Public Health Heats Up: Global and Local Impacts of Climate Disruption

Ali S. Khan, MD, MPH
Dean and Professor, UNMC College of Public Health
Retired Assistant Surgeon General, USPHS

UNIVERSITY OF NEBRASKA MEDICAL CENTER℠
COLLEGE OF PUBLIC HEALTH

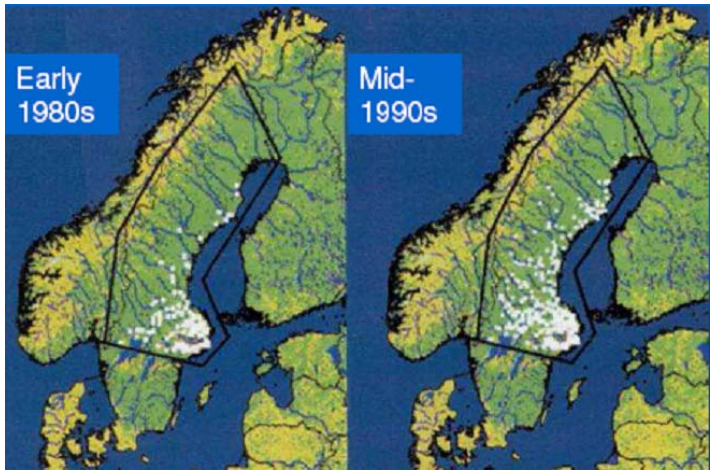

BEWARE CLIMATE CHANGE
WHEN?

Current Effects of Climate on ID

- *Cryptococcus gattii*
- *Vibrio vulnificus*
- Tick-borne Encephalitis
- Shortened respiratory syncytial virus (RSV) season in northern climates

Vibrio vulnificus in Oysters

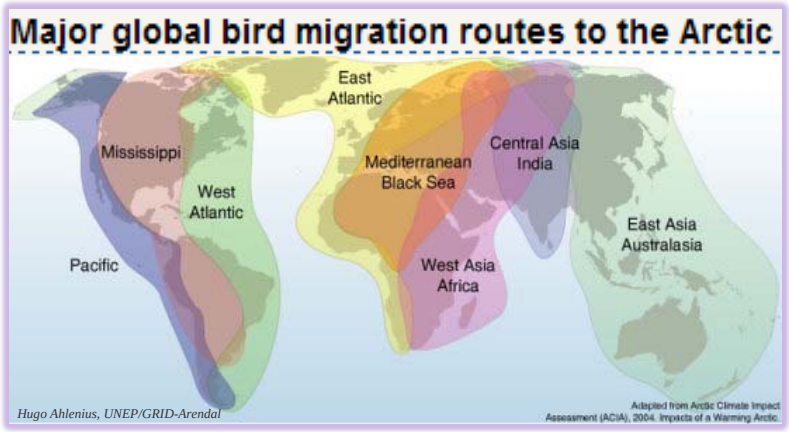
***Cryptococcus gattii*, a tropical pathogen emerging in a temperate climate zone**



TBE, Sweden

Environ Health Perspect. 2000; 108(2): 119-23
The Lancet 2001; 358(9275:16

Amplification of warming in Arctic has global implications for bird populations



- Advancement in species' phenology over past 30-60 years
  - Migration: 1.3-4.4 days earlier per decade
  - Breeding: 1.9-4.8 days earlier per decade
- Poleward shifts of range margins
  - 18.9 km average range movement northward over 20-year period

<u>Alterations in Habitat and Food Availability</u>

- Increased competition for nest sites for those species that do not migrate early
- Mismatch between the peak in insect availability and the peak food demands

Newsweek: International Editions

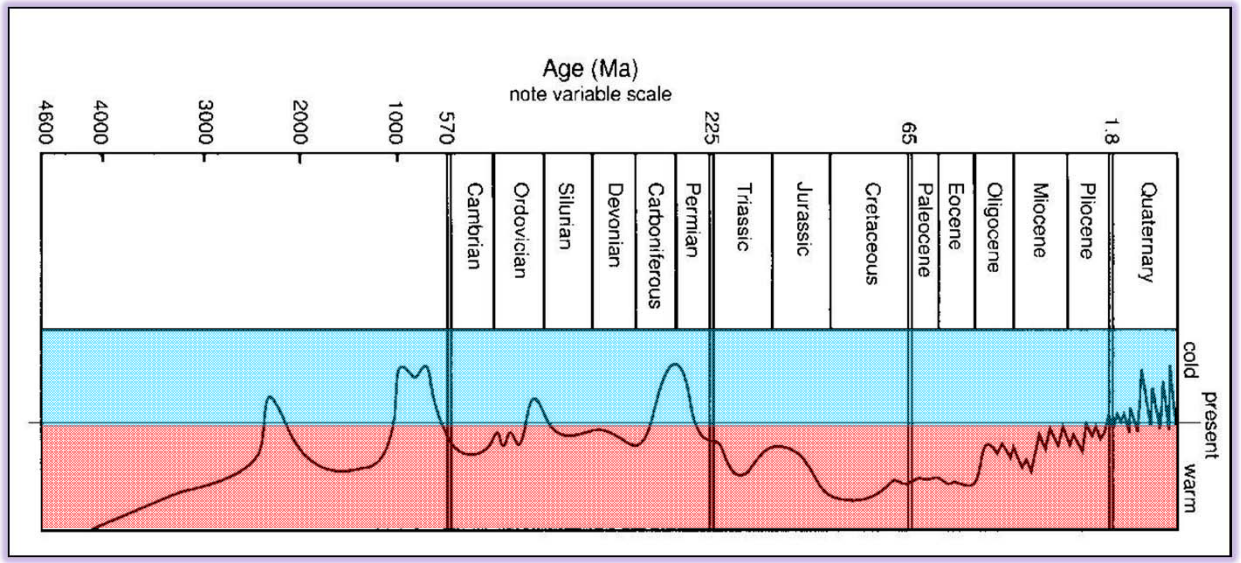
Frogs: Global Warming's First Victims

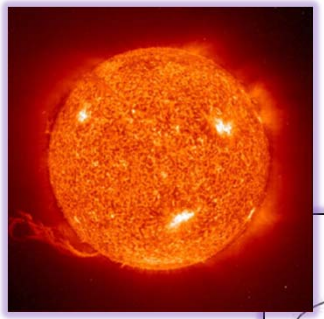
Changes in climate have been associated with:

- Population declines in Costa Rica
- Breeding phenology in Great Britain
- Physiological changes in female toads, leading to increased female mortality rates and decreased fecundity in survivors

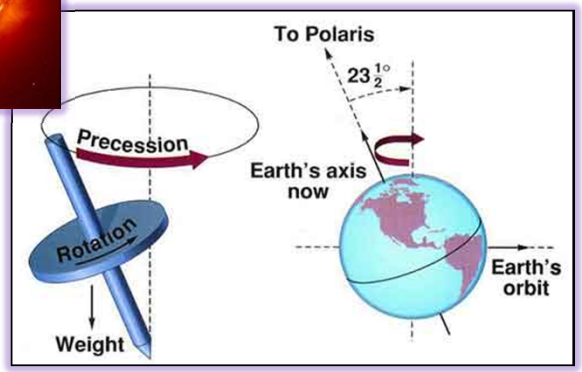
- Widespread amphibian extinctions
- Temperatures at many highland localities shifting towards the growth optimum of fatal fungus, chytrid *Batrachochytrium dendrobatidis*
- Unusual climatic conditions can alter development and increase frog susceptibility to various pathogens.
- Environmental stressors that can cause declines include loss of habitat, disease, pollutants, climate change

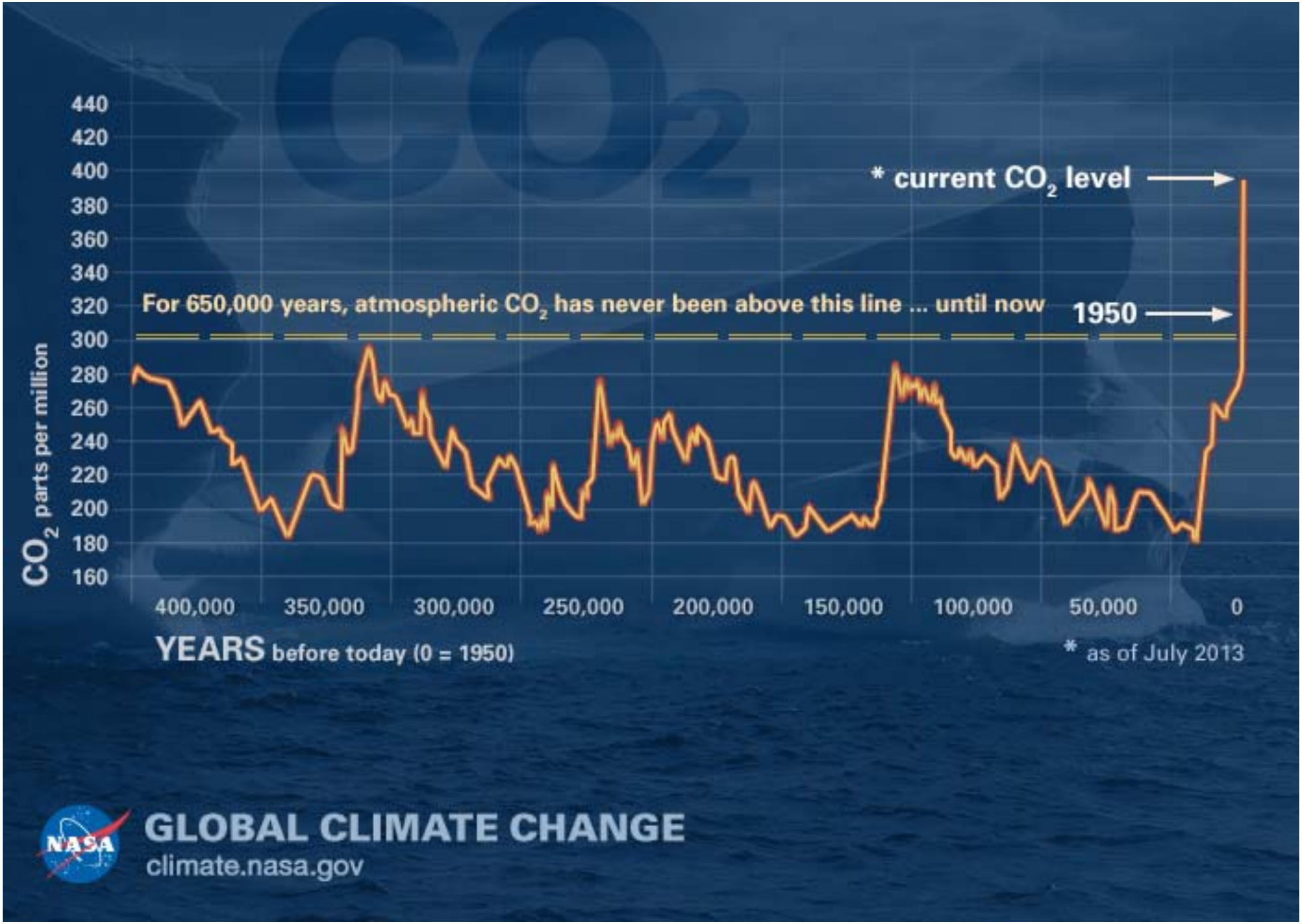
Natural Earth Cycles and Wobbles





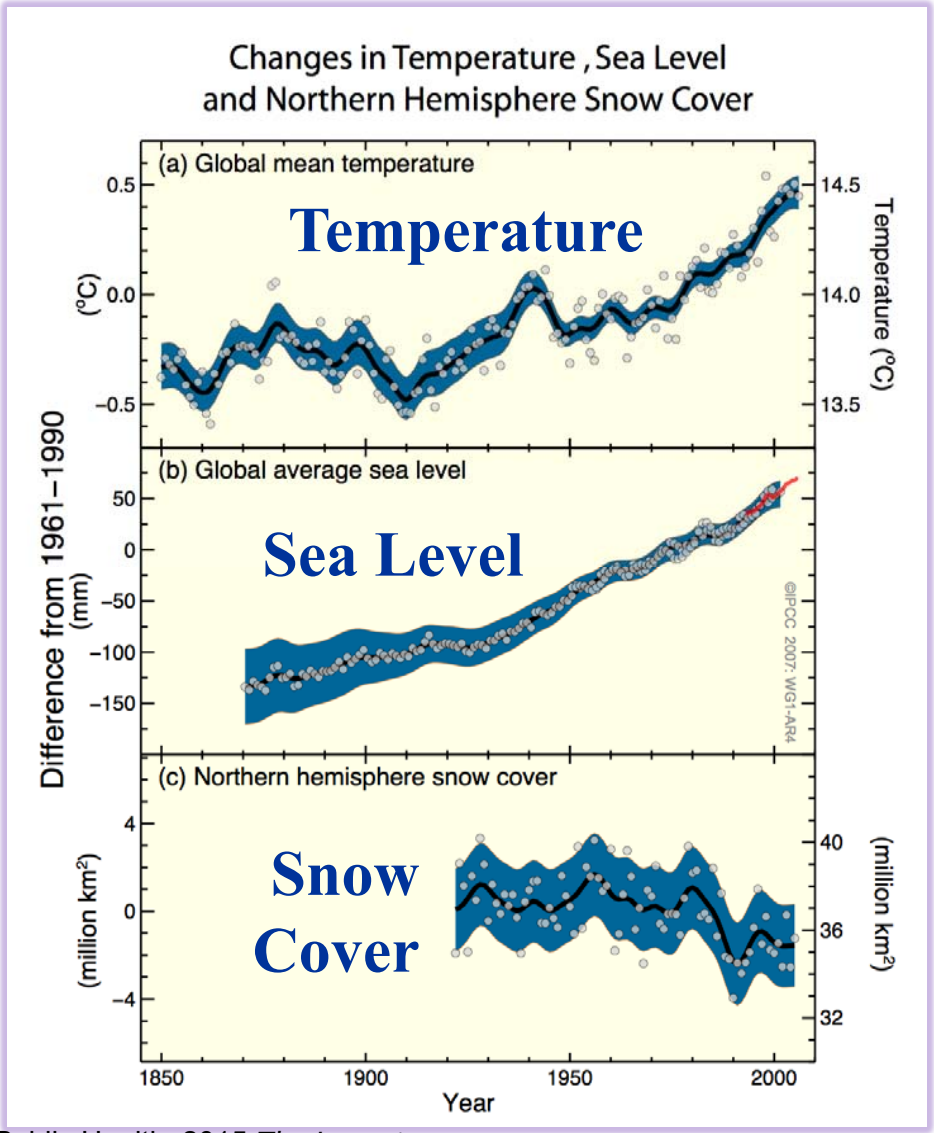
Mammals **Present**




440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
CO2 parts per million
* current CO2 level
For 650,000 years, atmospheric CO2 has never been above this line ... until now
1950
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
YEARS before today (0 = 1950)
* as of July 2013
GLOBAL CLIMATE CHANGE
climate.nasa.gov

