# CDC PUBLIC HEALTH GRAND ROUNDS

## Climate Change and Health
## From Science to Practice

**December 16, 2014**

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention

# Assessing the Impact of Climate Change on Health

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Division of Environmental Hazards and Health Effects
National Center for Environmental Health



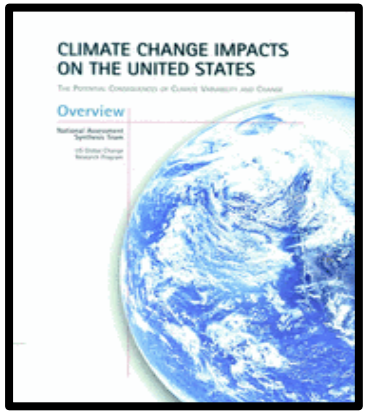
U.S. Department of Health and Human Services
Centers for Disease Control and Prevention

# Objectives

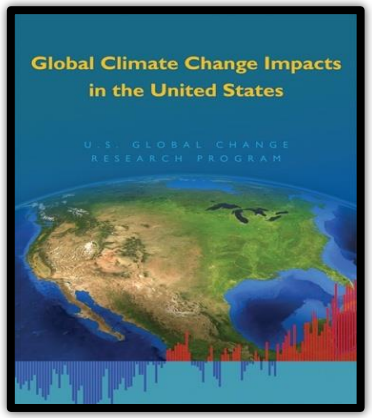
- Summarize findings from 3rd US National Climate Assessment
- Review evidence for climate change and its impact on human health
- Describe CDC and partner efforts to prepare for health effects of climate change

# What is the National Climate Assessment?

- Established through Global Research Act of 1990
- Led by White House Office of Science and Technology Policy
- Authored by experts from academia; local, state, and federal government; private and nonprofit sectors
- Published previously in 2000 and 2009




2000




2009

Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program

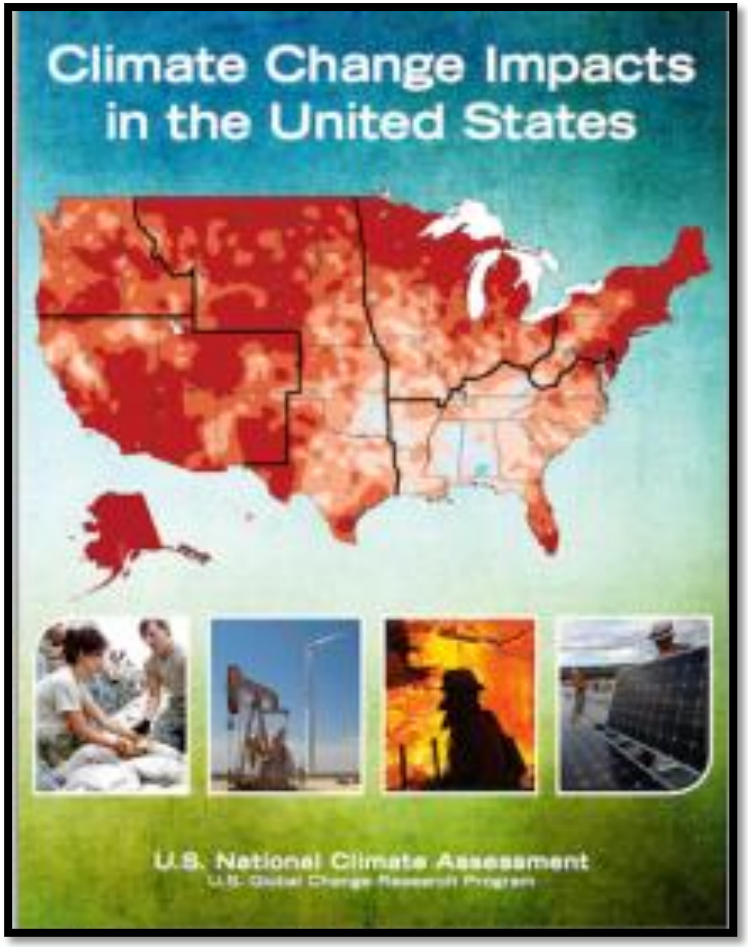
# What are the Goals of the National Climate Assessment?

- **Analyze impact of global climate change on various sectors of society, including public health**
- **Evaluate current trends in human-associated and natural climate change**
- **Project major climate trends in United States for next 25 - 100 years**

Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program

# 3rd National Climate Assessment

- **Published 2014**
- **Summarizes impacts for many sectors**
  - Public health
  - Energy
  - Water
  - Transportation
  - Agriculture
- **Represents 3-year effort**
- **Includes work of 240 authors in 30 chapters**




Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program

# 3rd National Climate Assessment Key Findings Temperature and Precipitation Impacts

## Temperature increases

- Average US temperature has increased by about 1.5°F (0.8°C) since 1895
- Temperatures are projected to rise between 2° to 11.5°F (1.1° to 6.4°C) more by 2100
- Shorter periods of frost since the 1980s

## Precipitation changes

- Heavy downpours have increased in most regions of the United States
- More precipitation as rain; less as snow
- In general, wet areas will get wetter, dry areas will get drier

Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program

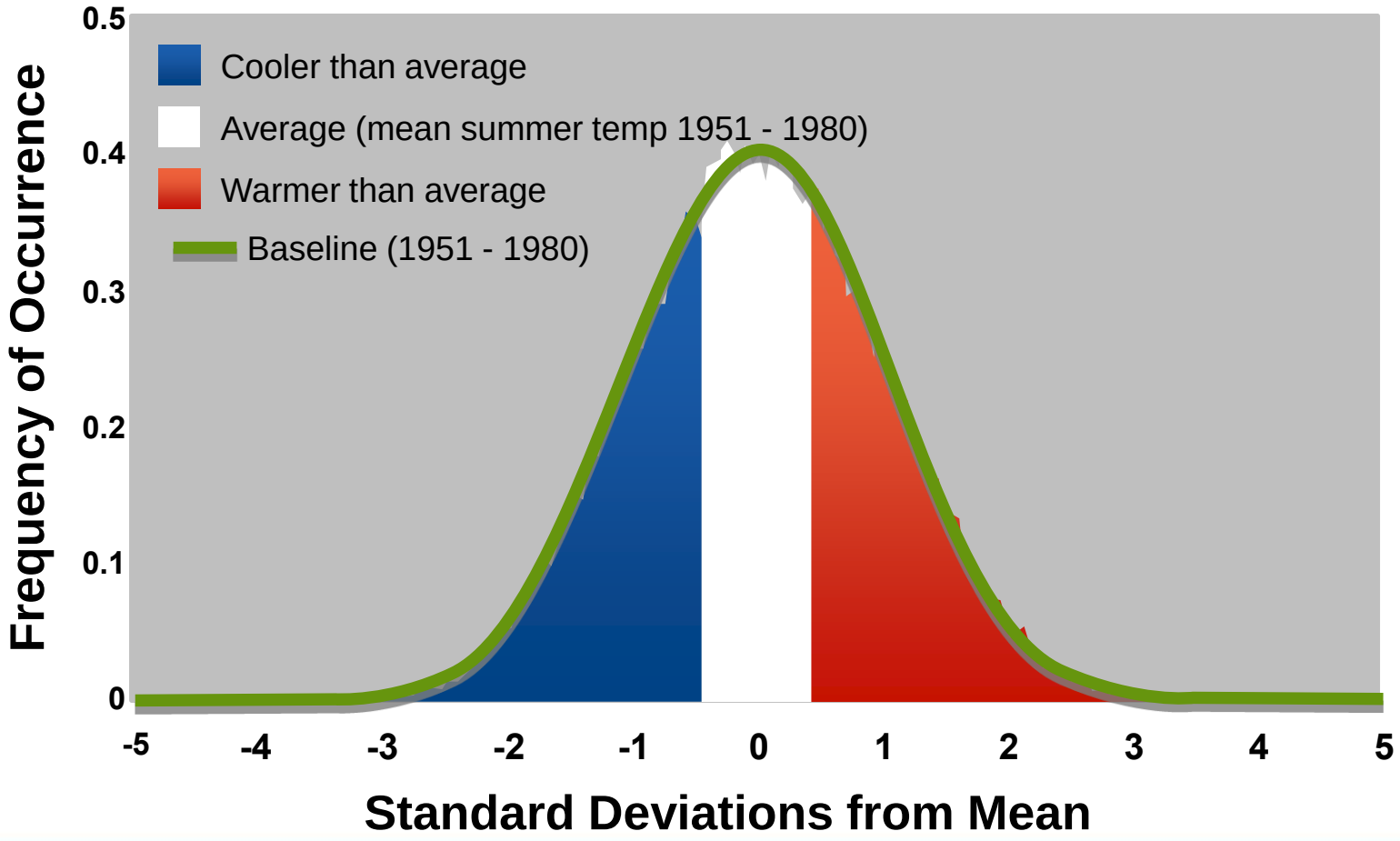
# 3rd National Climate Assessment Key Findings Extreme Weather and Ocean Impacts

- **Increases in extreme weather events**
  - Heat waves, floods, and droughts have become more frequent and intense
  - Number of Category 4 and 5 hurricanes in the North Atlantic has increased since early 1980s

- **Impacts on oceans**
  - Sea level has risen about 8 inches since 1880
  - Sea level is projected to rise another 1 to 4 feet by 2100
  - Ocean acidity has increased 26% since the start of the industrial era as a result of the ocean's carbon dioxide absorption

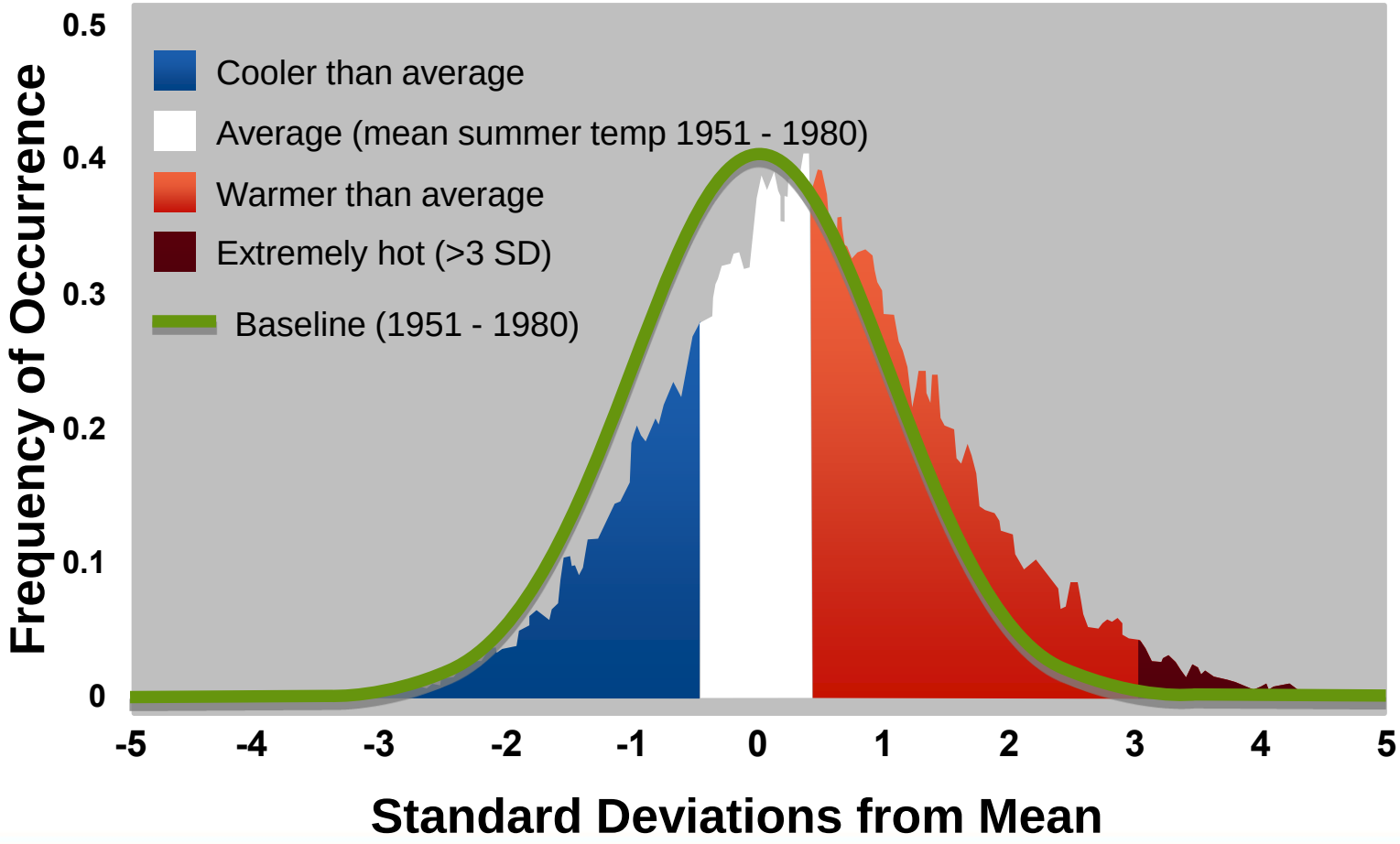
Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program

# Average Summer Temperatures 1951–1980




NASA/GISS; Hansen, et al., “Perceptions of Climate Change,” Proc. Natl. Acad. Sci. USA 10.1073, August 2012

