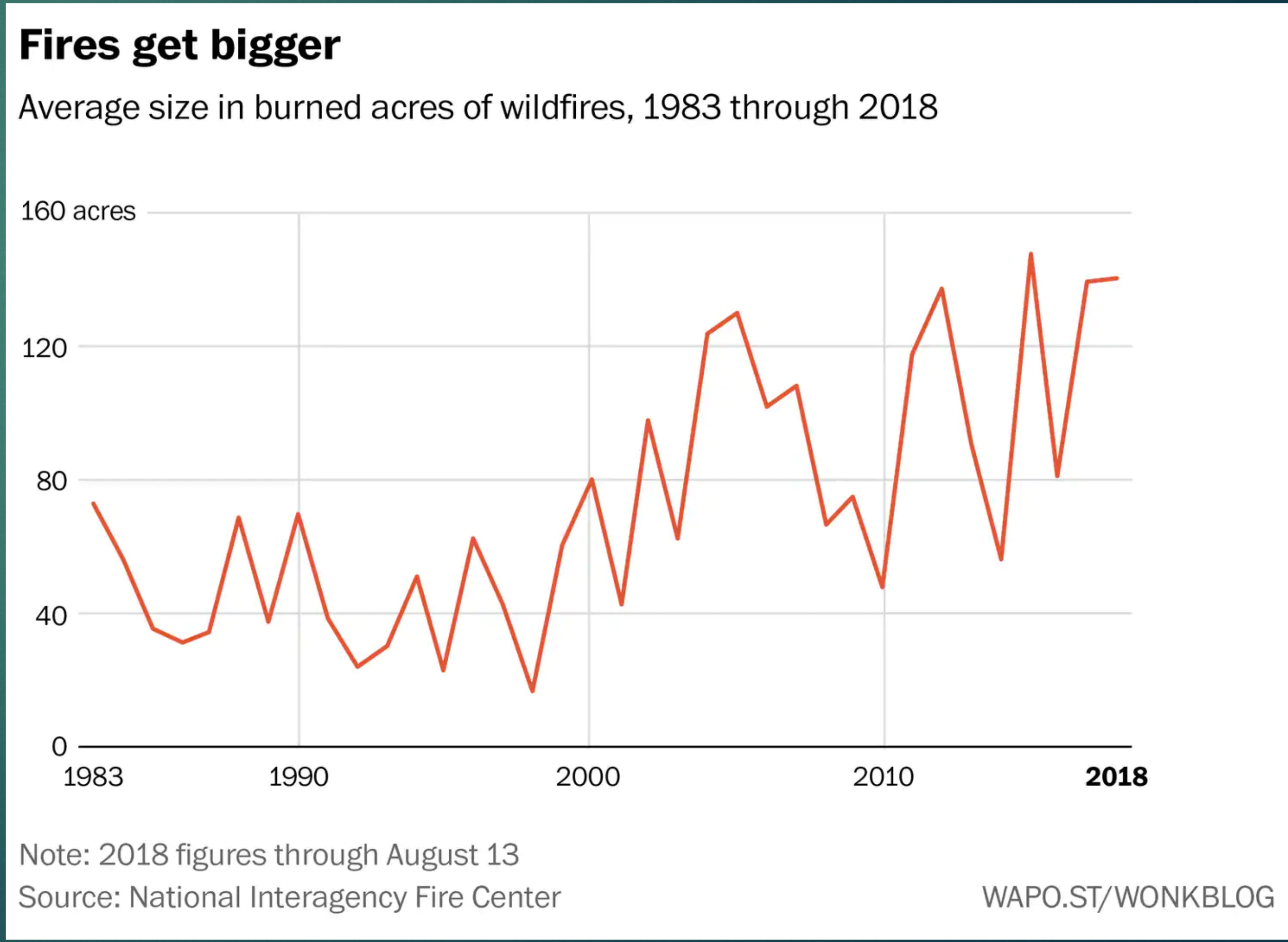


INDOOR AIR QUALITY

CHEMICAL	• GASES (CO, CO_2, O_3, NO) • VOLATILE ORGANIC CHEMICALS (PERFUMES, CLEANERS, DISINFECTANTS, PAINTS, PESTICIDES, OFF-GASES) • ASBESTOS
BIOLOGICAL	• HUMANS • PET ANIMALS (CATS, DOGS, BIRDS) • VERMIN (MICE, COCKROACHES) • HOUSE PLANTS • MICROBES (FREE-FLOATING, BIOFILM-BASED, MYCOTOXINS) • POLLEN & ALLERGENS (ANIMAL DANDER, DUST MITES)
PHYSICAL	• RADON • PARTICULATES (CIGARETTE SMOKE, PRINTERS/COPIERS) • SMOKE FROM COOKING & HEATING FUELS • DUST
ENVIRONMENTAL	• OUTDOORS (WEATHER & CLIMATE) • HVAC SYSTEM • LIFE-STYLES (AIR TEMP., RH, OCCUPANT TYPE & DENSITY)

Let's look at just <u>one</u> pollutant (that just happens to have most of the agents of concern...)





- Wildfires are occurring with greater frequency, intensity, and duration

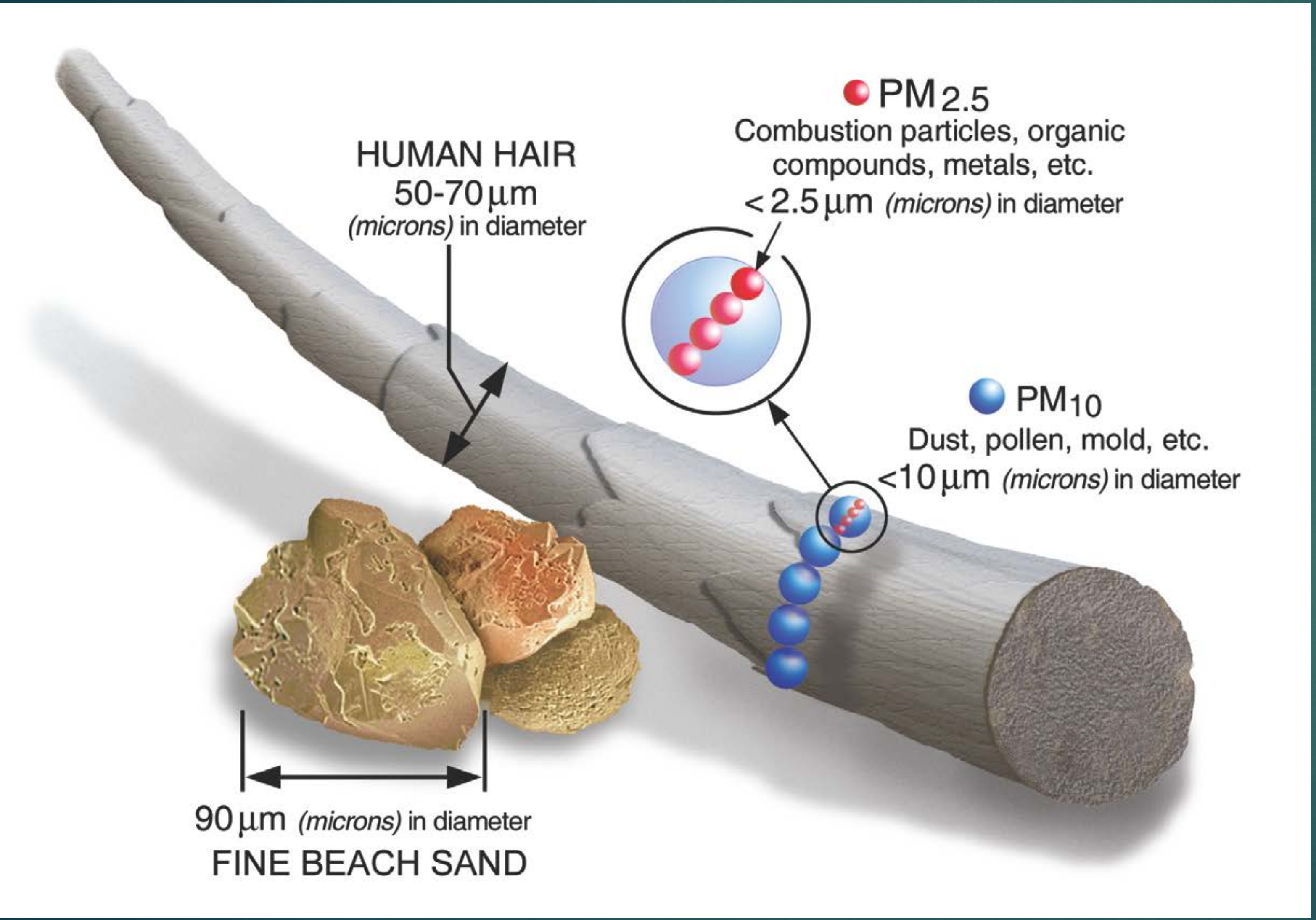
- Today, as much as 12% of homes (or up to 75% in rural or tribal areas) may burn wood as primary or secondary heating source

Table 1: Summary of the Toxic Chemical Agents Identified in Woodsmoke.

Chemical class	Number of compounds	Mode of toxicity	Representative compounds *
Toxic gases	4+	Irritant, acute toxicity	Carbon monoxide Ammonia Nitrogen dioxide Sulfur dioxide
VOCs (C2-C7)	30+	Irritant, possibly carcinogenic	Methyl chloride Methylene chloride
Saturated hydrocarbons	25+	Irritant, neurotoxicity	Hexane
Unsaturated hydrocarbons	40+	Irritant, carcinogenic, mutagenic	1,3-butadiene Acrolein
Mono-aromatics	28+	Irritant, carcinogenic, mutagenic	Benzene Styrene
Polycyclic aromatic hydrocarbons (PAHs)	20+	Carcinogenic, mutagenic, Immunotoxic	Benzo[163]pyrene, Dibenz[a,h]anthracene
Organic alcohols and acids	25+	Irritant, acute toxicity, Teratogenic	Methanol Acetic acid
Aldehydes	20+	Irritant, carcinogenic, mutagenic	Formaldehyde, Acetaldehyde
Phenols	33+	Irritant, carcinogenic, mutagenic, teratogenic	Catechol Cresol (methyl-phenols)
Quinones	3	Irritant, allergenic, Redox active, causes oxidative stress and inflammation response, possibly carcinogenic	Hydroquinone Fluorenone Anthraquinone
Free radicals		Redox active, cause oxidative stress and inflammation response, possibly carcinogenic	Semi-quinone type radicals
Inorganic compounds	14+	Carcinogenic, acute toxicity	Arsenic Lead Chromium
Fine particulate matter		Inflammation, may be allergenic	$PM_{2.5}$
Chlorinated dioxins		Irritant, may be carcinogenic or teratogenic	
Particulate acidity		Irritant	Sulfuric acid

* Compounds in italics are either criteria air pollutants, or are included on the EPA list of hazardous air pollutants. At least 26 hazardous air pollutants are known to be present in woodsmoke

Why the concern?

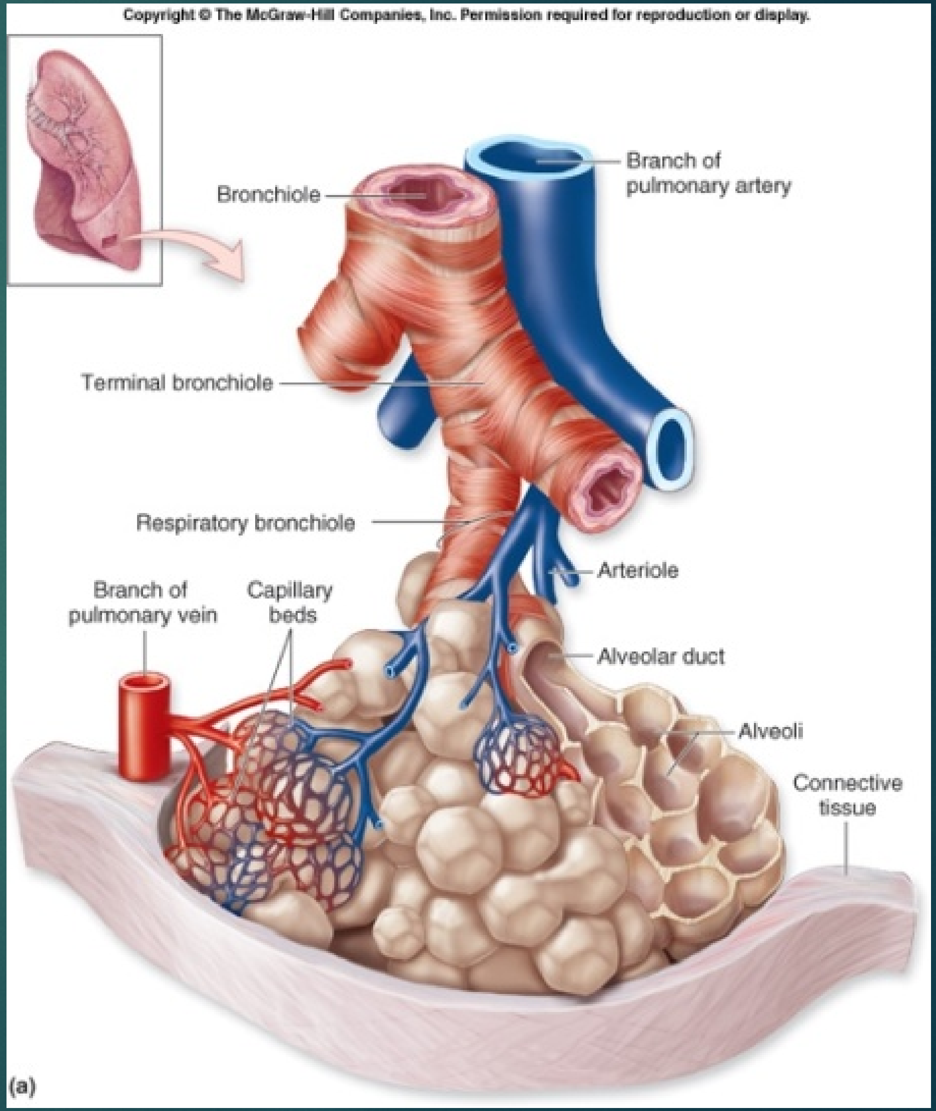


Over 90% of woodsmoke particles are smaller than 1 micron - behaving more like a gas than a particle

What particles do to the body...

Epidemiological studies have associated exposure to "particles less than 10 μm (microns) in diameter with increased pulmonary and cardiovascular morbidity and mortality."

Franklin et al., 2007; Katsouyanni et al., 2001; Metzger et al., 2004; Ostro et al., 2006; Pope III et al., 2002; Zanobetti et al., 2000

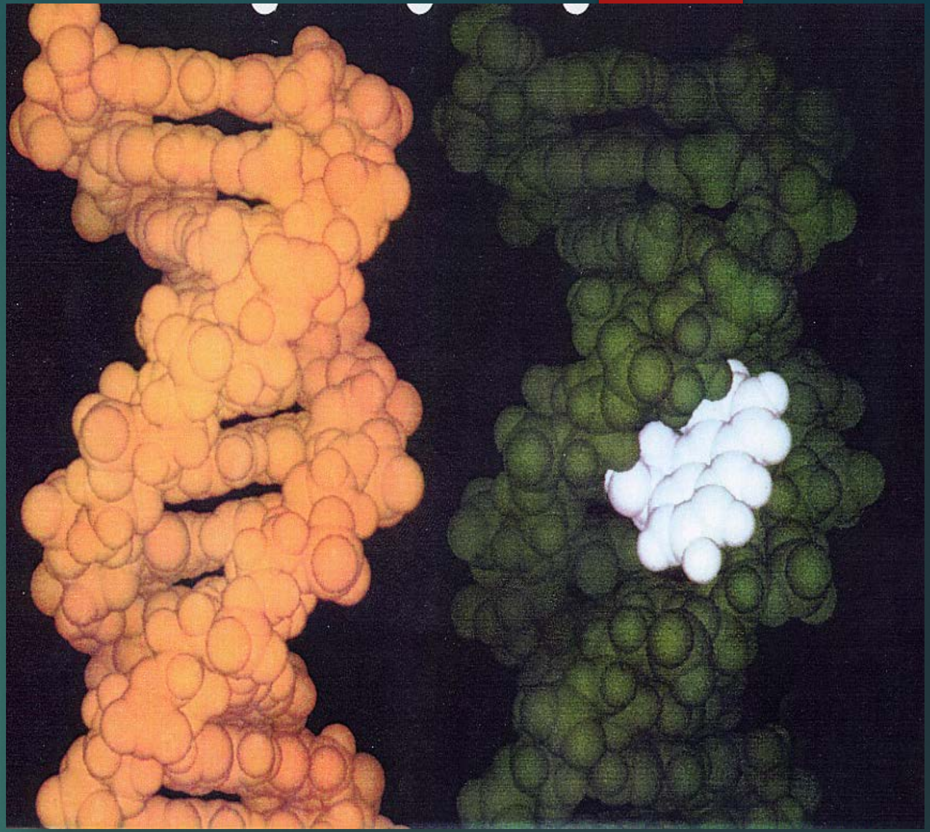


The results and the "term"......