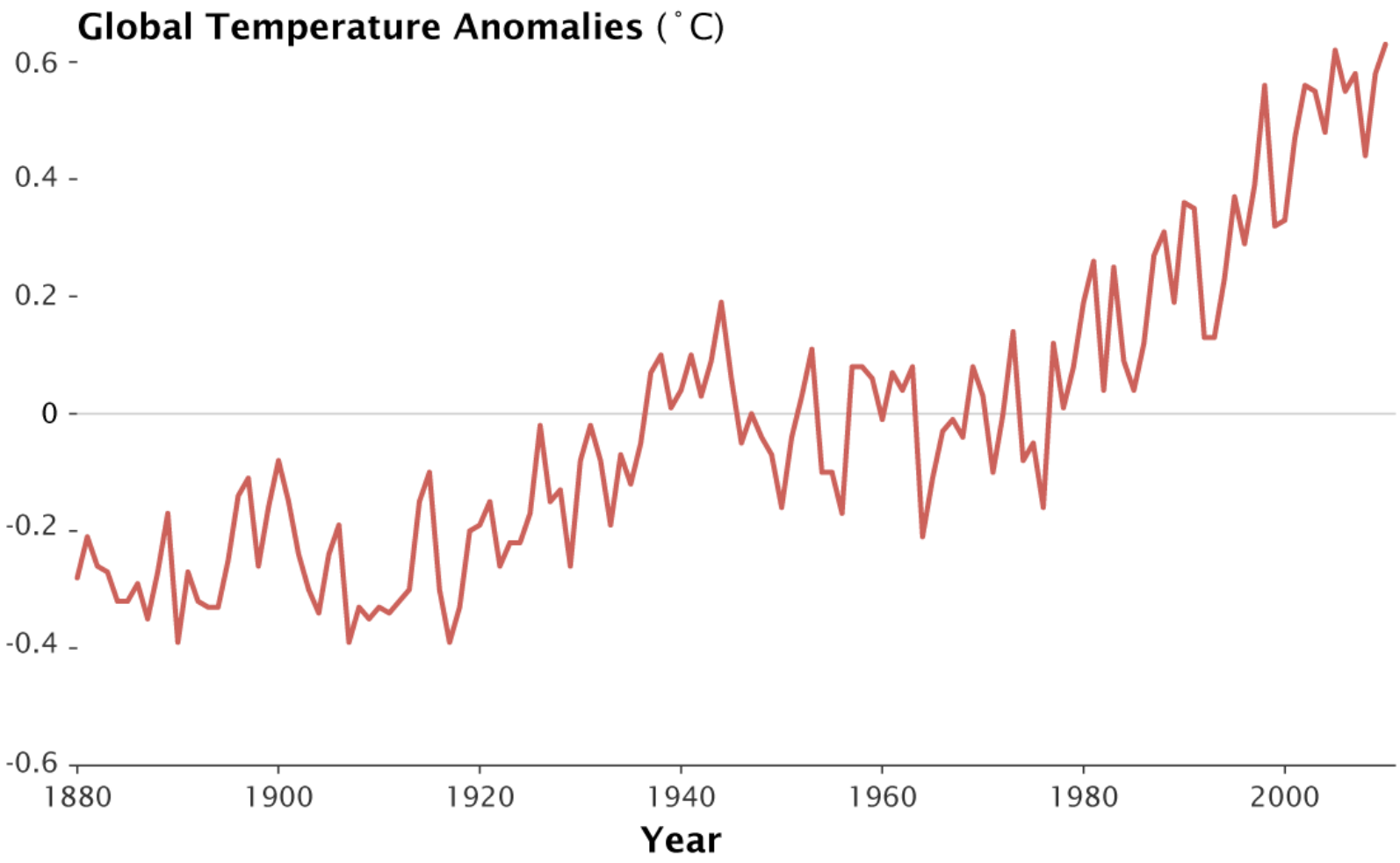
Climate Change is Happening Now

- Warming is unequivocal
- Physical and biological systems on all continents and oceans are already affected by climate changes
- Overall the earth has warmed .85°C from 1880-2012
- Arctic sea ice is disappearing at a rate of up to 50,000 km^2 per year
- Antarctic ice sheets are losing 159 billion tons of ice each year



IPCC 2007

Health and Climate Change: Policy Responses to Protect Public Health. 2015 *The Lancet*



Nasa – Projected U.S. Temperature Changes by 2100

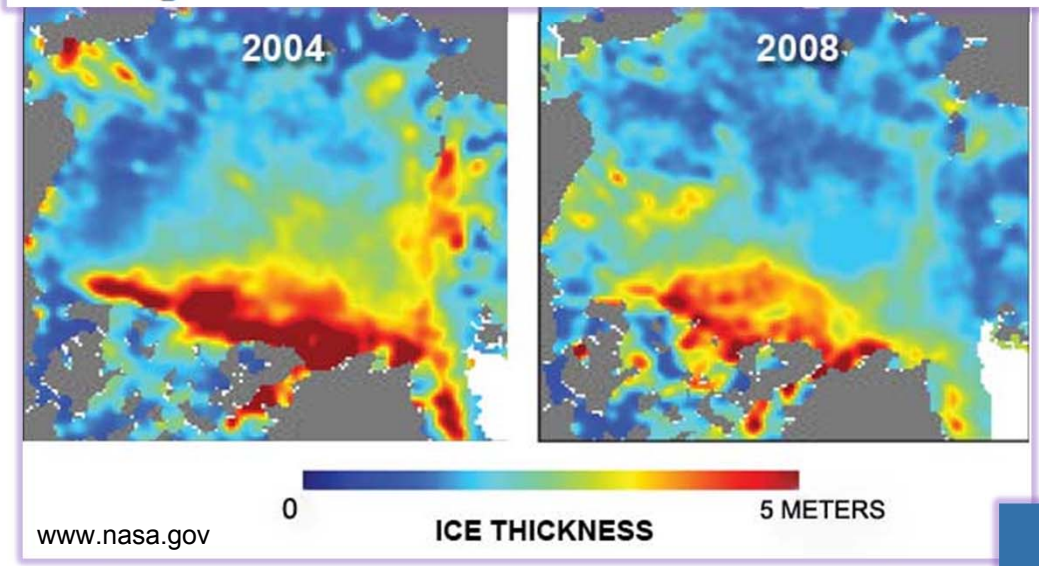
https://www.youtube.com/watch?v=39cBqY1sszY#action=share

Temperature Changes in Nebraska

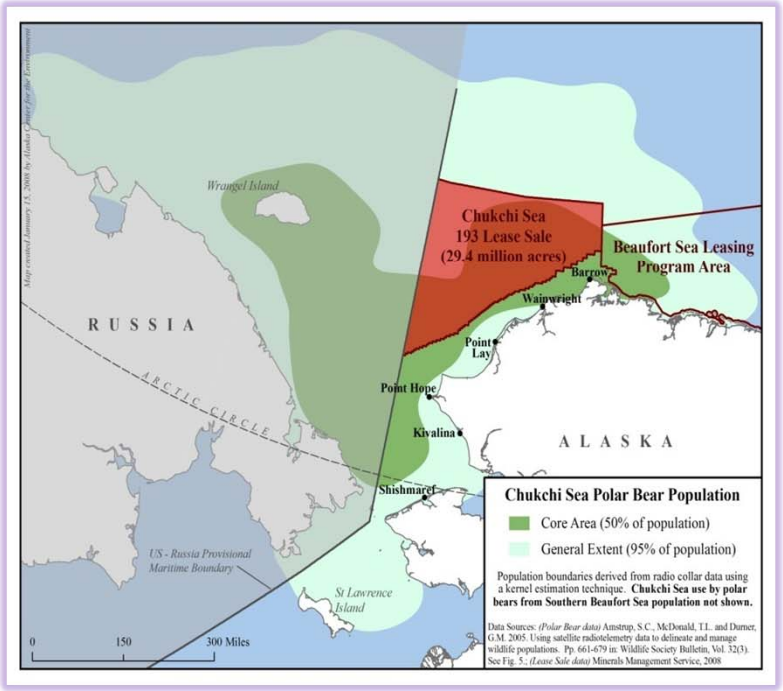
- Nebraska has experienced an overall warming of about 1°F since 1895, with warming trends that are highest in winter and spring and for the nighttime lows than for daytime highs.
- Since1895, the length of the frost-free season has increased by 5 to 25 days across Nebraska.
- Projected temperature changes for Nebraska range from an increase of 4-5°F (low emission scenarios) to 8-9°F (high emission scenarios) by the end of the twenty-first century.

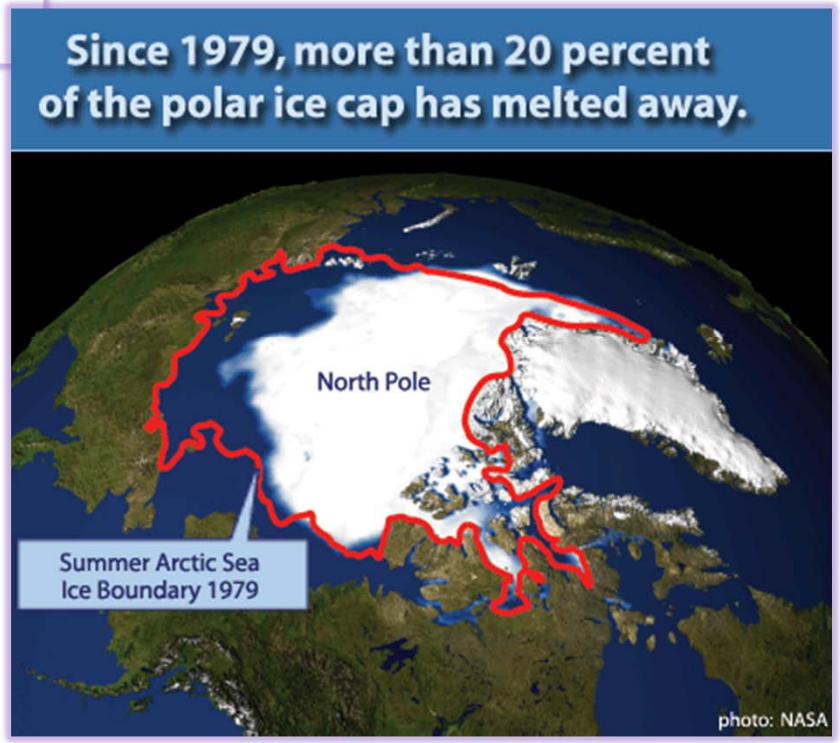
Source: Understanding and Assessing Climate Change: Implications for Nebraska, September 2014

New NASA Satellite Survey Reveals Dramatic Arctic Sea Ice Thinning



www.nasa.gov





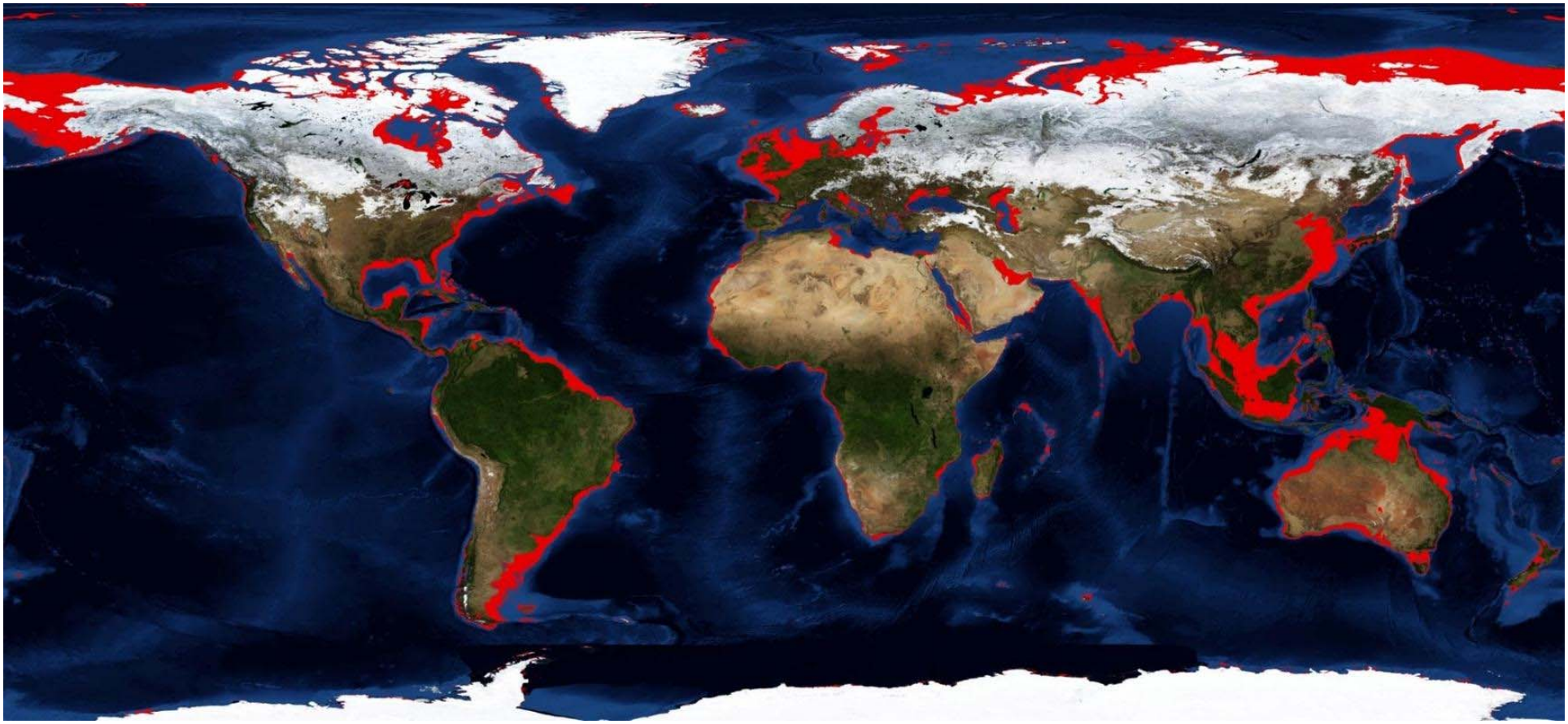
Source: IPCC

Extreme Weather

- Globally, the number of reported weather-related natural disasters has more than tripled since the 1960s.
- Every year, disasters result in over 60,000 deaths, mainly in developing countries.
- By the 2090s, climate change is expected to widen the area affected by drought, double the frequency of extreme droughts, and increase their average duration six-fold.
- Health Hazards associated with extreme weather events:
  - Death, injury, or disease
  - Negative effects on physical, mental, and social well-being
  - Exacerbation of existing medical conditions

Source: WHO. http://www.who.int/mediacentre/factsheets/fs266/en/

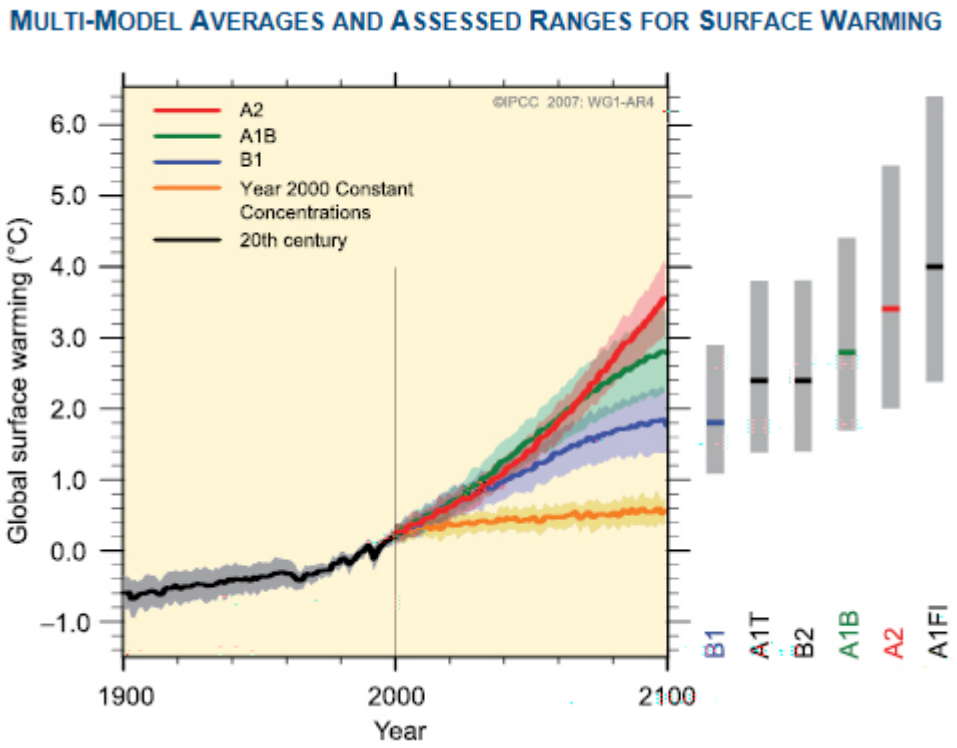
Global sea level has risen by about 8 inches since reliable record keeping began in 1880. It is projected to rise another 1 to 4 feet by 2100.



Source: http://nca2014.globalchange.gov/report/our-changing-climate/sea-level-rise

A 2°C increase in global temperature is inevitable even if we take dramatic action

Even if countries meet their current non-binding pledges to reduce carbon emission, we will still be on course to reach 3°C by the end of this century.



Climate Change Affects Human Health in Two Ways

1. Changing the severity and frequency of health problems that are already affected by climate and weather factors
2. Creating unanticipated health problems or health threats in places where they have no previously occurred.