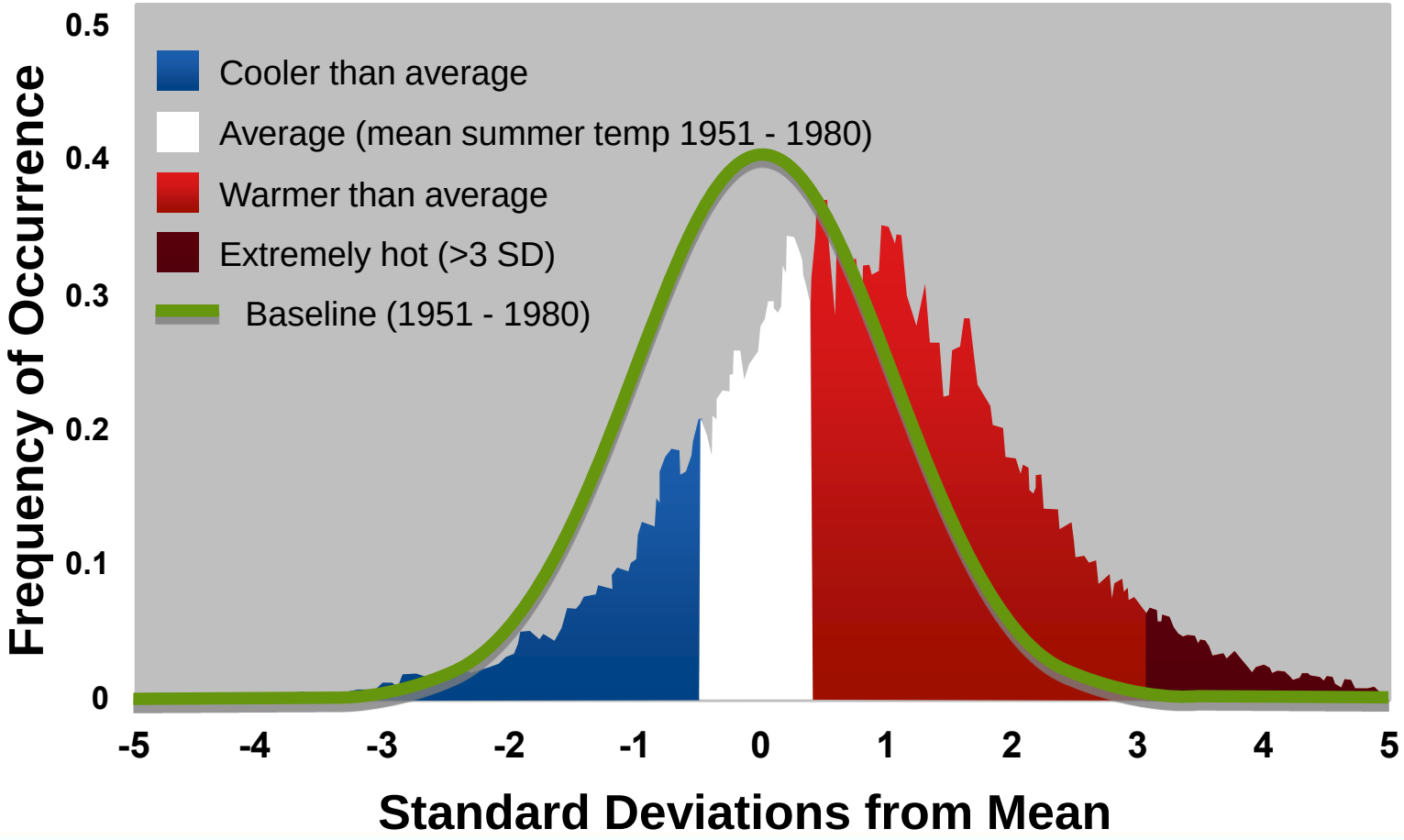
# Average Summer Temperatures 1981–1991




NASA/GISS; Hansen, et al., "Perceptions of Climate Change," Proc. Natl. Acad. Sci. USA 10.1073, August 2012

SD: standard deviation

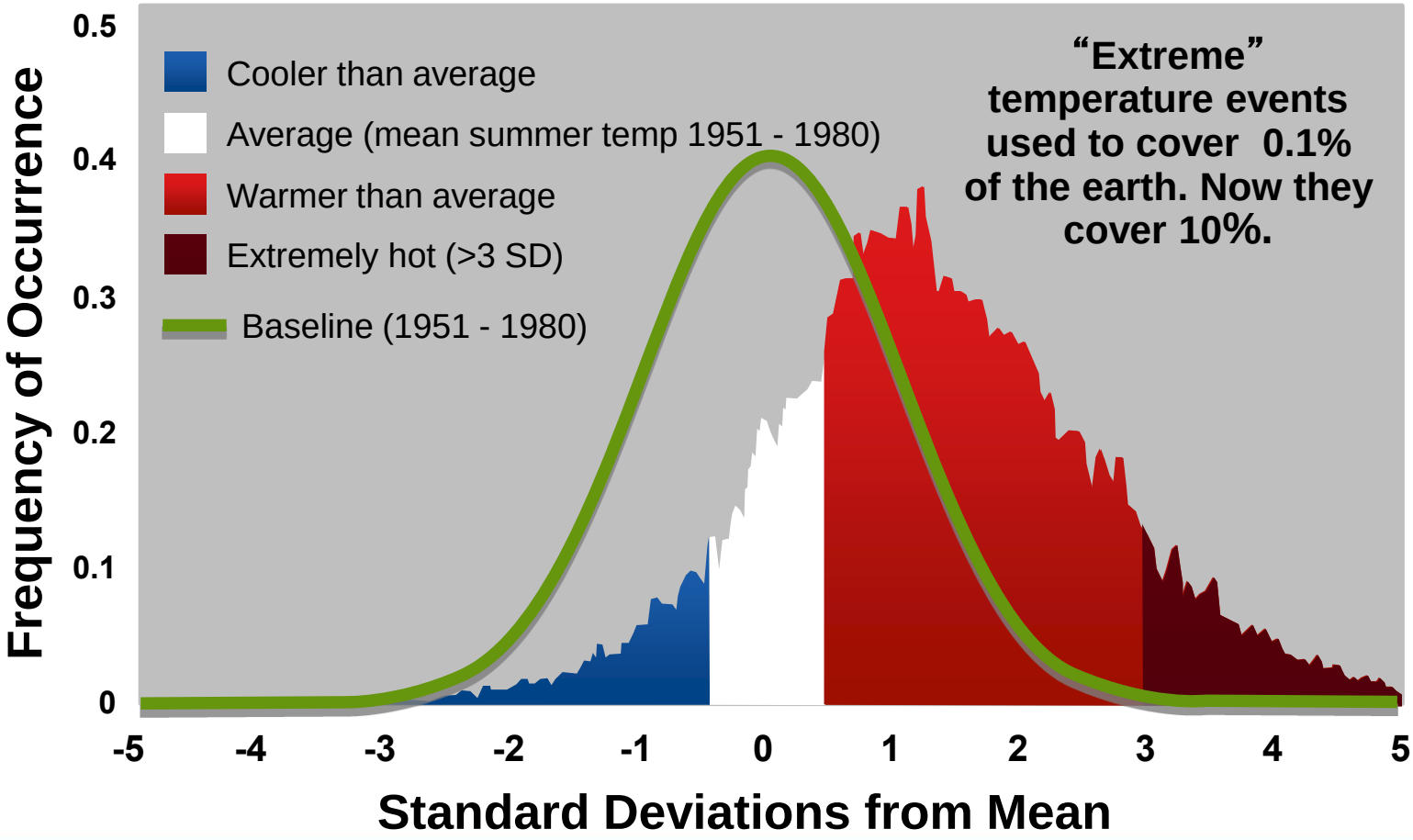
# Average Summer Temperatures 1991–2001




NASA/GISS; Hansen, et al., "Perceptions of Climate Change," Proc. Natl. Acad. Sci. USA 10.1073, August 2012

SD: standard deviation

# Average Summer Temperatures 2001–2011

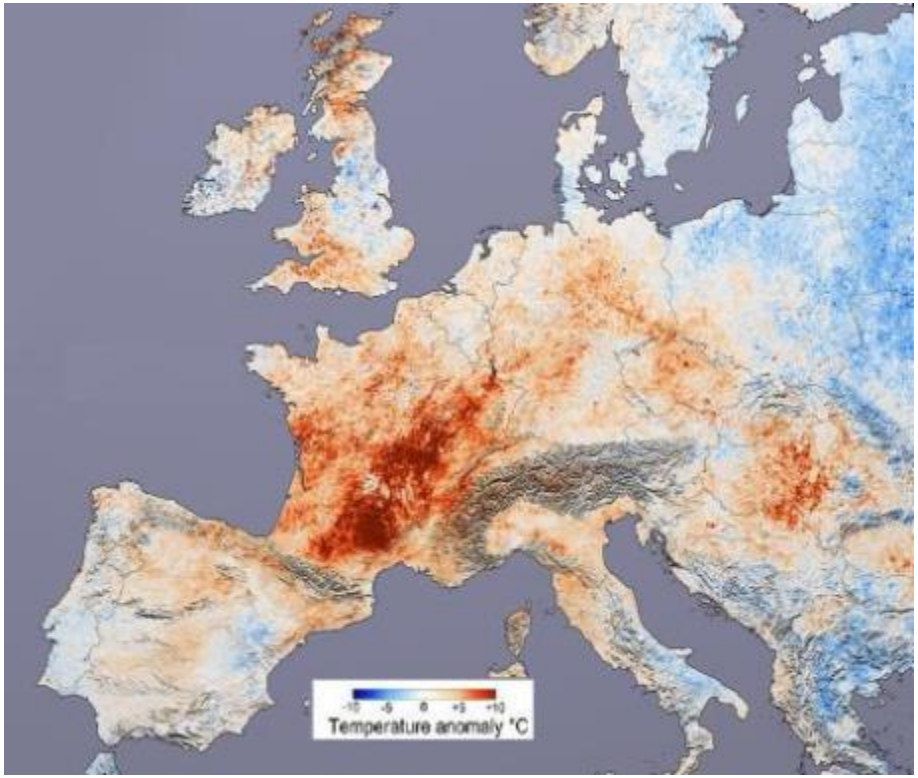



NASA/GISS; Hansen, et al., "Perceptions of Climate Change," Proc. Natl. Acad. Sci. USA 10.1073, August 2012

SD: standard deviation

# Heat Waves Are Deadly

## European Heat Wave of 2003



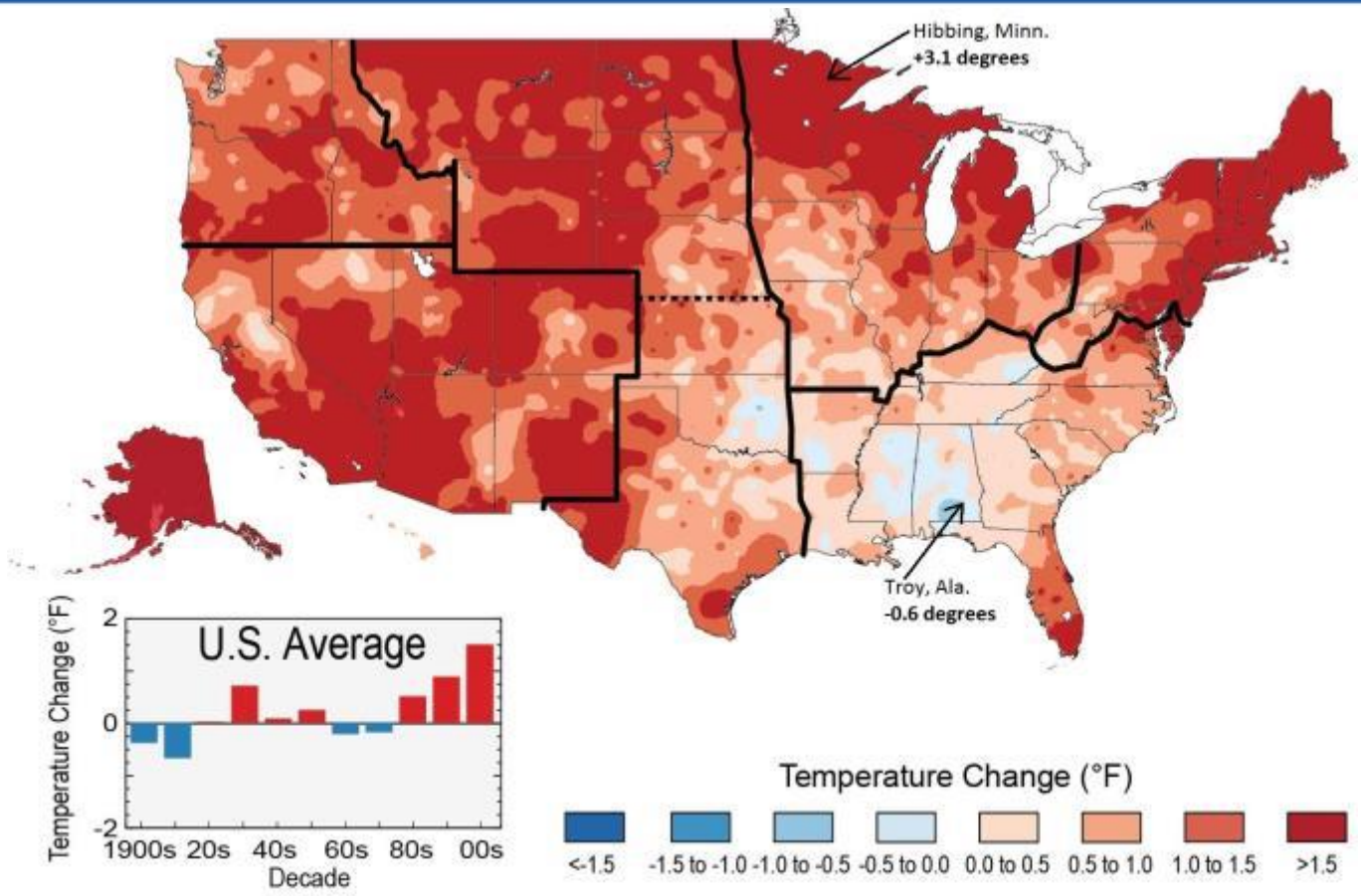

## Confirmed Mortality

| | |
|---|---|
| UK | 2,091 |
| Italy | 3,134 |
| France | 14,802 |
| Portugal | 1,854 |
| Spain | 4,151 |
| Switzerland | 975 |
| Netherlands | 1,400 - 2,200 |
| Germany | 1,410 |
| TOTAL | 29,817 - 30,617 |

**Excess (all-cause) mortality was double the confirmed mortality**

Vandentorren et al. *Am J Public Health* 2004; 94(9):1518-20.
Haines et al. *Public Health* 2006;120:585-96.
UK: United Kingdom

