



# THE IMPACTS OF CLIMATE CHANGE ON HUMAN HEALTH

IN THE UNITED STATES:  
A SCIENTIFIC ASSESSMENT

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U.S. Global Change  
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[Health2016.globalchange.gov](http://Health2016.globalchange.gov)



# Executive Summary



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# Executive Summary



## Climate change is a significant threat to the health of the American people.

- Climate change threatens human health and well-being in the United States. The U.S. Global Change Research Program (USGCRP) Climate and Health Assessment has been developed to enhance understanding and inform decisions about this growing threat. This scientific assessment, called for under the President's Climate Action Plan, is a major report of the sustained National Climate Assessment (NCA) process. The report responds to the 1990 Congressional mandate to assist the Nation in understanding, assessing, predicting, and responding to human-induced and natural processes of global change. The agencies of the USGCRP identified human health impacts as a high-priority topic for scientific assessment.
- The purpose of this assessment is to provide a comprehensive, evidence-based, and, where possible, quantitative estimation of observed and projected climate change related health impacts in the United States. The USGCRP Climate and Health Assessment has been developed to inform public health officials, urban and disaster response planners, decision makers, and other stakeholders within and outside of government who are interested in better understanding the risks climate change presents to human health.

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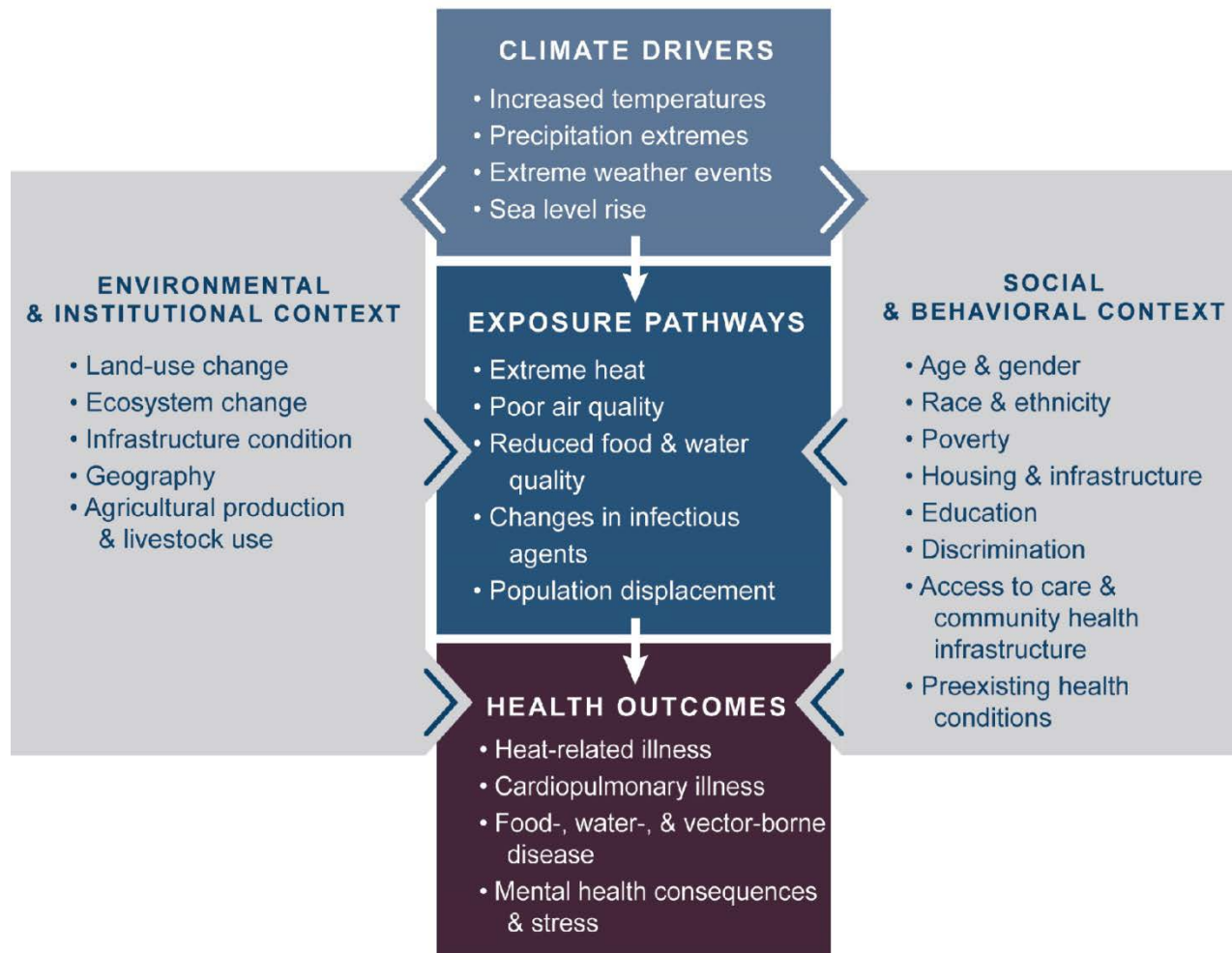
*Every American is vulnerable to the health impacts associated with climate change*

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# 1 Climate Change and Health














# 1 Climate Change and Health

## Examples of Climate Impacts on Human Health

	Climate Driver	Exposure	Health Outcome	Impact
 <b>Extreme Heat</b>	More frequent, severe, prolonged heat events	Elevated temperatures	Heat-related death and illness	Rising temperatures will lead to an increase in heat-related deaths and illnesses.
 <b>Outdoor Air Quality</b>	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 will lead to increases in ozone and particulate matter, elevating the risks of cardiovascular and respiratory illnesses and death.
 <b>Flooding</b>	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.
 <b>Vector-Borne Infection (Lyme Disease)</b>	Changes in temperature extremes and seasonal weather patterns	Earlier and geographically expanded tick activity	Lyme disease	Ticks will show earlier seasonal activity and a generally northward range expansion, increasing risk of human exposure to Lyme disease-causing bacteria.
 <b>Water-Related Infection (<i>Vibrio vulnificus</i>)</b>	Rising sea surface temperature, changes in precipitation and runoff affecting coastal salinity	Recreational water or shellfish contaminated with <i>Vibrio vulnificus</i>	<i>Vibrio vulnificus</i> induced diarrhea & intestinal illness, wound and bloodstream infections, death	Increases in water temperatures will alter timing and location of <i>Vibrio vulnificus</i> growth, increasing exposure and risk of water-borne illness.
 <b>Food-Related Infection (<i>Salmonella</i>)</b>	Increases in temperature, humidity, and season length	Increased growth of pathogens, seasonal shifts in incidence of <i>Salmonella</i> exposure	<i>Salmonella</i> infection, gastrointestinal outbreaks	Rising temperatures increase <i>Salmonella</i> prevalence in food; longer seasons and warming winters increase risk of exposure and infection.
 <b>Mental Health and Well-Being</b>	Climate change 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 cause or exacerbate stress and mental health consequences, with greater risk for certain populations.