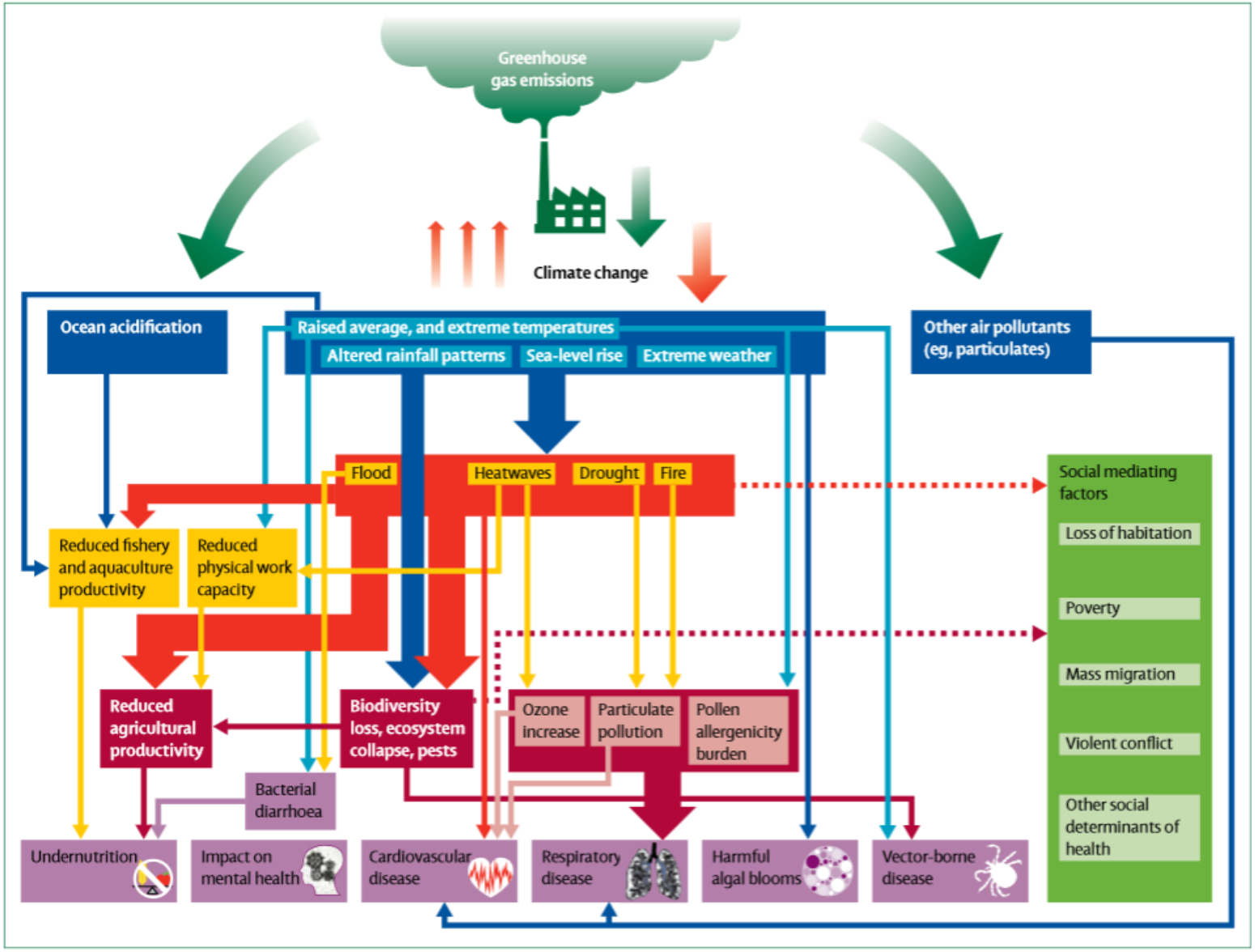
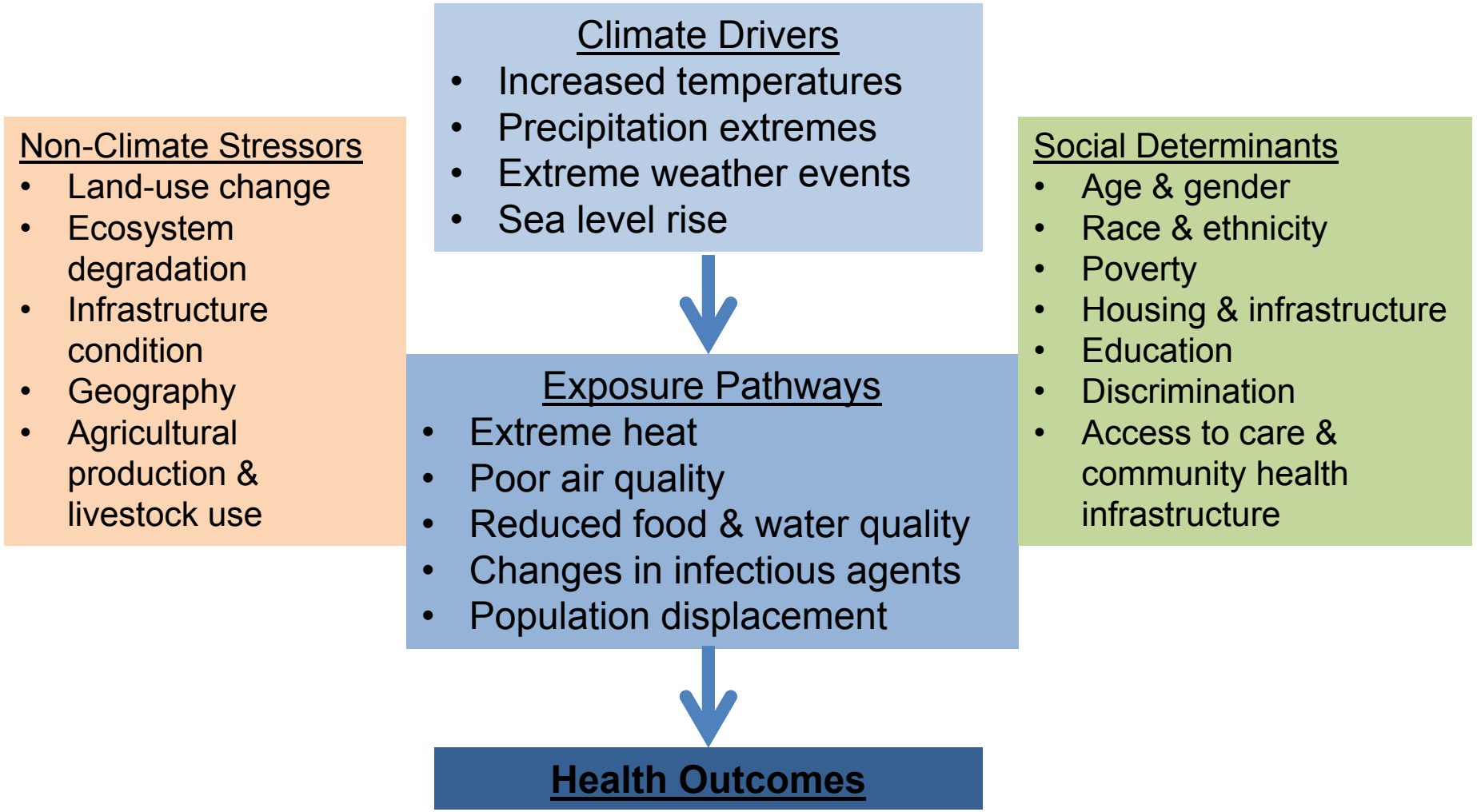


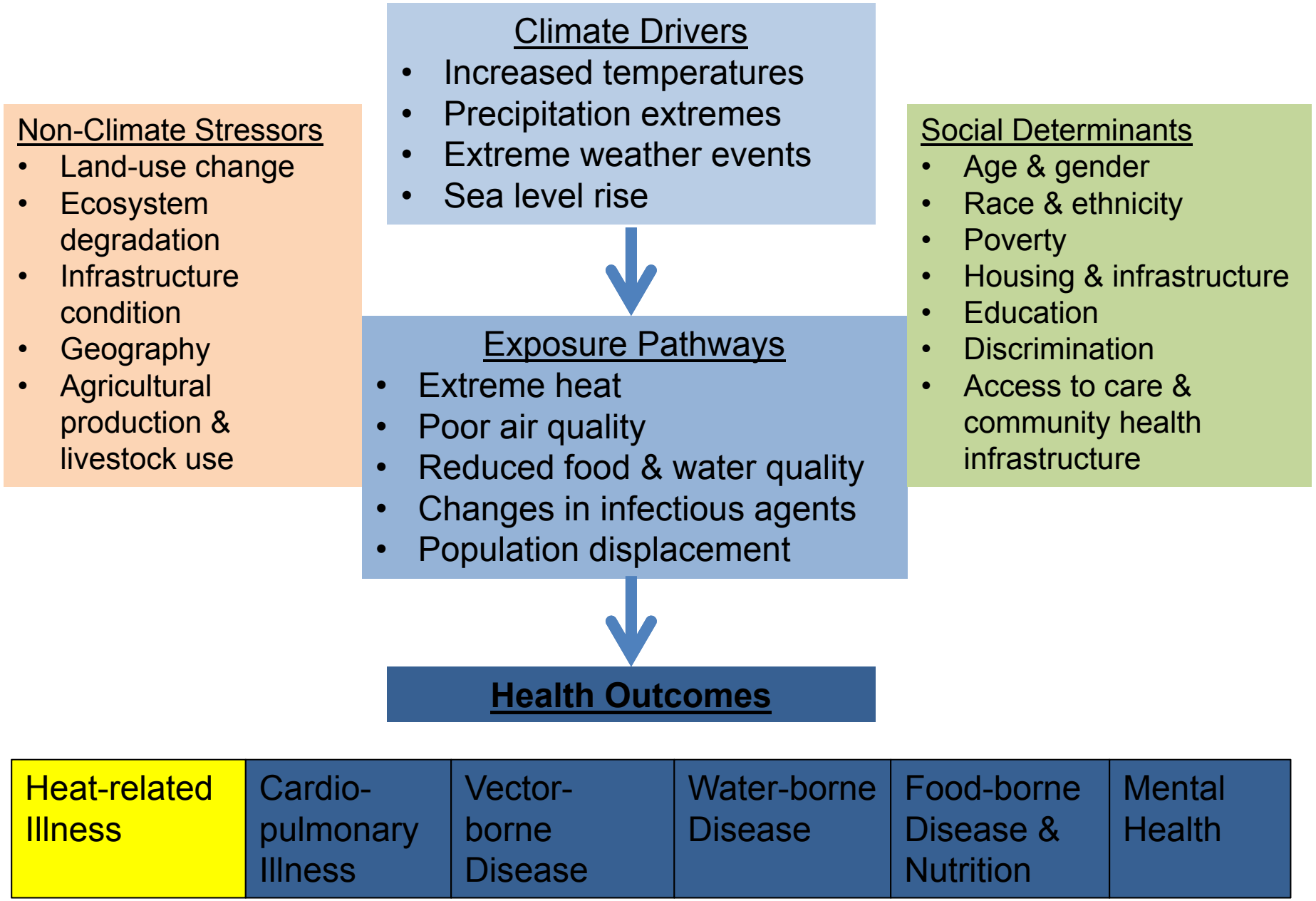
Figure 1: **An overview of the links between greenhouse gas emissions, climate change, and health**
The causal links are explained in greater detail in the section about climate change and exposure to health risks.

www.thelancet.com **Published online June 23, 2015 http://dx.doi.org/10.1016/S0140-6736(15)60854-6**

Climate Change and Health



Climate Change and Health



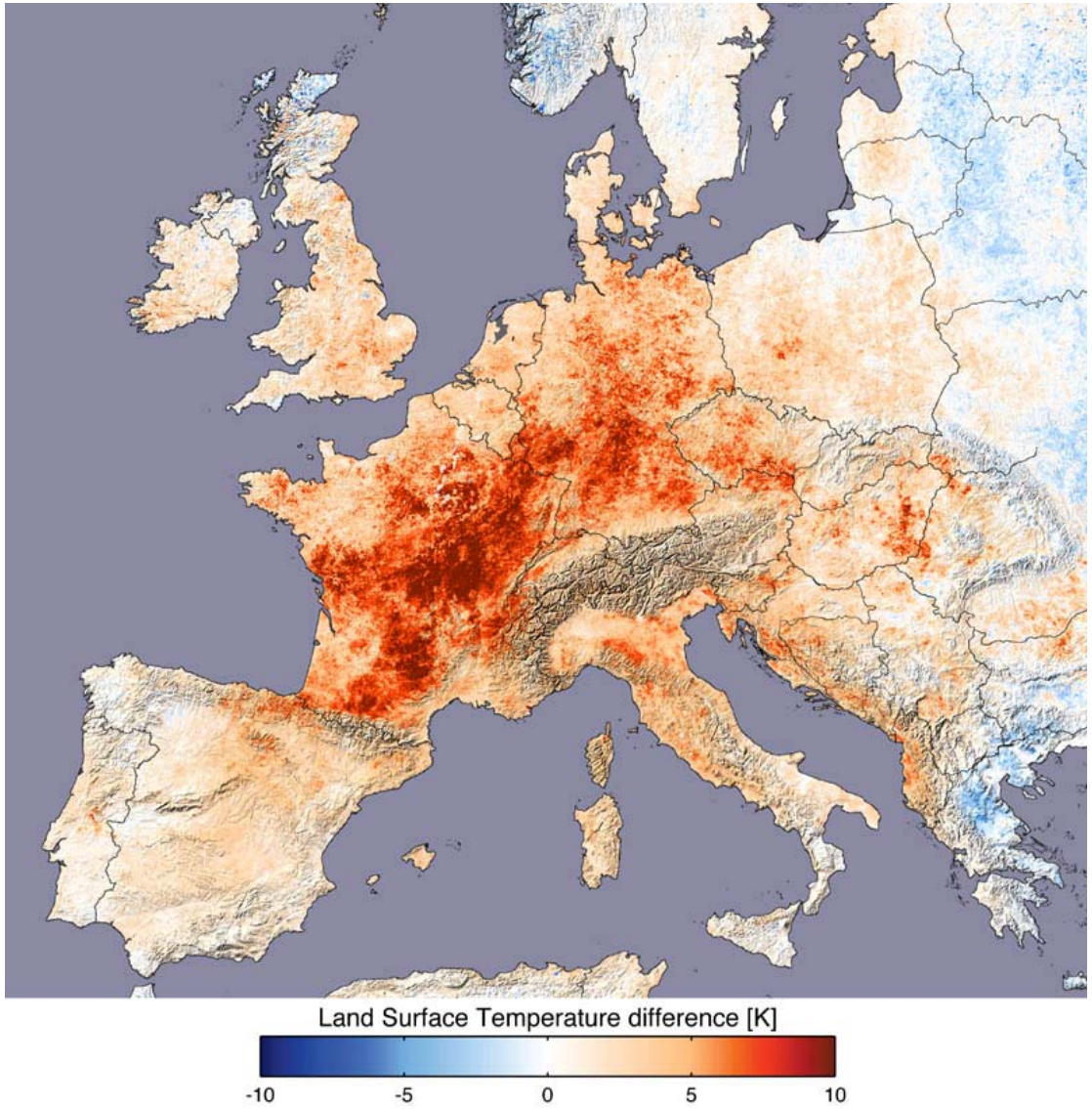
Heat-Related Death and Illness

- Hotter than normal or colder than normal days can compromise the body's ability to regulate temperature
- In the presence of extreme heat, loss of temperature control can result in heat cramps, heat exhaustion, heatstroke, hyperthermia, and worsening of already present chronic conditions.
- The elderly, children, people working outdoors, and economically disadvantaged groups are at an increased risk of death during a heat wave.
- Between the years 2030 and 2050, climate change is expected to cause an additional 38,000 deaths per year due to heat exposure in the elderly.