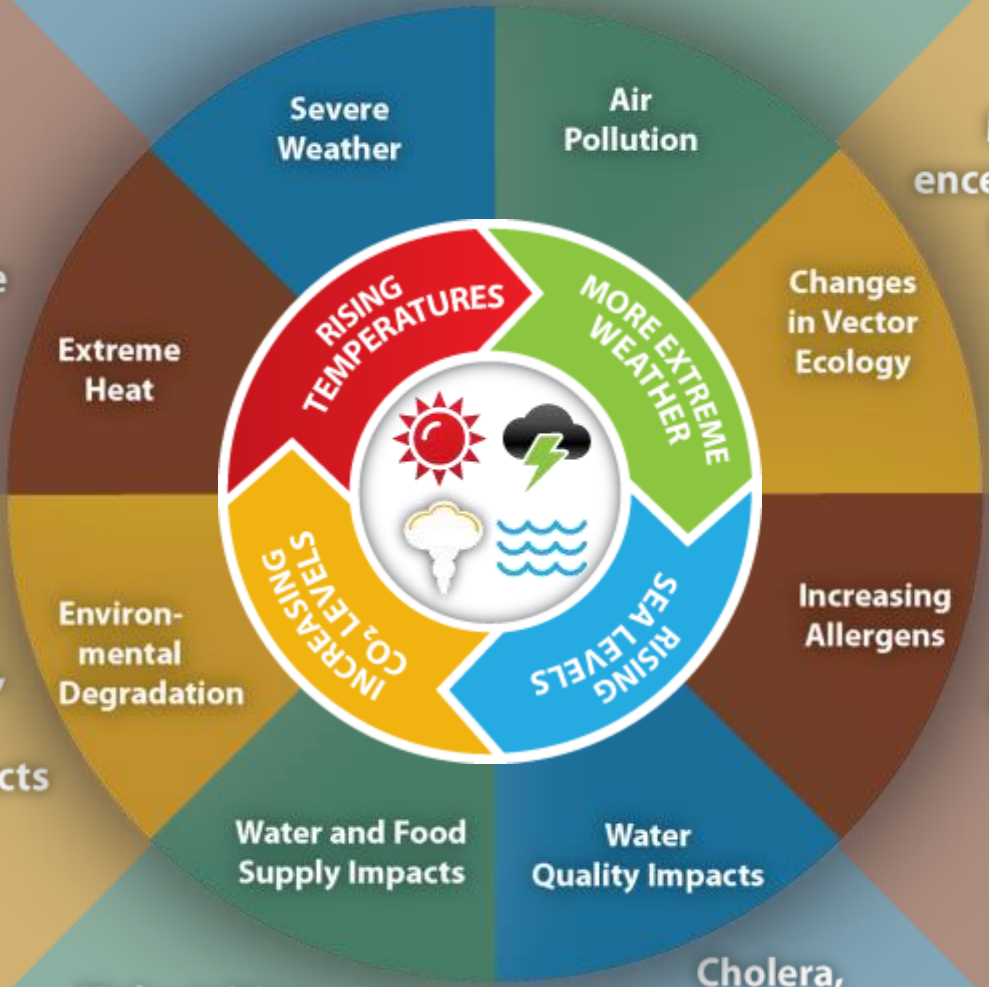
# Warming Has Varied Significantly By Region




**1991 - 2012 average temperature compared with 1901 - 1960 average**

Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program

# Impact of Climate Change on Human Health




Injuries, fatalities, mental health impacts

Asthma, cardiovascular disease

Heat-related illness and death, cardiovascular failure

Malaria, dengue, encephalitis, hantavirus, Rift Valley fever, Lyme disease, chikungunya, West Nile virus

Forced migration, civil conflict, mental health impacts

Respiratory allergies, asthma

Malnutrition, diarrheal disease

Cholera, cryptosporidiosis, campylobacter, leptospirosis, harmful algal blooms

# Climate Change Effects on Health: A Multifaceted Problem

**Kim Knowlton, DrPH**

*Assistant Clinical Professor*, Environmental Health Sciences
Columbia University Mailman School of Public Health
*Senior Scientist* and *Co-Deputy Director,* Science Center
Natural Resources Defense Council

Columbia Climate & Health Program at the Mailman School of Public Health

NRDC

CDC

U.S. Department of Health and Human Services
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# Effect of Climate Change on Health

**In a 2014 National Medical Association survey, 61% of physicians reported their patients' health has been affected by climate change**

FEMA/Andrea Booher (post-Sandy); Frans Lanning/Corbis (wildfire)
National Medical Association and George Mason University
Center for Climate Change Communication, June 25, 2014

# Key Message 1: Wide-ranging Health Impacts

- **Climate change threatens human health and well-being in many ways, including**
  - Impacts from increased extreme weather events, wildfire, and decreased air quality
  - Threats to mental health
  - Illnesses transmitted by food, water, and disease carriers such as mosquitoes and ticks

- **Some of these health impacts are already happening in the United States**

USGCRP, 3rd National Climate Assessment, Downloads and Materials, available at: www.globalchange.gov/nca3-downloads-materials

# Rising Temperatures Projected to Worsen Asthma by the 2020s

## Estimated Increase in Ozone-related Emergency Room Visits for Children in 14 New York Counties

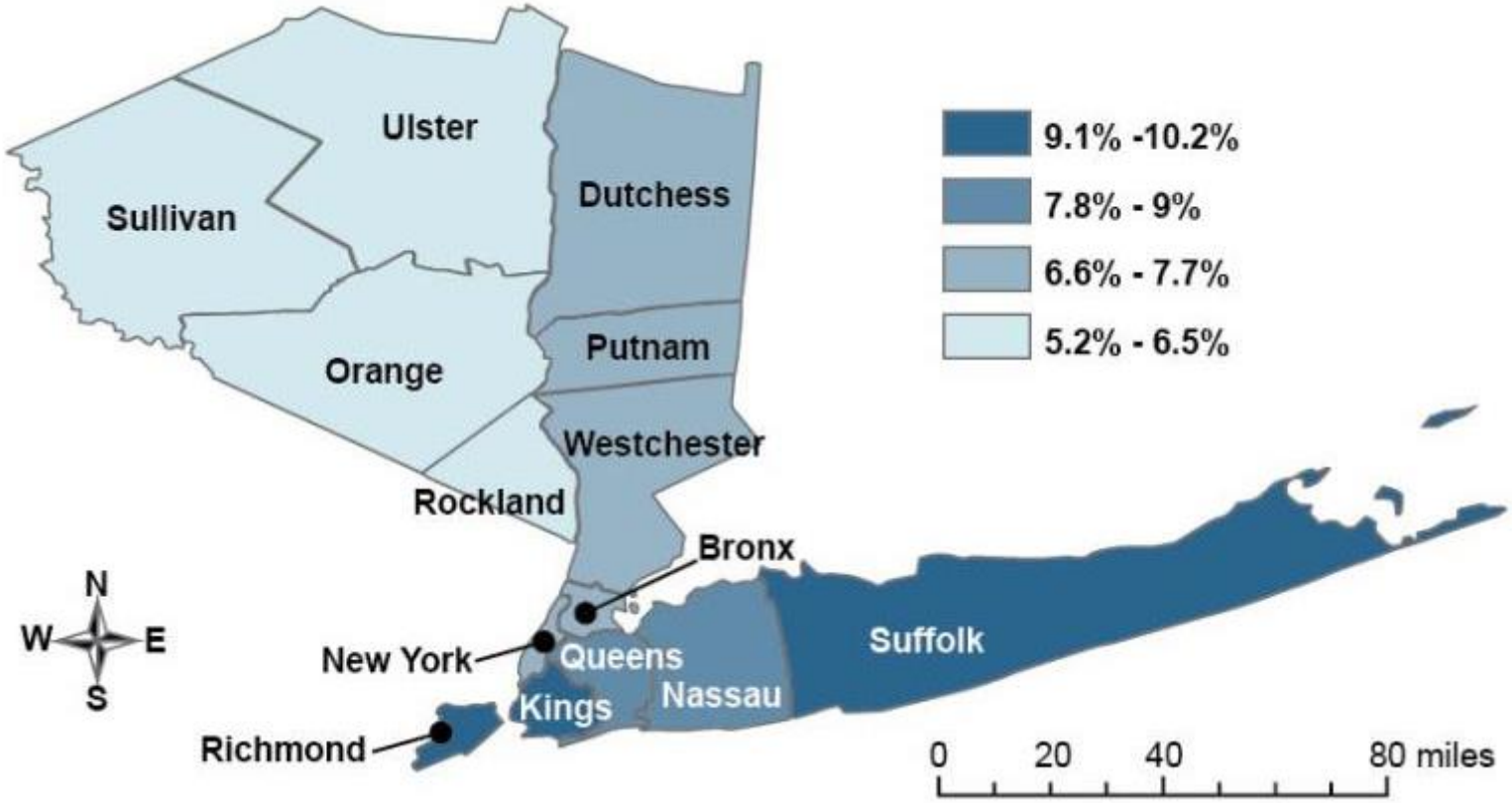



Figure 9.1, Health chapter, NCA3 [from Sheffield et al. 2011);
USGCRP, 3rd National Climate Assessment, Downloads and Materials, available at: www.globalchange.gov/nca3-downloads-materials

# Health Effects of Climate Change: Longer Ragweed Pollen Seasons, 1995-2011

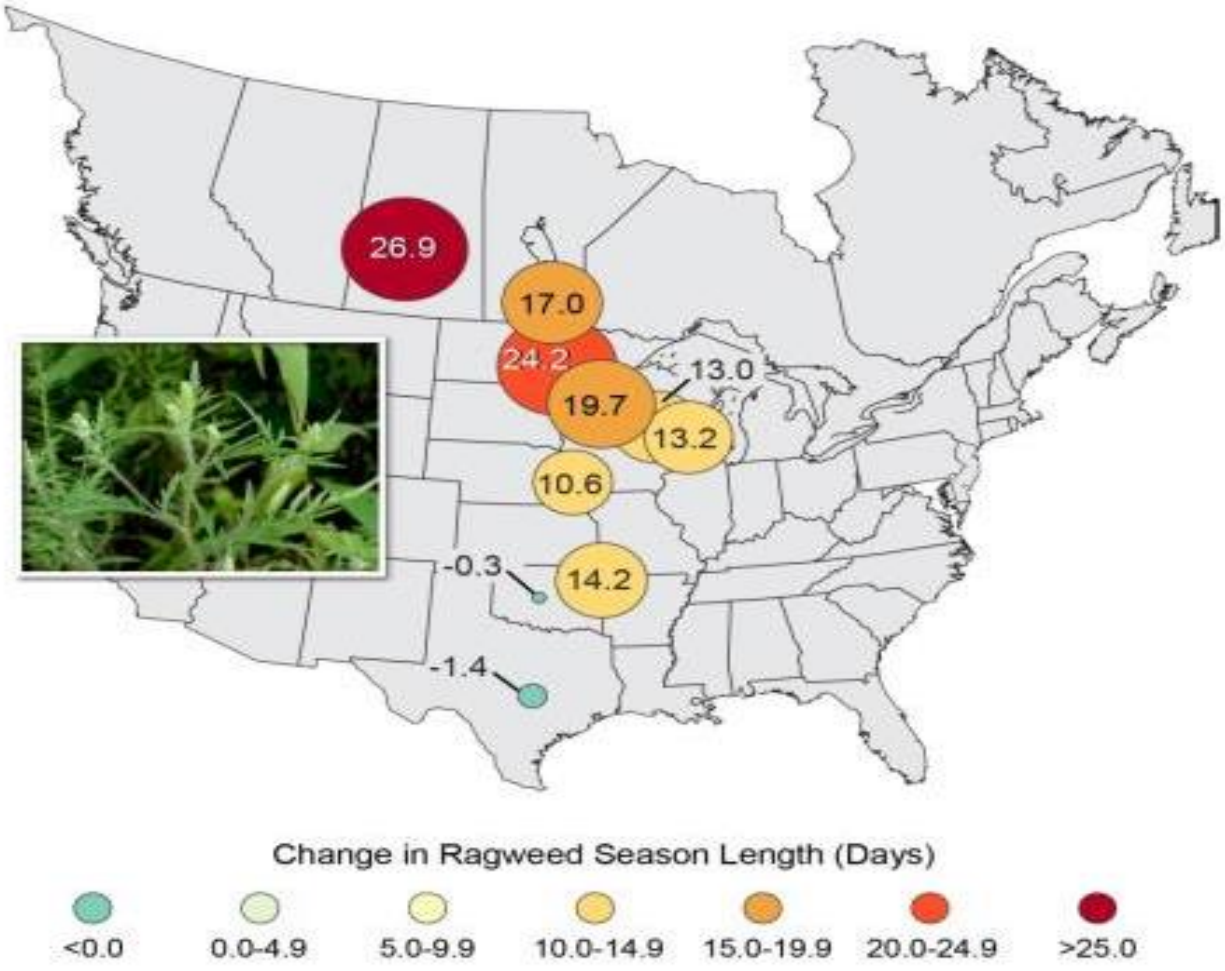



Figure 9.2, Health chapter, NCA3 (from Ziska et al. 2011)
Photo: Lew Ziska

# Wildfire Smoke Increases Airborne Fine Particle Concentrations

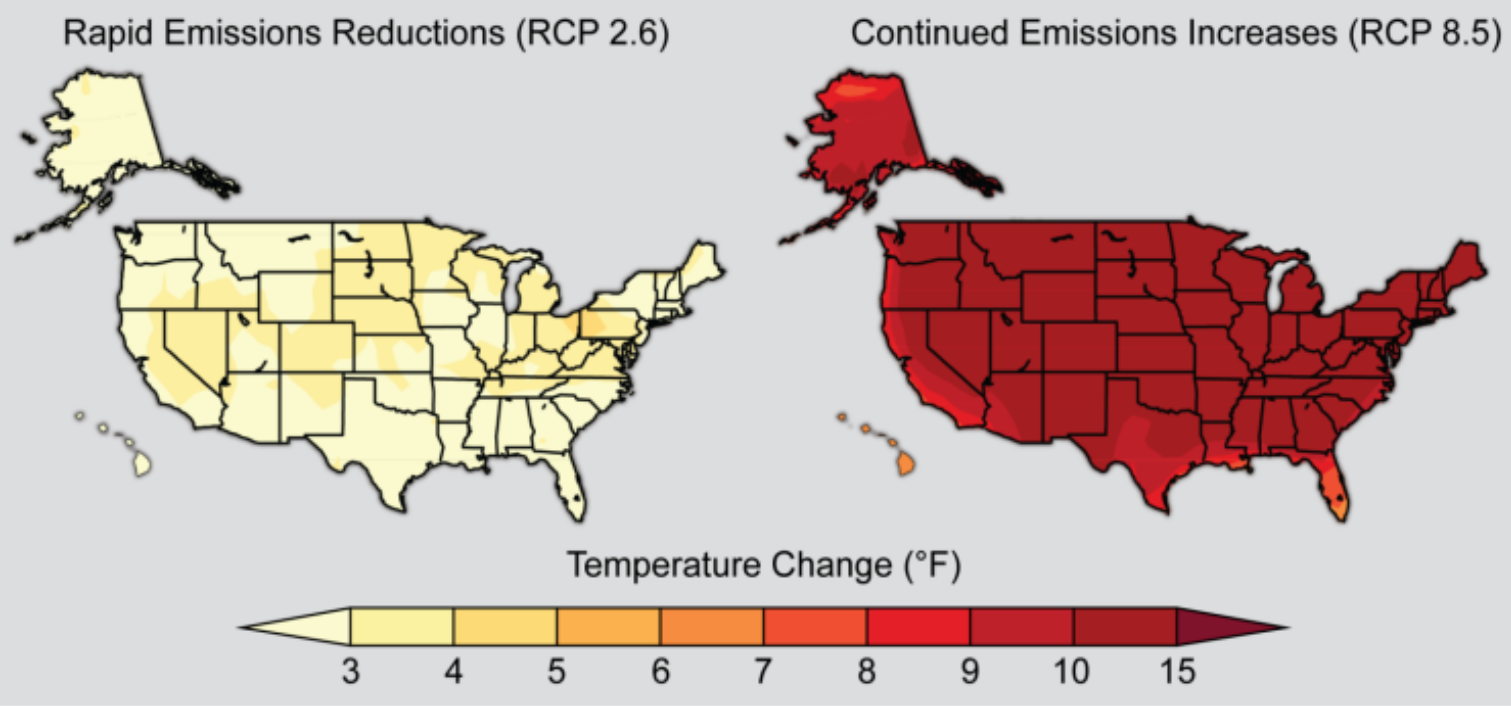
**Wildfires in Quebec, 2002**

Total deaths from effects of landscape fire smoke
~ 260,000-600,000 persons annually, worldwide