# Confidence/Likelihood Terminology

## Likelihood

<b>Very Likely</b> ≥9 in 10	<b>Likely</b> ≥2 in 3	<b>As Likely as Not</b> ≈ 1 in 2	<b>Unlikely</b> ≤ 1 in 3	<b>Very Unlikely</b> ≤1 in 10
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## Confidence Level

<b>Very High</b> Strong evidence (established theory, multiple sources, consistent results, well documented and accepted methods, etc.), high consensus	<b>High</b> Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.), medium consensus	<b>Medium</b> Suggestive evidence (a few sources, limited consistency, models incomplete, methods emerging, etc.), competing schools of thought	<b>Low</b> Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.), disagreement or lack of opinions among experts
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# TEMPERATURE-RELATED DEATH AND ILLNESS

## Future Increases in Temperature-Related Deaths

**Key Finding 1:** Based on present-day sensitivity to heat, an increase of thousands to tens of thousands of premature heat-related deaths in the summer [*Very Likely, High Confidence*] and a decrease of premature cold-related deaths in the winter [*Very Likely, Medium Confidence*] are projected each year as a result of climate change by the end of the century. Future adaptation will very likely reduce these impacts (see the Changing Tolerance to Extreme Heat Finding). The reduction in cold-related deaths is projected to be smaller than the increase in heat-related deaths in most regions [*Likely, Medium Confidence*].



# TEMPERATURE-RELATED DEATH AND ILLNESS

## Even Small Differences from Seasonal Average Temperatures Result in Illness and Death

**Key Finding 2:** Days that are hotter than usual in the summer or colder than usual in the winter are both associated with increased illness and death [*Very High Confidence*]. Mortality effects are observed even for small differences from seasonal average temperatures [*High Confidence*]. Because small temperature differences occur much more frequently than large temperature differences, not accounting for the effect of these small differences would lead to underestimating the future impact of climate change [*Likely, High Confidence*].





# TEMPERATURE-RELATED DEATH AND ILLNESS

## Changing Tolerance to Extreme Heat

**Key Finding 3:** An increase in population tolerance to extreme heat has been observed over time [*Very High Confidence*]. Changes in this tolerance have been associated with increased use of air conditioning, improved social responses, and/or physiological acclimatization, among other factors [*Medium Confidence*]. Expected future increases in this tolerance will reduce the projected increase in deaths from heat [*Very Likely, Very High Confidence*].



# TEMPERATURE-RELATED DEATH AND ILLNESS

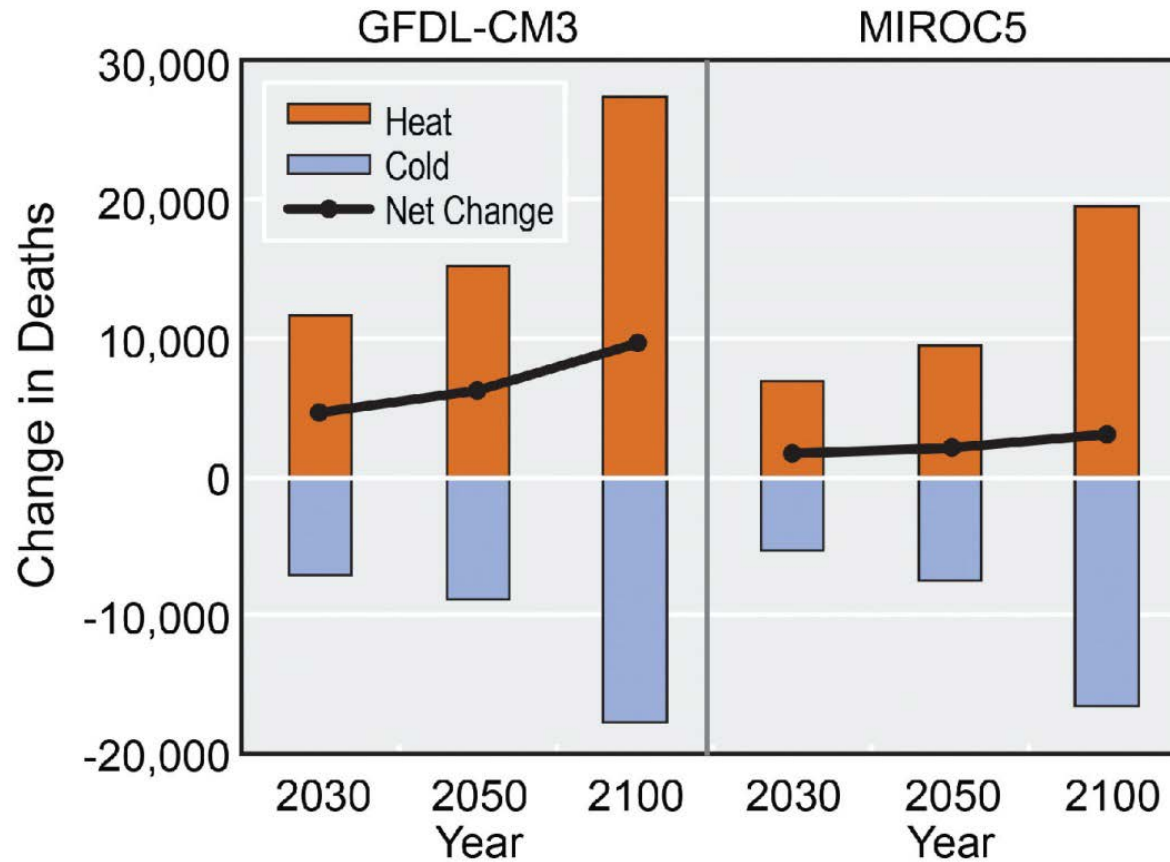
## Some Populations at Greater Risk

***Key Finding 4:*** Older adults and children have a higher risk of dying or becoming ill due to extreme heat [*Very High Confidence*]. People working outdoors, the socially isolated and economically disadvantaged, those with chronic illnesses, as well as some communities of color, are also especially vulnerable to death or illness [*Very High Confidence*].