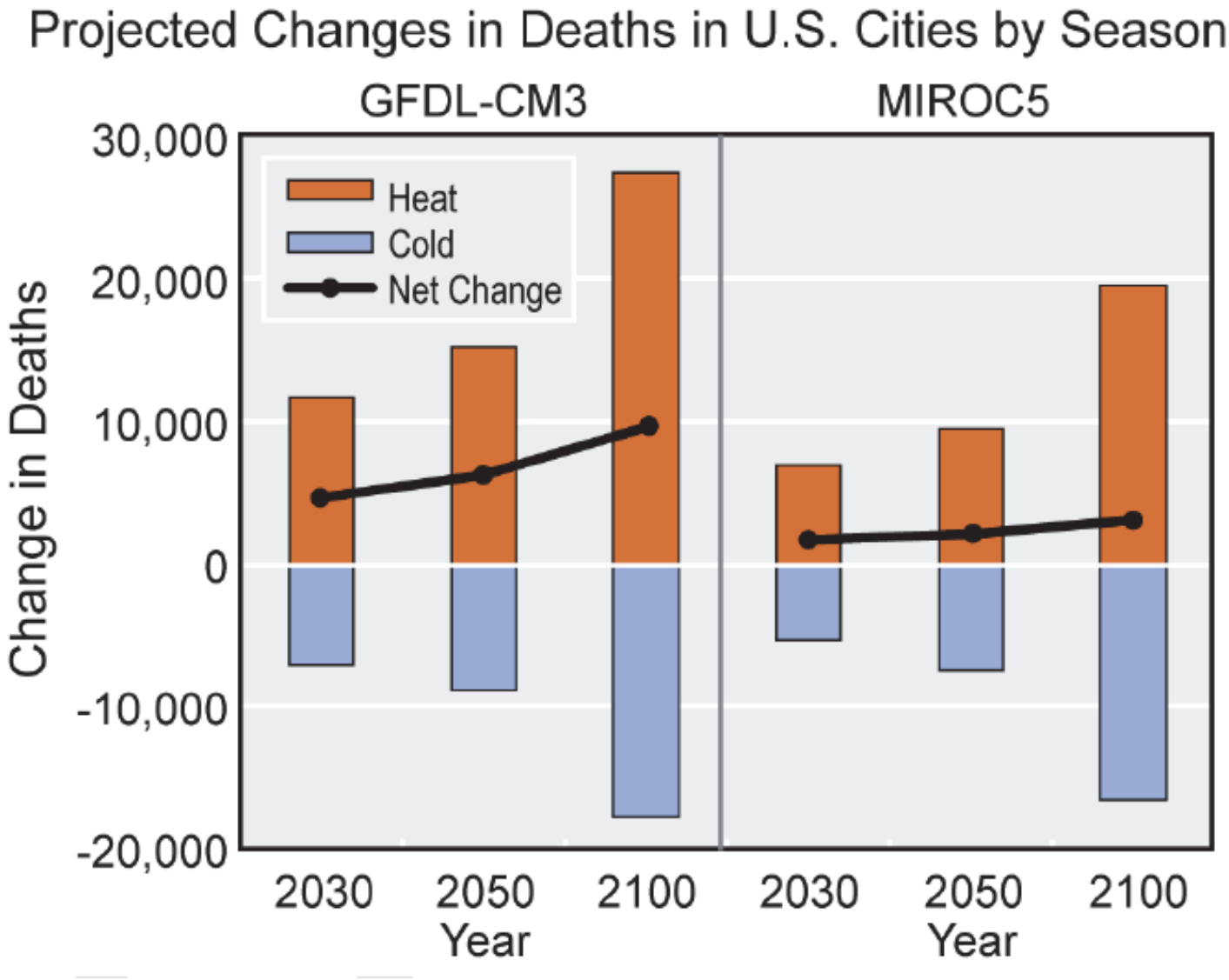
Source: WHO. http://www.who.int/mediacentre/factsheets/fs266/en/

European Heat Wave

- The summer 2003 European heat wave caused more than 30,000 excess deaths.
- Hottest summer in Europe since 1500 AD.



Sources:
WHO.
http://www.who.int/mediacentre/factsheets/fs266/en/
Stott PA, Stone DA, & Allen MR. Human Contribution to European Heatwave of 2003. *Nature*. 2004. 432; 610-614


Projected Changes in Deaths in U.S. Cities by Season
GFDL-CM3
MIROC5
Heat
Cold
Net Change
Change in Deaths
30,000
20,000
10,000
0
-10,000
-20,000
2030
2050
2100
Year

S.C. flood is 6th 1,000-year rain since 2010

Doyle Rice, USA TODAY 9:35 a.m. EDT October 6, 2015

South Carolinians are struggling to
recorded in parts of the state. USA

Running dry: How the drought is forging a new California

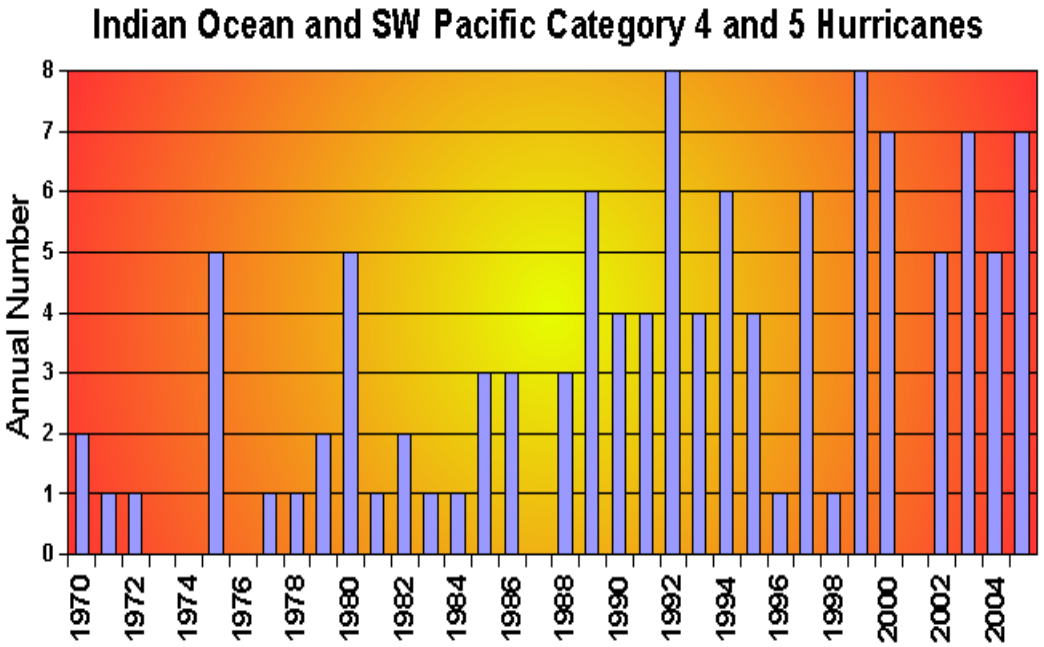
By Carolyn Lochhead | June 12, 2015 | Updated: July 24, 2015 3:24pm

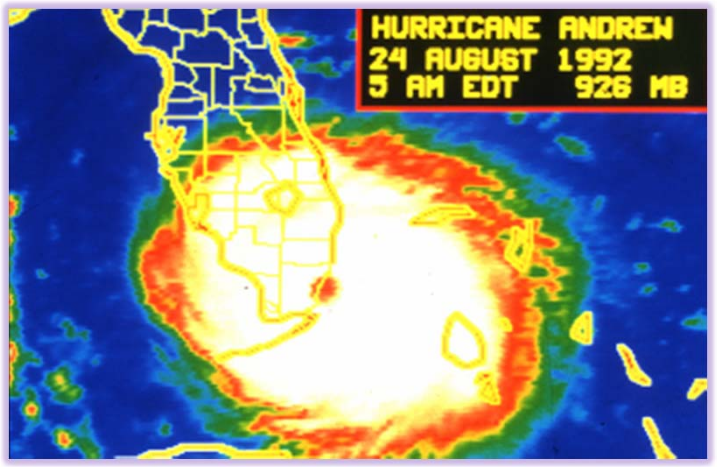
5

Californians are living through a slow-motion natural disaster, a four-year drought that is combining with record heat to challenge the state in unprecedented ways.

Tropical Cyclones

↑ sea-surface temperatures → ↑ tropical cyclone intensity and ↑ height of storm surges



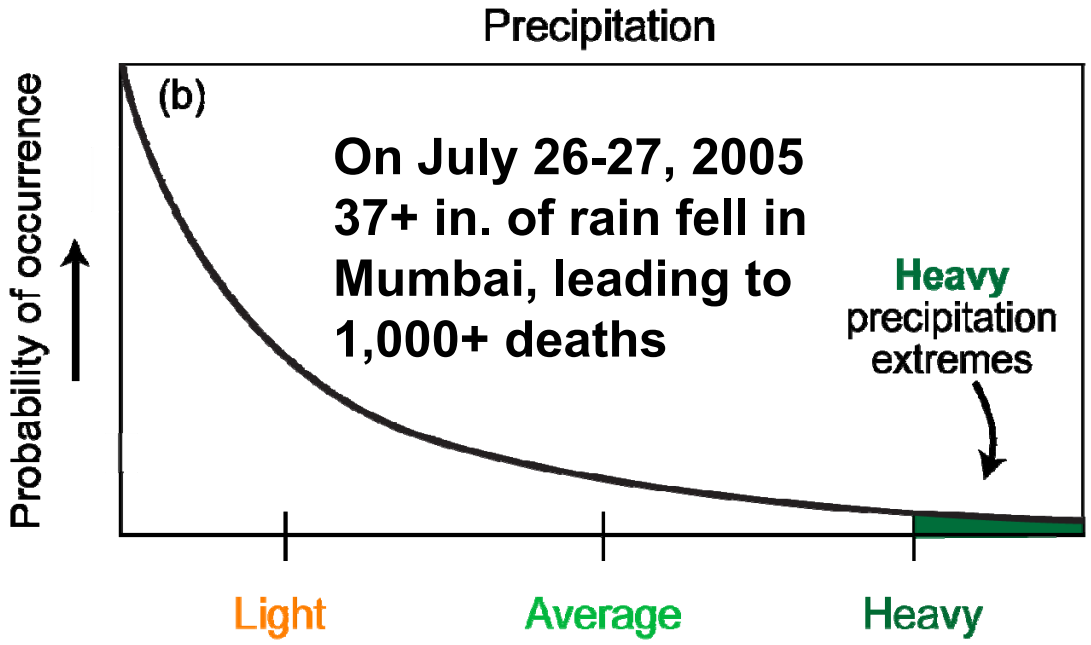


Ali, 1999

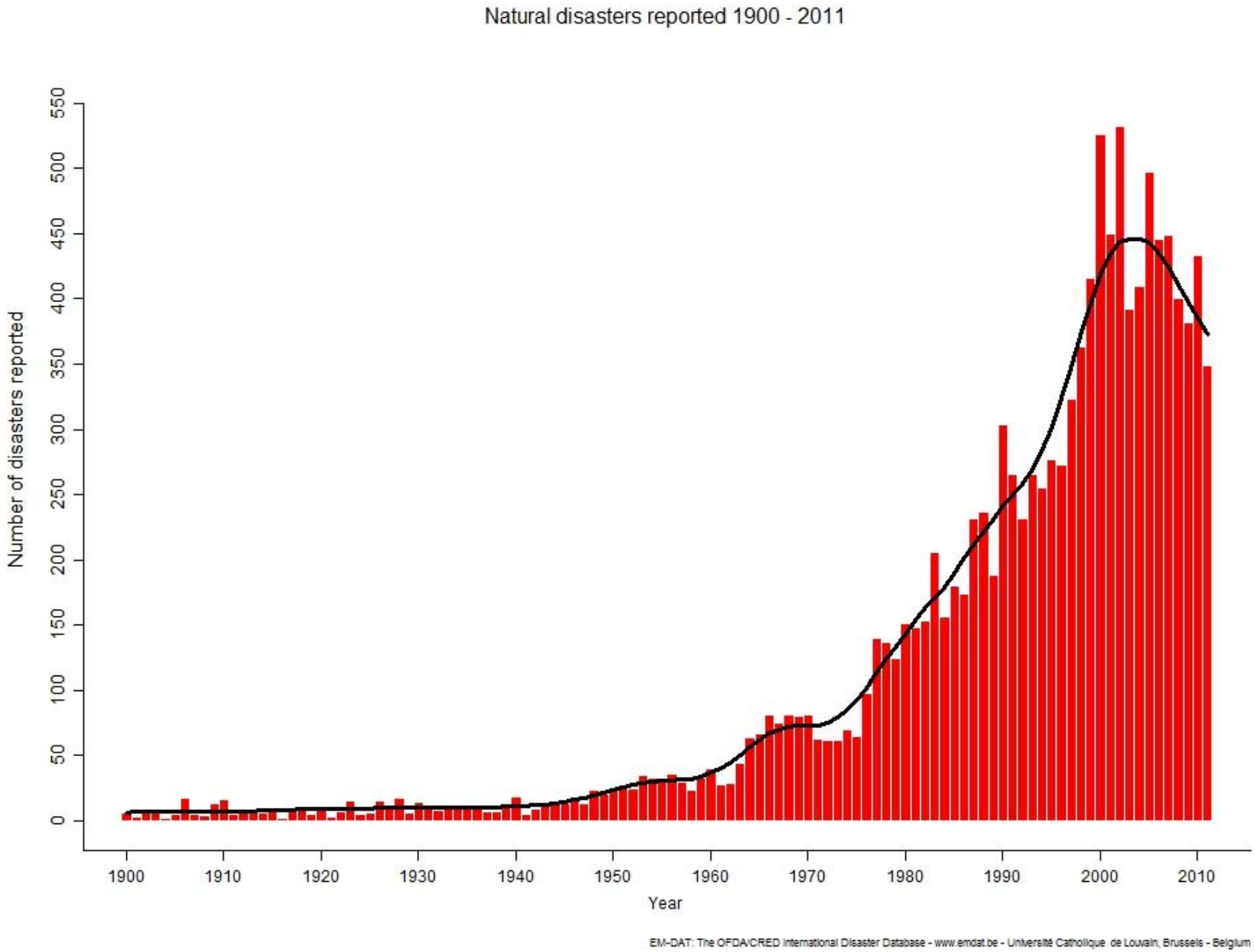
Images: NOAA.gov; www.weatherunderground.com

Extreme Precipitation Events

↑ frequency of more intense rainfall → severe floods, landslides, and debris and mud flows



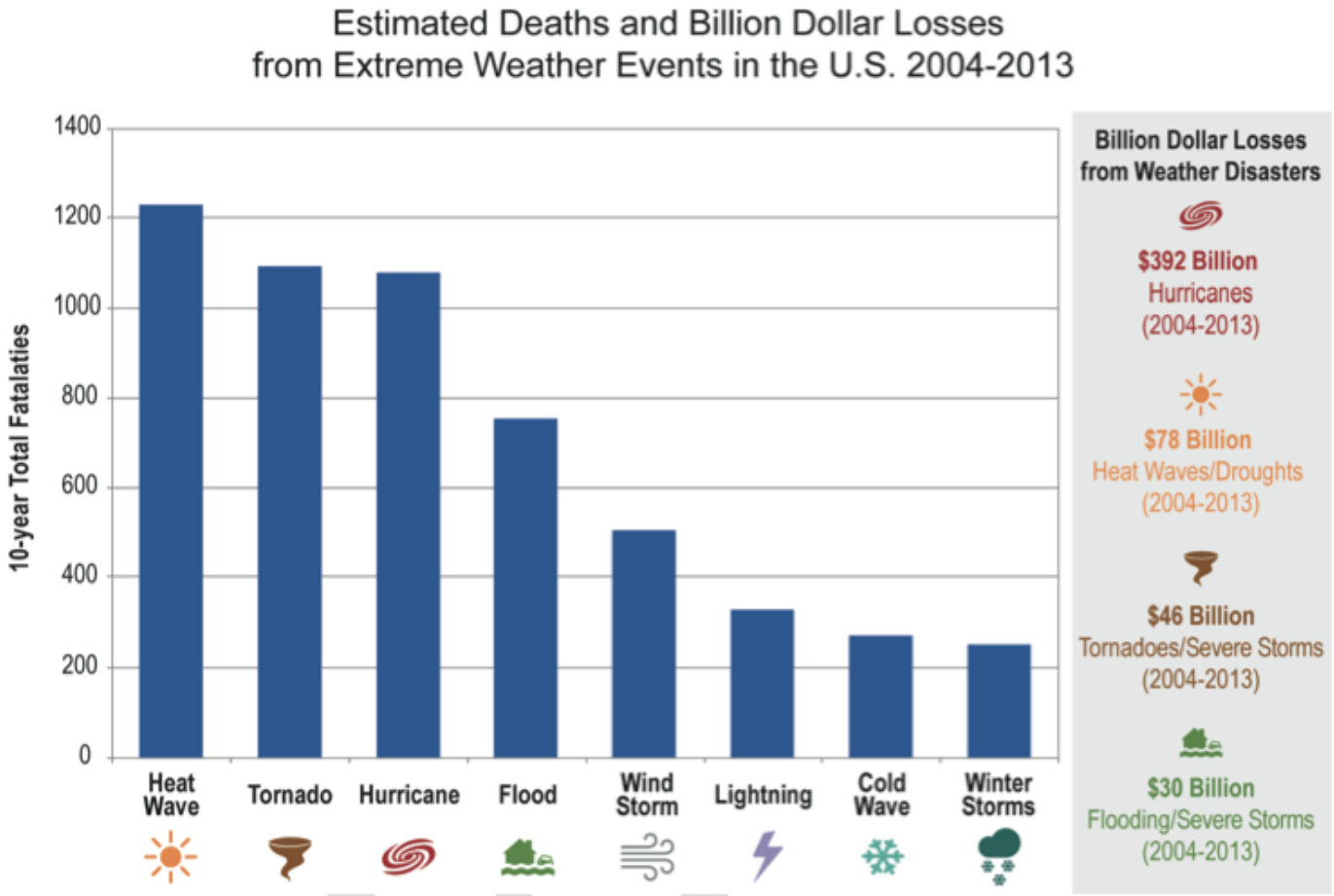
SCruz et al., 2007;
Image: Peterson et al., 2007b; news.bbc.co.uk