**Increased harmful fine particle levels in Baltimore**

Figure 9.3, NCA3 Health chapter [Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on the Terra satellite, Land Rapid Response Team, NASA/GSFC. From Sapkota et al. 2002 and Kinney 2008

# By 2090, the Hottest Days Will Get Even Hotter




**Heat waves can result in increased hospitalizations and deaths**

**(e.g., Chicago, 1995)**

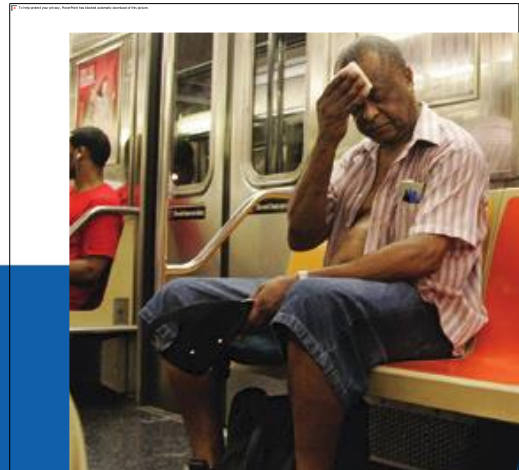
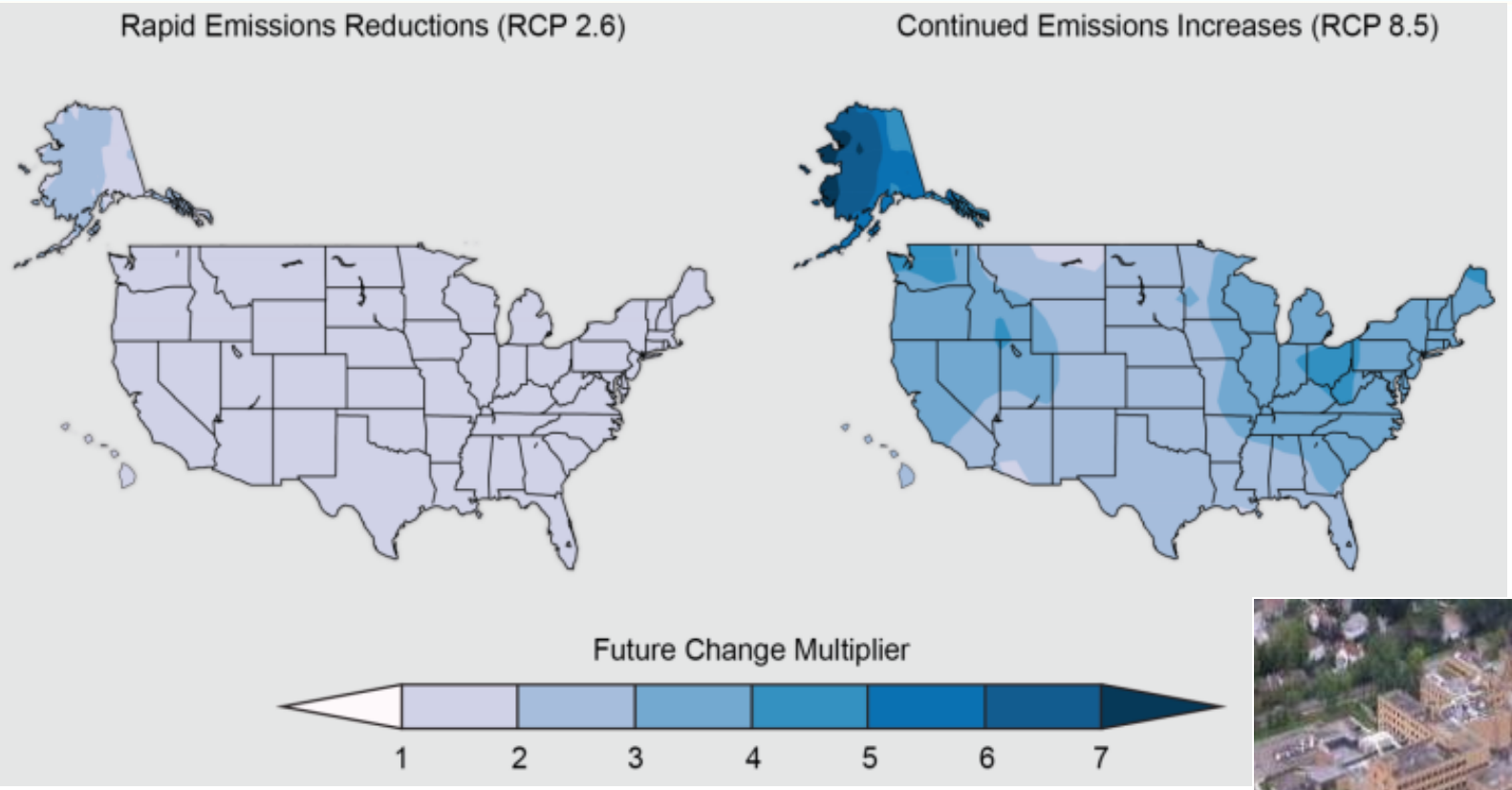


Figure 9.4, Health chapter NCA3; NOAA NCDC / CICS-NC
RCP: Representative Concentration Pathways

# Increases in Heavy Precipitation Events and Flooding by 2090



Flooding of Lourdes Hospital, Binghamton NY, 2006

Figure 9.6, Health chapter NCA3; NOAA NCDC/CICS-NC
Photo: Floodbreak
RCP: Representative Concentration Pathways

# Heavy Downpours Increase Exposure to Waterborne Diseases

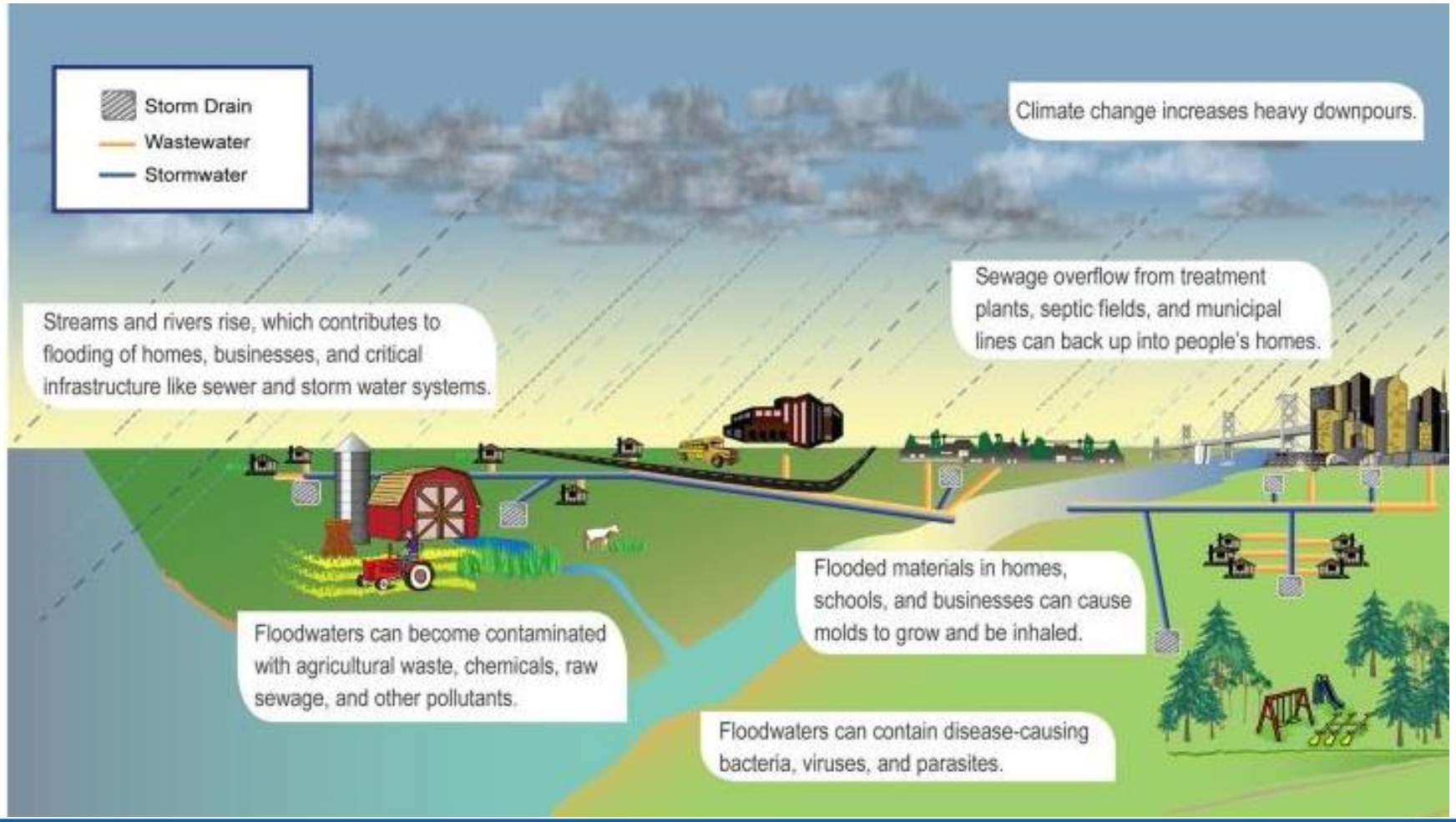



Figure 9.7, Health chapter NCA3; NOAA NCDC/CICS-NC

# Increase in Harmful Algal Blooms: Effects on Drinking Water Safety

**Harmful bloom of algae, Lake Erie, 2011**

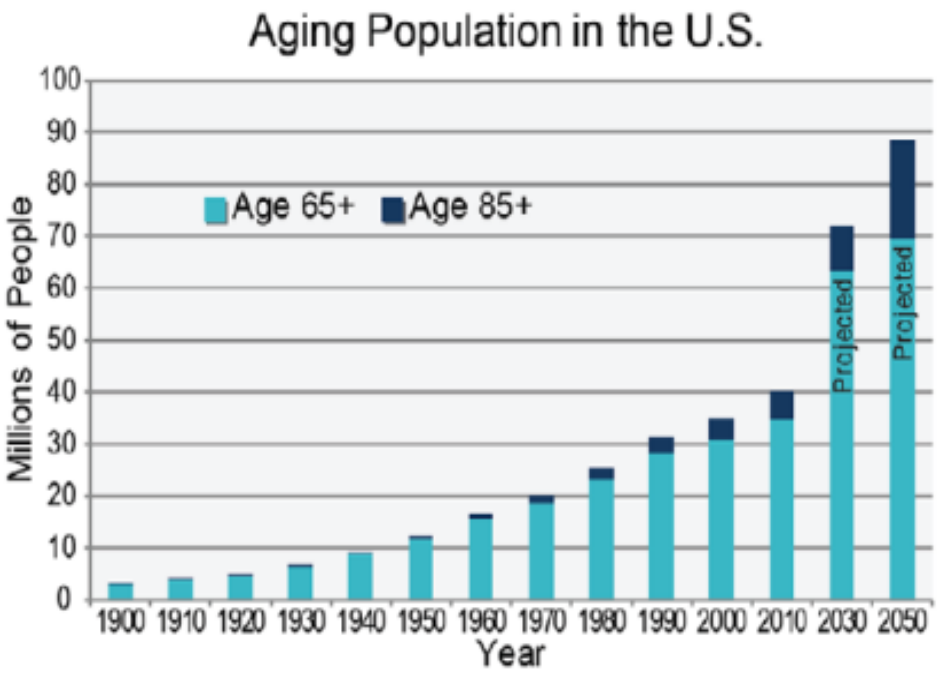
Figure 9.8, NCA3 Health chapter
Figure source: NASA Earth Observatory
Photo: AP/Haraz N. Ghanbari

# Key Message 2: Most Vulnerable at Most Risk

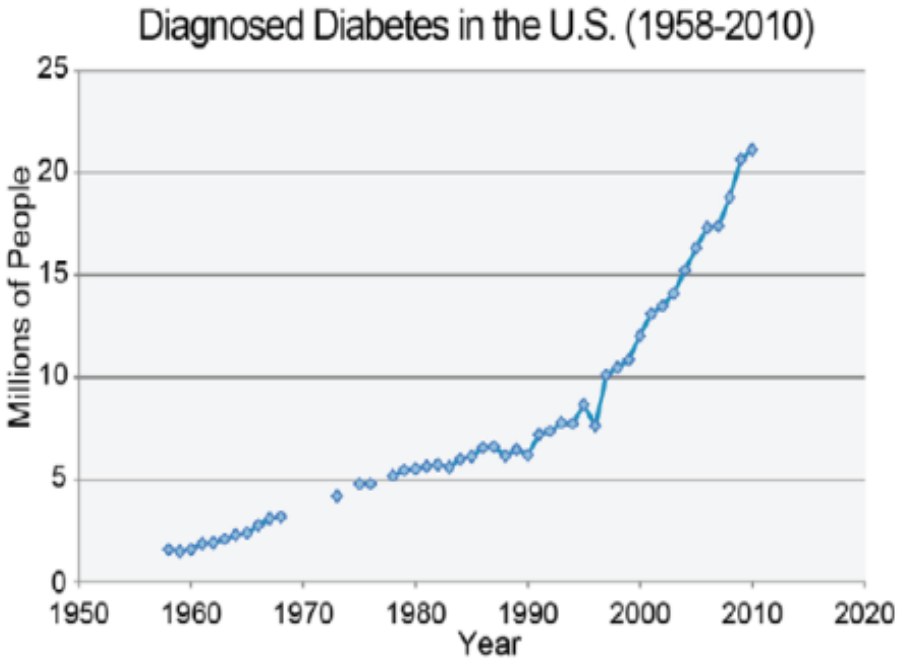
- **Absent other changes, climate change will amplify existing health threats the nation faces**
- **Certain people and communities are especially vulnerable:**
  - **People**
    - **Under age 5**
    - **Age 65 and older**
    - **With chronic health conditions**
  - **Places**
    - **River and coastal floodplains**
    - **Urban "heat island" areas**

USGCRP, 3rd National Climate Assessment: www.globalchange.gov/nca3-downloads-materials.
Hospital photo Tipz4yo.