Transgenerational epigenetic inheritance

- "...wood smoke particulates were found to be more powerful than other kinds of air pollution in causing potentially cancerous changes to DNA"

Journal of Chemical Research in Toxicology Steffen Loft

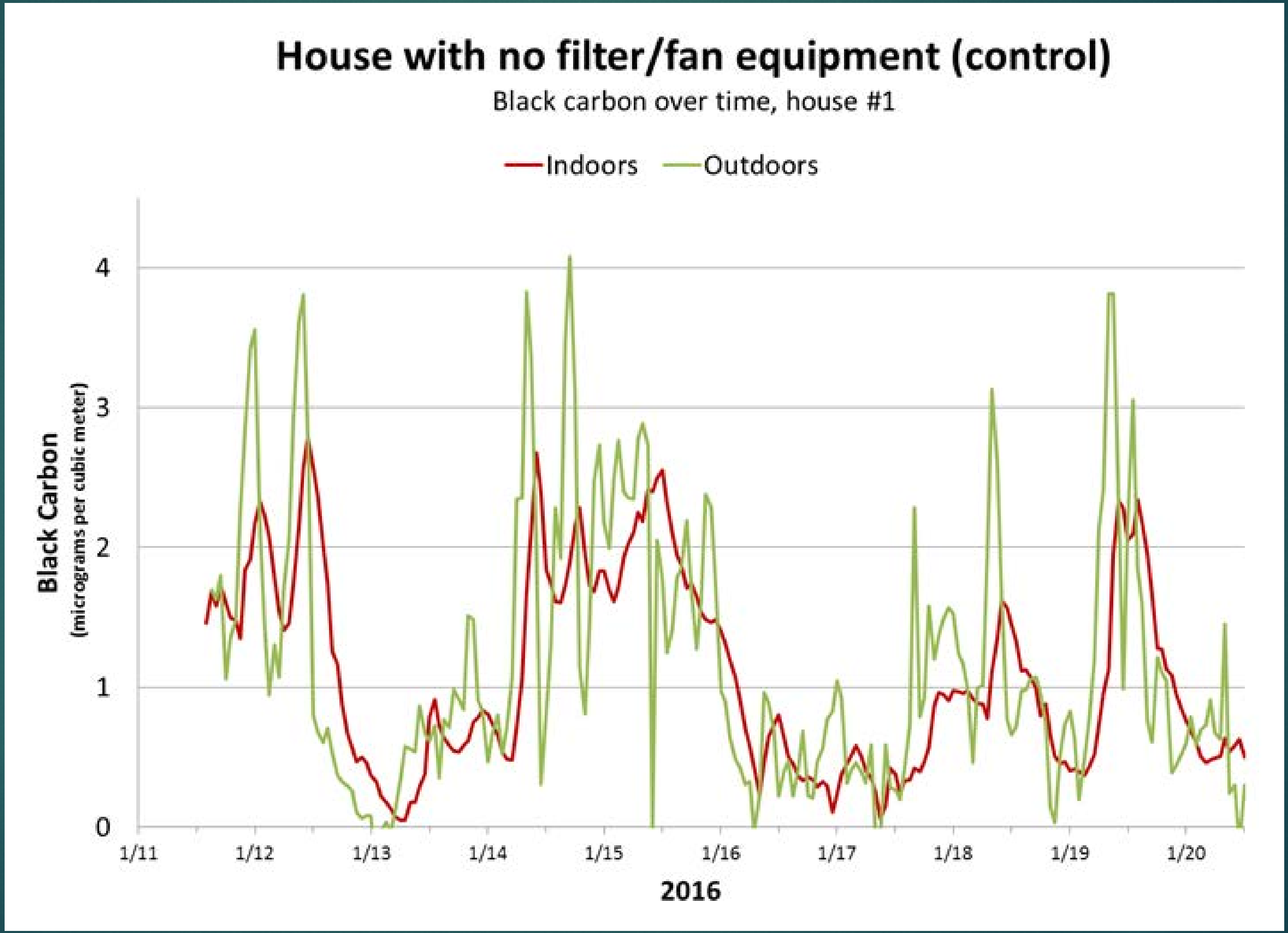


The white area shows where cancer-causing woodsmoke chemicals altered and damaged the DNA in lung cells

“Proactively preparing for climate change can reduce impacts while also facilitating a more rapid and efficient response to changes as they happen. ....to build adaptive capacity and resilience to climate change impacts”

https://www.globalchange.gov/

Outside air IS indoor air



So…what can we do about wood/wildfire smoke in our homes?

How many people here have filtration systems in their homes?

When was the last time you changed your filter?

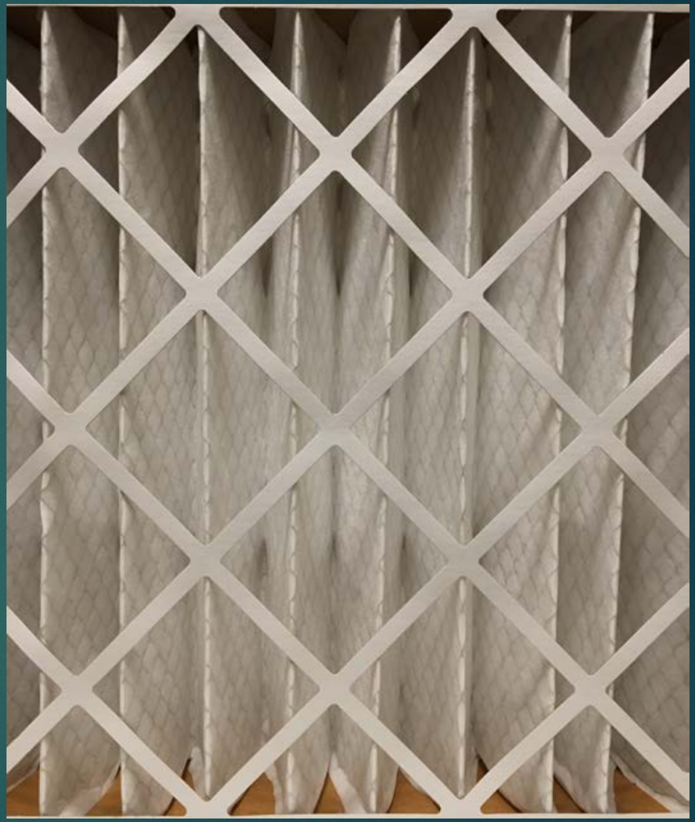
Study from a Seattle home August 2018

- 1906 home retrofitted with MERV 11 filter in whole-house HVAC system
- New filter installed July 2018 in anticipation of wildfire event
- Dylos air quality monitor installed and readings taken between 8.6.18 – 8.17.18
- HVAC system ran continuously for duration of wildfire event
- Two HEPA air cleaners in continuous operation in first-floor office and second-floor master bedroom

Filters

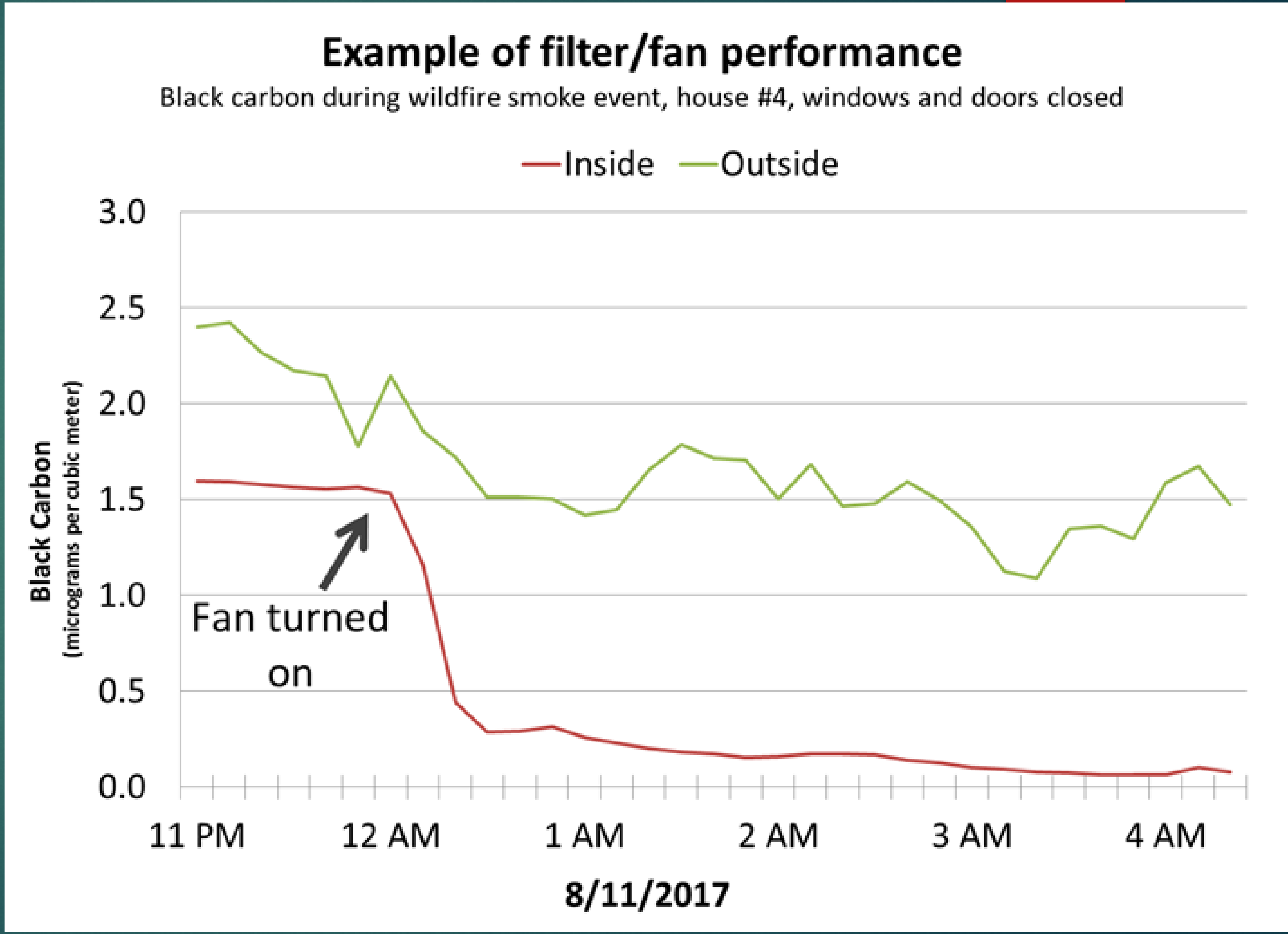
Filter post 8.18. wildfire event

Filter 10.8.18

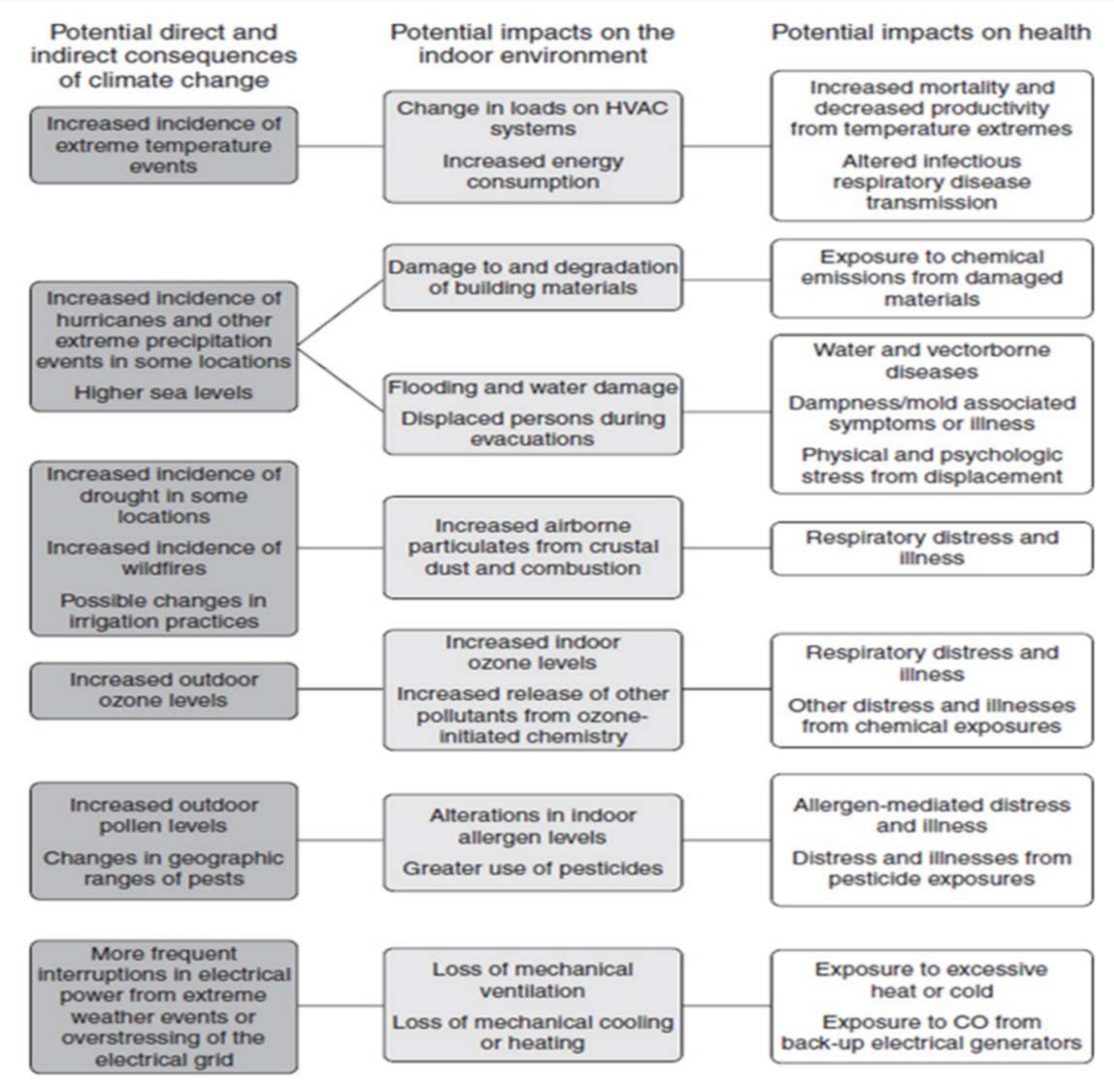


New filter


AIR FLOW DIRECTION


Example of filter/fan performance
Black carbon during wildfire smoke event, house #4, windows and doors closed
Inside
Outside
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Black Carbon
(micrograms per cubic meter)
Fan turned on
11 PM
12 AM
1 AM
2 AM
3 AM
4 AM
8/11/2017

Climate change, potential impacts on the indoor environment and the potential impacts on health



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Respiratory Impacts, General Health Risks, and the IAQ Implications of Increased Flooding and Wildfires