# TEMPERATURE-RELATED DEATH AND ILLNESS

Projected Changes in Deaths in U.S. Cities by Season





# 3 AIR QUALITY IMPACTS

## Exacerbated Ozone Health Impacts

**Key Finding 1:** 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 of ozone precursors, these climate-driven increases in ozone will cause premature deaths, hospital visits, lost school days, and acute respiratory symptoms *[Likely, High Confidence]*.



# 3 AIR QUALITY IMPACTS

## Increased Health Impacts from Wildfires

**Key Finding 2:** 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]*.







# 3 AIR QUALITY IMPACTS

## Worsened Allergy and Asthma Conditions

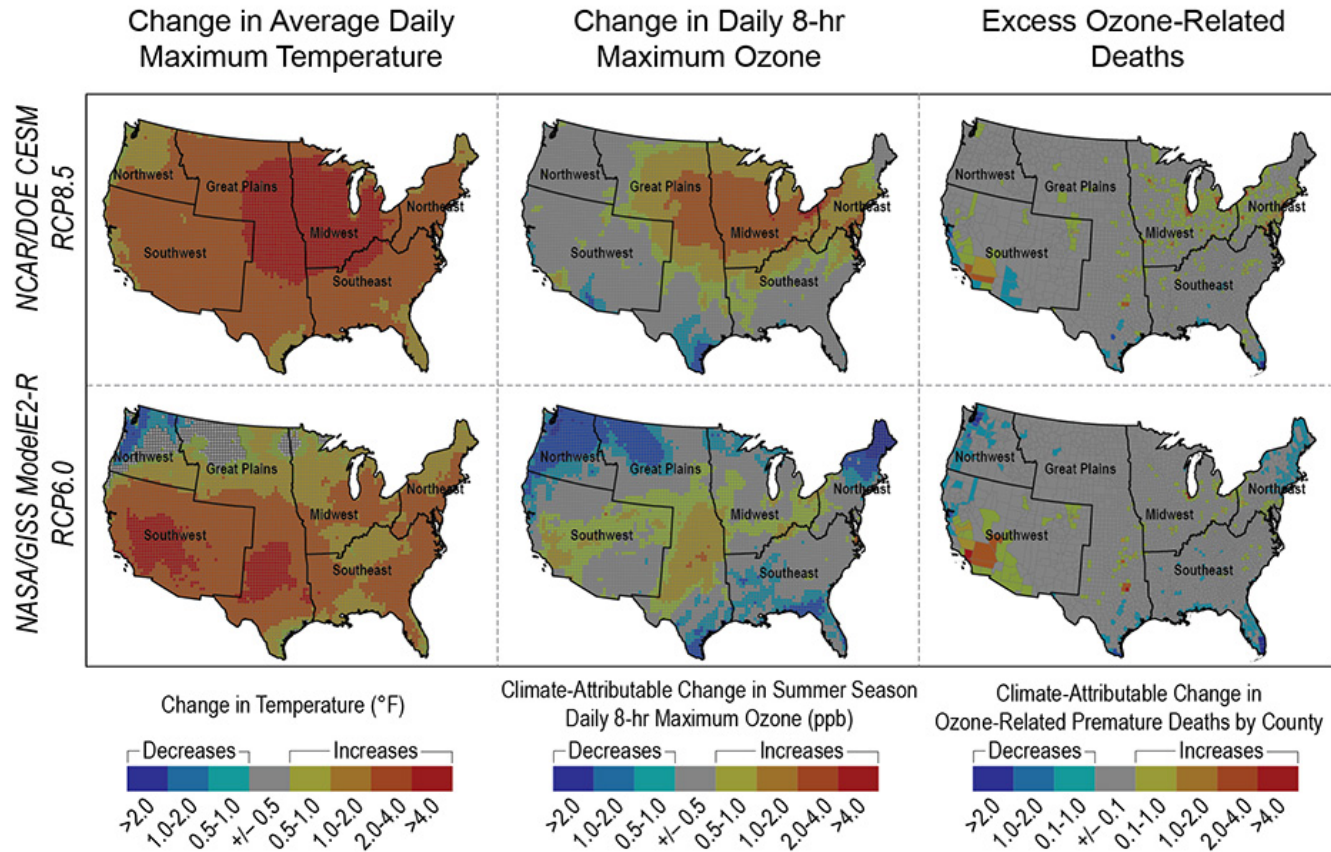
**Key Finding 3:** Changes in climate, specifically rising temperatures, altered precipitation patterns, and increasing concentrations of atmospheric carbon dioxide, are expected to contribute to increases in the levels of some airborne allergens and associated increases in asthma episodes and other allergic illnesses *[High Confidence]*.





# 3 AIR QUALITY IMPACTS

Projected Changes in Temperature, Ozone,  
and Ozone-Related Premature Deaths in 2030





# 4

## IMPACTS OF EXTREME EVENTS ON HUMAN HEALTH

### Increased Exposure to Extreme Events

**Key Finding 1:** Health impacts associated with climate-related changes in exposure to extreme events include death, injury, or illness; exacerbation of underlying medical conditions; and adverse effects on mental health [*High Confidence*]. Climate change will increase exposure risk in some regions of the United States due to projected increases in the frequency and/or intensity of drought, wildfires, and flooding related to extreme precipitation and hurricanes [*Medium Confidence*].



# 4

## IMPACTS OF EXTREME EVENTS ON HUMAN HEALTH

### Disruption of Essential Infrastructure

***Key Finding 2:*** Many types of extreme events related to climate change cause disruption of infrastructure, including power, water, transportation, and communication systems, that are essential to maintaining access to health care and emergency response services and safeguarding human health *[High Confidence]*.