# Elements of Population Vulnerability to Climate Change




**The proportion of Americans age 65 or older is growing at the fastest rate in a century. Older adults are more vulnerable to extreme heat, air pollution, and infectious illnesses**




**The number of Americans diagnosed with diabetes has grown sharply over 50 years. Those with diabetes are more vulnerable to heat-related illnesses**

Figure 9.9, Health chapter NCA3
US Census Bureau, 2010 summary file (left); CDC Diabetes Data and Trends 2013 (right)

# Key Message 3: Prevention Provides Protection

- **Public health actions can do much to protect people from some of the impacts of climate change**
  - Especially preparedness and prevention
- **Early action provides the largest health benefits**
- **As threats increase, our ability to adapt to future changes may be limited**

USGCRP, 3rd National Climate Assessment, Downloads and Materials, available at: www.globalchange.gov/nca3-downloads-materials

# Diaspora after Natural Disaster: Population Displacement Following Hurricane Katrina

**Hurricane Katrina displaced more than 800,000 Louisiana residents, with evacuees found in every US state**

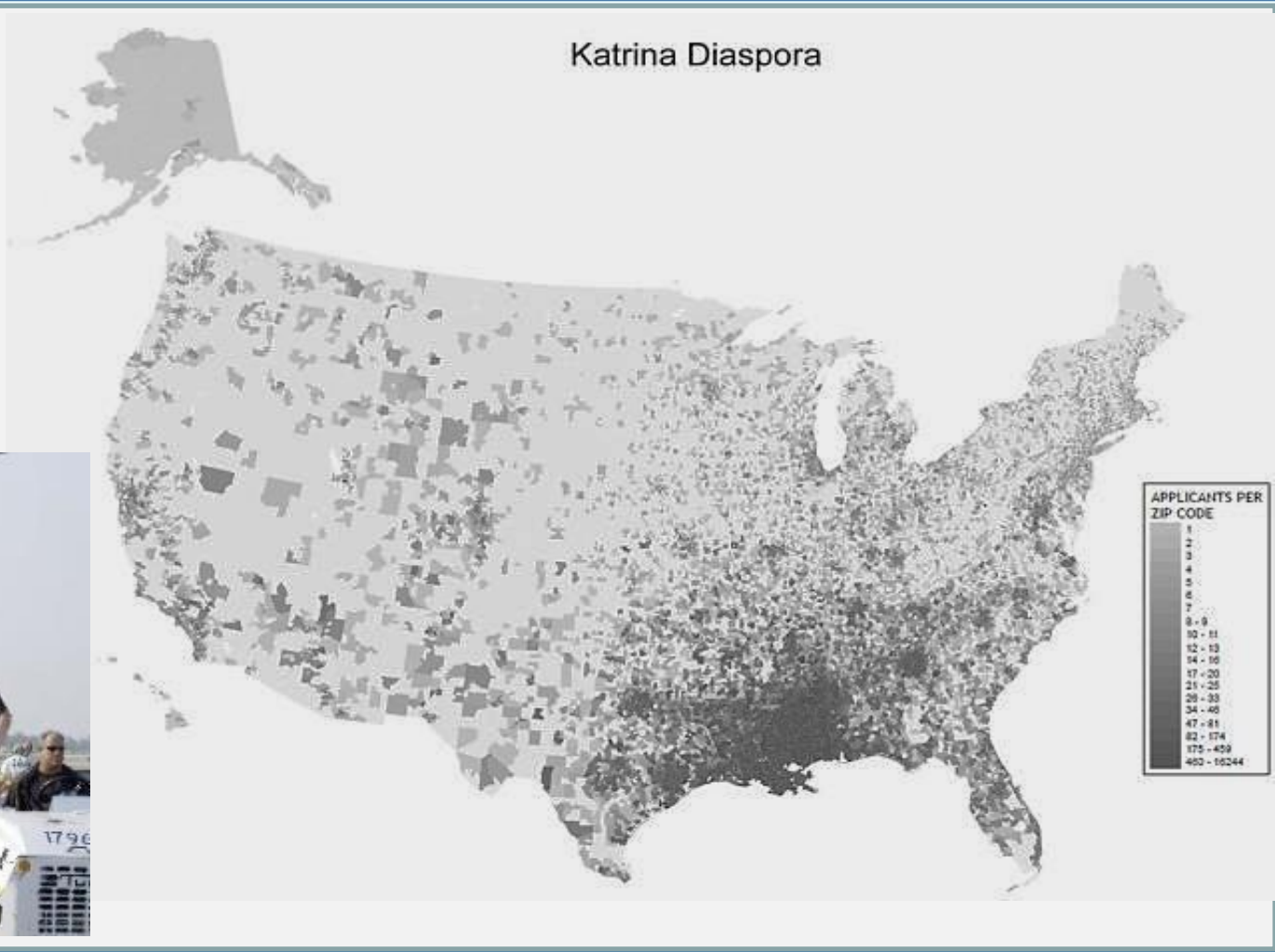



Figure 9.10, Health chapter NCA3
Figure source: Kent 2006
Photo: Michael Rieger/FEMA

# Key Message 4: Responses Have Multiple Benefits

- **Responding to climate change provides opportunities to improve human health and well-being across many sectors, including energy, agriculture, and transportation**

- **Many of these response strategies offer a variety of benefits, protecting people while combating climate change and providing other societal benefits**

USGCRP, 3rd National Climate Assessment, Downloads and Materials, available at: www.globalchange.gov/nca3-downloads-materials

# Climate Change Preparedness Benefits Health Today and Tomorrow

**Reducing fossil fuel use means:**

***Substantial immediate health benefits***

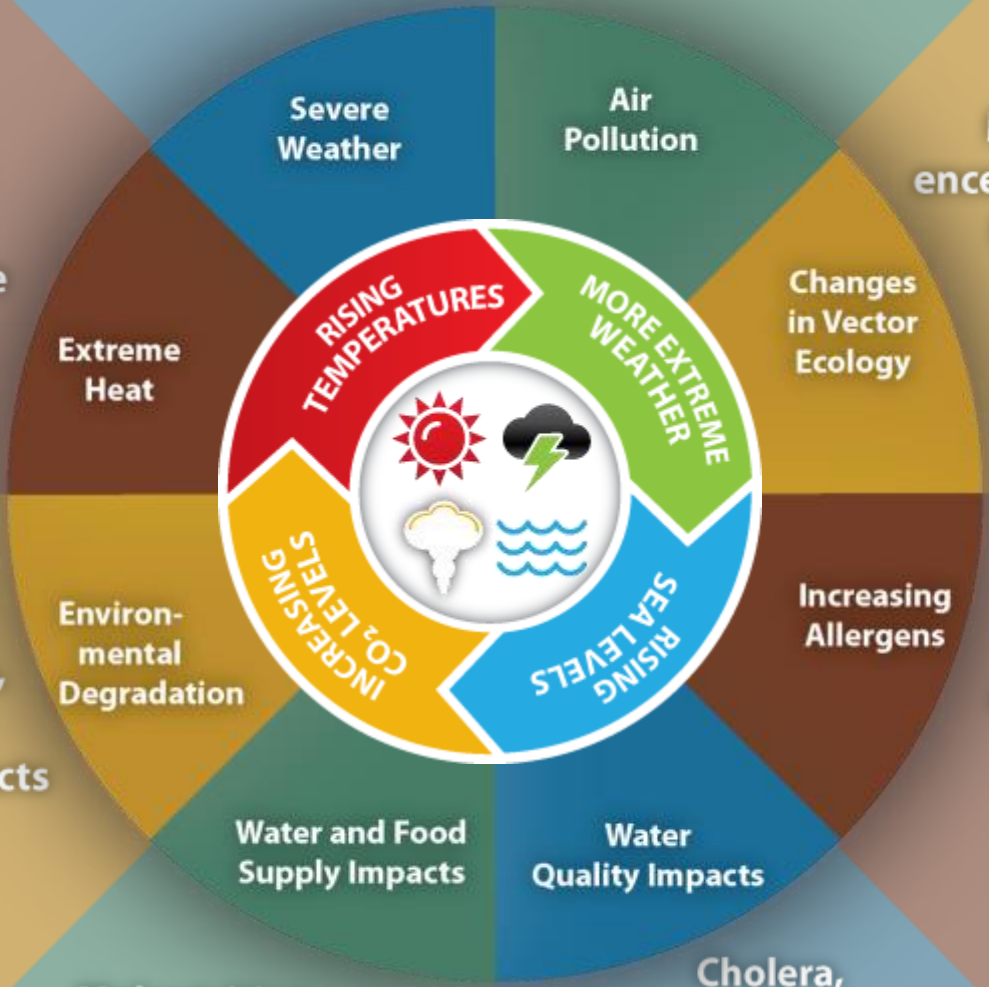
- In 11 upper Midwest cities, replacing 50% of short car trips with bicycling and the other 50% with public transit or walking avoids 1,300 deaths and $8 billion in health costs annually
- More healthy outdoor exercise improves fitness and health

***Longer-term climate-health benefits***

- Include reduced risks of waterborne illnesses and beach closures in the Great Lakes
- Otherwise, projected to increase

From Grabow et al. (2012); Patz et al. (2008)
Human Health chapter (ch.9, pp. 232 and 226), NCA3

# Impact of Climate Change on Human Health

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Malnutrition, diarrheal disease

Cholera, cryptosporidiosis, campylobacter, leptospirosis, harmful algal blooms

# Third National Climate Assessment

## Climate Change Impacts in the United States

http://nca2014.globalchange.gov

**#NCA2014**

**facebook.com/usgcrp**

**@usgcrp**

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GlobalChange.gov
U.S. Global Change Research Program

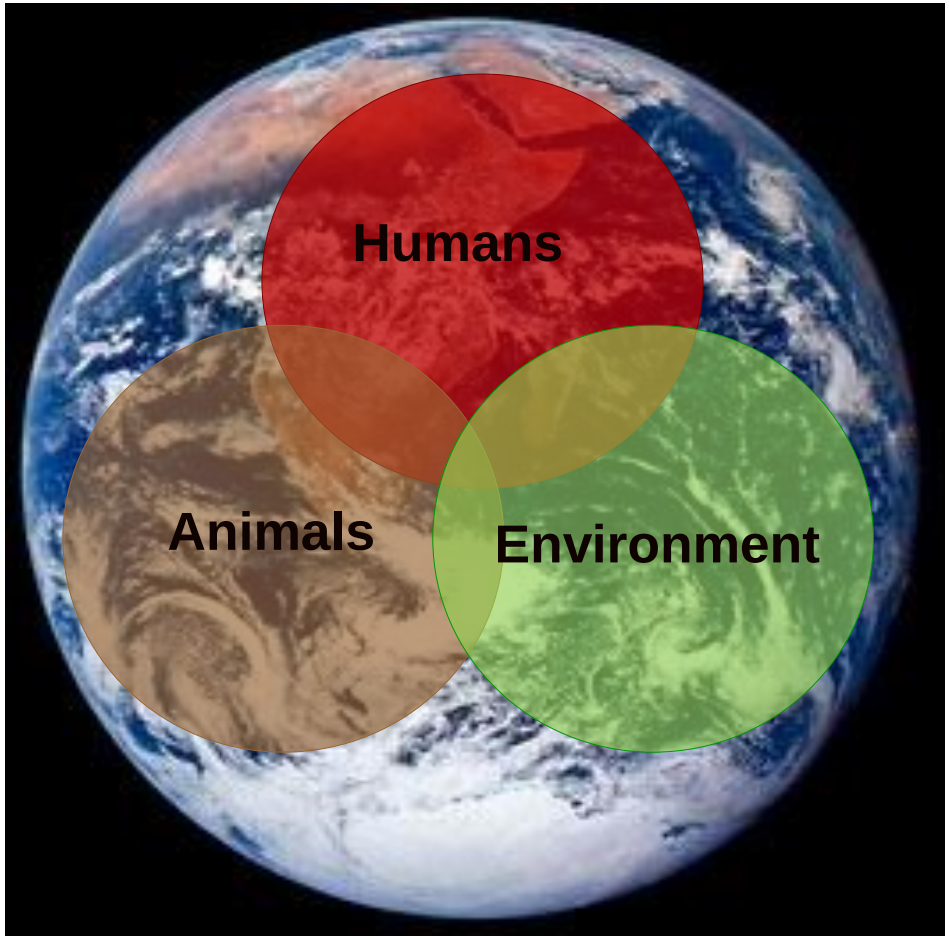
# How Climate Influences the Infectious Disease Landscape

**C. Ben Beard, MS, PhD**
*Associate Director for Climate Change*
*Chief,* Bacterial Diseases Branch
Division of Vector-Borne Diseases
National Center for Emerging and Zoonotic Infectious Diseases



U.S. Department of Health and Human Services
Centers for Disease Control and Prevention

# Emerging Diseases Seen Through a "One Health" Lens




**One Health:**
**the collaborative effort of multiple disciplines — working locally, nationally, and globally — to attain optimal health for people, animals, and the environment**

www.avma.org/KB/Resources/Reports/Documents/onehealth_final.pdf

# Climate, Weather, and Infectious Diseases: The Big Picture

- **Changes in climate lead to changes in the environment, which result in changes in the incidence and distribution of diseases with environmental linkages**