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Lancet Report 2018

Climate Change greatest health threat of the 21st century

Impact of weather and climate change with indoor and outdoor air quality in asthma

Poole JA, Barnes CS, Demain JD, et al. J Allergy Clin Immunol 2019; 143(5): 1702-09

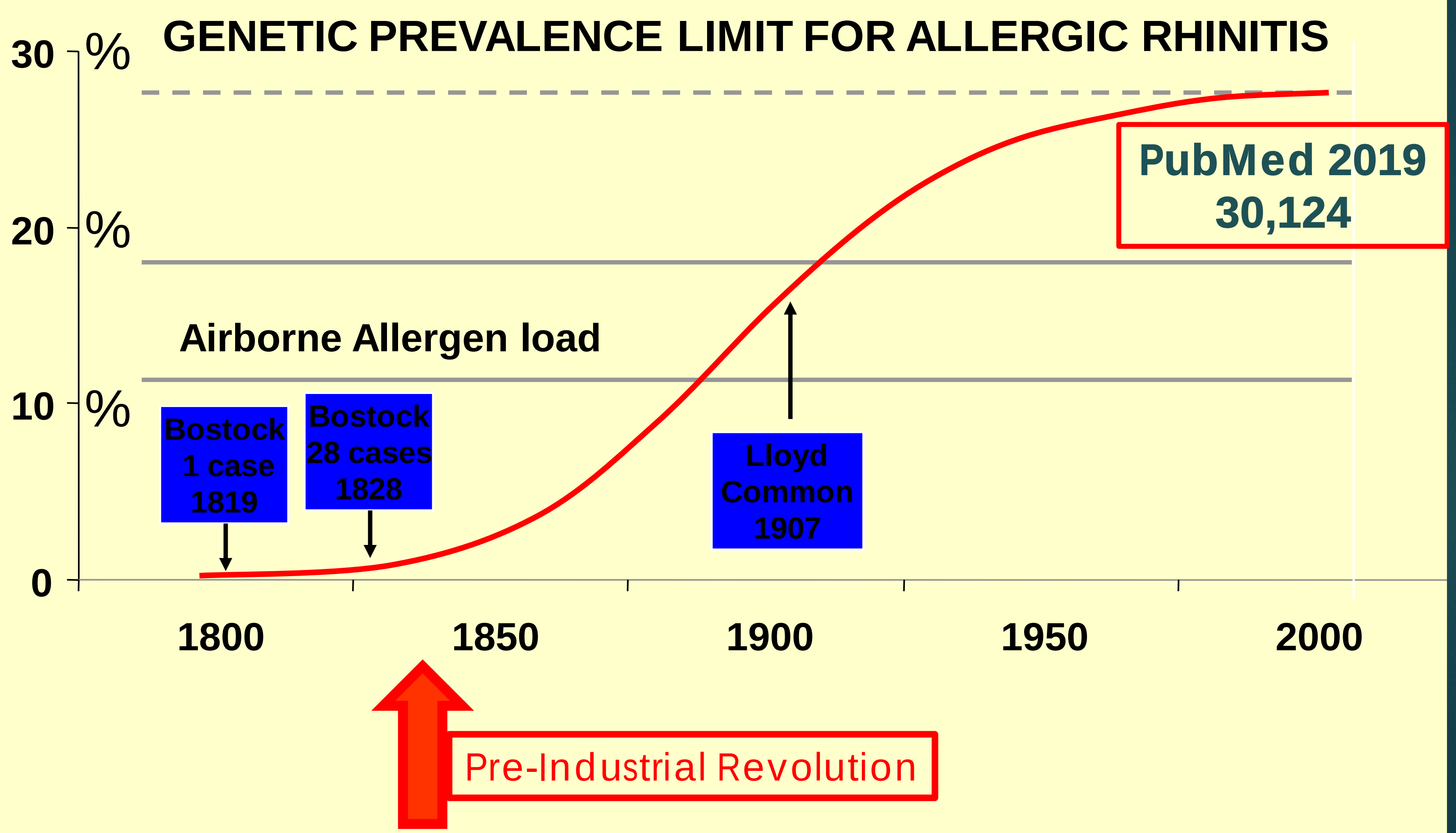
- Robust data on the direct effects of climate change on respiratory allergy are lacking
- Current knowledge is provided by epidemiolocal factors
  - Environmental factors
  - Meteorological variables
  - Airborne allergen patterns
  - Air pollution and air quality levels
- Considerable data associating air quality and pollen levels with prevalence and severity of asthma & allergy

Suspected factors contributing to the rising prevalence of allergic & pulmonary disease

- Industrialization
- Changes in antigen exposure
- Changes in childhood infections
- Changes in home construction
- Changes in activity: location and intensity
- Changes in dietary habits
- Smoking by infant's care givers
- Hygiene Hypothesis
- Biodiversity loss / Microbiota

Climate Change

PREVALENCE OF ALLERGIC RHINITIS SINCE THE INDUSTRIAL REVOLUTION



Changes in Asthma Prevalence

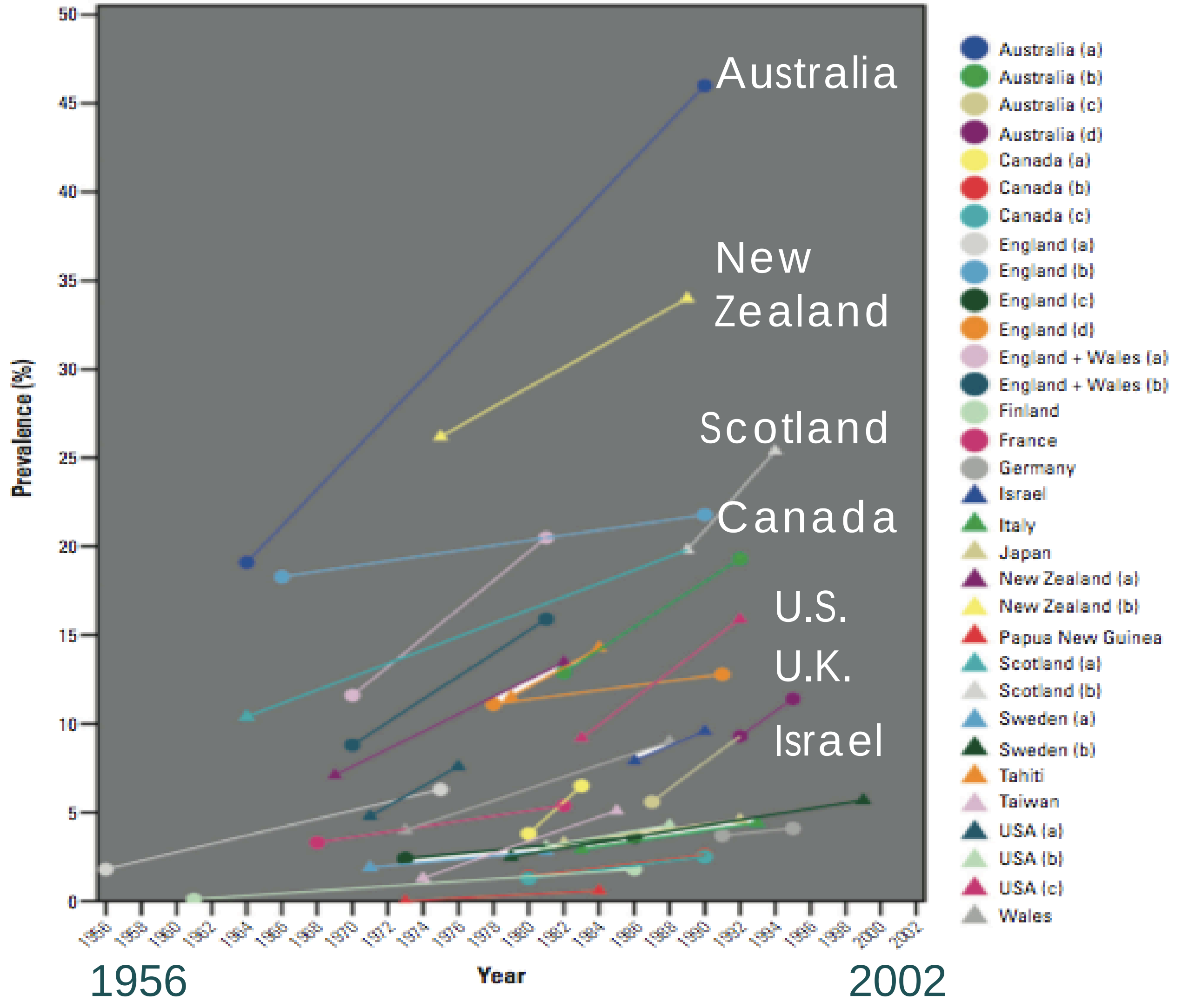
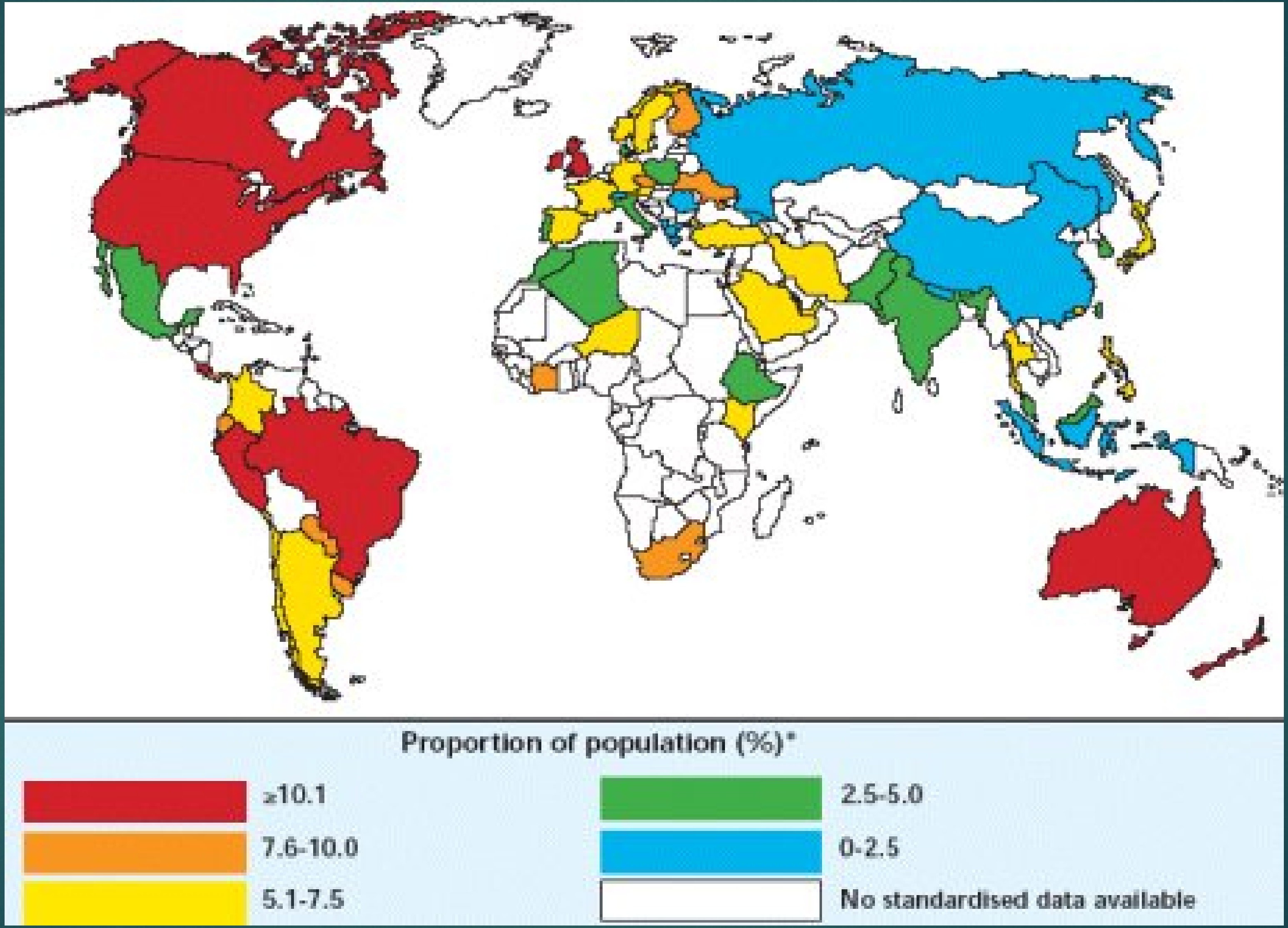


Figure 1. Changes in asthma point prevalence observed since 1956. The locations used different diagnostic criteria, but these were consistent within each study location. Different studies for the same nation are distinguished by a, b, c, and d. Data from Pearce et al. (2000).

Beggs PJ et al. Environ Health Perspect 2005 (Australia)