# 4

## IMPACTS OF EXTREME EVENTS ON HUMAN HEALTH

### Vulnerability to Coastal Flooding

**Key Finding 3:** Coastal populations with greater vulnerability to health impacts from coastal flooding include persons with disabilities or other access and functional needs, certain populations of color, older adults, pregnant women and children, low-income populations, and some occupational groups [*High Confidence*]. Climate change will increase exposure risk to coastal flooding due to increases in extreme precipitation and in hurricane intensity and rainfall rates, as well as sea level rise and the resulting increases in storm surge [*High Confidence*].



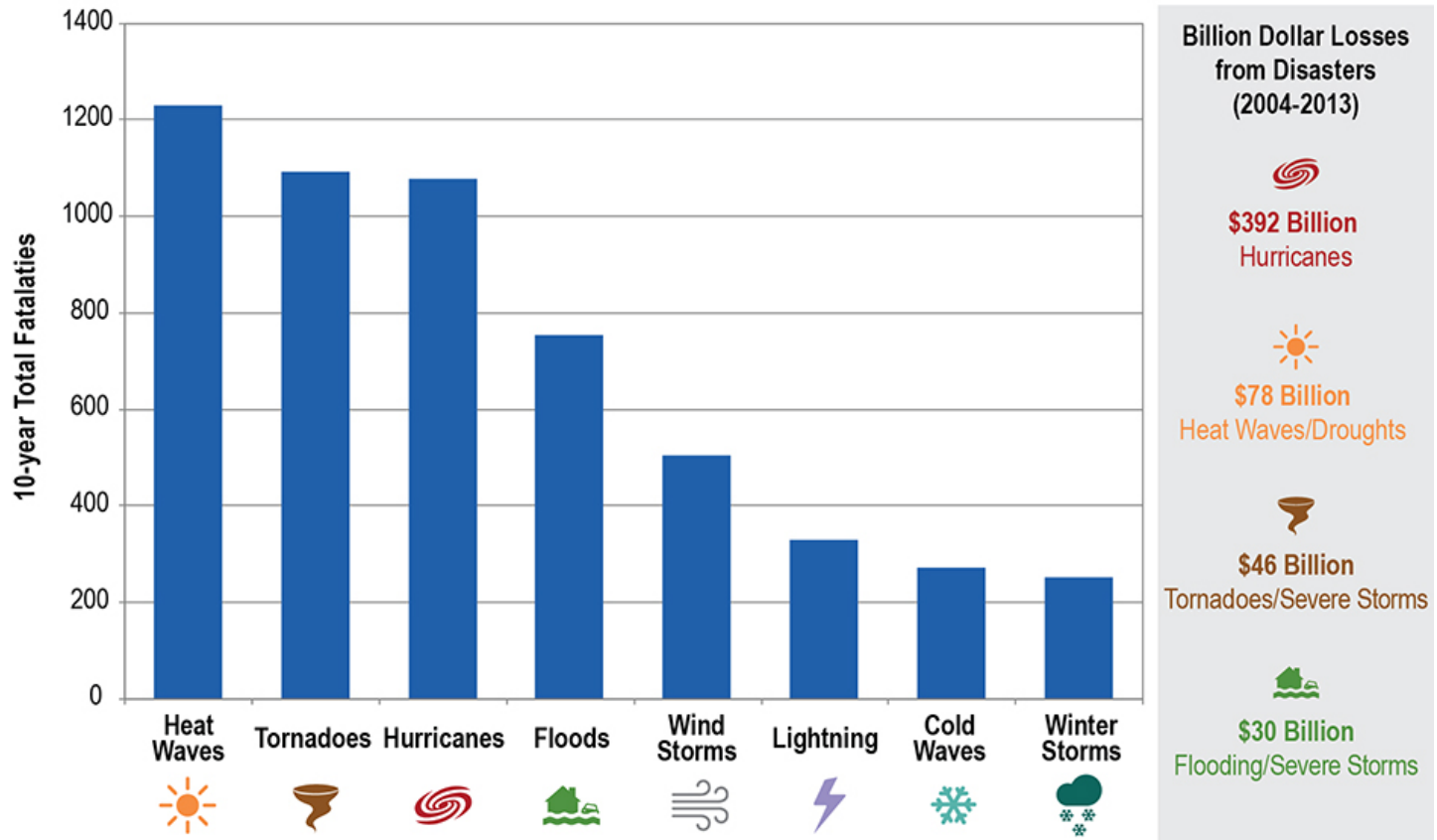




# 4

# IMPACTS OF EXTREME EVENTS ON HUMAN HEALTH

Estimated Deaths and Billion Dollar Losses from Extreme Events in the U.S., 2004–2013





# VECTOR-BORNE DISEASES

## Changing Distributions of Vectors and Vector-Borne Diseases

***Key Finding 1:*** Climate change is expected to alter the geographic and seasonal distributions of existing vectors and vector-borne diseases [*Likely, High Confidence*].



# VECTOR-BORNE DISEASES

## Earlier Tick Activity and Northward Range Expansion

**Key Finding 2:** Ticks capable of carrying the bacteria that cause Lyme disease and other pathogens will show earlier seasonal activity and a generally northward expansion in response to increasing temperatures associated with climate change [*Likely, High Confidence*]. Longer seasonal activity and expanding geographic range of these ticks will increase the risk of human exposure to ticks [*Likely, Medium Confidence*].



# VECTOR-BORNE DISEASES

## Changing Mosquito-Borne Disease Dynamics

**Key Finding 3:** Rising temperatures, changing precipitation patterns, and a higher frequency of some extreme weather events associated with climate change will influence the distribution, abundance, and prevalence of infection in the mosquitoes that transmit West Nile virus and other pathogens by altering habitat availability and mosquito and viral reproduction rates [*Very Likely, High Confidence*]. Alterations in the distribution, abundance, and infection rate of mosquitoes will influence human exposure to bites from infected mosquitoes, which is expected to alter risk for human disease [*Very Likely, Medium Confidence*].