- **Climate affects the distribution and abundance of pathogens and the vectors that carry them (e.g., ticks, mosquitoes) and their animal hosts**

U.S. Global Change Research Program. The Third U.S. National Climate Assessment, 2014. nca2014.globalchange.gov/report
K.R. Smith, A. Woodward, D. Campbell-Lendrum, D.D. Chadee, Y. Honda, Q. Liu, J.M. Olwoch, B. Revich, and R. Sauerborn, 2014: Human health: impacts, adaptation, and co-benefits. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. www.ipcc.ch/report/ar5/wg2

# Climate, Weather, and Infectious Diseases: The Big Picture

- **Climatic variables (temperature and rainfall) affect disease transmission by impacting the replication, interaction, and survival of disease agents in animals, disease vectors, and the environment**

- **Climatic perturbations such as severe storms, droughts, and ENSO affect disease occurrence patterns and drive disease outbreaks**
  - ENSO (El Niño Southern Oscillation) describes both warm (El Niño) and cool (La Niña) ocean-atmosphere events that begin in the tropical Pacific Ocean

Luber, G., et al. 2014: Ch. 9: Human Health. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 220-256

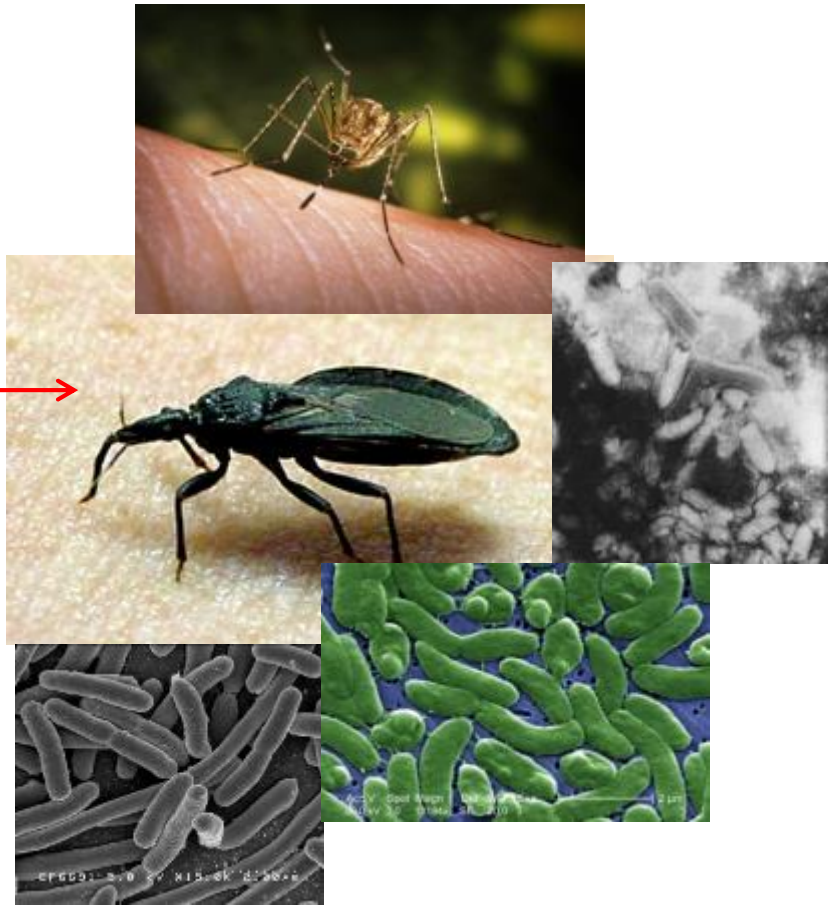
Gage, K. L., T. R. Burkot, R. J. Eisen, and E. B. Hayes. American Journal of Preventive Medicine, 35, 436-450

# Types of Climate-sensitive Infectious Diseases

- **Zoonotic**
  - Diseases that can be spread from animals to humans
- **Vector-borne**
  - Diseases that are transmitted to humans through carriers (vectors) such as mosquitoes or ticks and are usually harbored in wild animals
- **Waterborne**
- **Foodborne**
- **Soil and dust associated**

# Selected Infectious Diseases Potentially Affected by Climate Change

- **Vector-borne and Zoonotic**
  - West Nile virus infection
  - Lyme disease
  - Rabies
  - Dengue
  - Malaria
  - Chagas disease
- **Environmentally-associated**
  - *E. coli* O157H7 infection
  - Cholera
  - Leptospirosis
  - Vibriosis
  - Valley fever
  - Primary amoebic meningoencephalitis

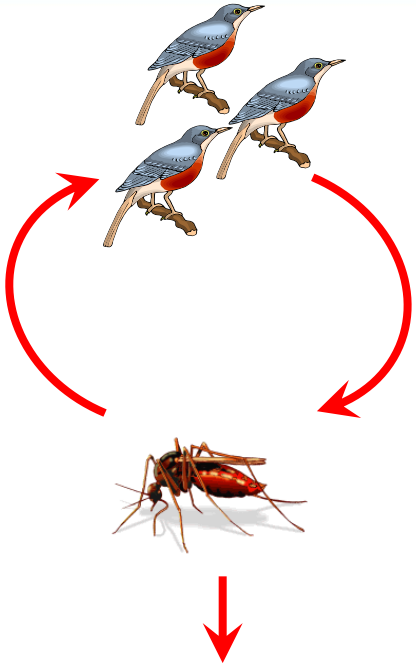


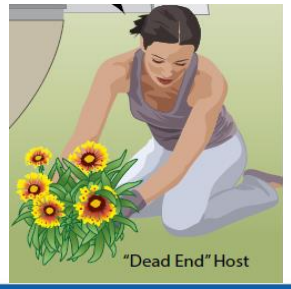
# Vector-borne Disease Case Studies

- West Nile virus infection
- Lyme disease

# West Nile Virus: Biology, Life Cycle, and Human Disease

- **Member of the *Flavivirus* genus in the JE virus subcomplex**
- **Transmitted primarily by *Culex* species mosquitoes**
- **Amplified by birds**
- **Humans and other mammals are "dead end" hosts**
  - Not essential for pathogen life cycle
- **Clinical syndromes:**
  - West Nile fever (about 25% of cases)
  - Neuroinvasive disease (<1% of infections)






JE: Japanese encephalitis

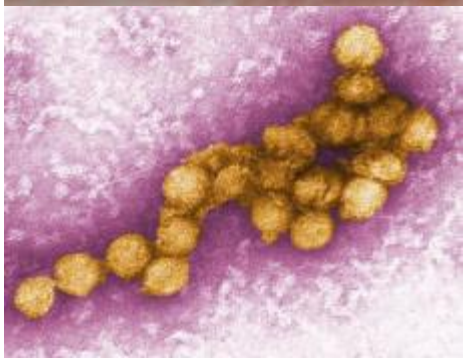
# Temperature, Precipitation, and West Nile Virus (WNV) Transmission

- **Temperature has a significant effect on mosquito life cycle and rate of viral replication**
  - Milder winters
  - Earlier onset of spring
  - Warmer summers
- **Precipitation also has a significant effect, but the relationship is more complicated and varies regionally**
  - The mosquito vectors for WNV vary in the eastern and western US
  - Rainfall can have different effects on the breeding habitat of these different vector species
  - The effects of rainfall vary depending on the region of the country

Reisen et al. 2006. J. Med. Entomol. 43: 309–317
Chuang et al, 2011. J. Med. Entomol. 48: 669–679
Morin & Comrie, 2013. PNAS; doi:10.1073/pnas.1307135110

# West Nile Virus Outbreak of 2012

- **More than 5,600 human cases**
  - 2,873 neuroinvasive disease cases
  - 286 deaths
- **Largest outbreak since 2003**
- **Cases reported from all lower 48 states**
- **Focally-intense outbreak distribution**
  - ~ One-third of cases reported from Texas
  - ~ Half of Texas cases reported from the 4-county area around Dallas
- **Aerial spraying with insecticides was used around Dallas for the first time in almost 50 years**



# Factors Associated with the West Nile Virus (WNV) Outbreak of 2012

- **High level of WNV activity in the U.S. in 2012 was likely influenced by**
  - Mild winter in 2011 - 2012
  - Early spring
  - Hot summer

- **Long growing season combined with hot summer resulted in increased mosquito reproductive cycles and accelerated virus replication, facilitating WNV amplification and transmission to humans**

# Lyme Disease: Biology, Life Cycle, and Human Disease

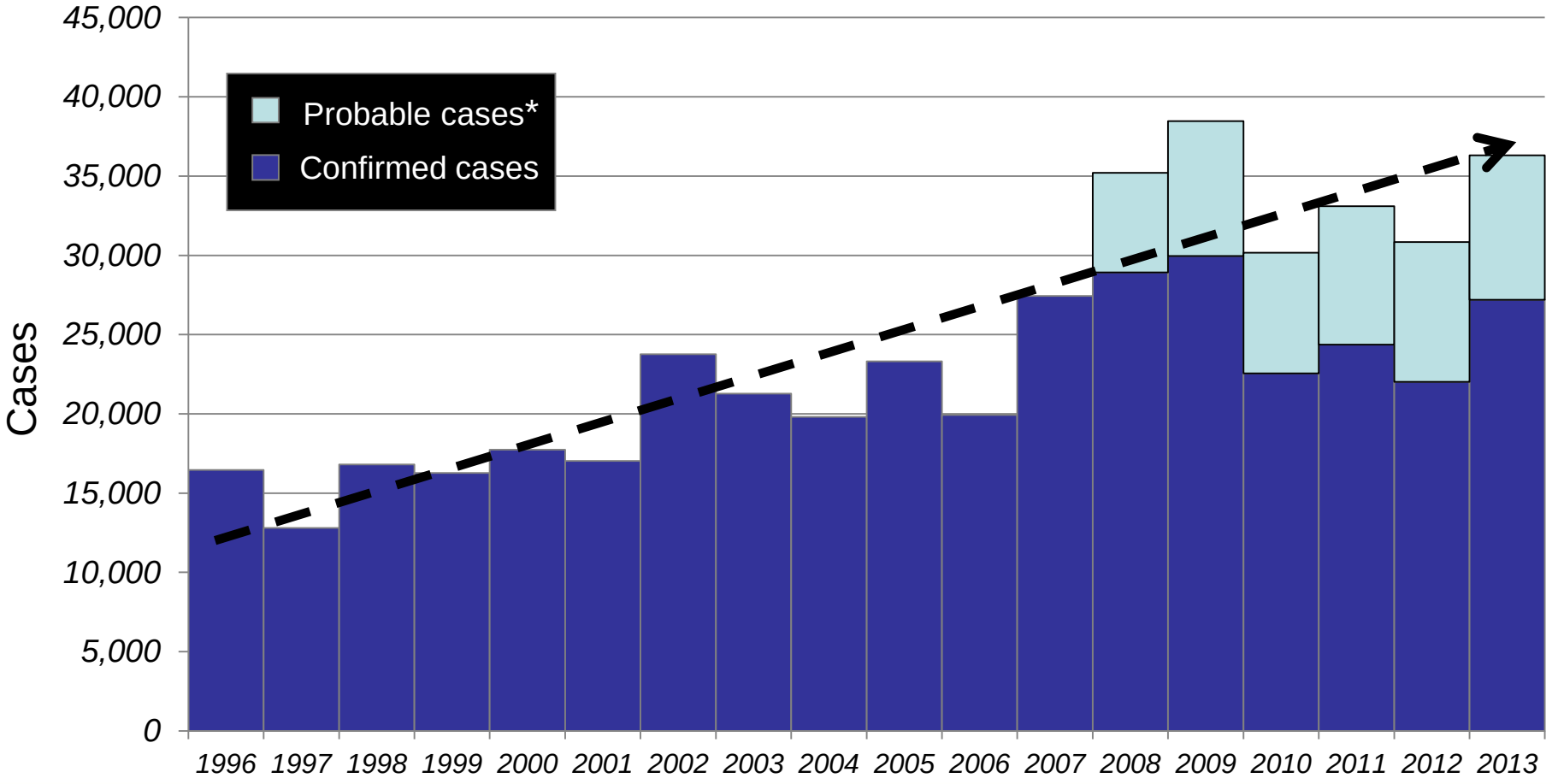
- **Caused by *Borrelia burgdorferi***
- **Transmitted by *Ixodes* species ticks**
- **Reservoirs for the spirochete include small mammals (field mice, squirrels, chipmunks, etc.) and birds**
- **Hosts for the tick include**
  - Small mammals (larvae and nymphs)
  - Deer and other large mammals (adults)
- **Human illness can range from a fever, fatigue, and rash to carditis, facial palsy, and arthritis later in illness**

# Climate, Weather, and Lyme Disease

- Climate (primarily minimum temperature) defines the limit of northern distribution
- Warmer temperatures may increase the reproductive capacity of ticks, leading to larger populations and greater risk for disease transmission to humans
- Higher moisture levels allow ticks to survive in warmer environments
- Temperature and moisture affect the feeding behavior of ticks (“questing”)
- Temperature (measured by cumulative growing degree days) affects seasonality of disease

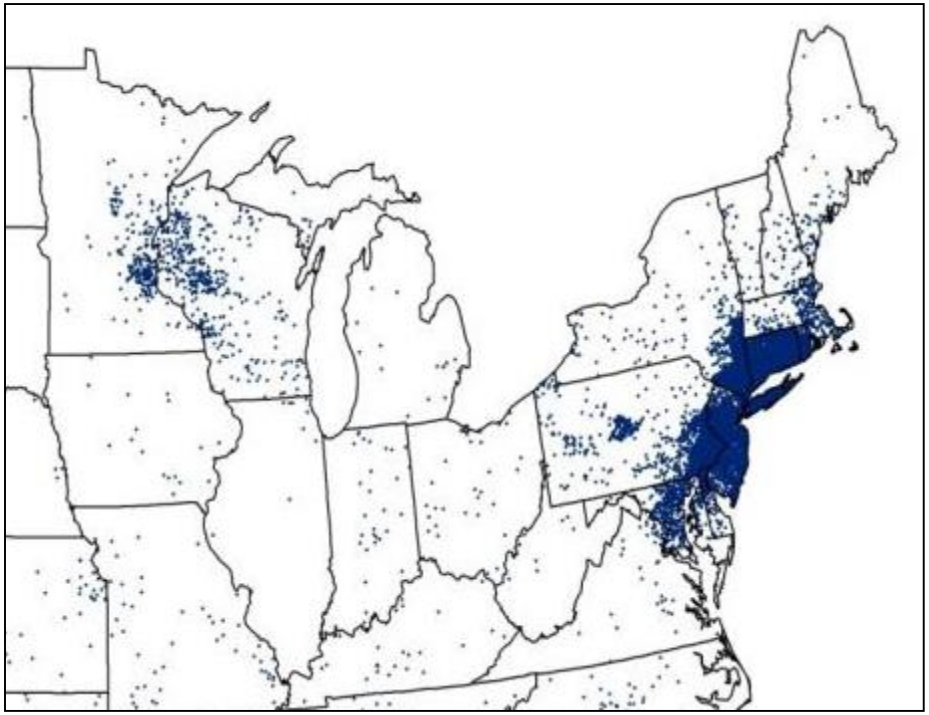
Brownstein, J. S., T. R. Holford, and D. Fish. 2003. Environ Health Persp 111: 1152-1157
Eisen, L., R. J. Eisen, and R. S. Lane. 2002. Med Vet Entomol 16: 235-244
Yuval, B., and A. Spielman. 1990. J Med Entomol 27: 196-201
Moore, S. M., R. J. Eisen, A. Monaghan, and P. Mead. 2014. Am J Trop Med Hyg 90: 486-496