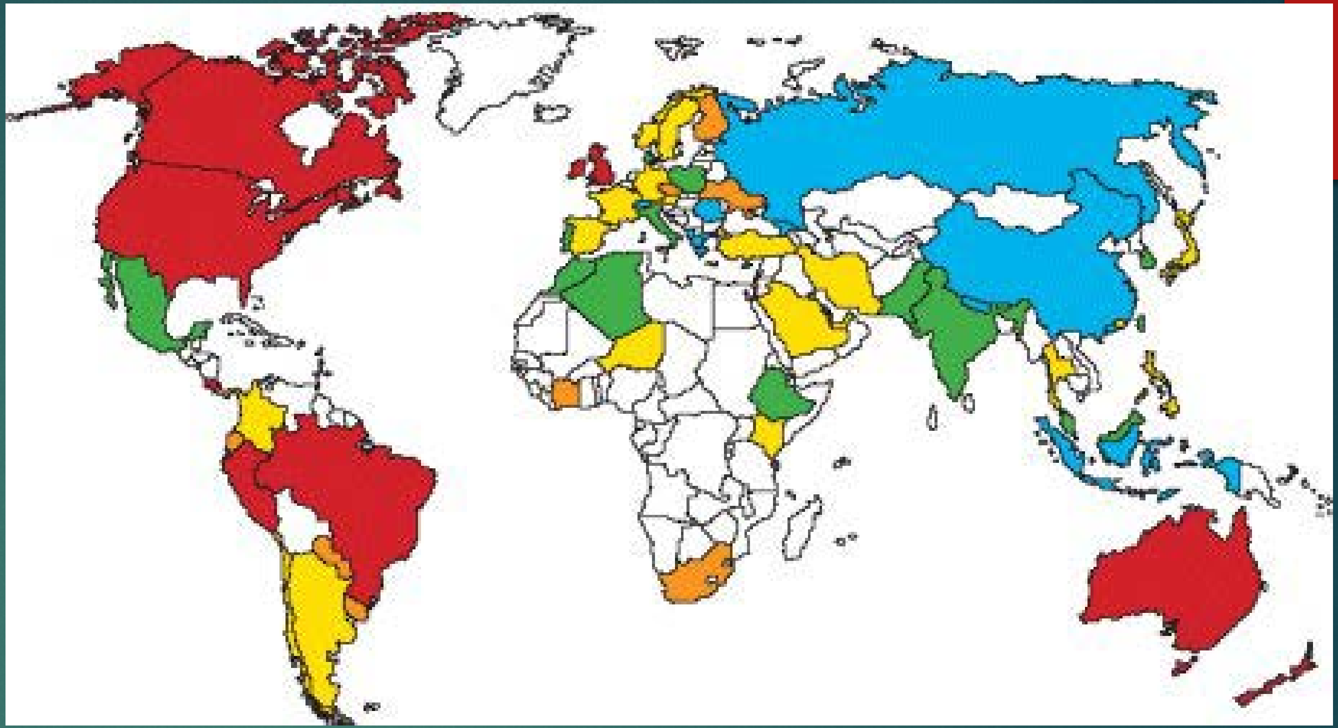
Worldwide Asthma

ISAAC
The International Study of Asthma and Allergies in Childhood

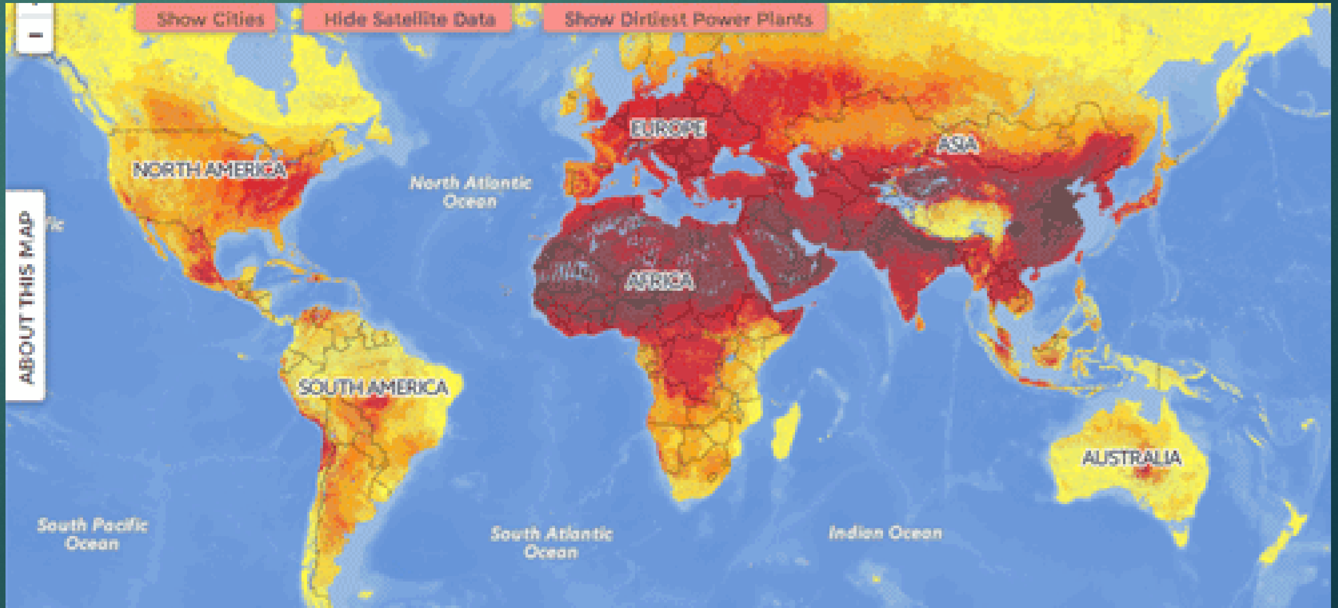


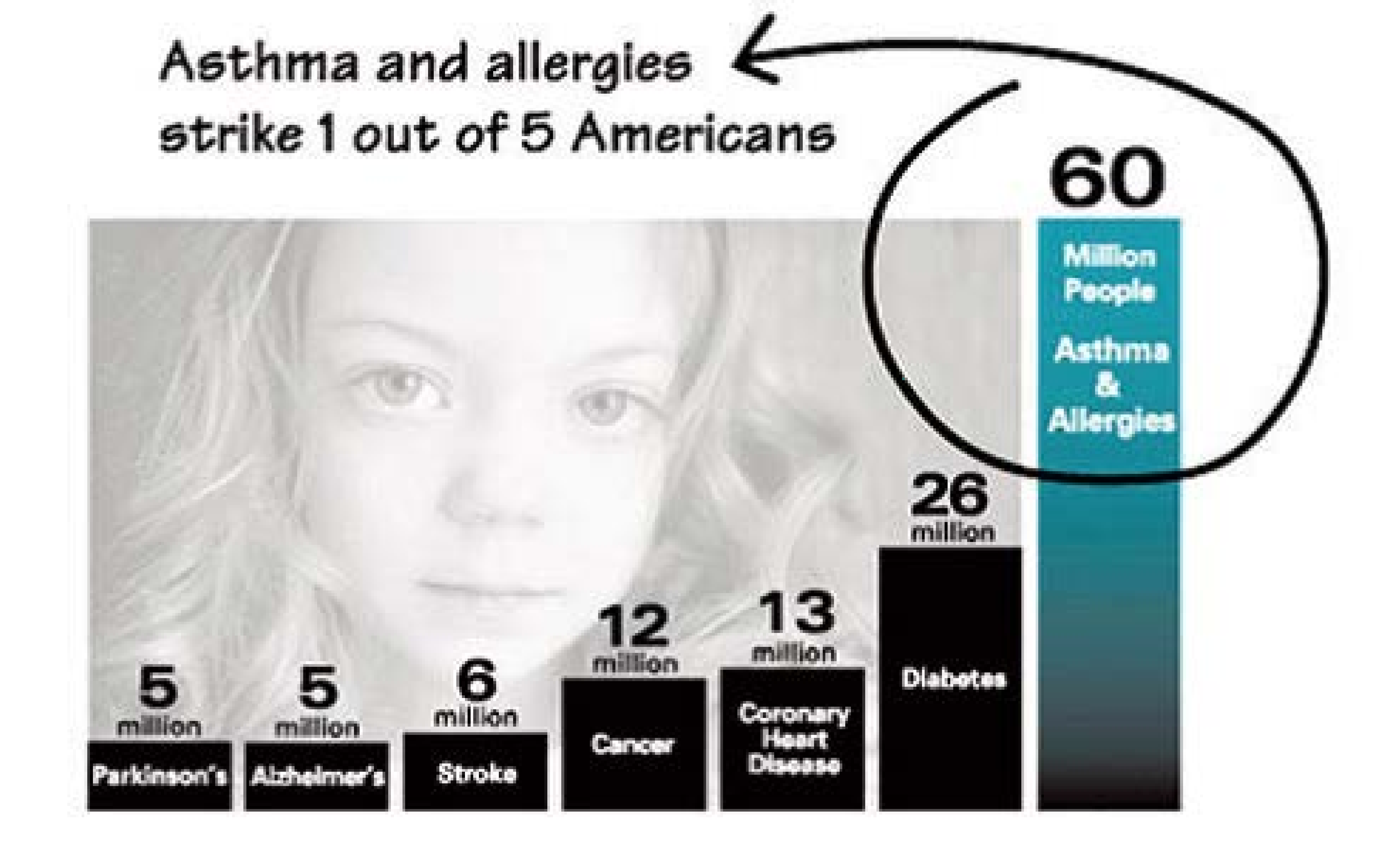
Nature Reviews Immunology, 2006

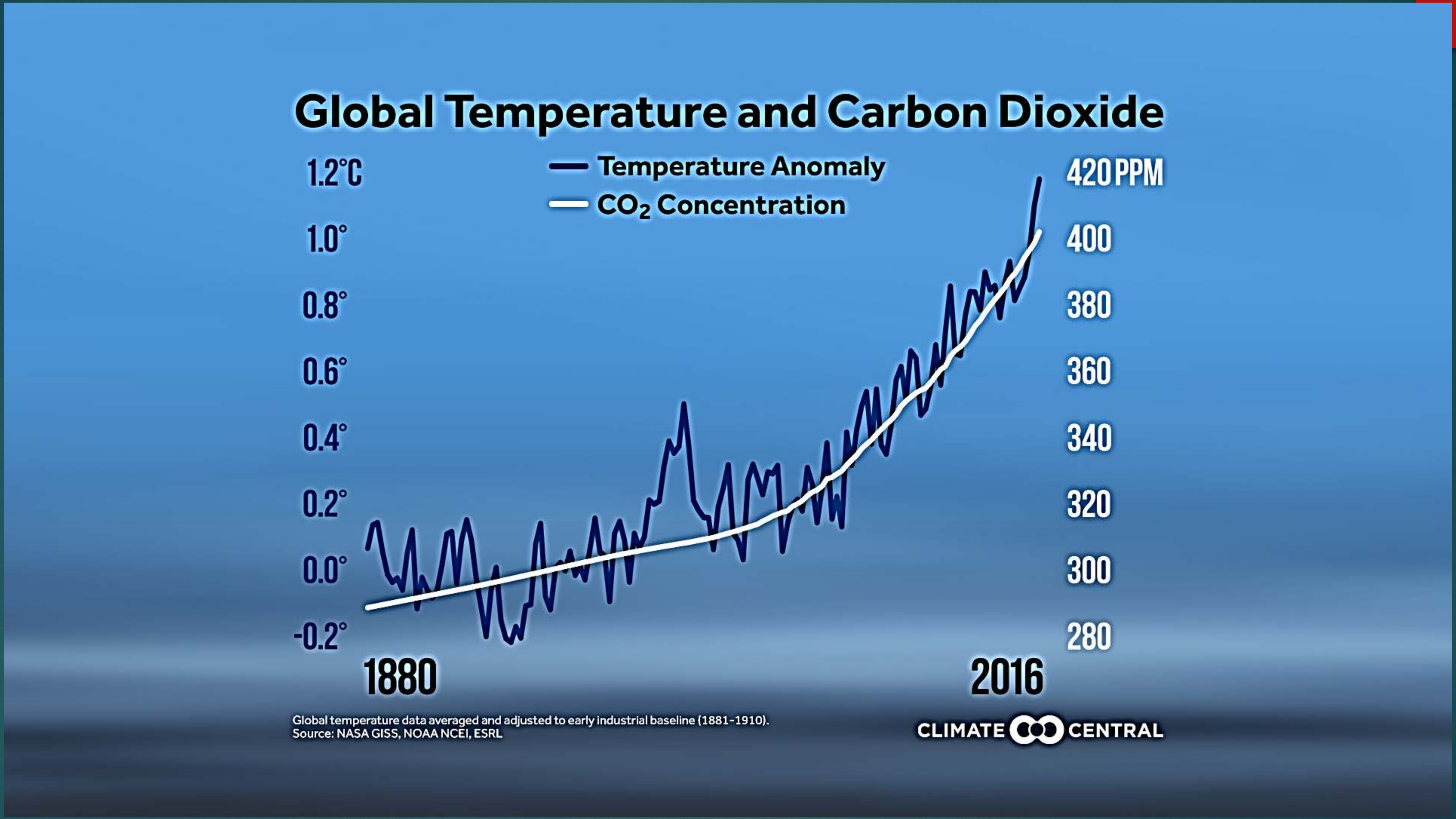
Asthma



Pollution




Asthma and allergies
strike 1 out of 5 Americans
60
Million
People
Asthma
&
Allergies
26
million
Diabetes
13
million
Coronary
Heart
Disease
12
million
Cancer
6
million
Stroke
5
million
Alzheimer's
5
million
Parkinson's



National Oceanic and Atmospheric Administration
Department of Commerce

HEALTH EFFECTS OF CLIMATE CHANGE

CLIMATE CHANGE

Temperature Rise [1]
Sea level Rise [2]
Hydrologic Extremes

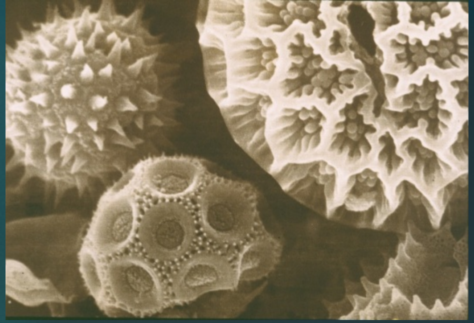
1 **3°C** by 2100
2 **40 cm** by 2100

IPCC estimates

Urban Heat Effect	→ Heat Stress Cardiorespiratory failure
Air Pollution & Aeroallergens	→ Respiratory diseases, COPD, Asthma & Allergy
Insect related Diseases	→ Malaria Dengue Encephalitis Hantavirus Rift Valley Fever Stings / Anaphylaxis
Water-borne Diseases	→ Cholera Vibrio parahaemolyticus Cryptosporidiosis Campylobacter Leptospirosis
Water resources & food supply	→ Malnutrition Diarrhea Toxic Red Tides Failed ice cellars Contaminated water
Mental Health & Environmental Refugees	→ Forced Relocation Overcrowding Infectious diseases

Adapted from Patz,1998

Climate Change is Correlated with Allergens



- Increased and faster plant growth
- Increase in plant height & biomass
- Increase in pollen production
- Increase in allergenic proteins in pollen
- Earlier and longer pollen seasons
  - Higher latitudes more affected

Demain JG. Curr Allergy Asthma Rep 2018;18 (22):1-5
Barnes CS, et al. J Allergy Clin Immunol:In Practice 2013;1:137-41
D'Amato GD, et al. WAO Journal 2011; 4:121-25
Ziska L, et al. Proc Natl Acad Sci 2011;108(10):4248-51
Shea K, et al. J Allergy Clin Immunol 2008;122:443-53
Wayne P et al. Ann Allergy Asthma Immunol 2002;88:279-82

Changes in Weed Pollination

Ziska L, Caulfield. Amer J of Plant Physiology,2000;27:893-8 (US)

- Tested the hypothesis that the increase in atmospheric CO_2 concentrations since the Industrial Revolution may alter growth and pollen production of ragweed

- Controlled chambers:
  - Pre-industrial levels of CO_2 (280 mcl/L)
  - Current levels of CO_2 (370 mcl/L) ⇒ **+ 132 %**
  - Projected 2100 of CO_2 (600 mcl/L) ⇒ **+ 90 %**

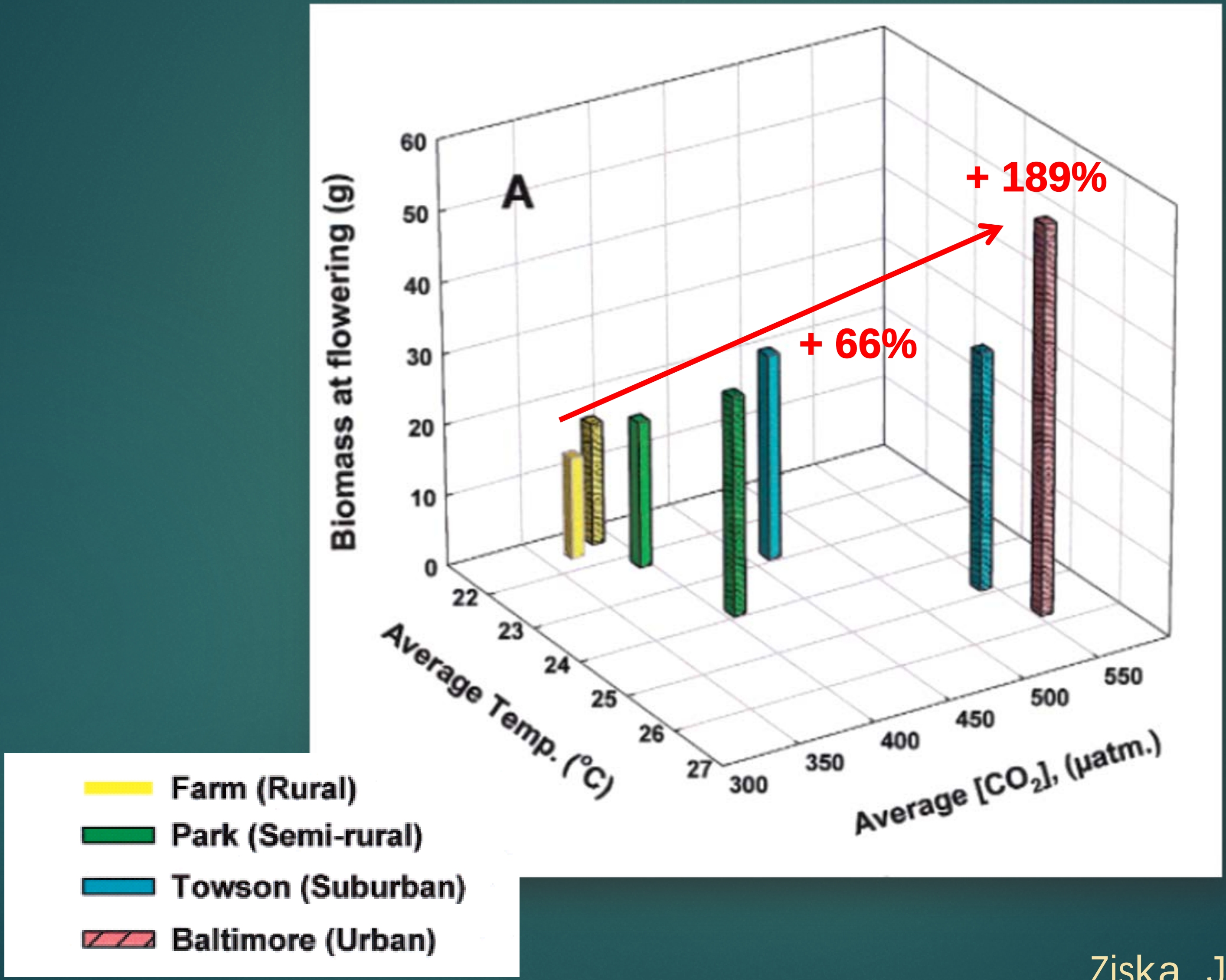
- Results
  - +132% increase in pollen production from preindustrial to current
  - +90% increase in pollen production from current to 2100