# VECTOR-BORNE DISEASES

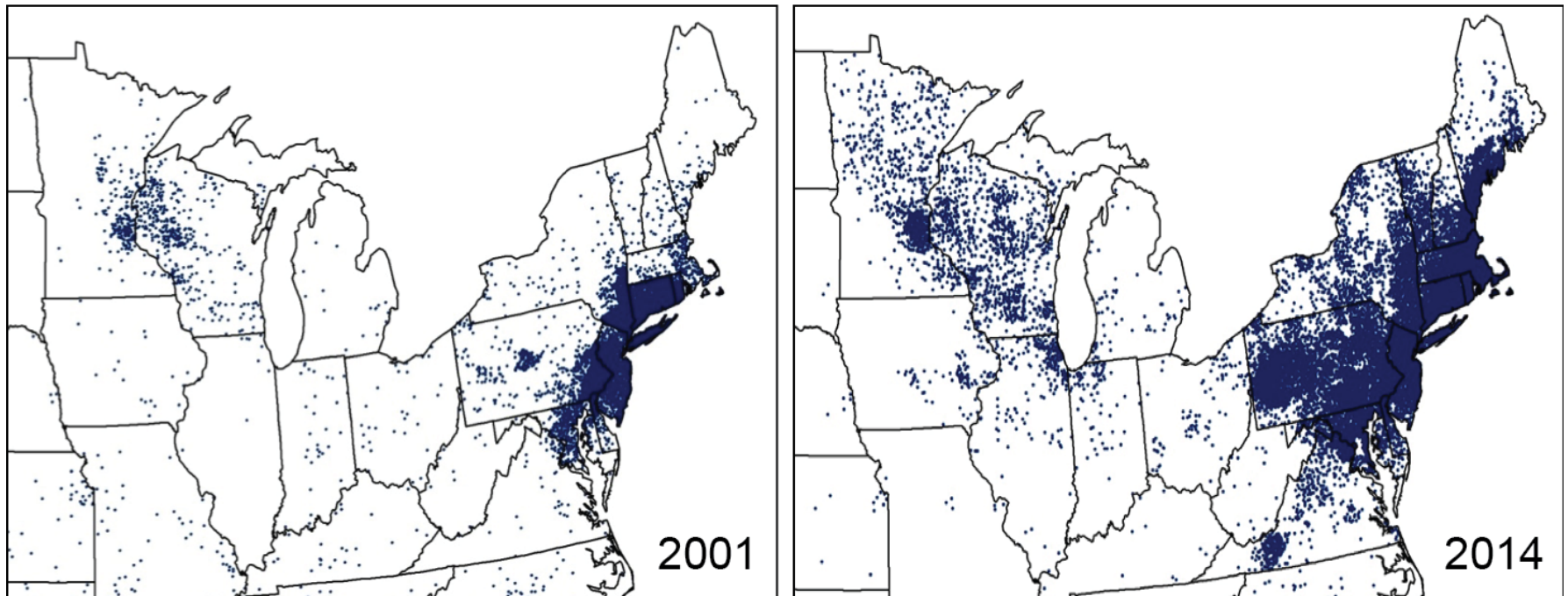
## Emergence of New Vector-Borne Pathogens

**Key Finding 4:** Vector-borne pathogens are expected to emerge or reemerge due to the interactions of climate factors with many other drivers, such as changing land-use patterns [*Likely, High Confidence*]. The impacts to human disease, however, will be limited by the adaptive capacity of human populations, such as vector control practices or personal protective measures [*Likely, High Confidence*].



# VECTOR-BORNE DISEASES

## Changes in Lyme Disease Case Report Distribution





# CLIMATE IMPACTS ON WATER-RELATED ILLNESSES

## Seasonal and Geographic Changes in Waterborne Illness Risk

**Key Finding 1:** Increases in water temperatures associated with climate change will alter the seasonal windows of growth and the geographic range of suitable habitat for freshwater toxin-producing harmful algae [*Very Likely, High Confidence*], certain naturally occurring *Vibrio* bacteria [*Very Likely, Medium Confidence*], and marine toxin-producing harmful algae [*Likely, Medium Confidence*]. These changes will increase the risk of exposure to waterborne pathogens and algal toxins that can cause a variety of illnesses [*Medium Confidence*].



# 6

## CLIMATE IMPACTS ON WATER-RELATED ILLNESSES

### Runoff from Extreme Precipitation Increases Exposure Risk

**Key Finding 2:** Runoff from more frequent and intense extreme precipitation events will increasingly compromise recreational waters, shellfish harvesting waters, and sources of drinking water through increased introduction of pathogens and prevalence of toxic algal blooms [*High Confidence*]. As a result, the risk of human exposure to agents of water-related illness will increase [*Medium Confidence*].