# Reported Cases of Lyme Disease
# United States 1996 - 2013

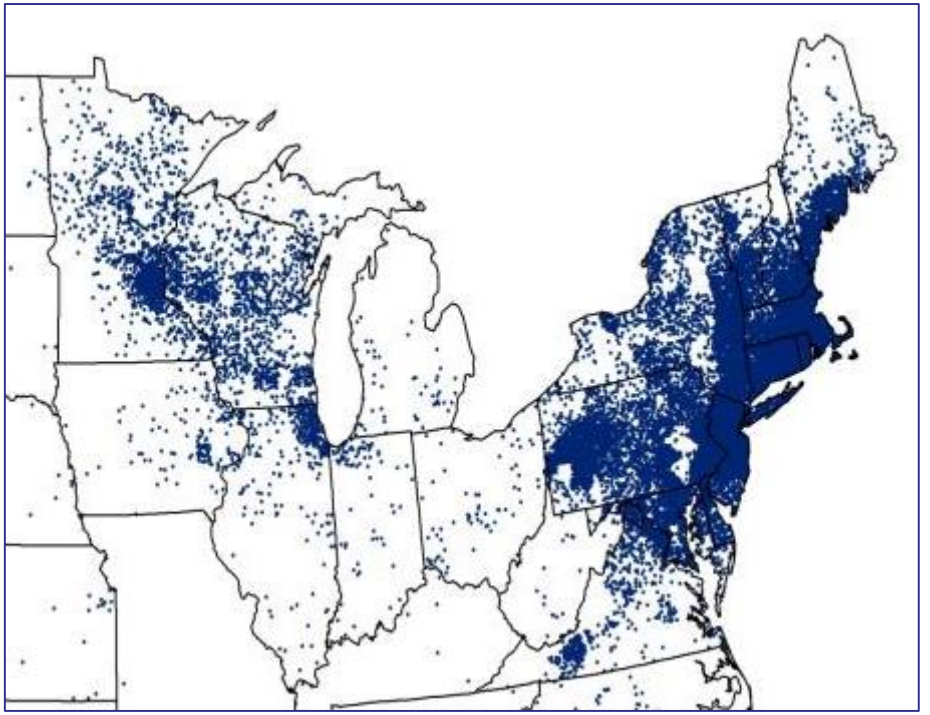



*National Surveillance case definition revised in 2008 to include probable cases; details at www.cdc.gov/ncphi/disss/nndss/casedef/lyme_disease_2008.htm

# Lyme Disease US Case Distribution: 18-year Trend



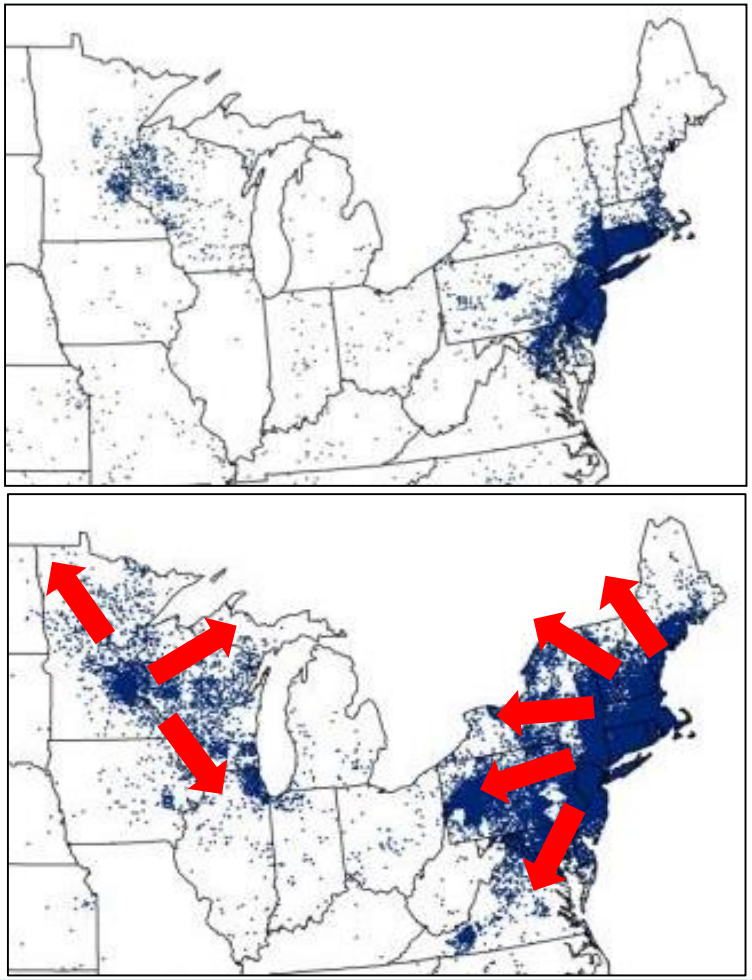
1996



2013

www.cdc.gov/lyme/stats/maps/interactiveMaps.html

# Climate, Weather, and Lyme Disease: Results from Modeling



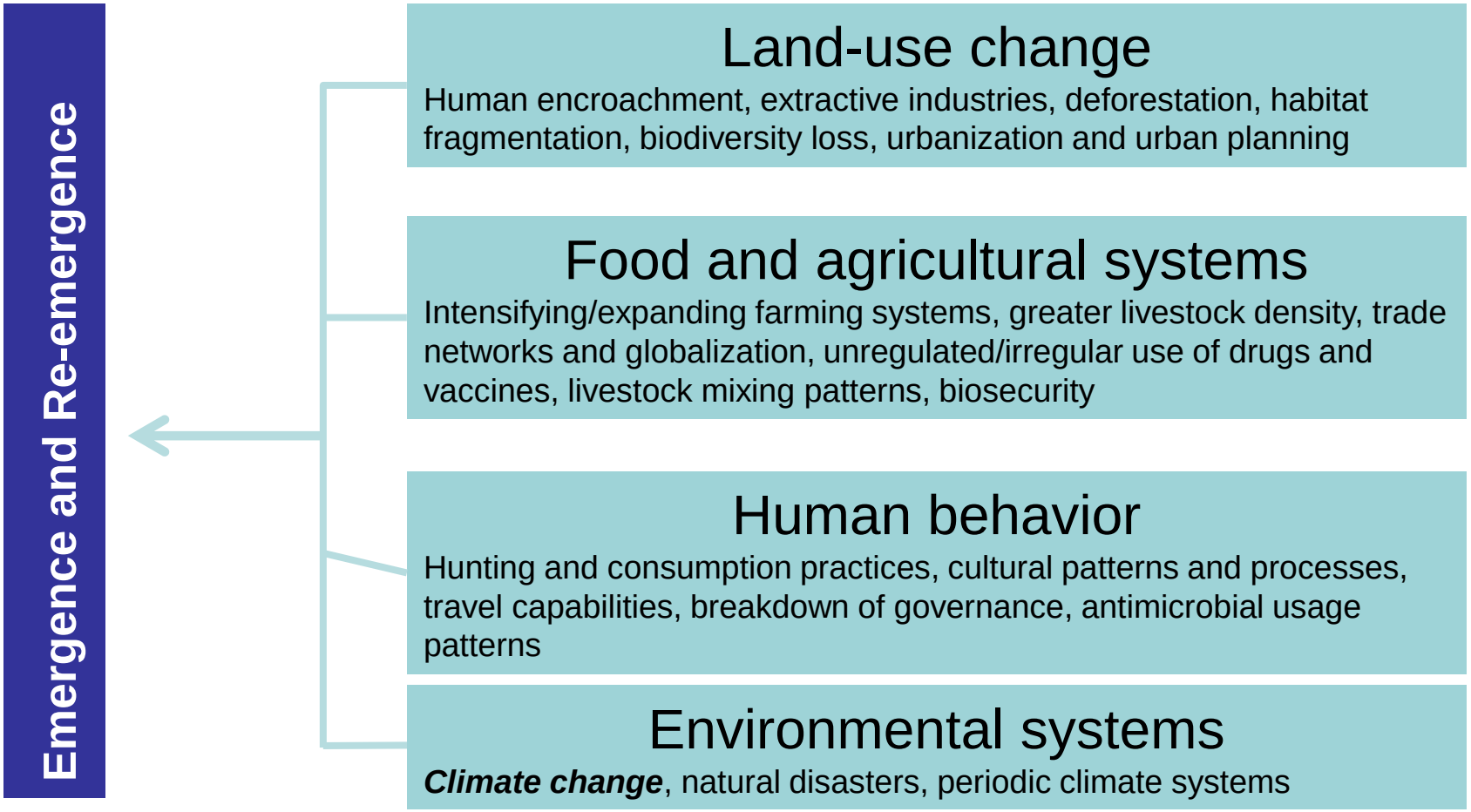
Climate warming may have co-driven Lyme disease emergence in northeastern North America and in the future may drive substantial disease spread into new geographic regions and increase tick-borne disease risk where climate is currently suitable.

Adapted from: Ogden NH et al. 2014

Map source: www.cdc.gov/lyme/stats/maps/interactiveMaps.html

Ogden NH, Radojevic M, Wu X, Duvvuri VR, Leighton PA, Wu J.Environ Health Perspect. 2014 Jun;122(6):631-8.

# Reasons Diseases Emerge at the Human-Animal-Environment Interface



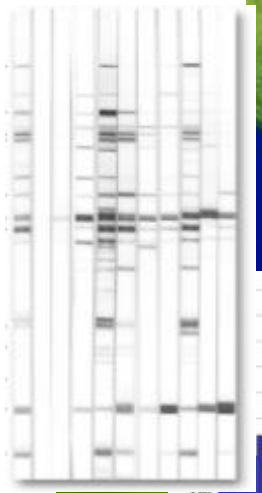

Matthew A. Dixon, Osman A. Dar and David L. Heymann. Veterinary Record 2014 174: 546-551.

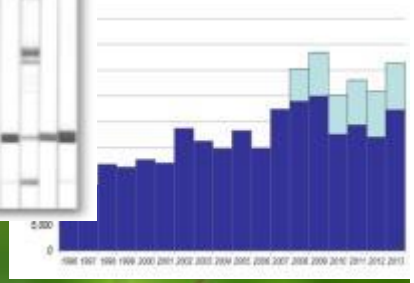
# Minimizing Adverse Health Effects of Climate-sensitive Infectious Diseases

- **Public health surveillance**
  - Establish baseline levels of disease occurrence
  - Track trends and monitor changes in geographic range of vectors and diseases
- **Preparedness**
  - Maintain capacity for detection and response
  - Develop decision-support tools
- **Research**
  - Develop predictive models for changes in distribution, risk of disease introductions
  - Identify cost-effective prevention methods

# Examples of Vector-borne Disease Prevention, Detection, and Response

- Vaccines for prevention of diseases like Lyme disease and West Nile virus infection
- Improved diagnostic tests that enhance our capacity for early and accurate diagnosis, treatment, and response
- Better information on disease burden and cost savings associated with specific prevention tools





# Building Resiliency to Climate Change: Helping Cities and States Respond

**George Luber, PhD**
*Associate Director for Climate Change*
Climate and Health Program
Division of Environmental Hazards and Health Effects
National Center for Environmental Health

# Climate and Health Program at CDC

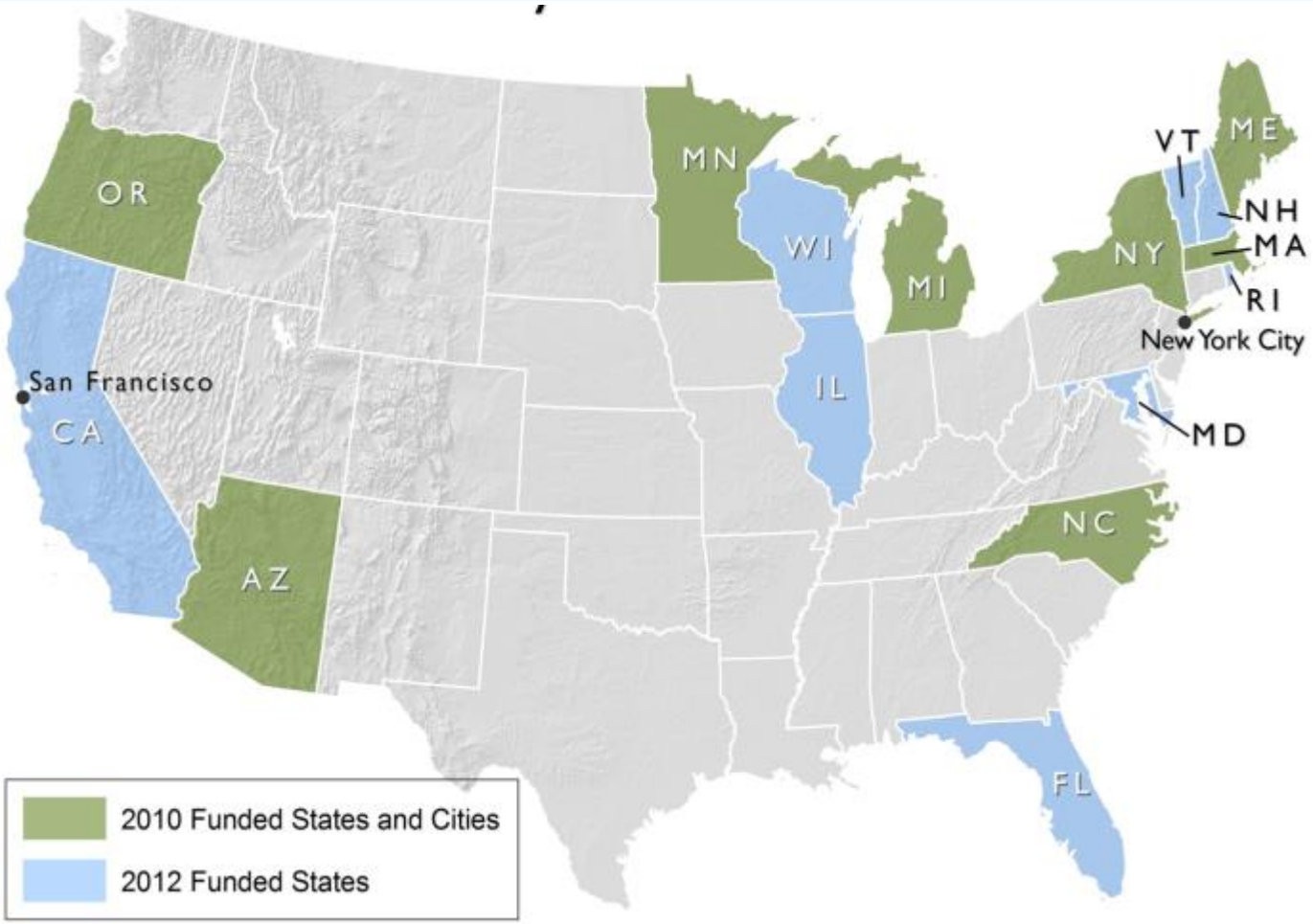
- **Established in 2009**
- **The only federal investment in building the climate change capabilities of health departments**
- **Helps states and cities prepare for health challenges of climate change by**
  - Providing scientific guidance
  - Developing decision support tools
  - Ensuring public health concerns are considered in climate change adaptation and mitigation strategies