Changes in Weed Pollination

Ziska L, et al. J Allergy Clin Immunol, 2003. 111(2):290-5

- URBAN versus SUBURBAN versus RURAL (Baltimore, USA)
- Existing temperature and CO_2 concentration
  - 2000
    - CO_2 30% higher in urban
    - Temperature 1.8° C higher in urban
  - 2001
    - CO_2 31% higher in urban
    - Temperature 2° C higher in urban
- Ragweed grew faster, flowered earlier, and produced significantly greater biomass & pollen in the urban areas (189%) versus rural
  - Associated with increased temperature & CO_2

Rural vs. Urban Ragweed



Urban ragweed emerged 3-4 days earlier vs. rural

Suburban ragweed 61-66% greater biomass vs. rural

Urban 189% greater vs. rural

Ziska, JACI 2003 (US)

Differential Amb a 1 Contents in Common Ragweed Depending on CO_2 Levels

Choi YJ, Oh HR, Kim KR, et al. Allergy Asthma Immunol Res. 2018;10(3):278-282

- 4 chambers
  - All variables controlled
  - Only variance was CO_2
- Ragweed plants, 3 colonies of 20 (60 plants) per chamber. 3 containers in each growth module.
  - Colonies originated with wild seeds
- Top growth harvested every 2 weeks until maturity
- Amb a 1 concentration measured with an Enzyme Linked Immunosorbant Assay (ELISA)

Differential Amb a 1 Contents in Common Ragweed Depending on CO_2 Levels

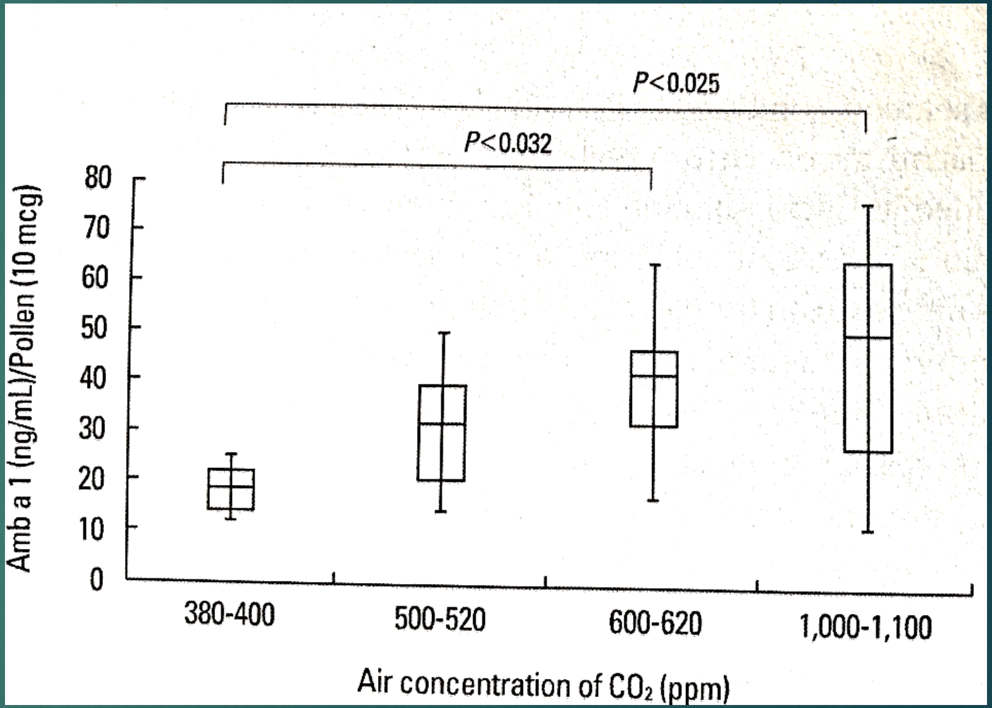
Choi YJ, Oh HR, Kim KR, et al. Allergy Asthma Immunol Res. 2018;10(3):278-282.

CO2 ppm	Amb a1 ng/mcg
380-400	1.88
500-520	3.14
600-620	4.44
1000-1100	5.36

67%

236%

285%



380-400	current outdoor conditions
500-520	1.2x current polluted urban conditions
600-620	1.5x projected world CO_2 by 2050
1000-1100	2x higher than predicted world CO_2 in 2050

Increasing Amb a 1 content in Ragweed pollen as a function of rising CO_2 concentration

Singer BD et al, Func Plant Biology 2005;32:667-70 (US)

Table 2. Protein and Amb a 1 in extracts of ragweed pollen obtained from plants grown under controlled conditions of $[CO_2]$

The $[CO_2]$ used correspond approximately to the pre-industrial concentration, the current concentration and that projected for 2050. Samples of pollen pooled from plants grown under the different $[CO_2]$ were extracted as described in the methods. ELISA was performed in triplicate with each sample; results are mean ± standard deviation.

CO2	Protein	Amb a 1	Amb a 1/pollen
$[CO_2]$ (μmol mol^{-1})	Protein concentration (μg mg^{-1} pollen)	Amb a 1 concentration (ELISA mg^{-1} protein)	Amb a 1 concentration (ELISA mg^{-1} pollen)
280	21 ± 2	4490 ± 960^A	93 ± 20^A
370	20 ± 2	5290 ± 560^B	103 ± 11^B
600	22 ± 2	8180 ± 900	178 ± 20

^{A}$P<0.005$ when compared with projected 21st century $[CO_2]$, *t*-test using unequal variances.
^{B}$P<0.01$ when compared with projected 21st century $[CO_2]$, *t*-test using unequal variances.

Estimated Amb a 1 exposure

Studies conducted in controlled environmental chambers
→Increased Amb a 1 concentrations as a function of CO_2.

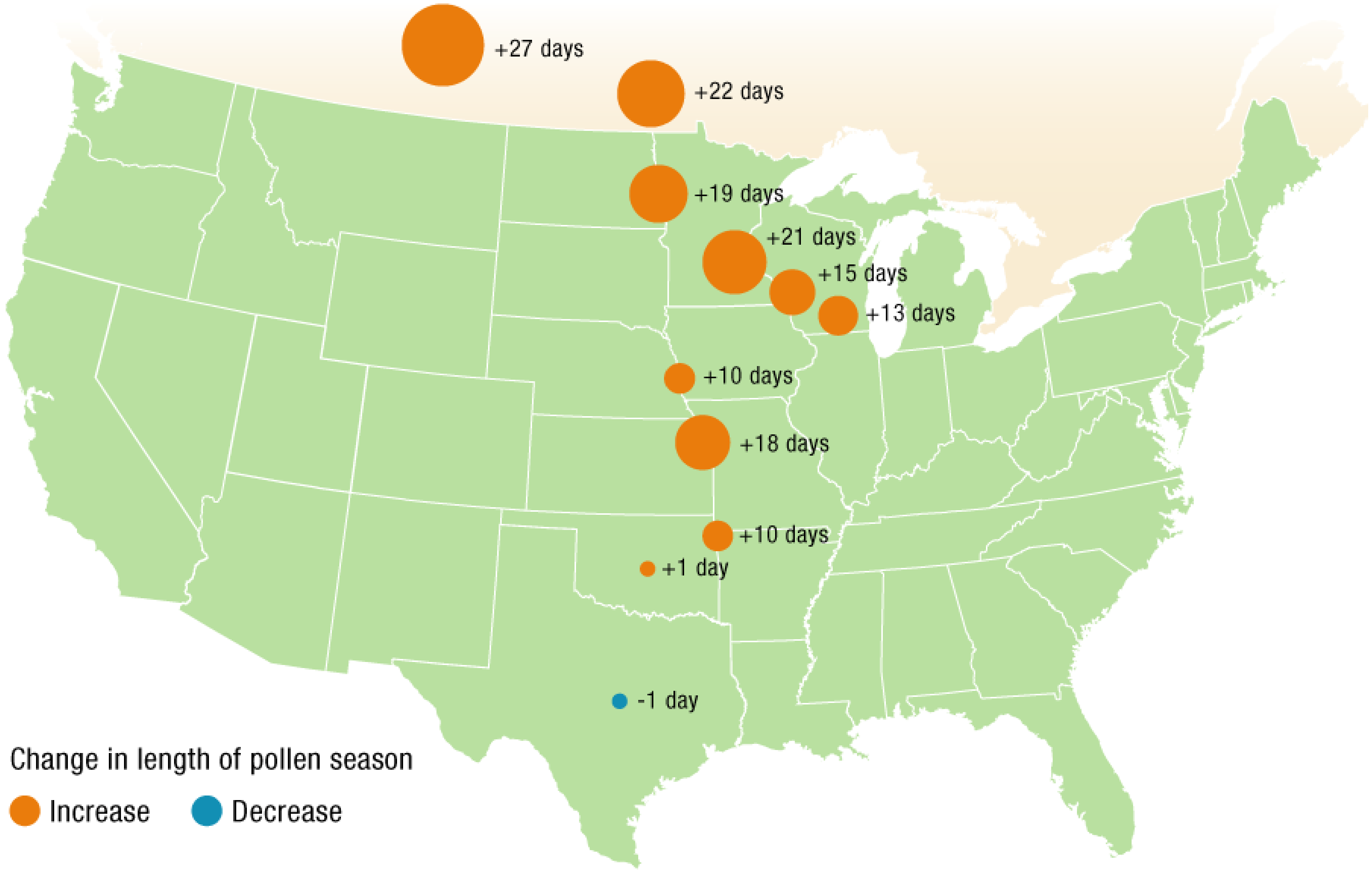
Change in relative exposure to Amb a 1 (mg plant-1) as a function of total pollen production

Recent warming by latitude associated with increased length of ragweed pollen season in central North America

Ziska L, et al. Proc Natl Acad Sci 2011, 108(10):4248-51

Northern latitude		Length	First-Frost	Frost-Free
Saskatoon Canada	52.07	+27	+18	-21
Winnipeg Canada	50.07	+25	+17	-23
Fargo ND	46.8	+16	+15	-20
Minneapolis MN	45.0	+16	+13	-22
LaCross WI	43.8	+13	+9	-18
Madison WI	43.0	+12	+8	-18
Papillon NE	41.15	+11	+8	-13
Rogers AR	36.33	-3	+3	-8
Oklahoma City OK	35.47	+1	+6	-11
Georgetown TX	30.63	-4	-1	+7

Change in ragweed pollen season, 1995-2013



Source: U.S. Environmental Protection Agency

Changes in Tree Pollination

- International research to identify pollen trends
  - Poland (Puc, Wolski. Ann Agric Environ Med, 2002)
    - increase in birch pollen concentration correlated with air temperature
  - Denmark (Rasmussen A. Aerobiologia, 2002)
    - earlier start, earlier peak and increased level of birch pollen correlated with increased winter and spring temperature
  - Spain (Vazquez L. et al. Int J Biometeorol, 2003)
    - projectors of pollen concentration included temperature and sunlight hours
- Summary
  - Pre-season temperature & sunlight are important projectors of tree pollen production and start date

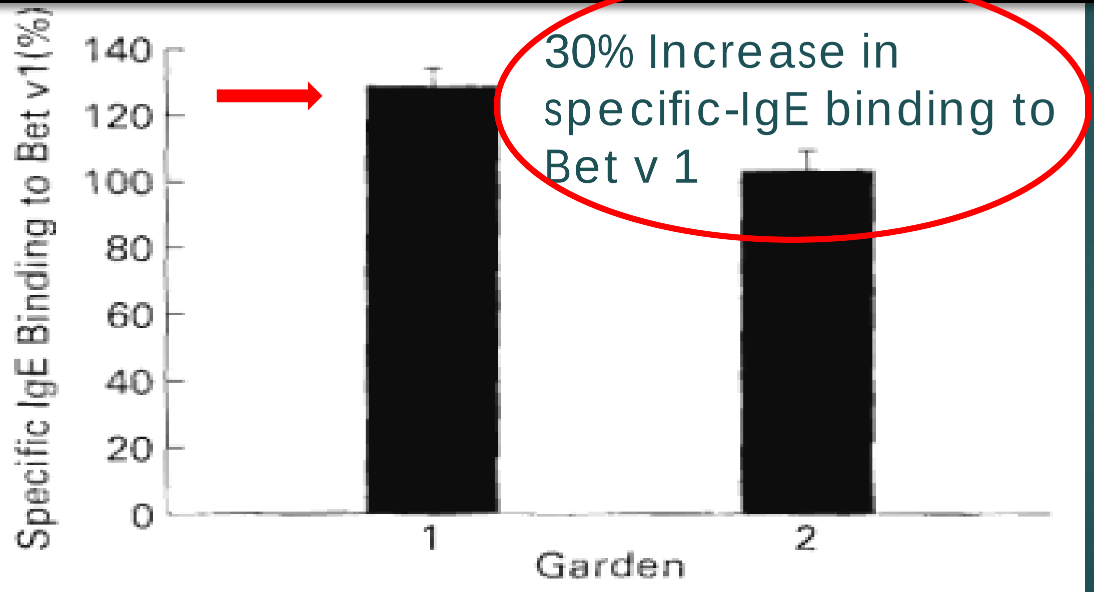
Changes in Birch Allergenicity (*Finland*)

Ahlholm JU, et al.Clin Exp Allergy, 1998, 28:1384-1388

Genetic and environmental factors affecting the allergenicity of birch (*Betula pubescens* ssp. *czerepanovii* [Orl.] Hämet-Ahti) pollen

J. U. AHLHOLM, M. L. HELANDER and J. SAVOLAINEN*

*Unit of Aerobiology and Mycological Ecology, Department of Biology and *Medicity Research Laboratory, Department of Pulmonary Diseases and Clinical Allergology, University of Turku, Turku, Finland*



P<0.05

Fig. 2. The means and the standard errors of the band intensities of Bet v 1 in pollen samples collected from the tree line gardens. Values are proportional to standard bands and expressed as percentages. The bars were significantly different (Tukey's test, $P < 0.05$).