# 6

## CLIMATE IMPACTS ON WATER-RELATED ILLNESSES

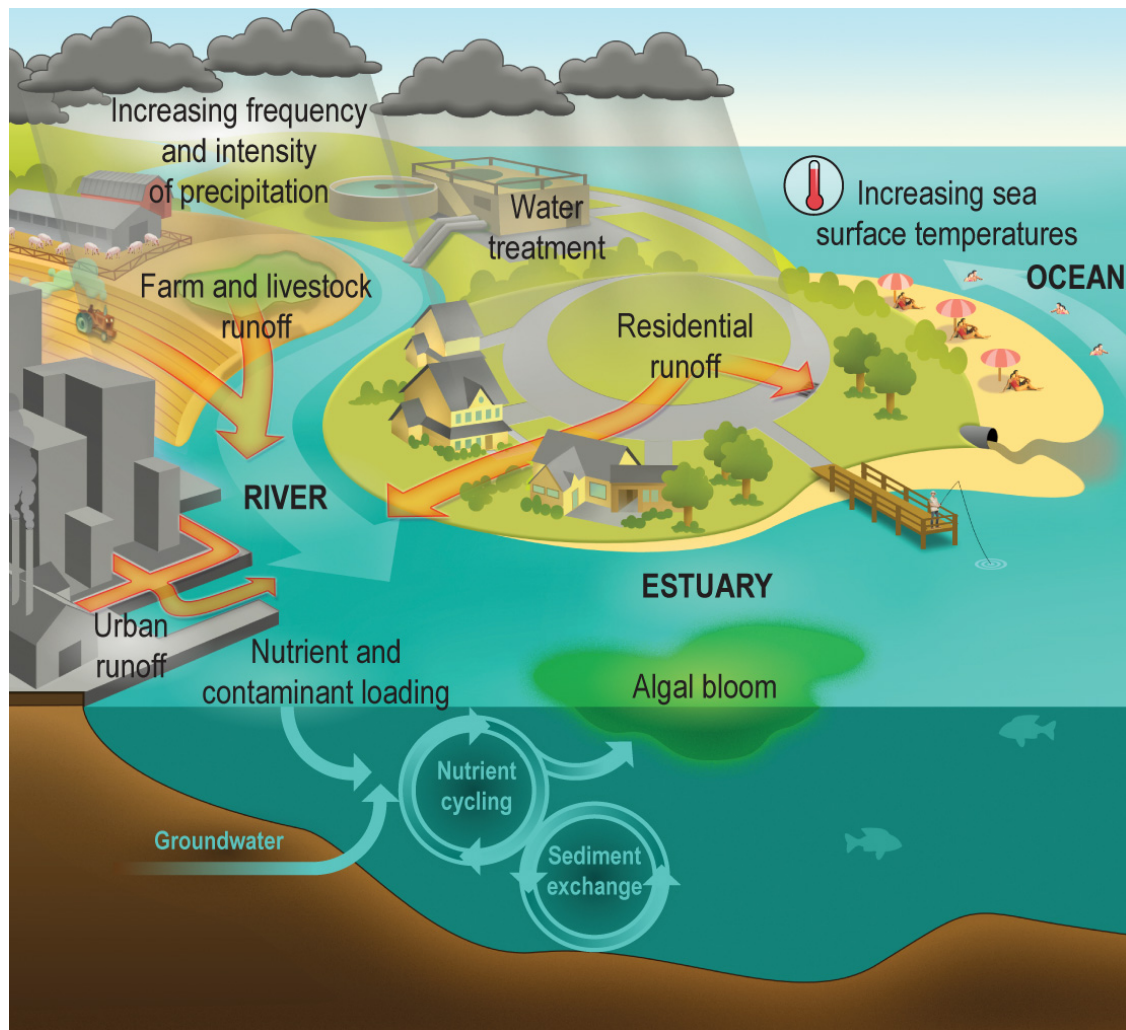
### Water Infrastructure Failure

**Key Finding 3:** Increases in some extreme weather events and storm surges will increase the risk that infrastructure for drinking water, wastewater, and stormwater will fail due to either damage or exceedance of system capacity, especially in areas with aging infrastructure [*High Confidence*]. As a result, the risk of exposure to water-related pathogens, chemicals, and algal toxins will increase in recreational and shellfish harvesting waters, and in drinking water where treatment barriers break down [*Medium Confidence*].



6

# CLIMATE IMPACTS ON WATER-RELATED ILLNESSES







# FOOD SAFETY, NUTRITION, AND DISTRIBUTION

## Increased Risk of Foodborne Illness

**Key Finding 1:** Climate change, including rising temperatures and changes in weather extremes, is expected to increase the exposure of food to certain pathogens and toxins [*Likely, High Confidence*]. This will increase the risk of negative health impacts [*Likely, Medium Confidence*], but actual incidence of foodborne illness will depend on the efficacy of practices that safeguard food in the United States [*High Confidence*].



# FOOD SAFETY, NUTRITION, AND DISTRIBUTION

## Chemical Contaminants in the Food Chain

**Key Finding 2:** Climate change will increase human exposure to chemical contaminants in food through several pathways [*Likely, Medium Confidence*]. Elevated sea surface temperatures will lead to greater accumulation of mercury in seafood [*Likely, Medium Confidence*], while increases in extreme weather events will introduce contaminants into the food chain [*Likely, Medium Confidence*]. Rising carbon dioxide concentrations and climate change will alter incidence and distribution of pests, parasites, and microbes [*Very Likely, High Confidence*], leading to increases in the use of pesticides and veterinary drugs [*Likely, Medium Confidence*].



# FOOD SAFETY, NUTRITION, AND DISTRIBUTION

## Rising Carbon Dioxide Lowers Nutritional Value of Food

***Key Finding 3:*** The nutritional value of agriculturally important food crops, such as wheat and rice, will decrease as rising levels of atmospheric carbon dioxide continue to reduce the concentrations of protein and essential minerals in most plant species *[Very Likely, High Confidence]*.



# FOOD SAFETY, NUTRITION, AND DISTRIBUTION

## Extreme Weather Limits Access to Safe Foods

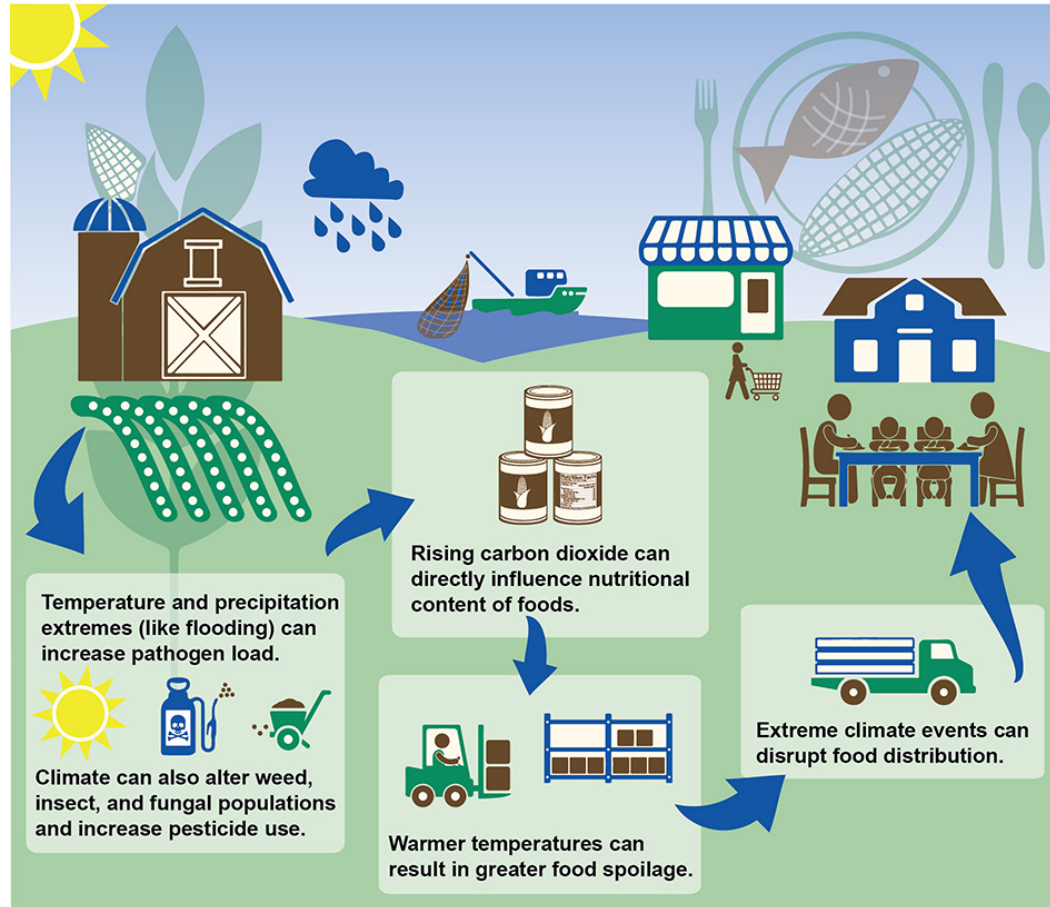
**Key Finding 4:** Increases in the frequency or intensity of some extreme weather events associated with climate change will increase disruptions of food distribution by damaging existing infrastructure or slowing food shipments [*Likely, High Confidence*]. These impediments lead to increased risk for food damage, spoilage, or contamination, which will limit availability of and access to safe and nutritious food depending on the extent of disruption and the resilience of food distribution infrastructure [*Medium Confidence*].