Source: www.emdat.be/natural-disasters-trends

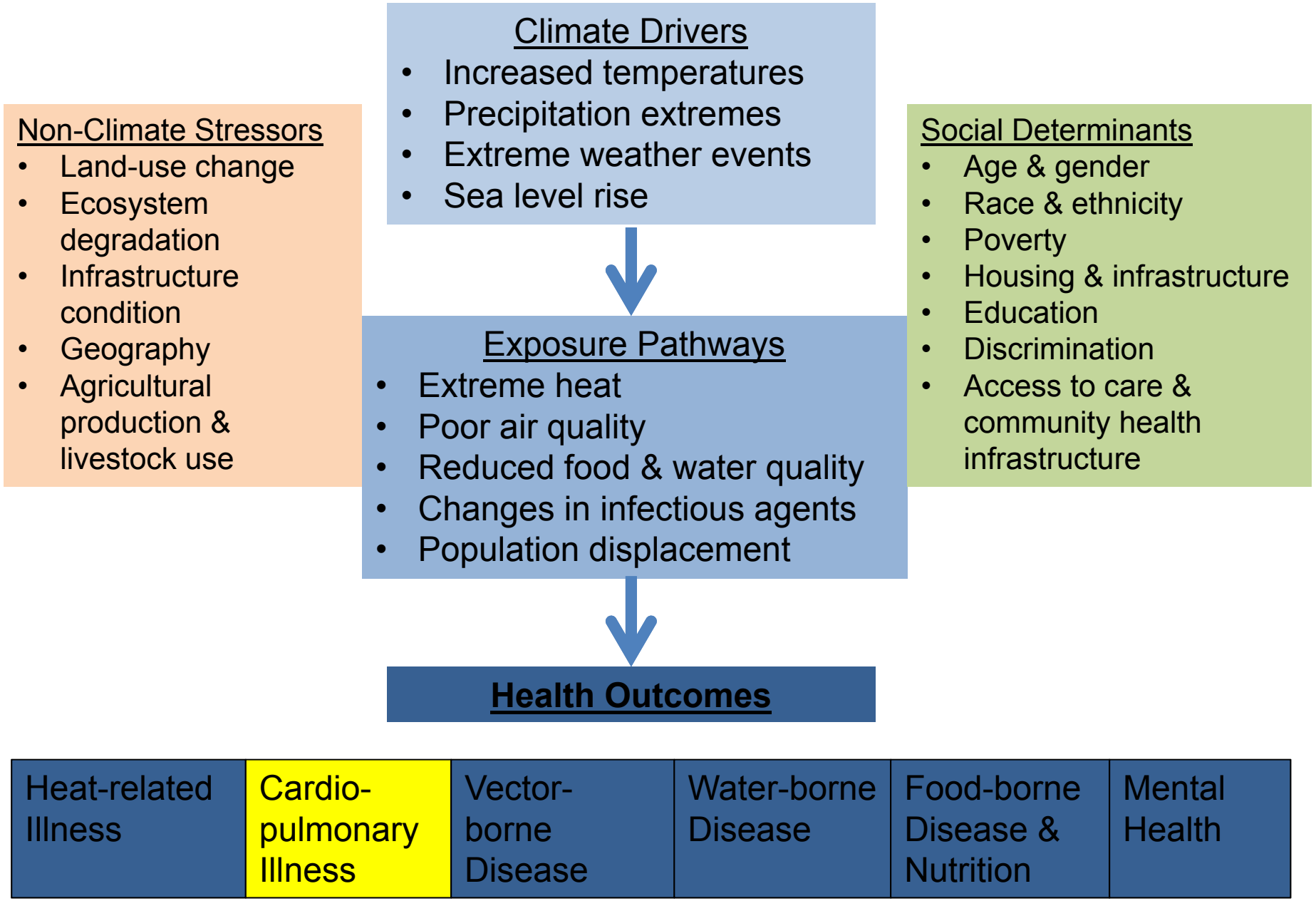
Cost of Natural Disasters

In 2014, the United States spent $25 billion for the economic and insured losses incurred from natural disasters.



Source: http://www.nytimes.com/interactive/2015/08/04/upshot/regional-natural-disasters.html?_r=0
Image: NOAA, 2015

Climate Change and Health



Climate change implication for air quality and respiratory illness

Modified weather patterns influence the level and location of outdoor air pollutants such as ground-level ozone and fine particulate matter

Droughts also tend to exacerbate respiratory illnesses through reduced air quality

- Soil drying
- Loss of vegetation
- Airborne particulate matter
- Dust storms
- Wildfires

Mississippi River. St. Louis, Missouri, 2012

Source: WHO. http://www.who.int/mediacentre/factsheets/fs266/en/

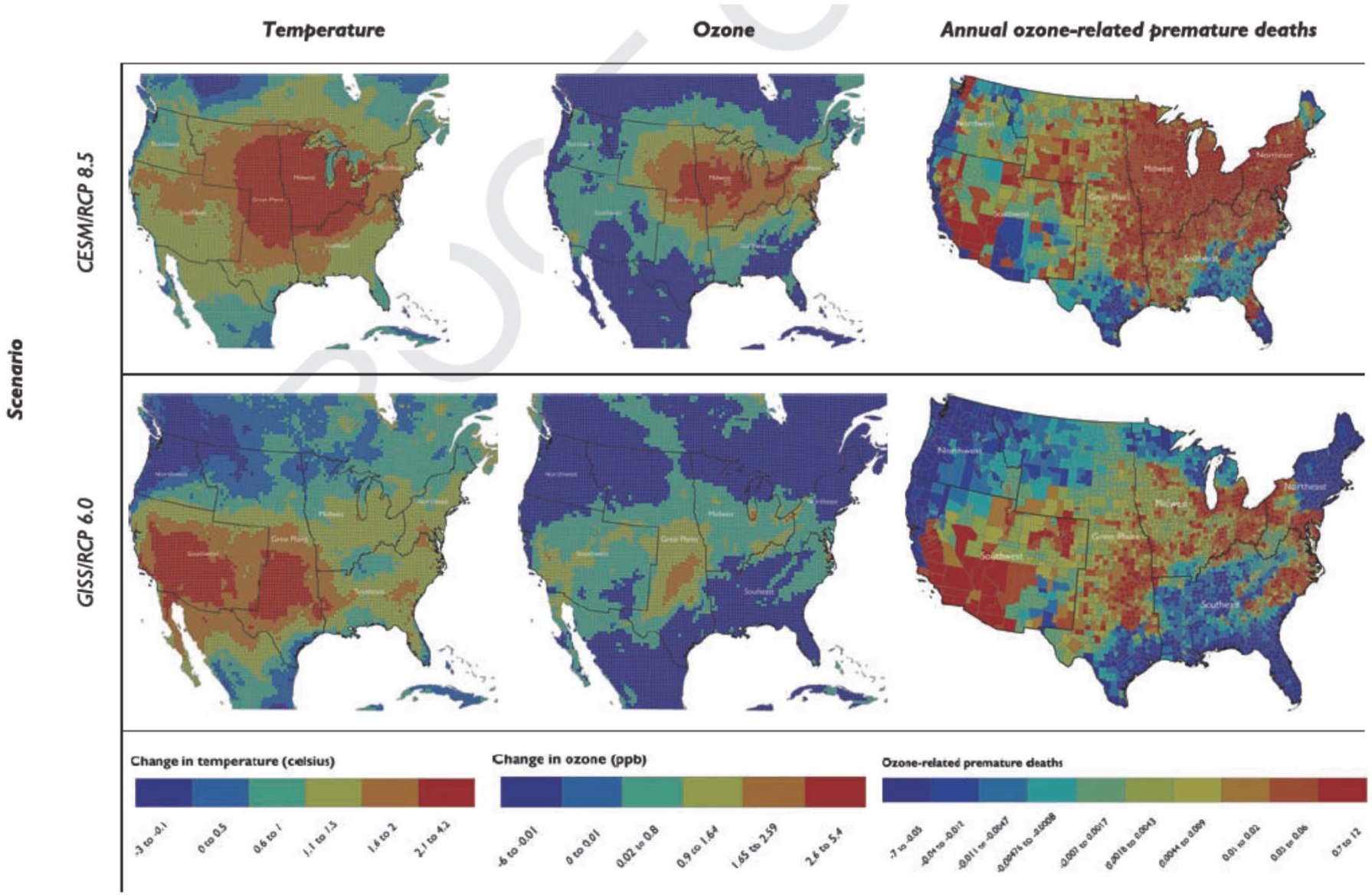
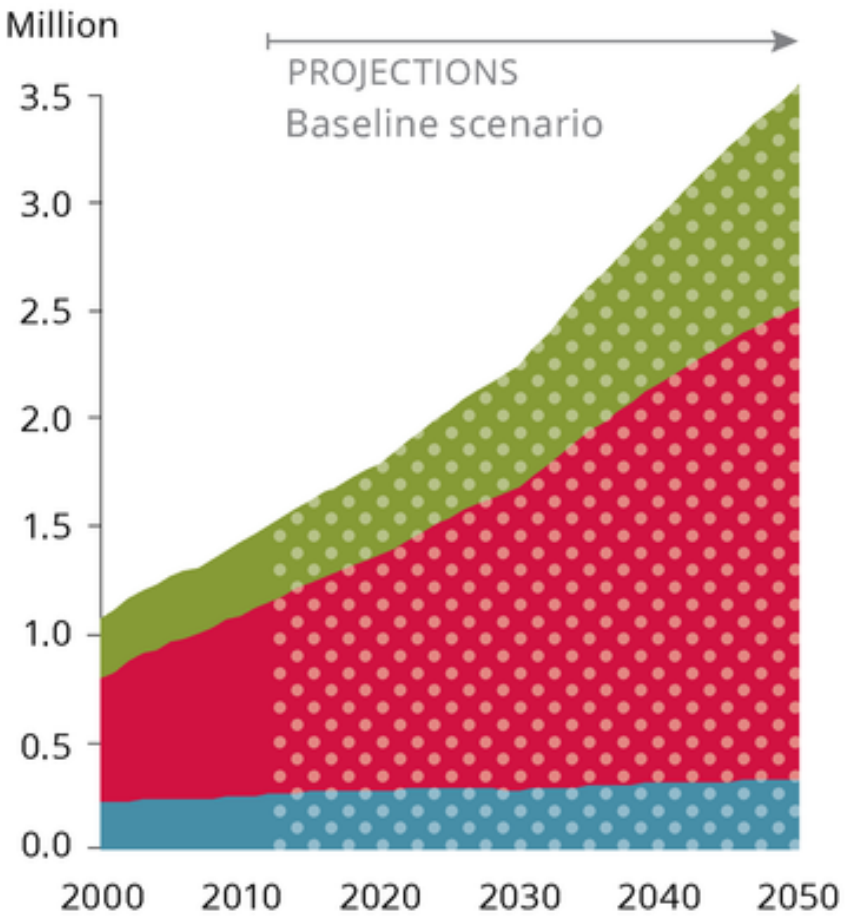
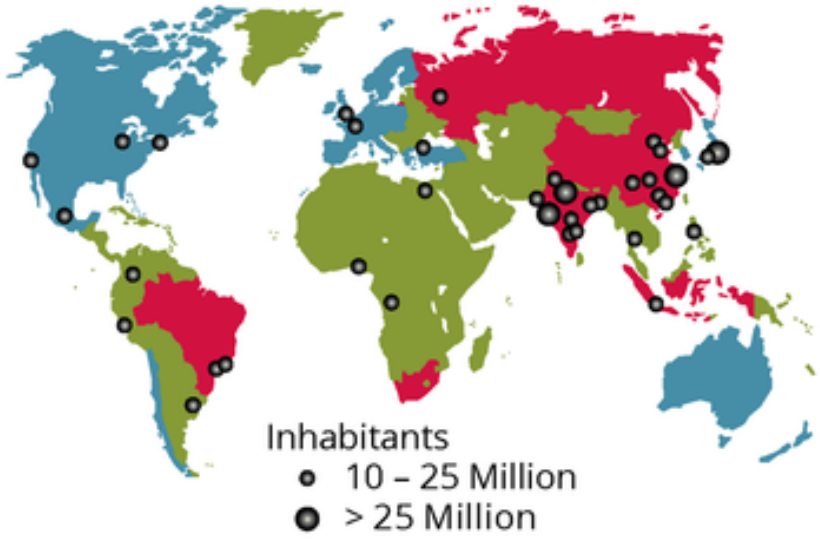


Figure 2. Projected change in average daily maximum temperature, seasonal average maximum daily 8-hr ozone, and ozone-related premature deaths in 2030.

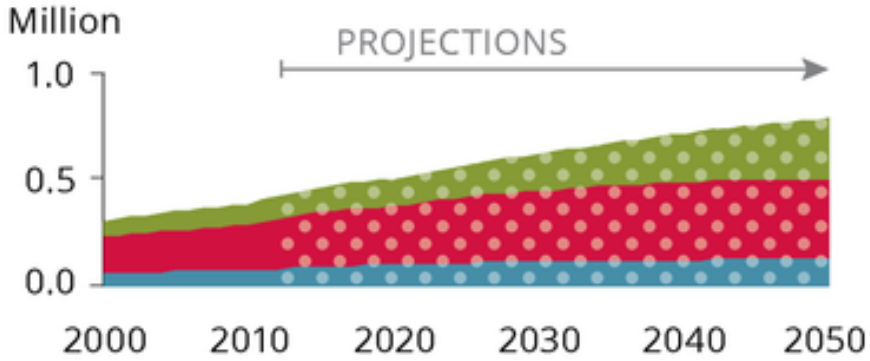
World premature deaths from exposure to particulate matter



Megacities of 2025



World premature deaths due to ozone pollution



OECD countries
BRIICS countries
Rest of the world

Direct Effects of Hydrologic Extremes

↑ drier climates → forest fires and smoke

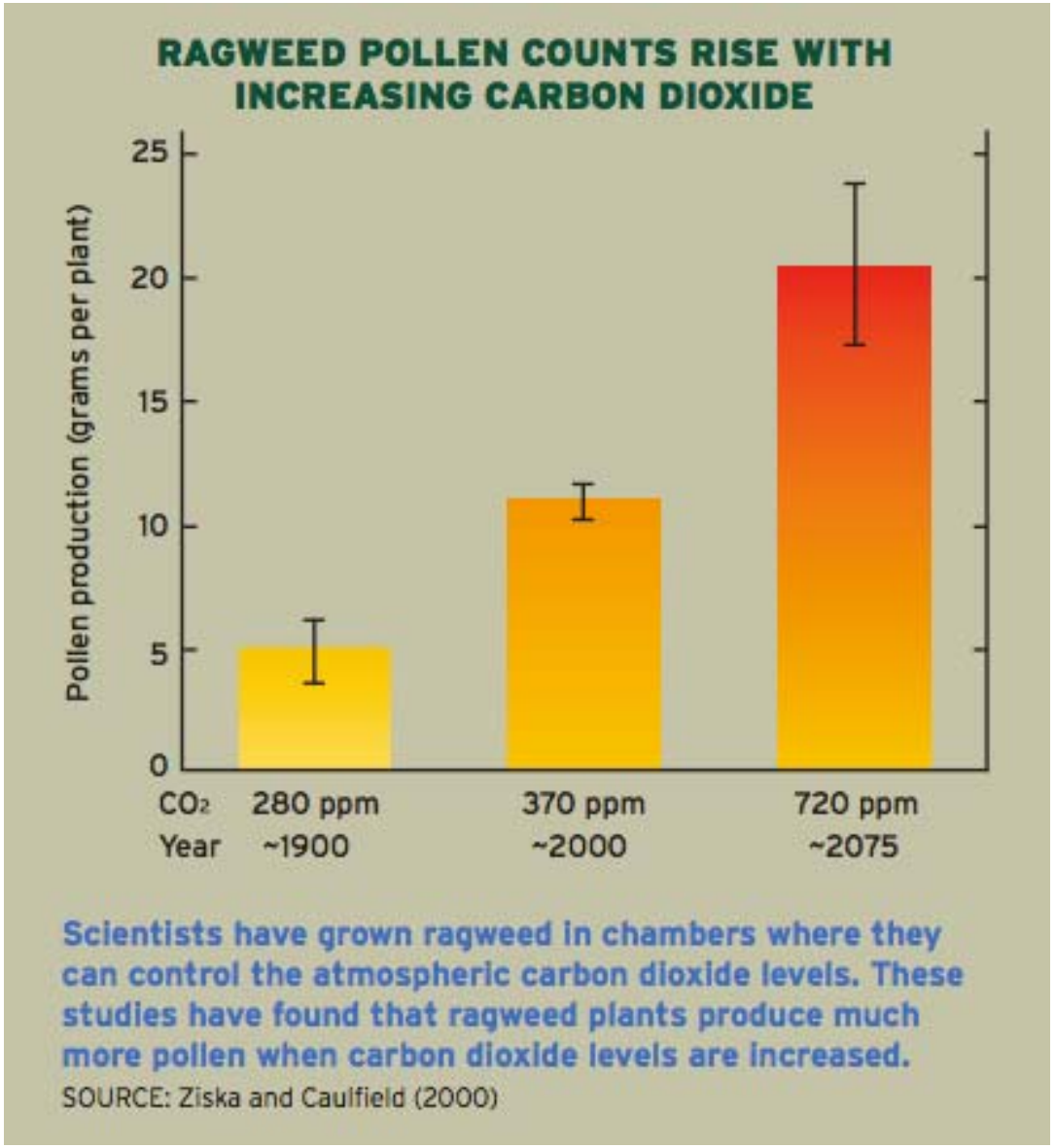
Vulnerable Populations:

- Young Children
- Elderly
- Pregnant Women
- People with pre-existing respiratory and cardiac diseases

Ziska et al., *J Allerg Clin Immunol* 2003;111:290-95
Image: www.abcnews.net/au

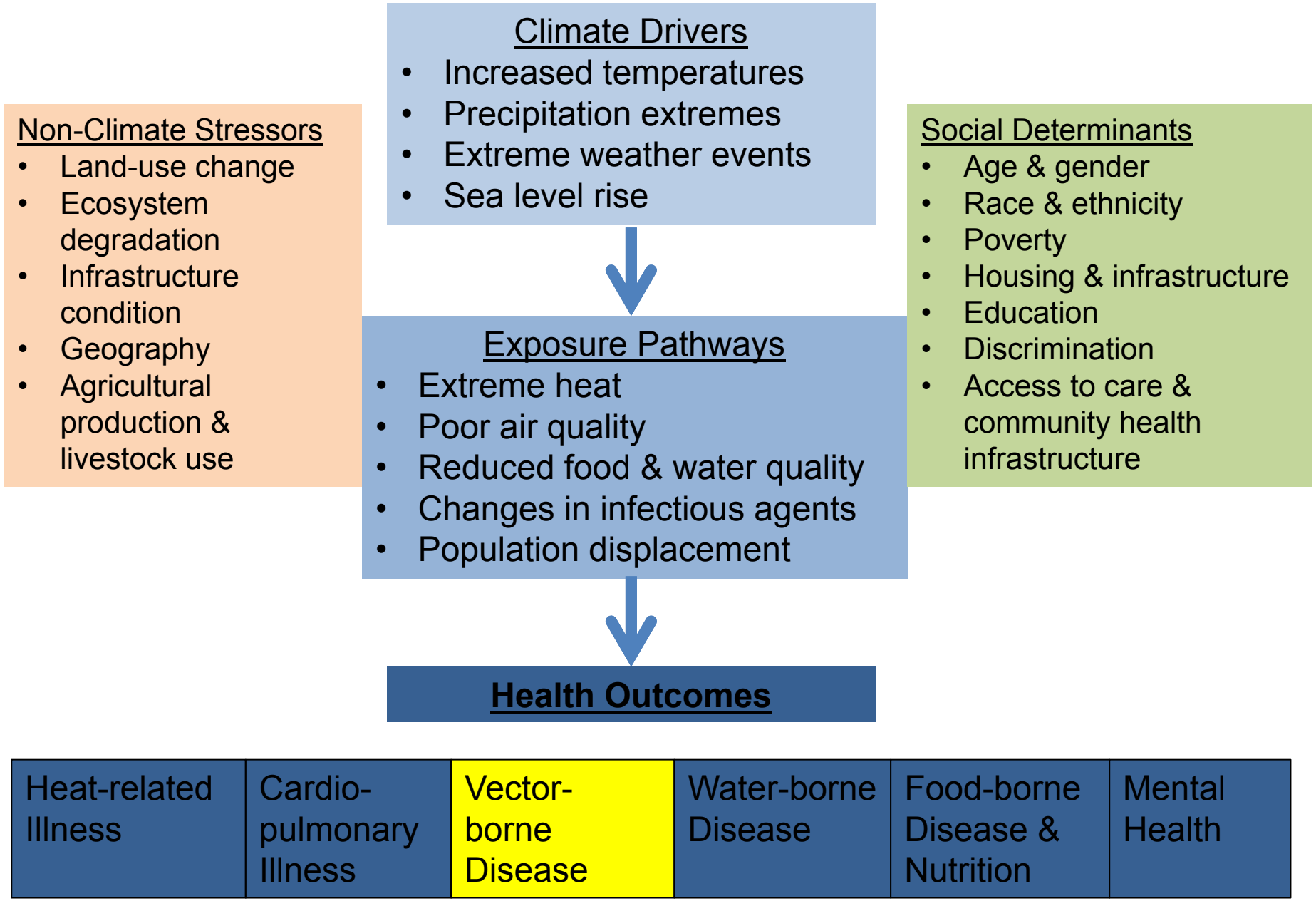
Greater Pollen Counts

- Pollen and other aeroallergen levels are higher in extreme heat.
- Longer growing seasons under a warmer climate allow for bigger ragweed plants that produce more pollen later into the fall.
- More airborne allergens could mean more asthma attacks.
- Asthma affects around 300 million people worldwide



Sources:
WHO. http://www.who.int/mediacentre/factsheets/fs266/en/
National Wildlife Foundation.
http://www.nwf.org/pdf/Reports/NWF_AllergiesFinal.pdf

Climate Change and Health




HEALTH PROFESSIONALS AND SCIENTISTS WARN OF SPREADING INFECTIOUS DISEASES.
Global Warming's greatest threat may also be the smallest.

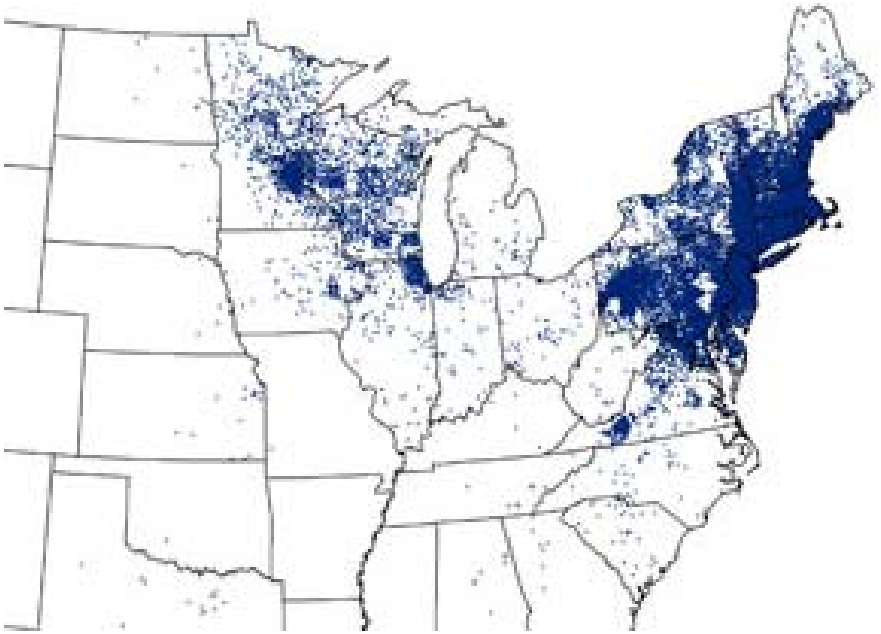
The Impact of Climatic Factors on Vectorborne Zoonotic Diseases

- Climatic factors (e.g., temperature, moisture) affect the distribution and abundance of vectors and vector-borne pathogens
- Climatic factors affect disease transmission efficiency (vector competence)
- Climatic variables and perturbations can affect disease occurrence patterns

Changes in Lyme Disease Case Distribution, United States

2001

2013



Source: CDC, http://www.cdc.gov/lyme/stats/index.html

Climatic perturbations can affect disease occurrence patterns

Plague Trophic Cascade Model

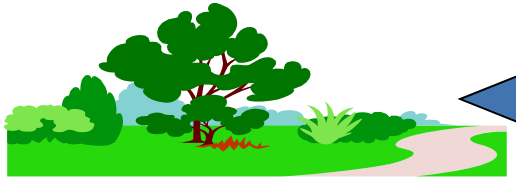
Effects of Increased Precipitation

Feb. – March (Major effect)

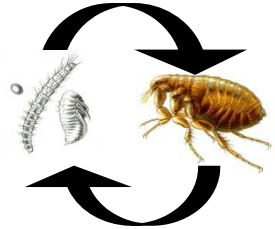
July – Aug (Minor effect)

Feb. – March (Minor effect)

Increased rodent food sources



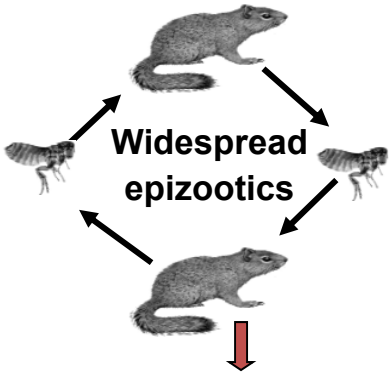
Increased soil moisture and available hosts



Increased rodent survival and reproduction

Cool summer, 15–18 mos after first wet winter (Major effect)

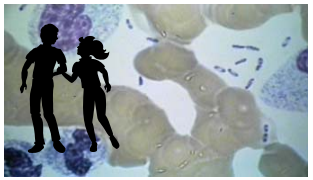
Increased flea survival and reproduction



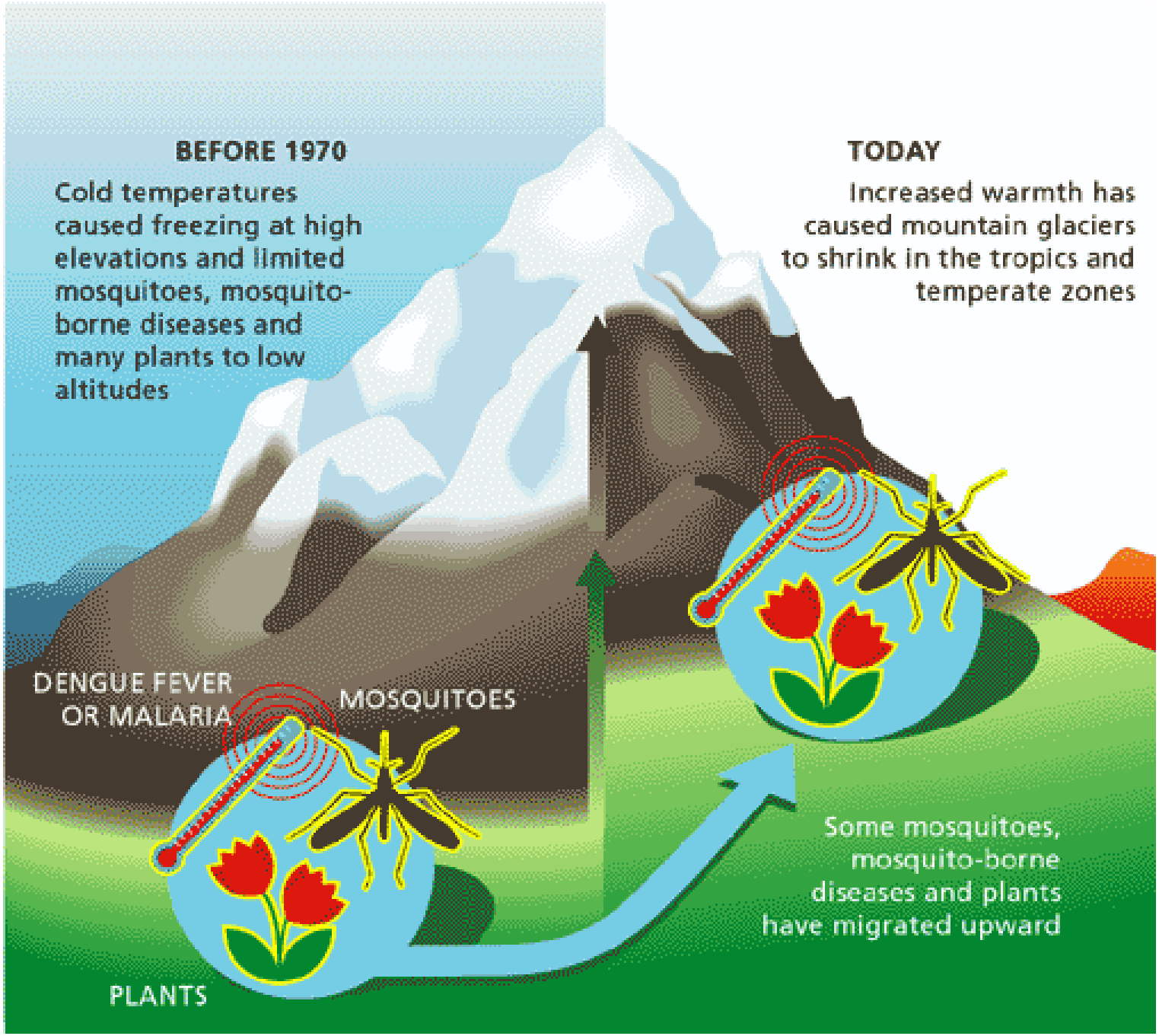
High rodent densities favor epizootic spread

Cool temperatures favor survival of infected fleas

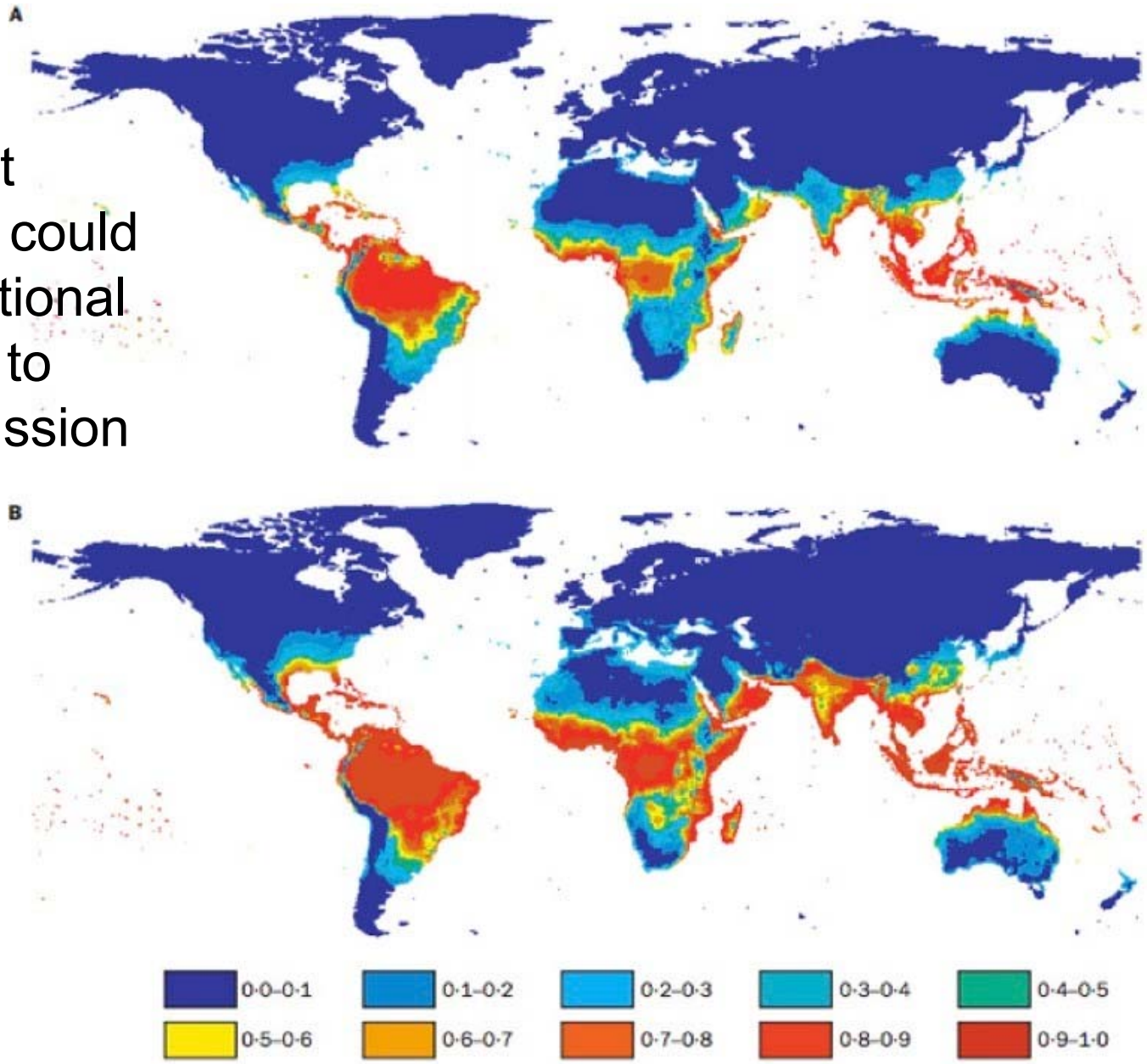
Increased human plague risks



Enscore et al. 2002 AJTMH 66: 186-196


BEFORE 1970
Cold temperatures caused freezing at high elevations and limited mosquitoes, mosquito-borne diseases and many plants to low altitudes
TODAY
Increased warmth has caused mountain glaciers to shrink in the tropics and temperate zones
DENGUE FEVER OR MALARIA
MOSQUITOES
PLANTS
Some mosquitoes, mosquito-borne diseases and plants have migrated upward

Studies suggest climate change could expose an additional 2 billion people to dengue transmission by 2080.