The Possible Role of Climate Changes In Variations of Pollen Seasons and Allergic Sensitizations over 27 years

Ariano R, Canonica GW, Passalaqua G; *Genoa Italy*

- Study Period 1981-2007
- Methods
  - Pollen collected with a Hirst-type trap

  - Pollens monitored
    - birch, cypress, olive, grass, weed (*parietaria*)
  - Patients evaluated
    - Prick skin test for both indoor and outdoor allergens
  - Climate variables monitored
    - Irradiation, Temperature, # days >30° C, Humidity & Rainfall

Ariano R, et al. Annals Allergy Asthma Immunol 2010;104:215-222 (Italy)

The Possible Role of Climate Changes in Variations of Pollen Seasons and Allergic Sensitizations over 27 years

Ariano R, et al. Annals Allergy Asthma Immunol 2010;104:215-222 (Italy)

- Results:
  - Pollen trends
    - ▶ Increased pollen cycle duration (earlier)
      - Trees & Weeds
    - ▶ Increased pollen load
      - Trees, Grasses & Weeds
  - Patient trends (# of patients with positive skin test)
    - ▶ Increased pollen sensitivity throughout study period
    - ▶ No change in DM sensitivity during same period
  - Correlation between Climate & Pollen/Patient trends
    - ▶ Increased irradiation > increased temp & # days >30° C
    - ▶ No correlation with humidity & rainfall

Findings

Variables

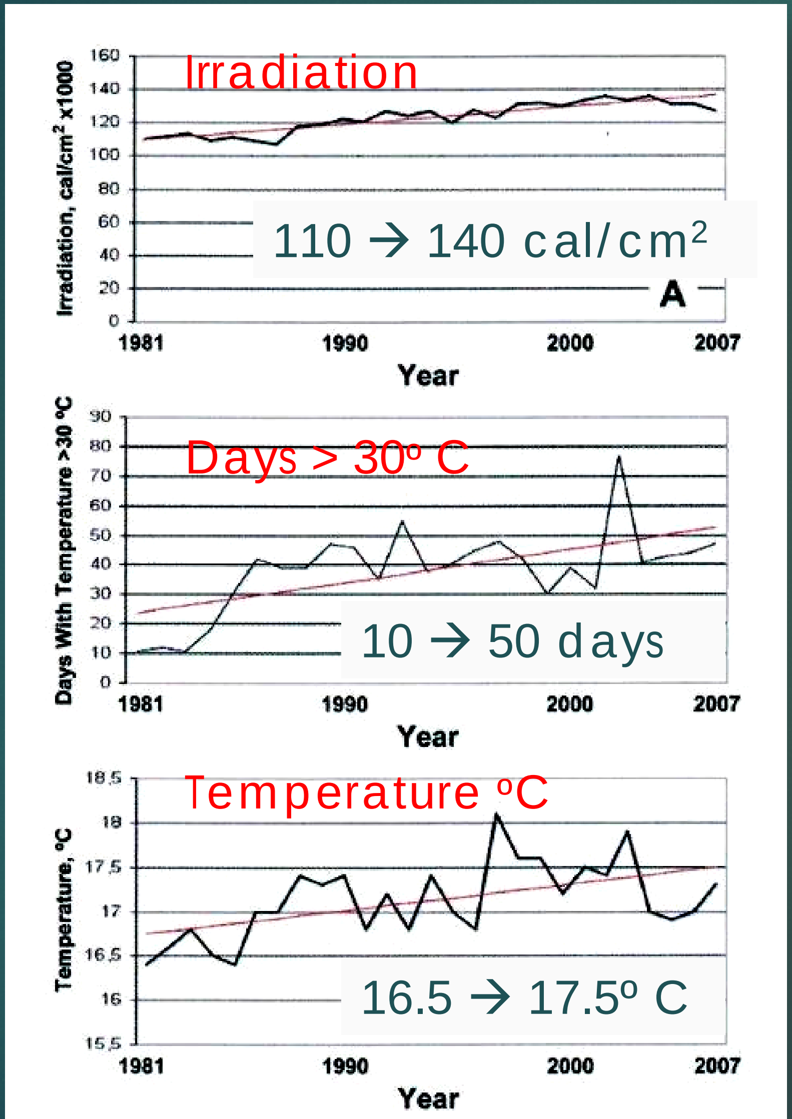


Figure 8. Year-by-year values of radiation (A), number of days with a temperature greater than 30°C (B), and average temperature (C). Linear trend lines are shown in red.

Olive Pollen

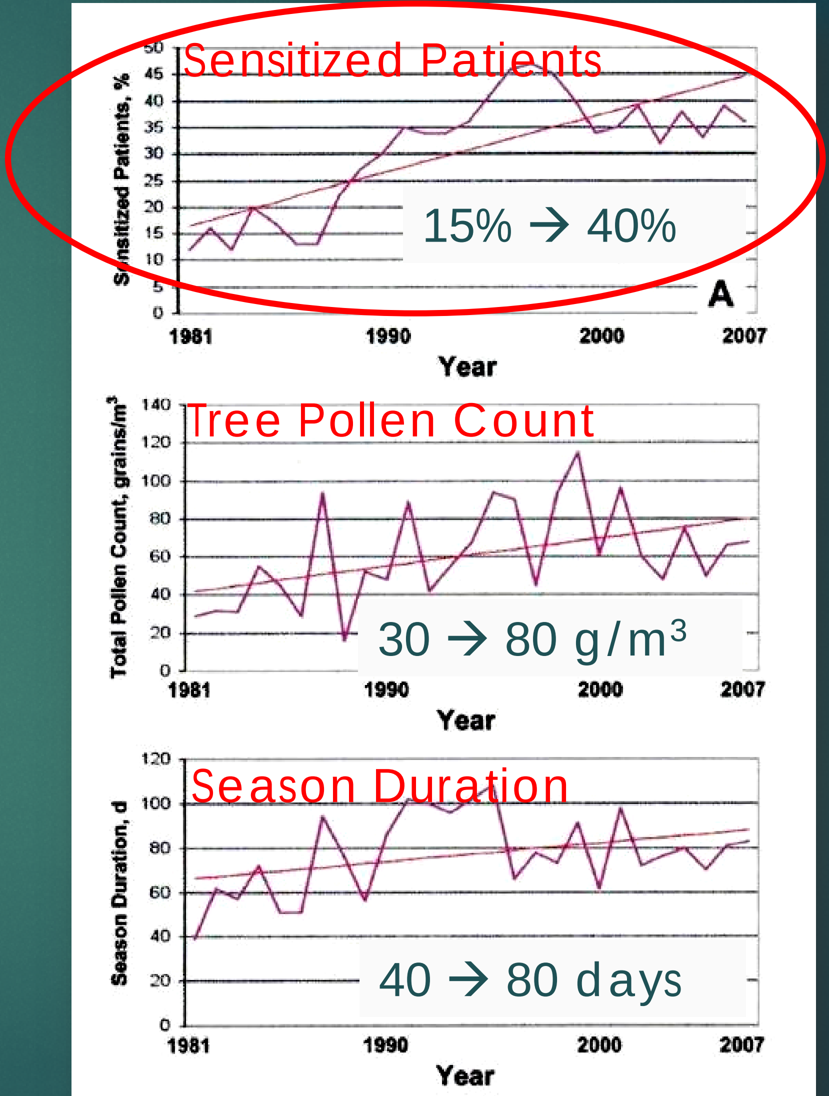


Figure 5. Olive. A, Percentage of sensitized patients. B, Total pollen count. C, Duration of the pollen season. Linear trend lines are shown in red.

Findings

Dust Mite (control)

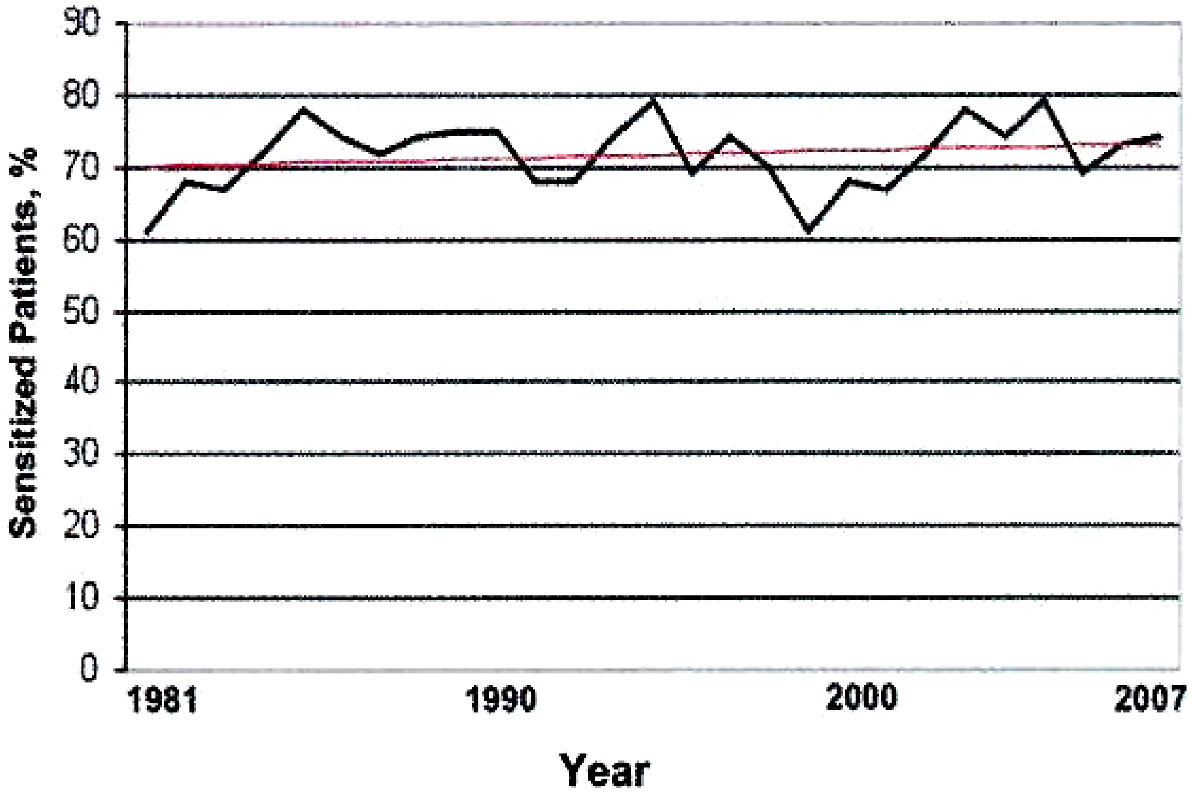


Figure 7. Percentage of patients sensitized to house dust mite during the study period. The linear trend line is shown in red.

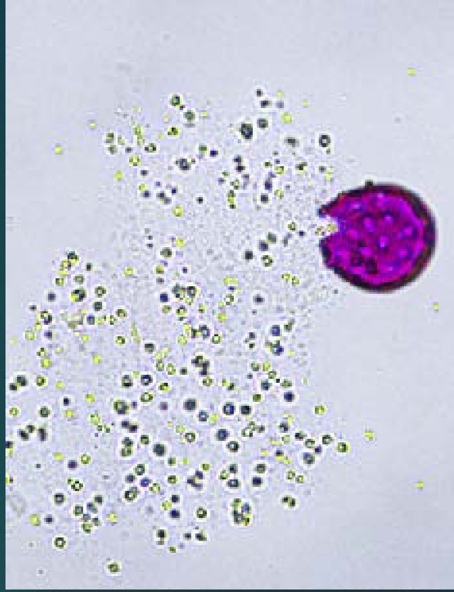
The Possible Role of Climate Changes in Variations of Pollen Seasons and Allergic Sensitizations over 27 years

Ariano R, et al. Annals Allergy Asthma Immunol 2010;104:215-222 (Italy)

Conclusion:

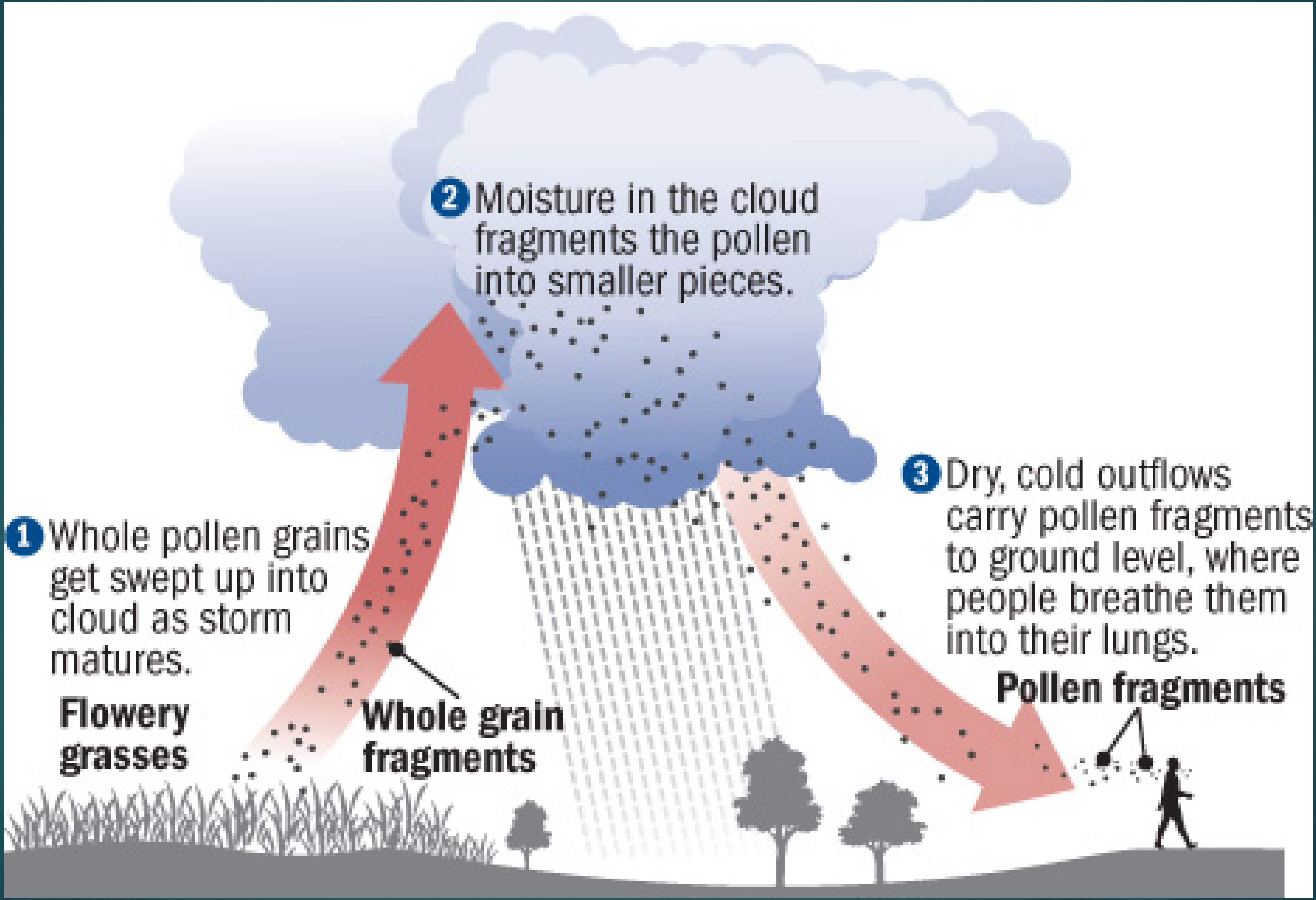
- The progressive climate changes, with
  - increased temperatures
  - days >30° C (86° F)
  - irradiation
- may modify the global pollen load and may influence the rate of allergic sensitization over long periods.