# 7

# FOOD SAFETY, NUTRITION, AND DISTRIBUTION

Farm to Table  
The Potential Interactions of Rising CO<sub>2</sub> and Climate Change  
on Food Safety and Nutrition





# MENTAL HEALTH AND WELL-BEING

## Exposure to Disasters Results in Mental Health Consequences

**Key Finding 1:** Many people exposed to climate-related or weather-related disasters experience stress and serious mental health consequences. Depending on the type of the disaster, these consequences include post-traumatic stress disorder (PTSD), depression, and general anxiety, which often occur at the same time *[Very High Confidence]*. The majority of affected people recover over time, although a significant proportion of exposed individuals develop chronic psychological dysfunction *[High Confidence]*.



# MENTAL HEALTH AND WELL-BEING

## Specific Groups of People Are at Higher Risk

**Key Finding 2:** Specific groups of people are at higher risk for distress and other adverse mental health consequences from exposure to climate-related or weather-related disasters. These groups include children, the elderly, women (especially pregnant and post-partum women), people with preexisting mental illness, the economically disadvantaged, the homeless, and first responders [*High Confidence*]. Communities that rely on the natural environment for sustenance and livelihood, as well as populations living in areas most susceptible to specific climate change events, are at increased risk for adverse mental health outcomes [*High Confidence*].



# MENTAL HEALTH AND WELL-BEING

## Climate Change Threats Result in Mental Health Consequences and Social Impacts

***Key Finding 3:*** Many people will experience adverse mental health outcomes and social impacts from the threat of climate change, the perceived direct experience of climate change, and changes to one's local environment [*High Confidence*]. Media and popular culture representations of climate change influence stress responses and mental health and well-being [*Medium Confidence*].





# MENTAL HEALTH AND WELL-BEING

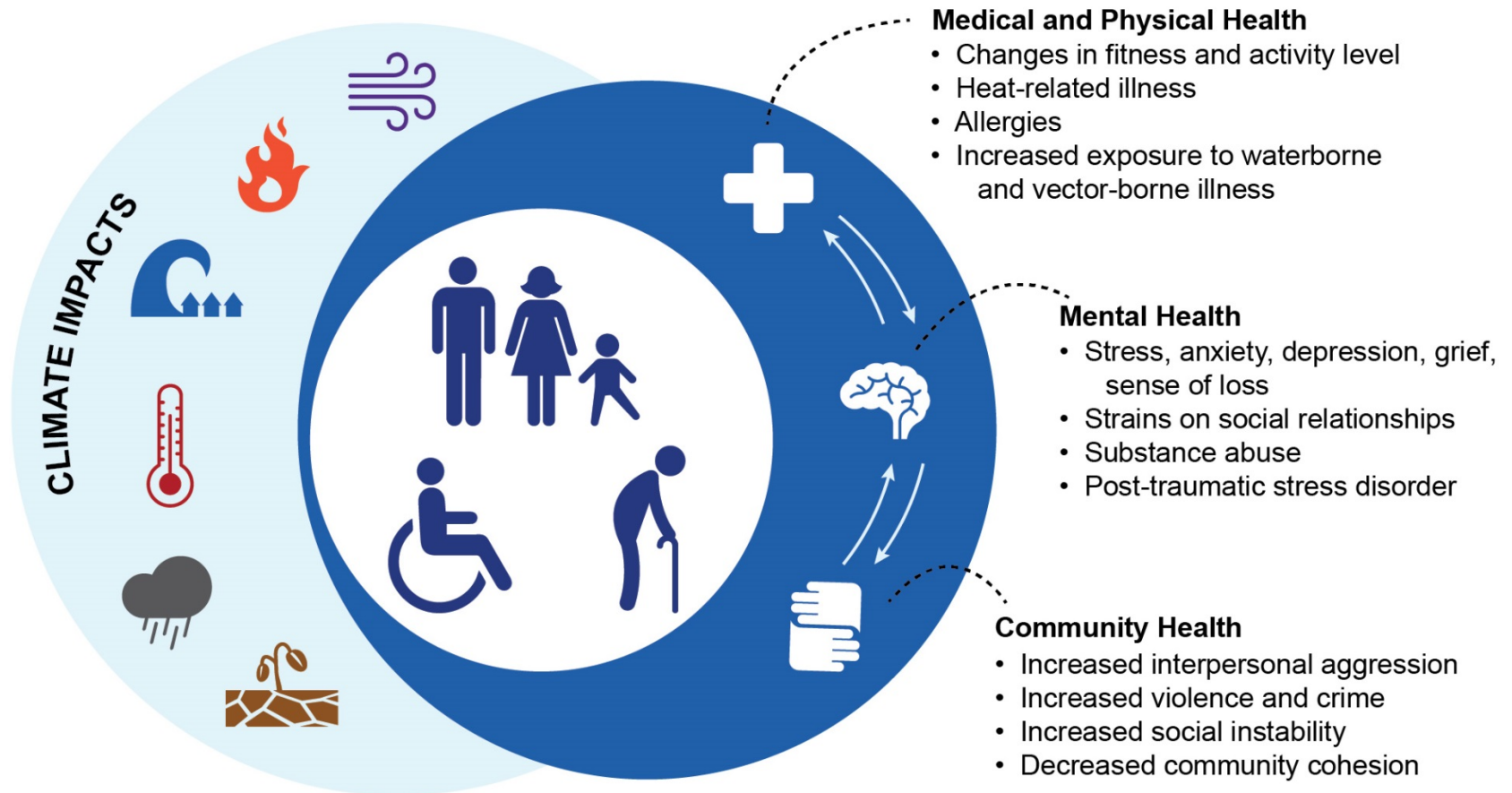
## Extreme Heat Increases Risks for People with Mental Illness

**Key Finding 4:** People with mental illness are at higher risk for poor physical and mental health due to extreme heat *[High Confidence]*. Increases in extreme heat will increase the risk of disease and death for people with mental illness, including elderly populations and those taking prescription medications that impair the body's ability to regulate temperature *[High Confidence]*.