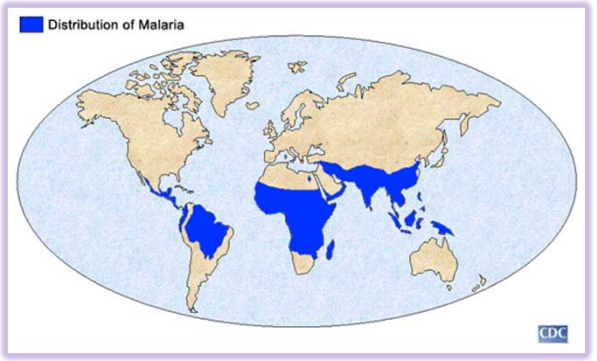
Estimated Population at Risk for Dengue Fever in 1990 (A) and 2085 (B) Based on Climate Data from 1961 to 1990

Dr. Simon Hales (http://image2.thelancet.com/extras/01art11175web.pdf) /The Lancet

Source: WHO. http://www.who.int/mediacentre/factsheets/fs266/en/

Projected Effects of Climate Change: Malaria

- Small, Goetz and Hay (2003) – Incidence in Africa would increase in some areas and decrease in others
- Tanser, Sharp and le Sueur (2003) – 16-28% increase in person-months of exposure
  - Little latitudinal change in risk, most change occurs in existing areas or with altitude
- Reiter et al. (2004) – Stressed local effects and other factors that could be confounded with climate effects
- Hay et al. (2002) – No association between long-term meteorological trends and malaria outbreaks in East Africa
- Dev (2007) – No association between rainfall and annual incidence of malaria in India.



Tropical Disease Burden
(Diseases Transmitted by Insects)

Data from the World Health Organization (2004)

Disease World Health Report	DALYs (Thousands)*	Deaths (Thousands)
Malaria	46,486	1,272
Lymphatic filariasis	5,777	0
Afr. Trypanosomiasis	1,525	48
Leishmaniasis	2,090	51
Onchocerciasis	484	0
Chagas disease	667	14
Dengue	616	19
TOTAL	57,643	1,404

* Disability Adjusted Life Years - the number of healthy years of life lost due to premature death and disability. Numbers reflect an overall 12% increase in DALYs and 20% mortality increase since 2001.

Droughts

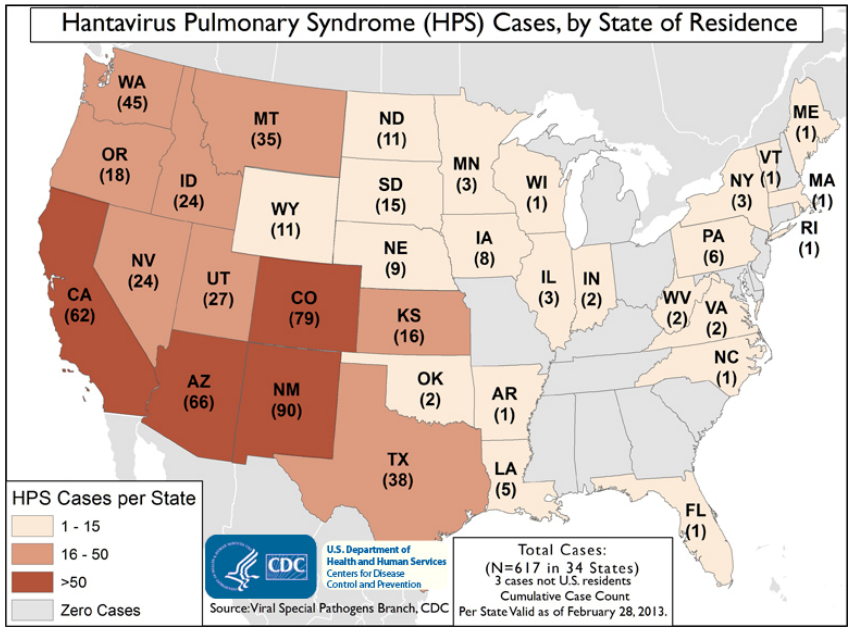
Reducing water quantity can reduce water quality from increased pollutant concentration, stagnation, and higher temperatures than can encourage pathogen growth.

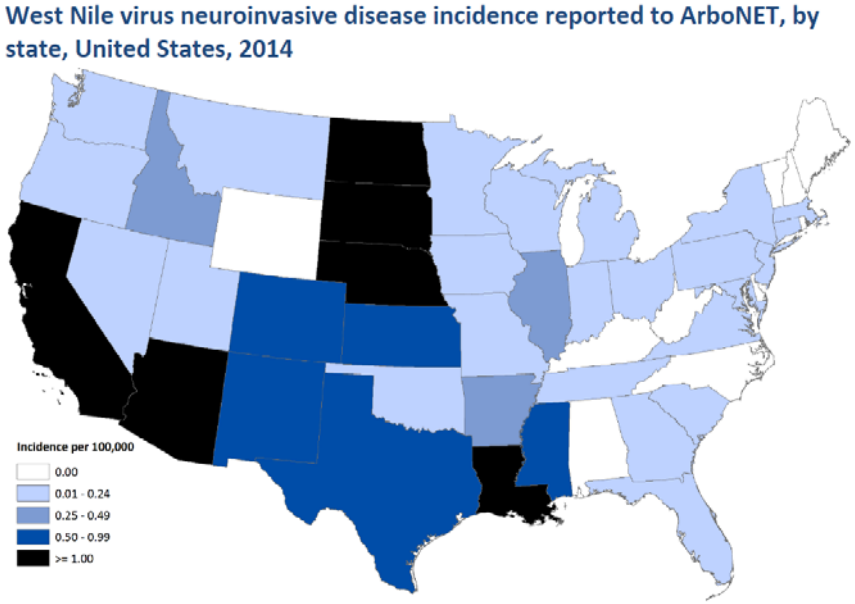
Drought has also increased the incidence of West Nile virus disease.

- During droughts mosquitos find the remaining water sources and transmit the virus to other species

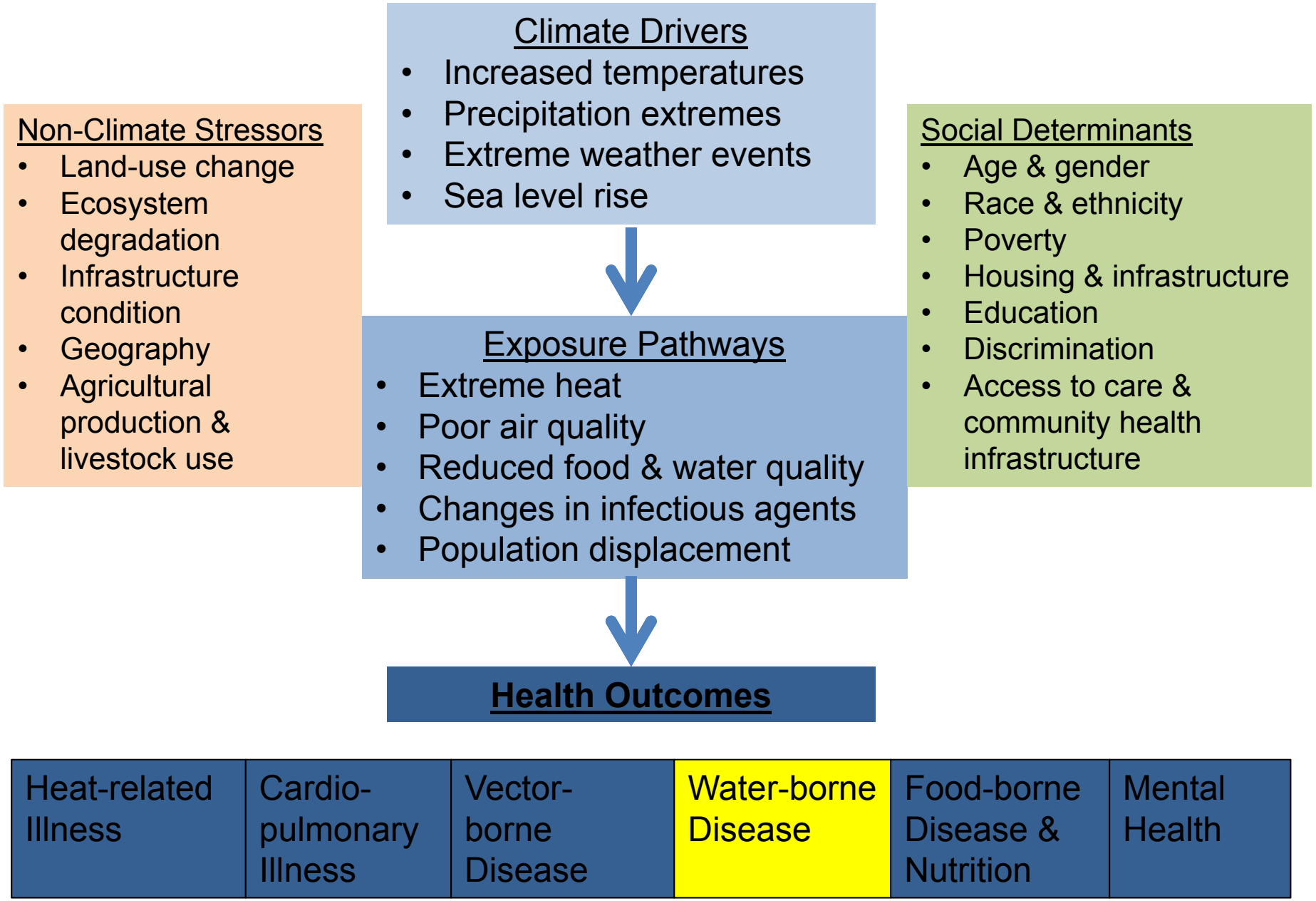
Droughts followed by periods of heavy rainfall have been associated with an increase in rodent populations

- Could potentially increase prevalence of hantavirus





Climate Change and Health



Water-Related Illnesses

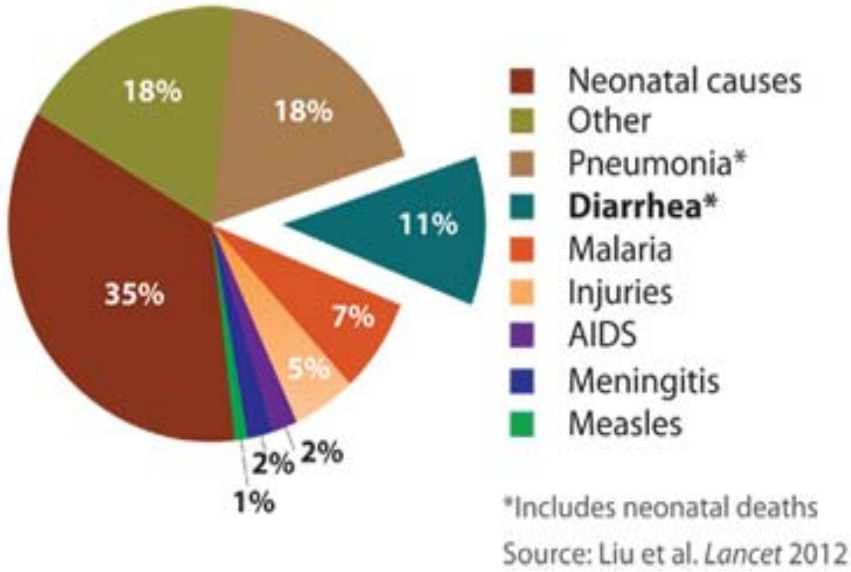
Water-related illnesses can be caused by pathogens, such as:

- Bacteria, virus, and protozoa
- Toxins produced by harmful algae and cyanobacteria
- Chemical introduced into the environment by humans

Increasingly variable rainfall patterns are likely to affect the supply of freshwater

Lack of safe water can compromise hygiene and increase the risk of diarrheal disease, which kills almost 600,000 children under 5, every year.

Between the year 2030 and 2050, climate change in expected to cause an additional 48,000 deaths per year due to diarrhea.



Diarrhea kills more children than malaria, measles, and AIDS combined. Proportional distribution of cause-specific deaths among children under five years of age, 2012 (excluding neonatal deaths)

Sources:

1. WHO. http://www.who.int/mediacentre/factsheets/fs266/en/
2. CDC. http://www.cdc.gov/healthywater/global/diarrhea-burden.html

Elevated Sea Surface Temperatures

Elevated sea surface temperatures associated with climate change will increase human exposure to water contaminants in food.

Warmer water in Alaska from 1997-2004 was associated with an outbreak of *Vibro parahaemolyticus* in 2004.