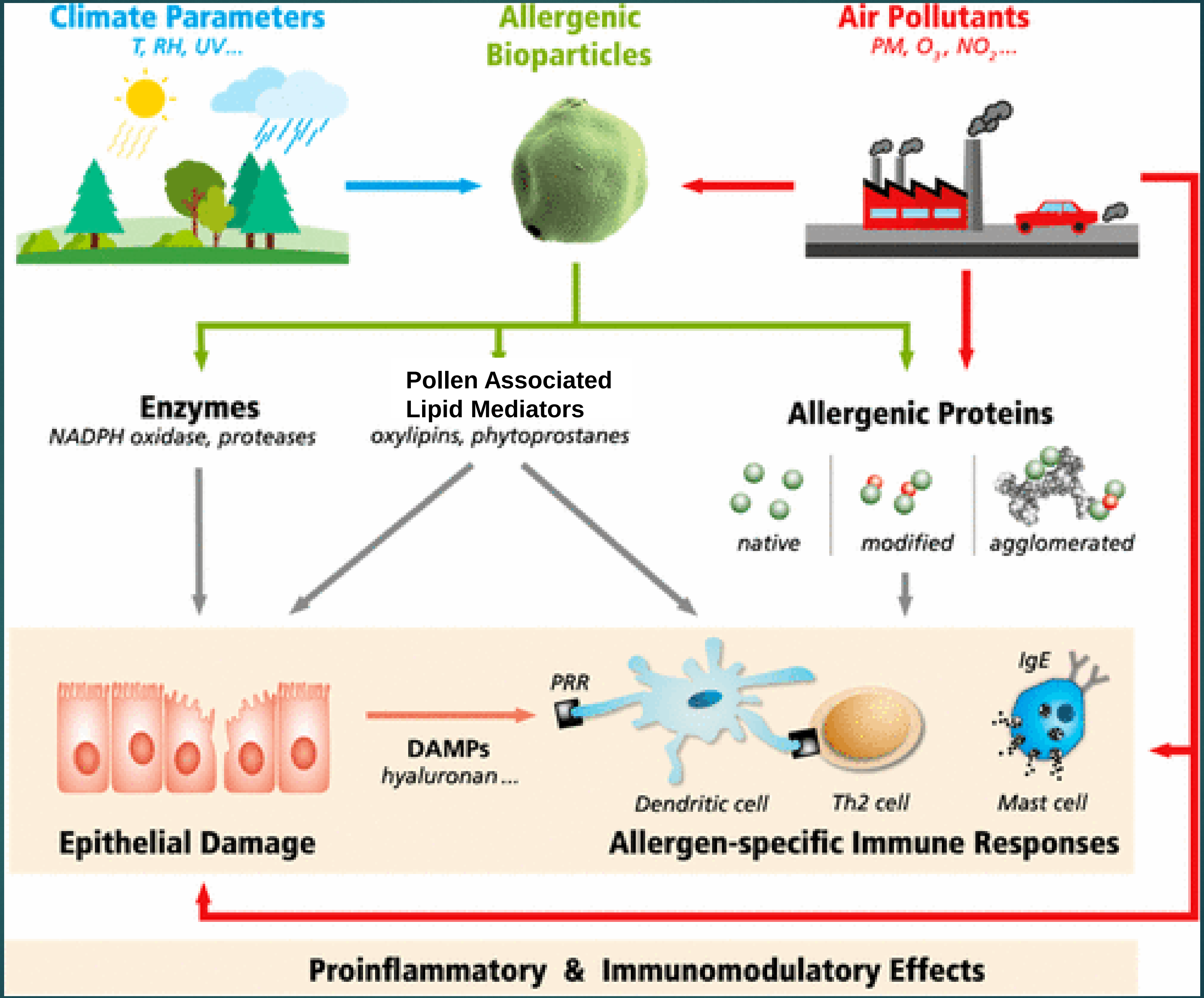
Pollen Grains ➔ Pollen Allergen



- Pollen allergens:
  - water-soluble proteins or glycoproteins, which make them readily available biologically, being capable of evoking an IgE antibody-mediated allergic reaction in seconds
- Pollen allergens rapidly diffuse releasing allergen-containing particles
  - Direct contact with mucosa (isotonic medium of tears and mucus)
  - Exposure to a hypotonic medium (such as rain-water)
- Environmental factors that induce pollen allergen release
  - High relative humidity
  - Heavy rainfall
  - Thunderstorms due to osmotic shock
  - Pollutants
    - Associated with carbon particles, many allergen molecules on a single particle
- High frequency of asthma crisis during heavy rainfall and thunderstorms

“Thunderstorm Asthma”





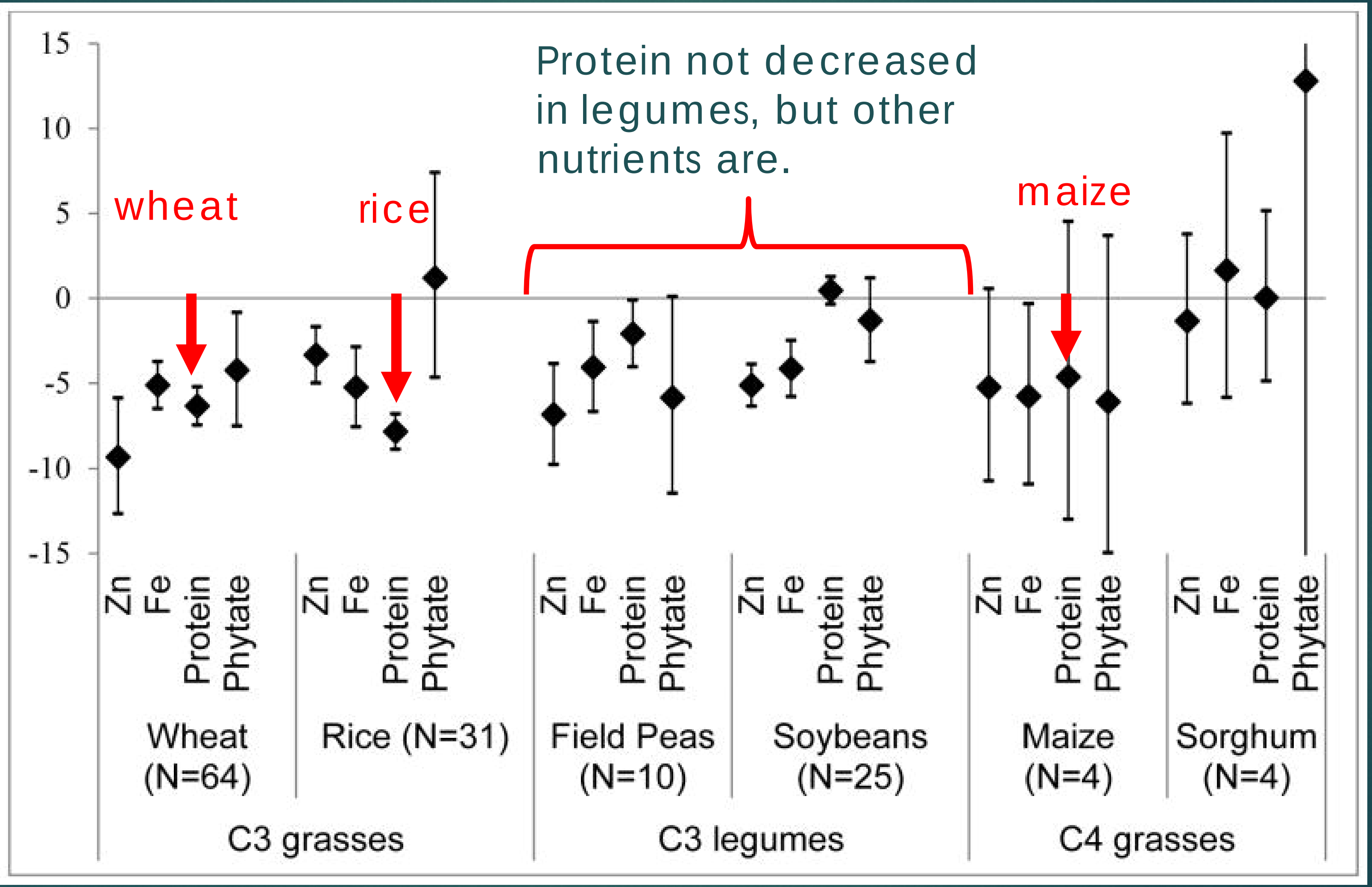
Reinmuth K, et al. Envir Sci Technol 2017

Increased CO_2 decreases Rice Protein

J Sci Food Agric.2016 Aug;96(11):3658-67

- Compared with the control (ambient CO_2 and air temperature), elevated CO_2:
  - Increased rice grain length and width
  - Increased grain chalkiness
  - Decreased protein concentrations.

Percent change in nutrient content at elevated $[CO_2]$ relative to ambient $[CO_2]$



Myers S, et al. Nature. 2014 Jun 5; 510(7503): 139–142 (metanalysis)

Projected 3-fold increase in severe storms

Hurricane Katrina 2005
-winds up to 175 mph
-death toll:1,836
-storm surge 20 feet

Hurricane Harvey 2017
-death toll 88,
-13 million impacted
-rainfall 24 inches in 24 hours
-204,000 homes water damaged

Hurricane Maria 2017
-death toll 2982
-sustained winds of 175 mph
-floodwaters 5-6 feet

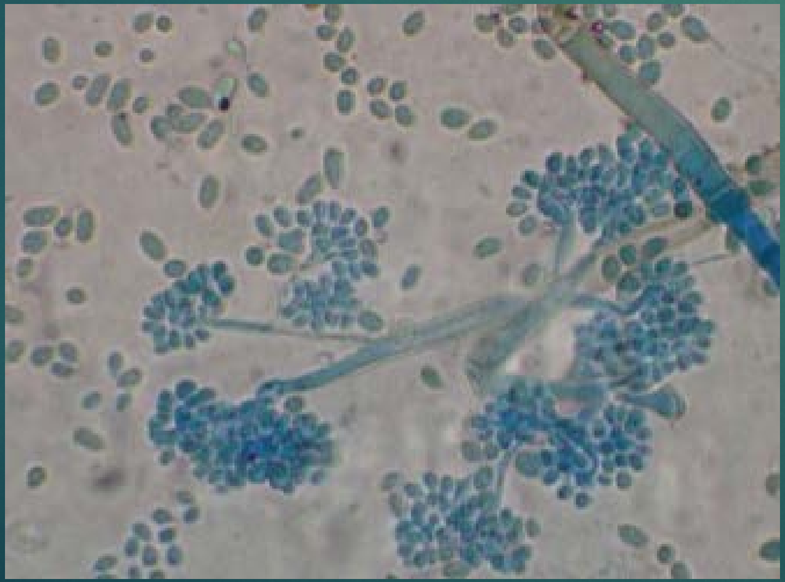
Health Effects: Intense Storms and Flooding

- Increased risk of deaths and injuries
- Water damage
  - risk of mold contamination
  - associated respiratory disease
- Water- and food-borne diseases
- Loss of homes
- Ecosystem and economic impacts
- Displacement of families
- Stress and mental health issues

Just add water and mold will grow

Mold and the Damp House

- Typical indoor mold include Aspergillus, Penicillium, Stachybotrys, fusarium, etc
- Spores are extremely small, airborne, and respirable



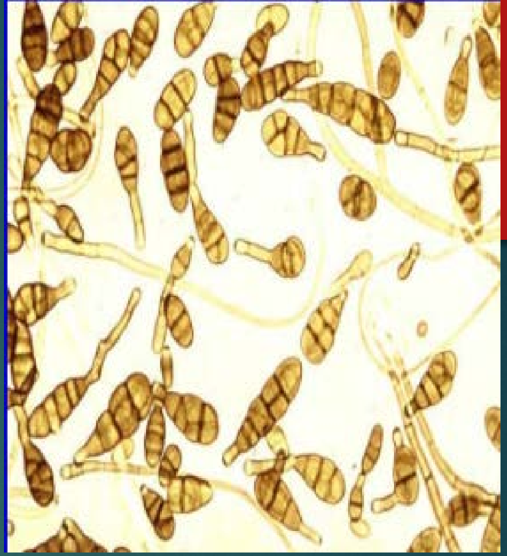
Changes in Mold Sporulation

- Although not well studied, several papers suggest a correlation between rising CO_2 & Temperature and increasing mold spore counts and mycelia growth

- Retrospective study of mold spore concentrations over 27 years in the UK
  Hollins PD, et al. Int J Biometerol.2004;48(3):137-43
  - Increased number of days *Cladosporium* spores exceeded allergenic concentration correlated with rising regional temperature

- Correlation between rising CO_2 and increasing mycelia colonies has been established Lake JA, et al. J Experimental Botany.2009;60(11):3123-3131
  - Increase of CO_2 from 400ppm to 800ppm
  - increased established mycelia colonies 40%.
  - Changes in C/N ratio (>30:1, slows decomposition)

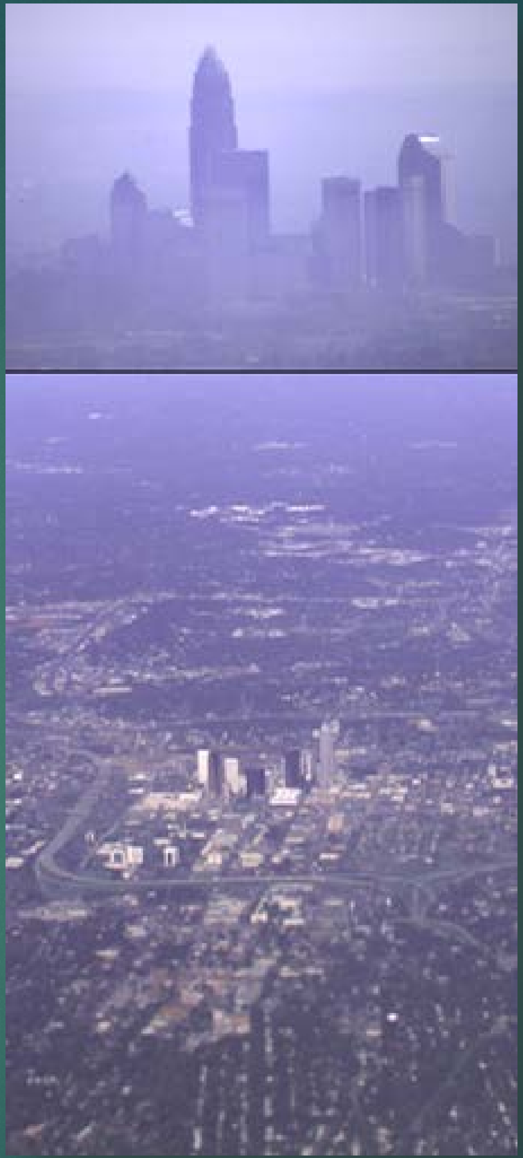
Health Effects of Mold



- Allergic reaction
  - Most common; nasal and eye symptoms
- Asthma
  - Can exacerbate asthma attacks
  - Associated with more severe asthma
- Hypersensitivity pneumonitis
  - Can occur with acute or chronic exposure
- Opportunistic infections
  - Immunocompromised
- Mycotoxin effect:
  - controversial, anecdotal

Hotspots: Cities

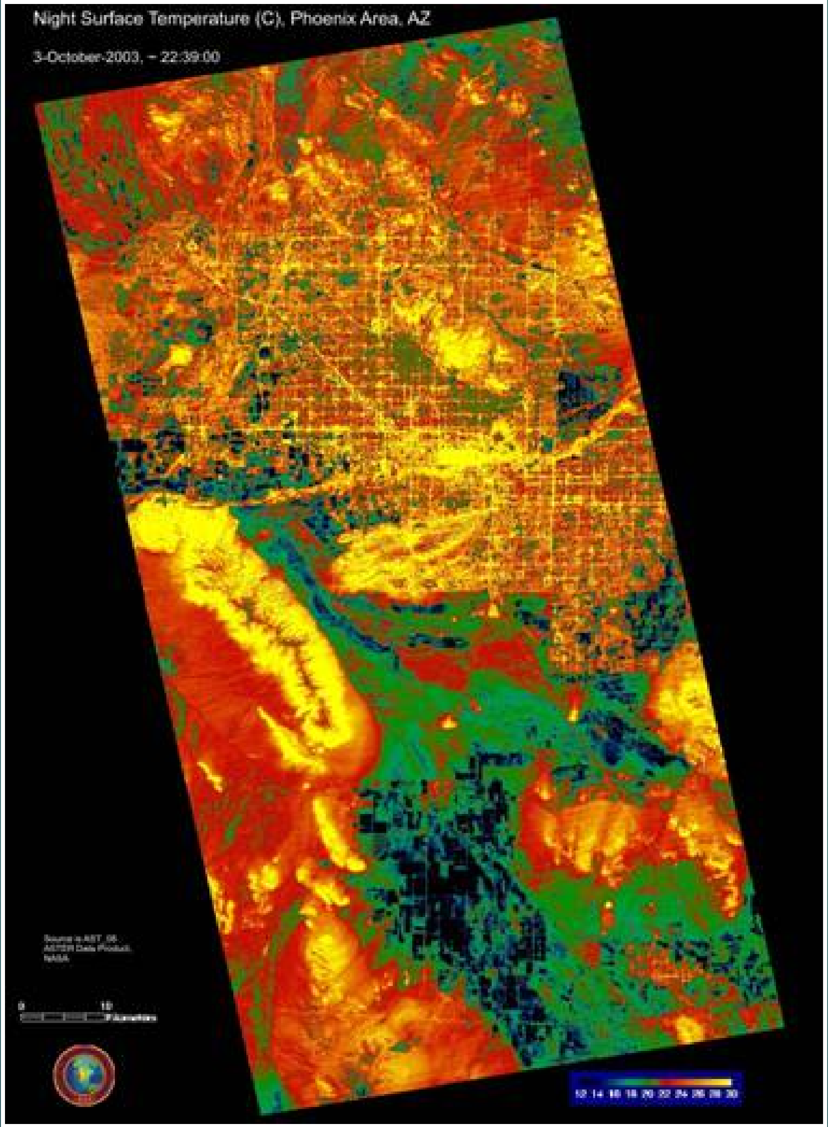
- Air pollution / CO_2
- Heat waves
- Increased pollen
- Exacerbations of chronic disease
- Extreme precipitation events and storms
- Heat-related impacts