# Climate-Ready States and Cities Initiative

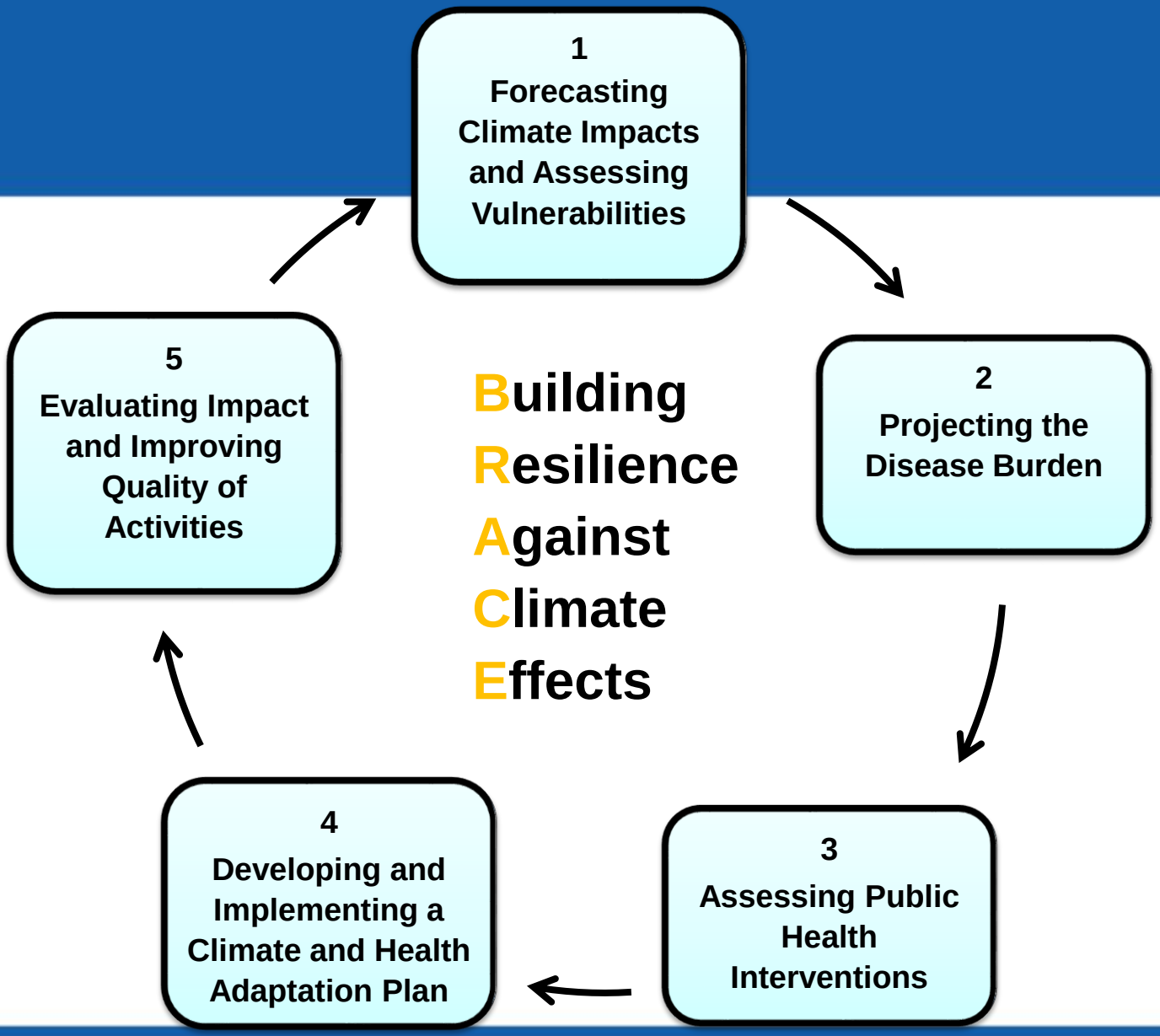
- **Effort to enhance capacity of state and local health agencies to deal with health challenges associated with climate change**
- **Accomplished by**
  - Funding 18 state and local health departments
  - Providing framework and tools for planning, implementing, and evaluating climate adaptation strategies
    - Tools to identify populations and places vulnerable to climate impacts
    - Materials to help communicate climate and health issues to public health partners (e.g., extreme heat tool kit)

      (Available at www.cdc.gov/extremeheat/materials.html)

# CRSCI Grantees Addressing Climate Change Challenges to Public Health




CRSCI: Climate-ready Cities and States Initiative




Climate and Health Program, National Center for Environmental Health, CDC

# Success Stories:
# New York City and Heat Warnings

## Problem

- Magnitude and intensity of heat waves likely to increase in New York City in the future

## Action

- With CDC funding and support, the New York City Department of Health and Mental Hygiene investigated sensitivity and effectiveness of its extreme heat warning system
- Collaboration helped to better understand
  - Historical death and hospitalization data
  - Future temperature and humidity projections
  - Urban heat island interactions with heat vulnerability

www.nasa.gov/centers/goddard/news/topstory/2005/nyc_heatisland.html

# Success Stories:
# New York City and Heat Warnings

- **Outcome**
  - Setting a lower threshold for a more sensitive and tailored heat-warning system

- **Impact**
  - Heat warnings and advisories now more protective for New Yorkers
  - Methodology being used by other jurisdictions to similarly tailor heat messaging and advisories to local conditions, resulting in lower heat thresholds for public health actions

www.nasa.gov/centers/goddard/news/topstory/2005/nyc_heatisland.html

# Success Stories: North Carolina and Storm Surge Forecasting

## Problem

- Storm surge associated with coastal storms can cause failure of drinking and wastewater infrastructure in coastal communities, leading to waterborne disease outbreaks

**Flooded wastewater treatment plant in Goldsboro, NC (1999)**

# Success Stories: North Carolina and Storm Surge Forecasting

## Action

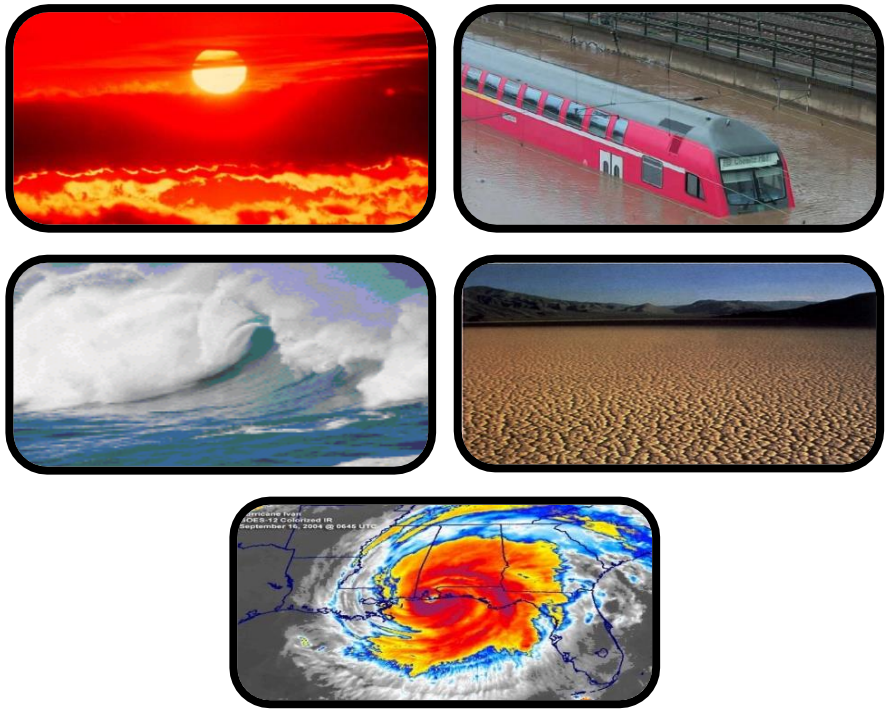
- North Carolina Department of Health and Human Services identified critical drinking and wastewater infrastructure in coastal communities
- Collaboration with local water authorities enabled health officials to use climate change models to estimate coastal flooding
- Health officials used estimates of 0.5, 1, and 2 meter storm surge to map at-risk drinking water and wastewater infrastructure

## Outcome

- Findings inform both preparedness planning for existing facilities and decisions on sites for future facilities

# Public Health Efforts to Prepare for and Respond to Health Effects of Climate Change

- **Climate-Ready States and Cities Initiative**
  - Partnering with state and city health departments across multiple US regions
  - Providing scientific, communications, and resource support
- **Building Resiliency Against Climate Effects (BRACE)**
  - Efforts to respond to location-specific climate-related threats
  - Better preparation for or prevention of environmental hazards caused by extreme temperatures, excess precipitation, or natural disasters




# George Luber, PhD

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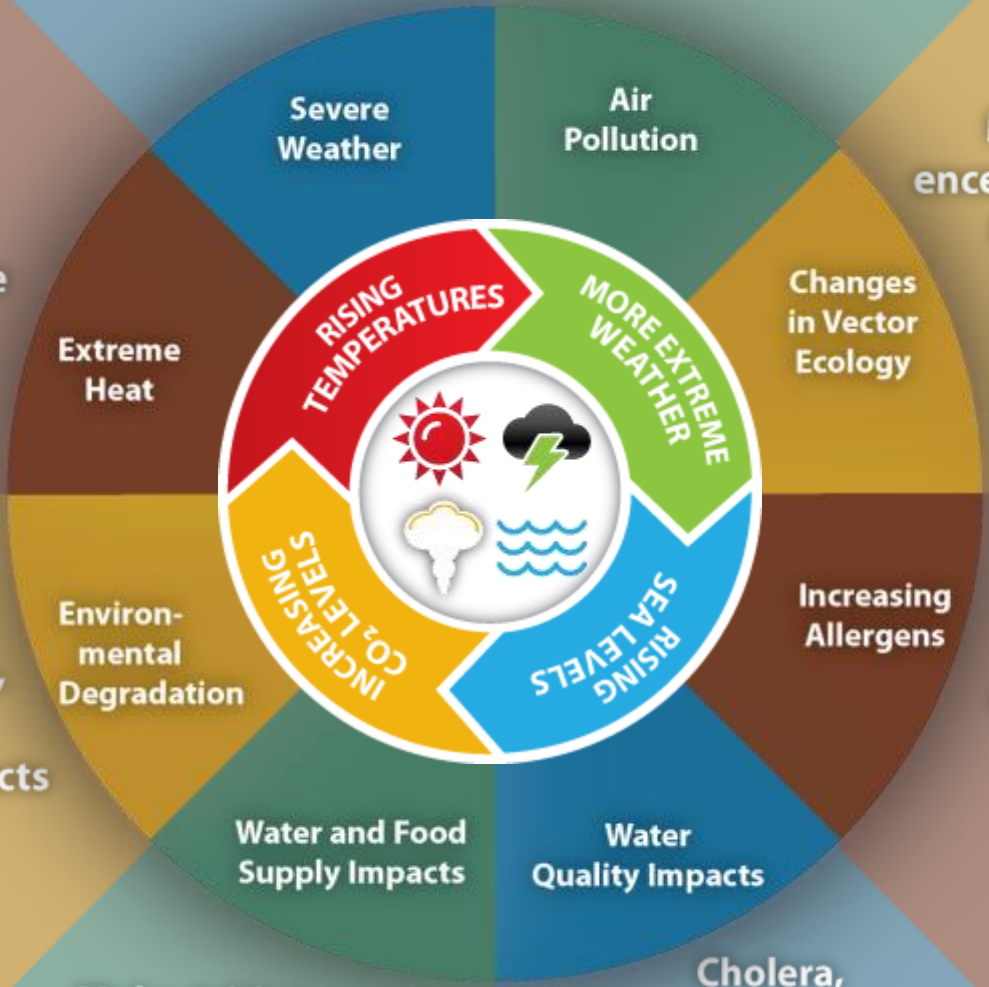
E-mail: cdcinfo@cdc.gov

Web: http://www.cdc.gov

# Impact of Climate Change on Human Health




Injuries, fatalities, mental health impacts

Asthma, cardiovascular disease

Heat-related illness and death, cardiovascular failure

Malaria, dengue, encephalitis, hantavirus, Rift Valley fever, Lyme disease, chikungunya, West Nile virus

Forced migration, civil conflict, mental health impacts

Respiratory allergies, asthma

Malnutrition, diarrheal disease

Cholera, cryptosporidiosis, campylobacter, leptospirosis, harmful algal blooms