# MENTAL HEALTH AND WELL-BEING

## Impact of Climate Change on Physical, Mental, and Community Health





# POPULATIONS OF CONCERN

## Vulnerability Varies Over Time and Is Place-Specific

**Key Finding 1:** Across the United States, people and communities differ in their exposure, their inherent sensitivity, and their adaptive capacity to respond to and cope with climate change related health threats *[Very High Confidence]*. Vulnerability to climate change varies across time and location, across communities, and among individuals within communities *[Very High Confidence]*.



# POPULATIONS OF CONCERN

## Health Impacts Vary with Age and Life Stage

**Key Finding 2:** People experience different inherent sensitivities to the impacts of climate change at different ages and life stages [*High Confidence*]. For example, the very young and the very old are particularly sensitive to climate-related health impacts.



# POPULATIONS OF CONCERN

## Social Determinants of Health Interact with Climate Factors to Affect Health Risk

***Key Finding 3:*** Climate change threatens the health of people and communities by affecting exposure, sensitivity, and adaptive capacity *[High Confidence]*. Social determinants of health, such as those related to socioeconomic factors and health disparities, may amplify, moderate, or otherwise influence climate-related health effects, particularly when these factors occur simultaneously or close in time or space *[High Confidence]*.



# POPULATIONS OF CONCERN

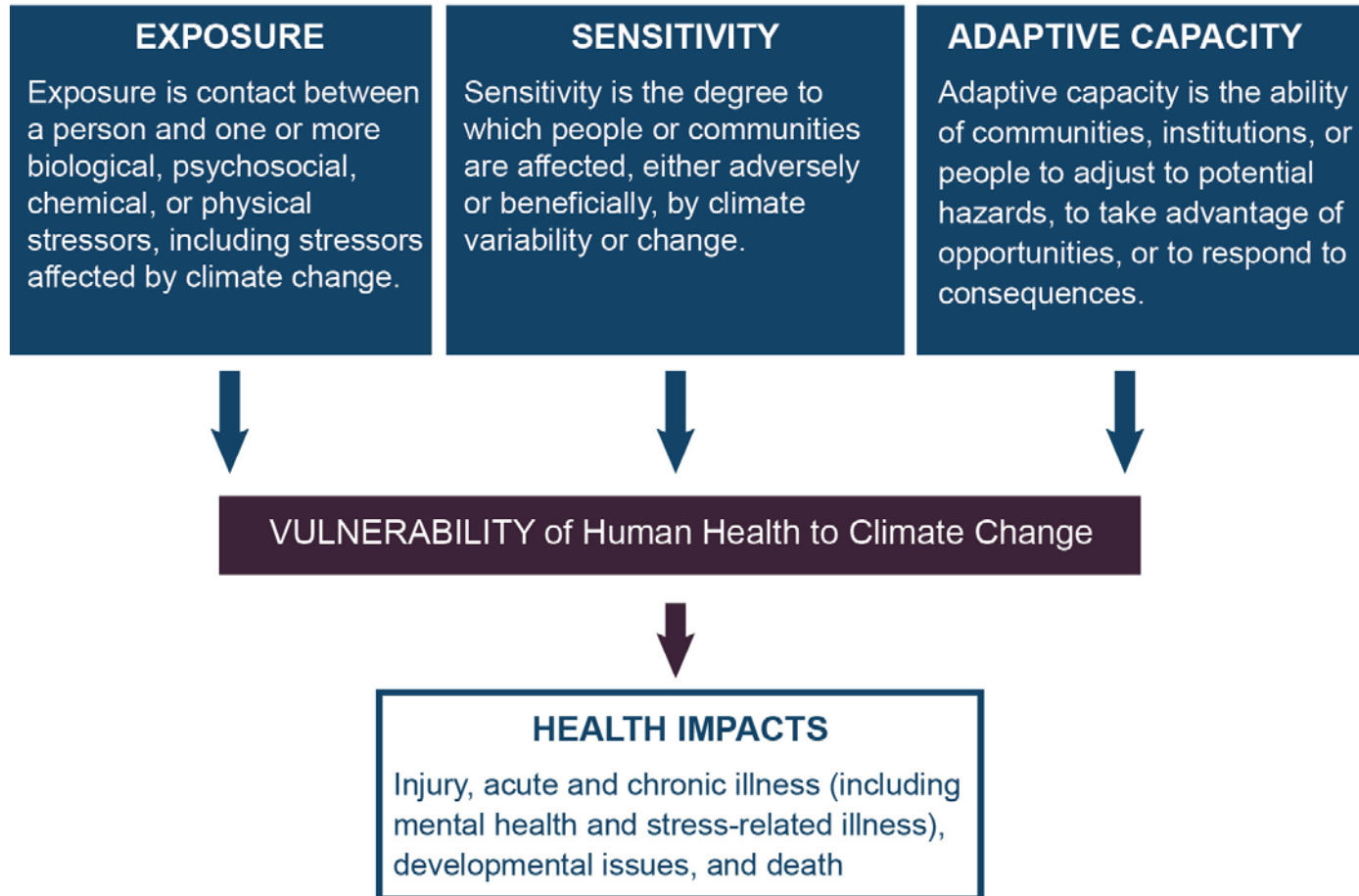
## Mapping Tools and Vulnerability Indices Identify Climate Health Risks

**Key Finding 4:** The use of geographic data and tools allows for more sophisticated mapping of risk factors and social vulnerabilities to identify and protect specific locations and groups of people *[High Confidence]*.



# POPULATIONS OF CONCERN

## Determinants of Vulnerability





# Executive Summary

**To view the full report:**

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