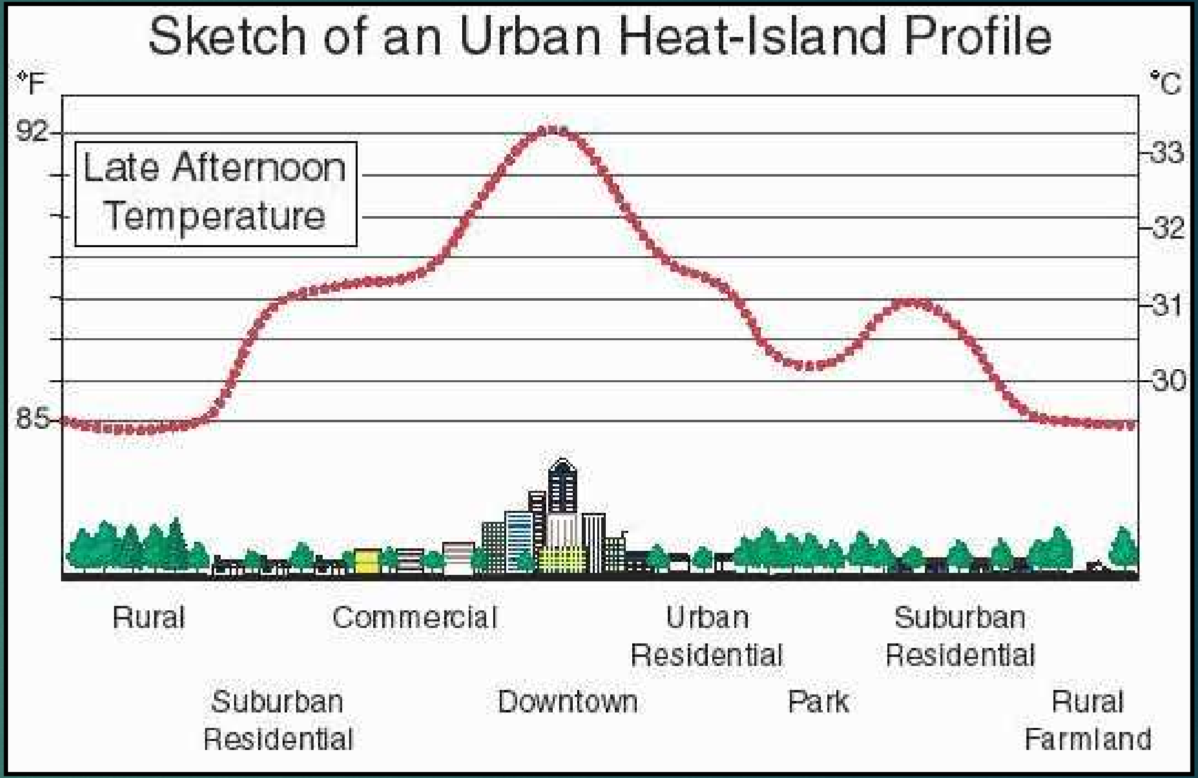


Atlanta

Anchorage

Urban Heat-Island Effect

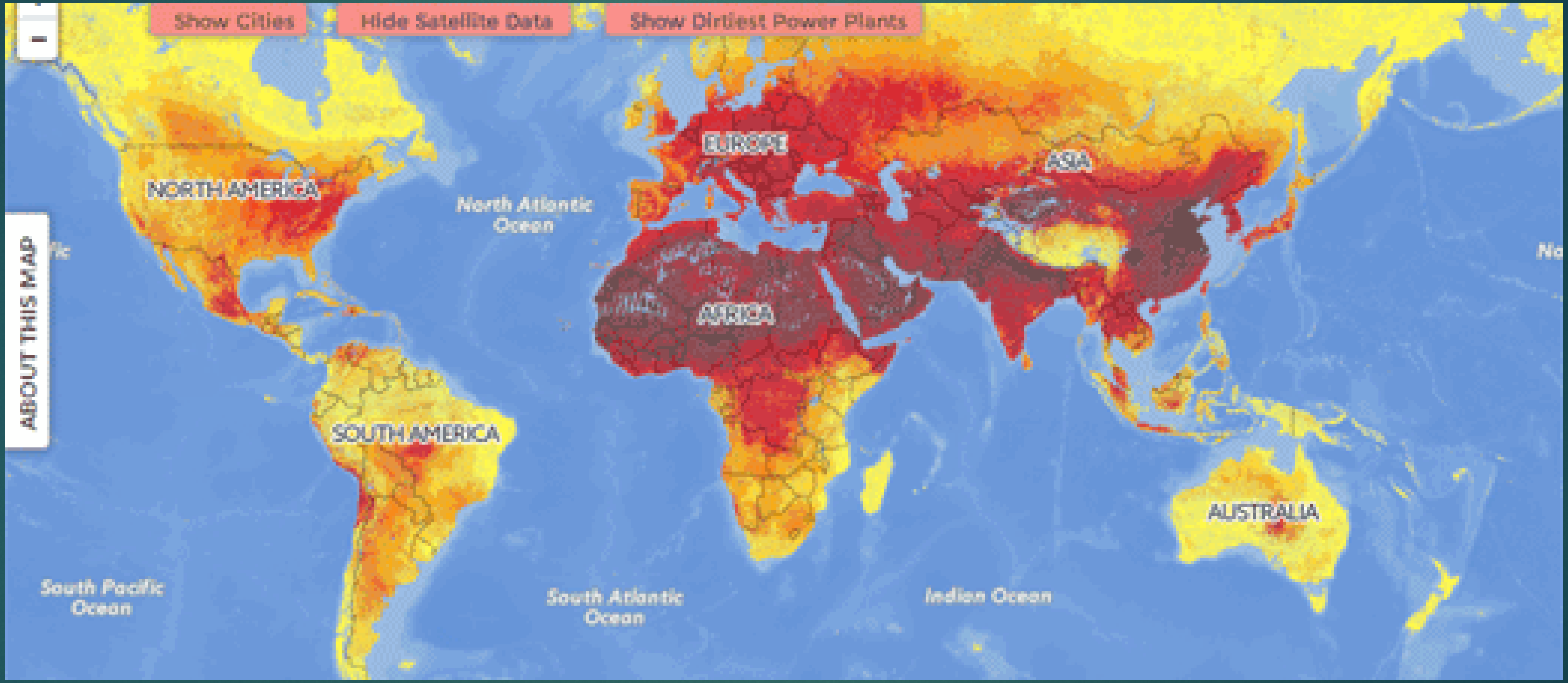




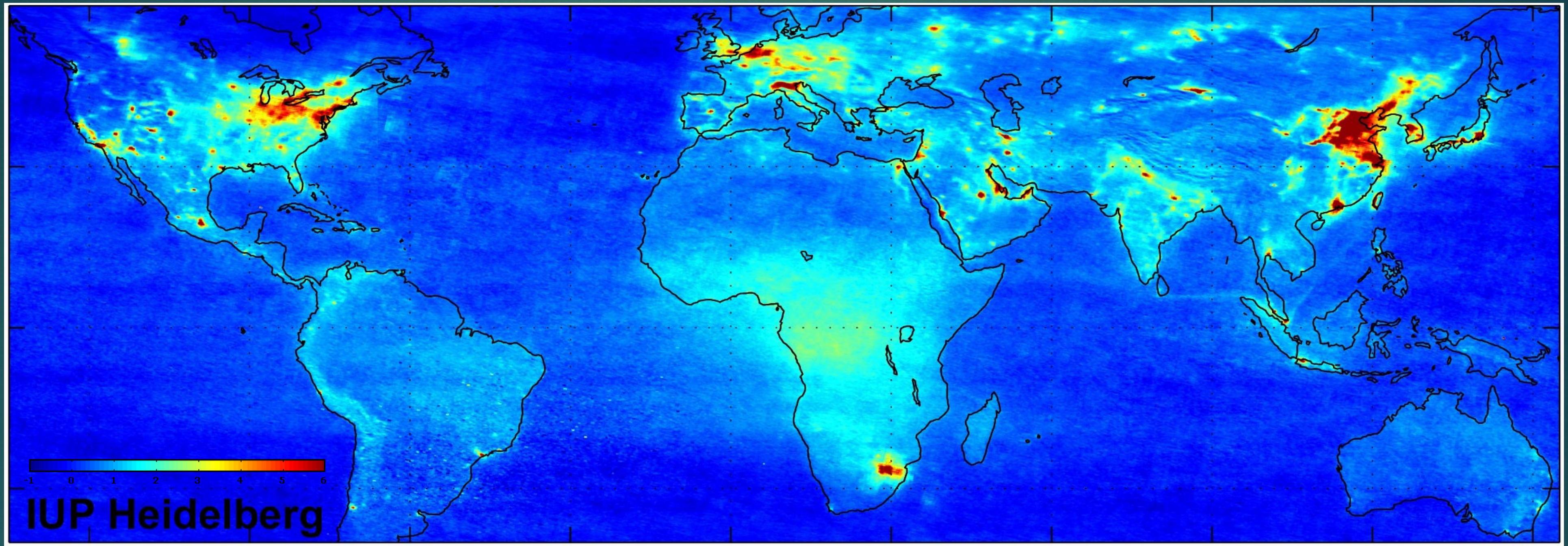
Thermal Satellite Image of Phoenix, AZ Night Surface Temperature

CDC Environmental Health

Air Pollution Hotspots



Air Pollution Hotspots



Common Air Pollutants

Ozone (ground ozone)

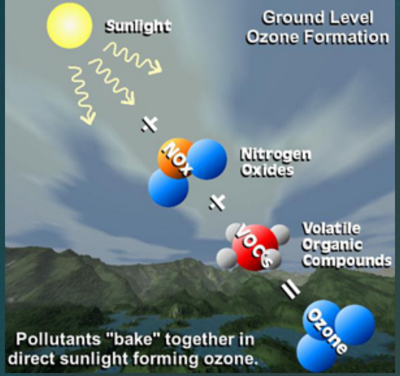
Nitrogen dioxide

Sulfur dioxide

Carbon monoxide

Lead

Particulate matter ($PM_{2.5}$)



Ozone (O_3^-)

Stratopheric Ozone

- Naturally occurring in the stratosphere (6-30 miles)
- Protective “ozone layer”
- Blocks most UV-B rays

Tropospheric Ozone (aka Ground Ozone)

- Near ground level (0-6 miles)
- Cars, factories, power plants, gasoline vapors & chemical solvents
- VOC + NOx + Heat + Sunlight = OZONE
- Increased risk of respiratory disease
- Interferes with the ability of plants to produce and store food, which increases susceptibility to disease, insects, other pollutants, and harsh weather

www.epa.gov

Asthma in Exercising Children Exposed to Ozone

- 3535 non-asthmatic children (9-16 y/o)
- 12 communities in CA
- 1993 – 1998, annual follow-up
- 265 developed asthma (7.4%)
  - 104 (0) sports 1.0 RR
  - 90 (1) sport 1.3 RR
  - 36 (2) sports 1.1 RR
  - 29 (3+) sports 1.8 RR

McConnell, Lancet 2002;359:386-91

Sports versus Ozone

	Low ozone		High ozone	
# sports	N	RR	N	RR
0	58	1.0	46	1.0
1	50	1.3	40	1.3
2	20	0.8	16	1.3
3/+	9	0.8	20	3.3

McConnell, Lancet 2002;359:386-91

Wildfires

- Associated with Increased $PM_{2.5}$

  (Fine particulate matter: 2.5mcl, 1/3 size of red blood cell)

  -Fine particulate matter penetrates deeper into Lungs

  -Greater impact on human health

  -Can bind with pollen allergens

- Increases in $PM_{2.5}$ is Linked to:

  -Cardiovascular disease

  -Respiratory disease

  -Increased hospital admissions

Health Effects: Air Pollution

- Increases in ground-level ozone, increase in allergens levels and potency
- Damaging lung tissue, reducing lung function, increased respiratory diseases (COPD, asthma, allergic rhinitis, bronchitis)
- Repeated exposure may permanently scar lung tissue

The greatest environmental risk to human health

- Air pollution has a range of negative impacts, including human health, damage to ecosystems, food crops, and the built environment.

- The World Health Organization (WHO) highlights air pollution as the greatest environmental risk to human health (note that this is based on current risk—longer-term environmental threats, such as climate change, may exceed this in the future).

- It’s estimated to be the cause of seven million premature deaths every year

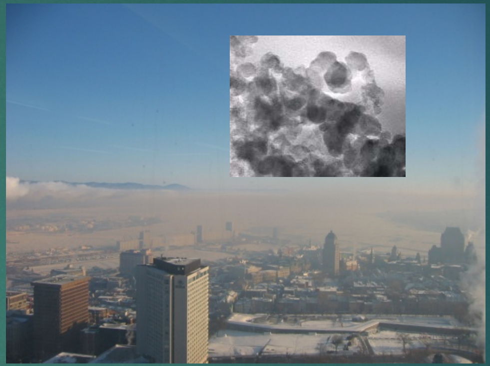
Respiratory Disease & Climate Change Summary

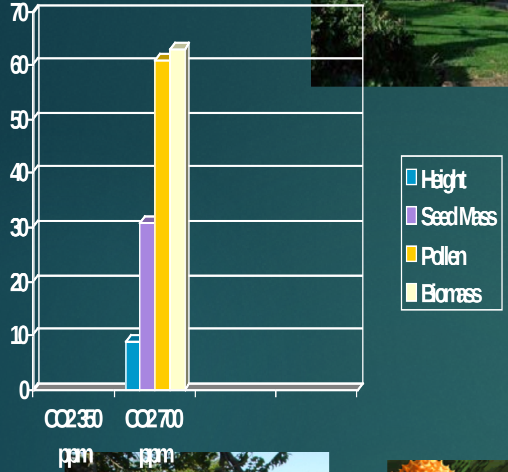
- Air quality affected by several pathways
  - Increases in regional ambient concentrations of O_3, $PM_{2.5}$ fine particles & dust
  - Increases in production & allergenicity of aeroallergens (pollen & mold spores)
- Aeroallergens act with other harmful air pollution worsening respiratory disease (asthma, COPD) and lasting lung disease
- Ozone causes direct lung injury; increases premature mortality; worsens asthma & COPD, and may cause lasting lung damage
- $PM_{2.5}$ are associated with respiratory and cardiovascular diseases

CO_2, Climate Change and Health in our Backyards

Bet v 1

Fire & Smoke Pollution





Mold

Heatwaves & smog

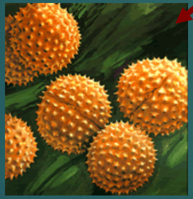
Particulates & pollen

Poison Ivy

Pollen

Mosquitoes

Tree pollen



Ragweed

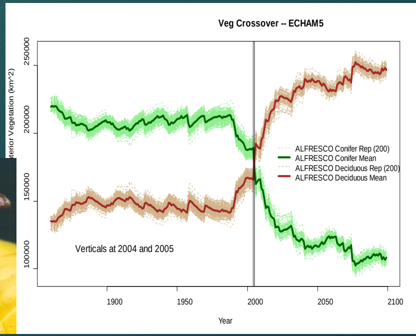
ELISA-quantified Amb a 1

2X CO_2

Changing Insect Patterns

Ticks

Hymenoptera



“You can observe a lot just by watching”

Lawrence Peter “Yogi” Berra

Questions?

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