Warmer waters associated with Cholera outbreaks

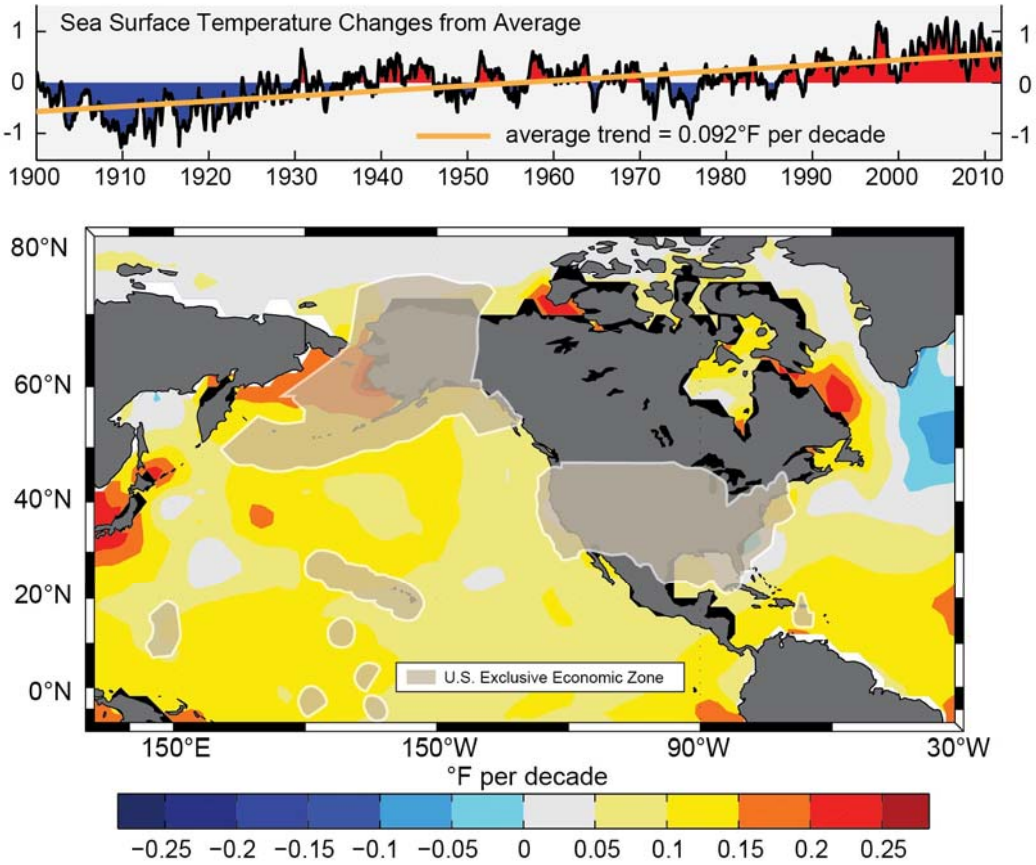
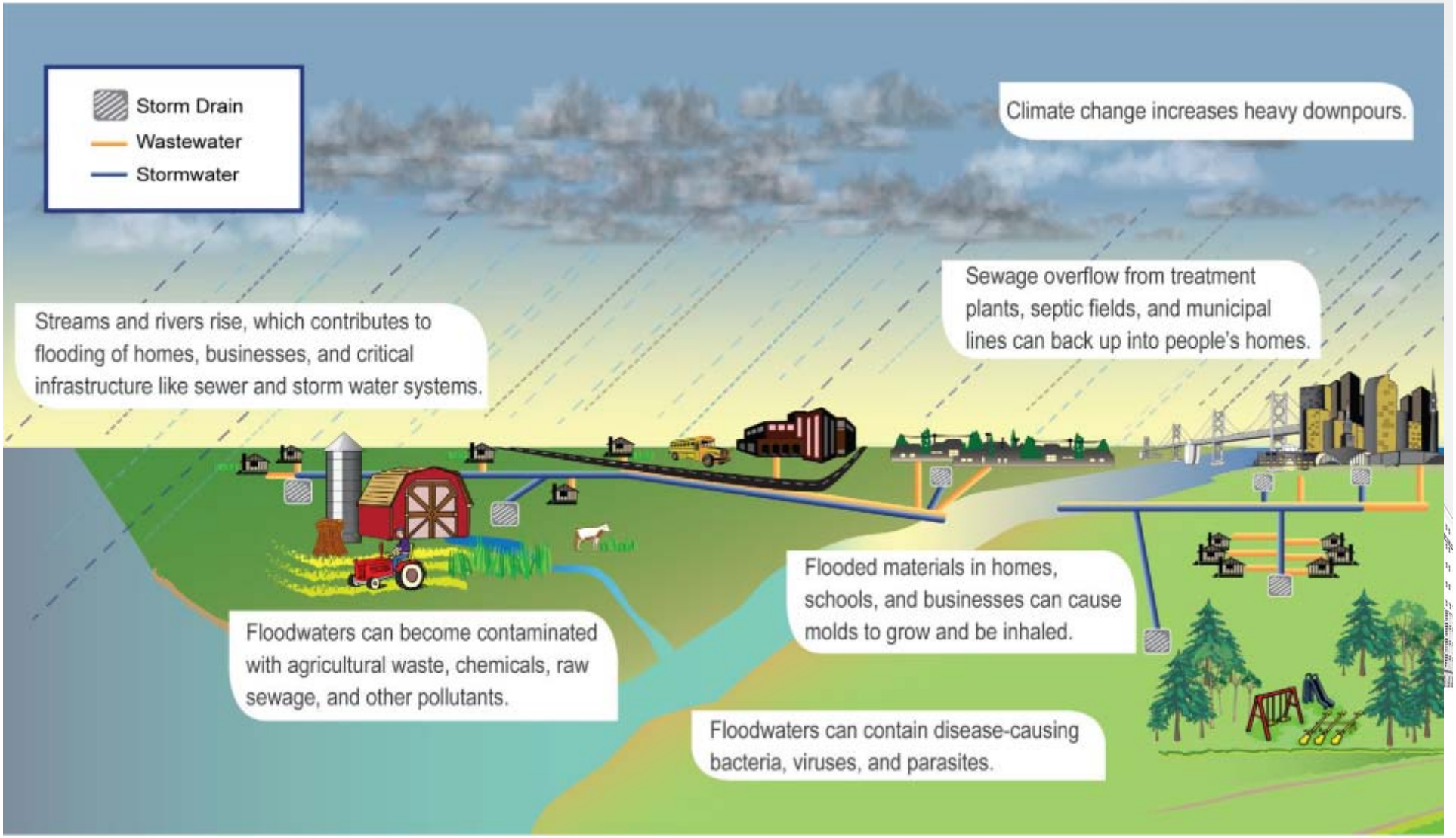


Image Source: http://nca2014.globalchange.gov/report/regions/oceans

Source: McLaughlin, J. A., A. DePaola, C. A. Bopp, K. A. et al, 2005: Outbreak of *Vibrio parahaemolyticus* gastroenteritis associated with Alaskan oysters. *The New England Journal of Medicine*

Heavy Downpours Are Increasing Exposure to Disease



Hydrologic Extremes and Waterborne Disease

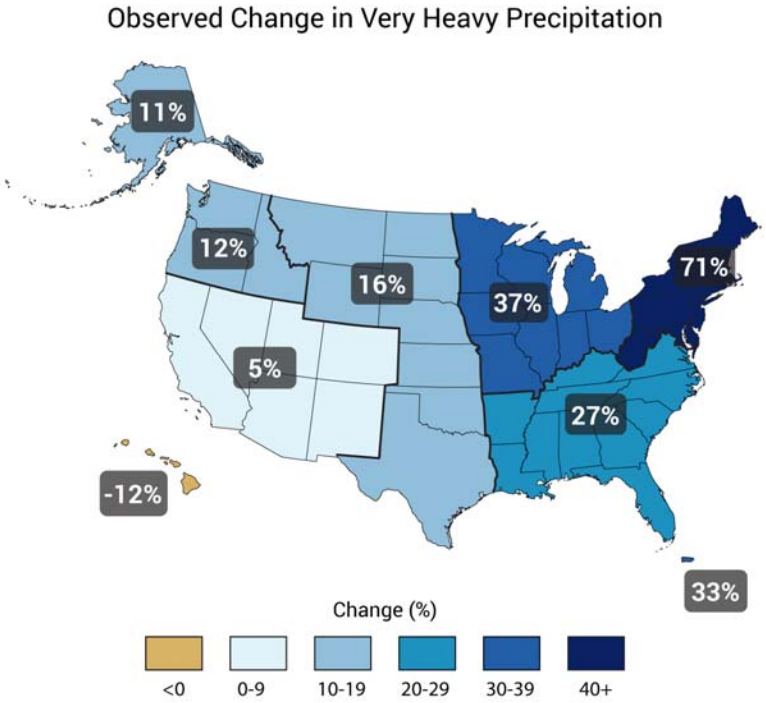
Milwaukee 1993:

- Cryptosporidiosis epidemic
- 405,000 cases, 54 deaths
- Preceded by heaviest rainfall in 50 years (Curriero et al., 2001)
- $31.7M in medical costs
- $64.6M in lost productivity

Corso et al., 2003

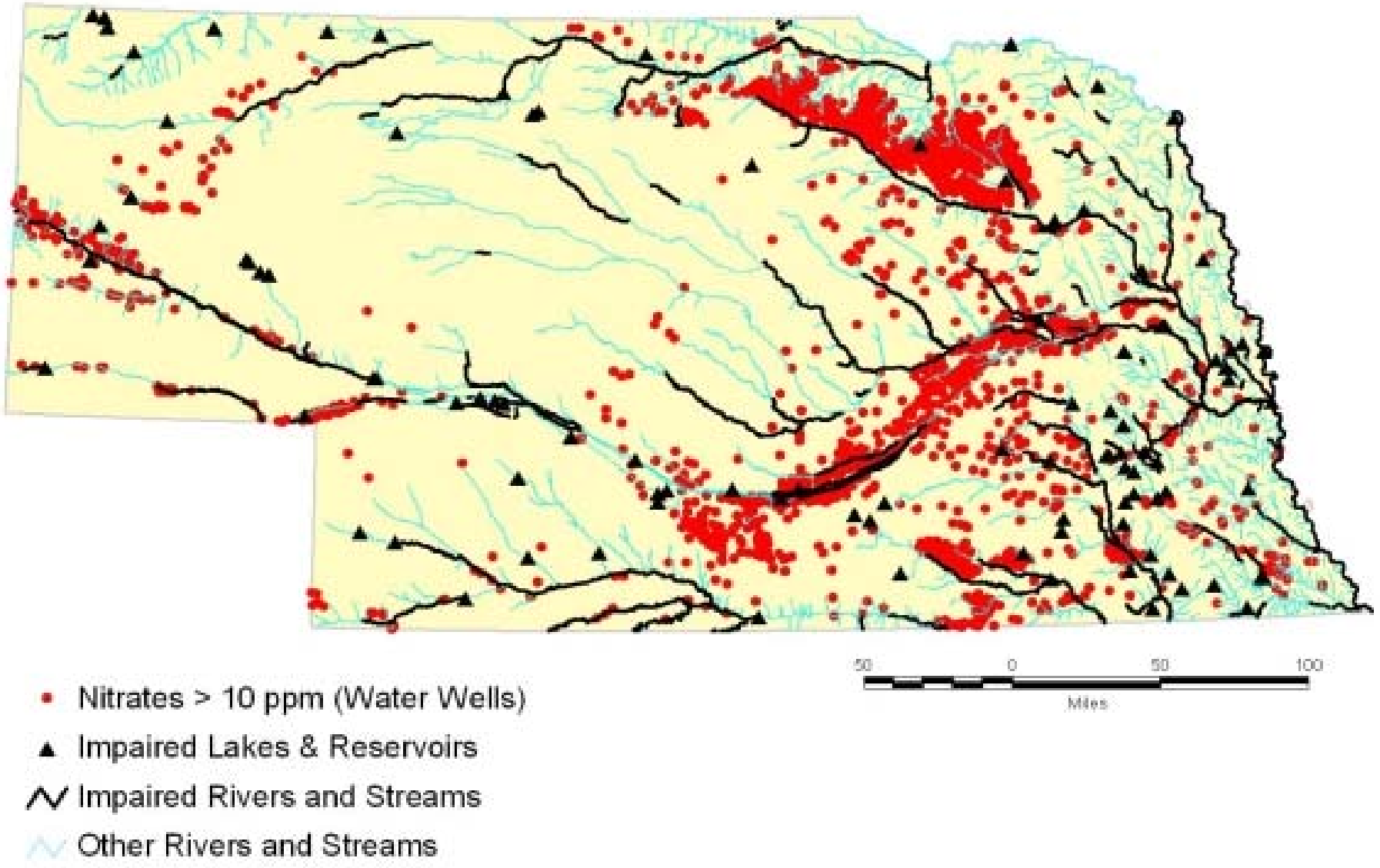
Intense Rainfall is Increasing in the Great Plains

Increases the risk of failure of, or damage to, water infrastructure for drinking water, wastewater, and stormwater, thus increasing risk of exposure to water-related pathogens, chemicals, and algal toxins.



Source: http://nca2014.globalchange.gov/highlights/overview/overview

Water Contamination & Impairment Nebraska – NDEQ website 2014



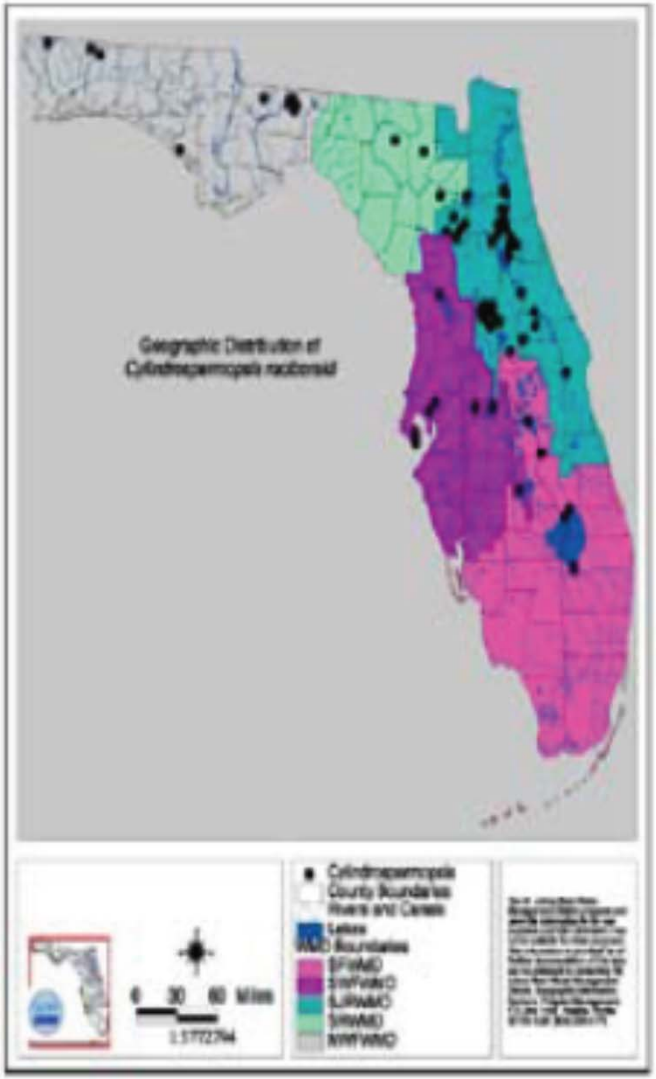
Source: Scott Holmes, Lincoln Lancaster County Health Department

Harmful Algal Blooms (Red Tides)

Enhanced by

- Increased water temps
- Nutrient runoff
- Upwelling events

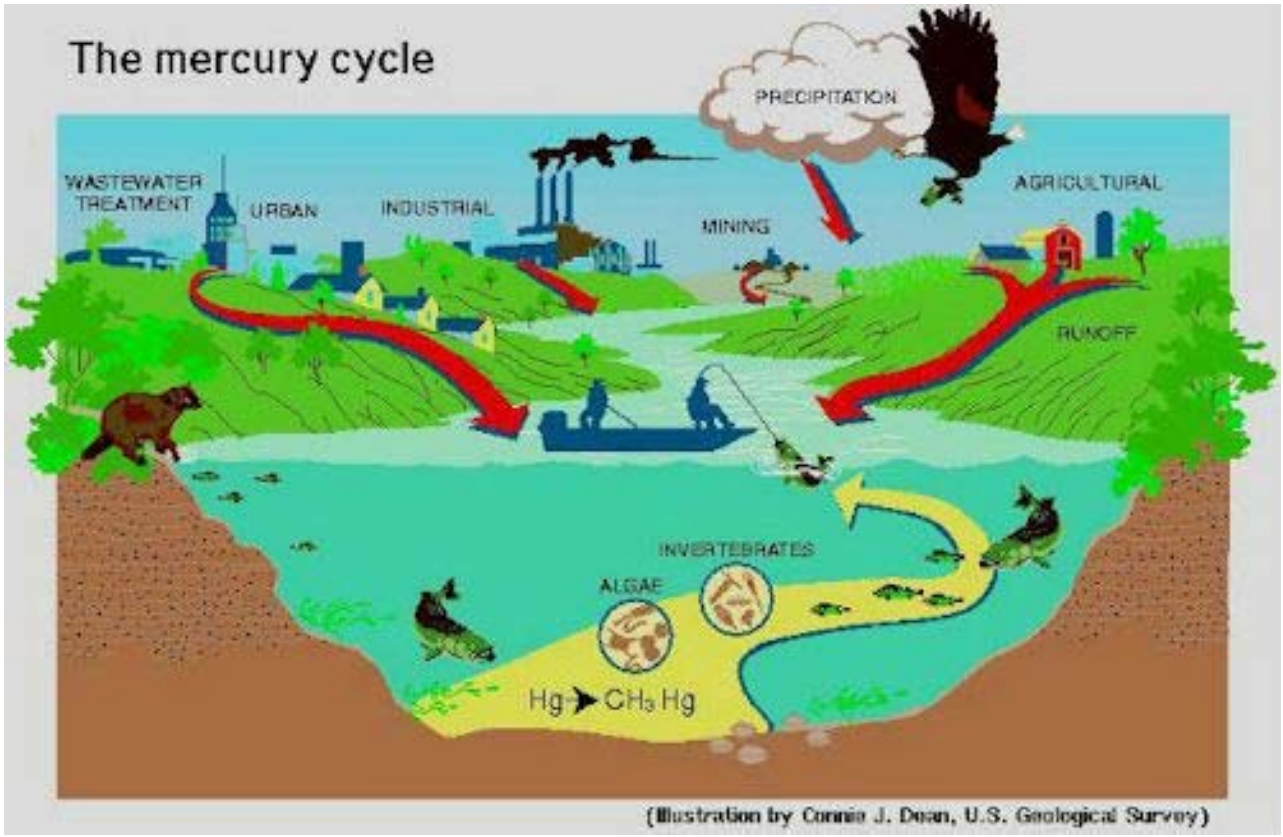
Figure 2. Distribution of the CyanoHAB, *Cylindrospermopsis raciborskii,* in Florida (Williams 2001, Fristachi et al. 2007). *C. raciborskii,* which produces potent hepatotoxins (Table 2), was originally found only in tropical areas but has recently spread to cooler regions.



Bioaccumulation of Methylmercury

Elevated water temperatures may lead to higher concentrations of methylmercury (a form of mercury that can be absorbed into the bodies of animals, including humans)

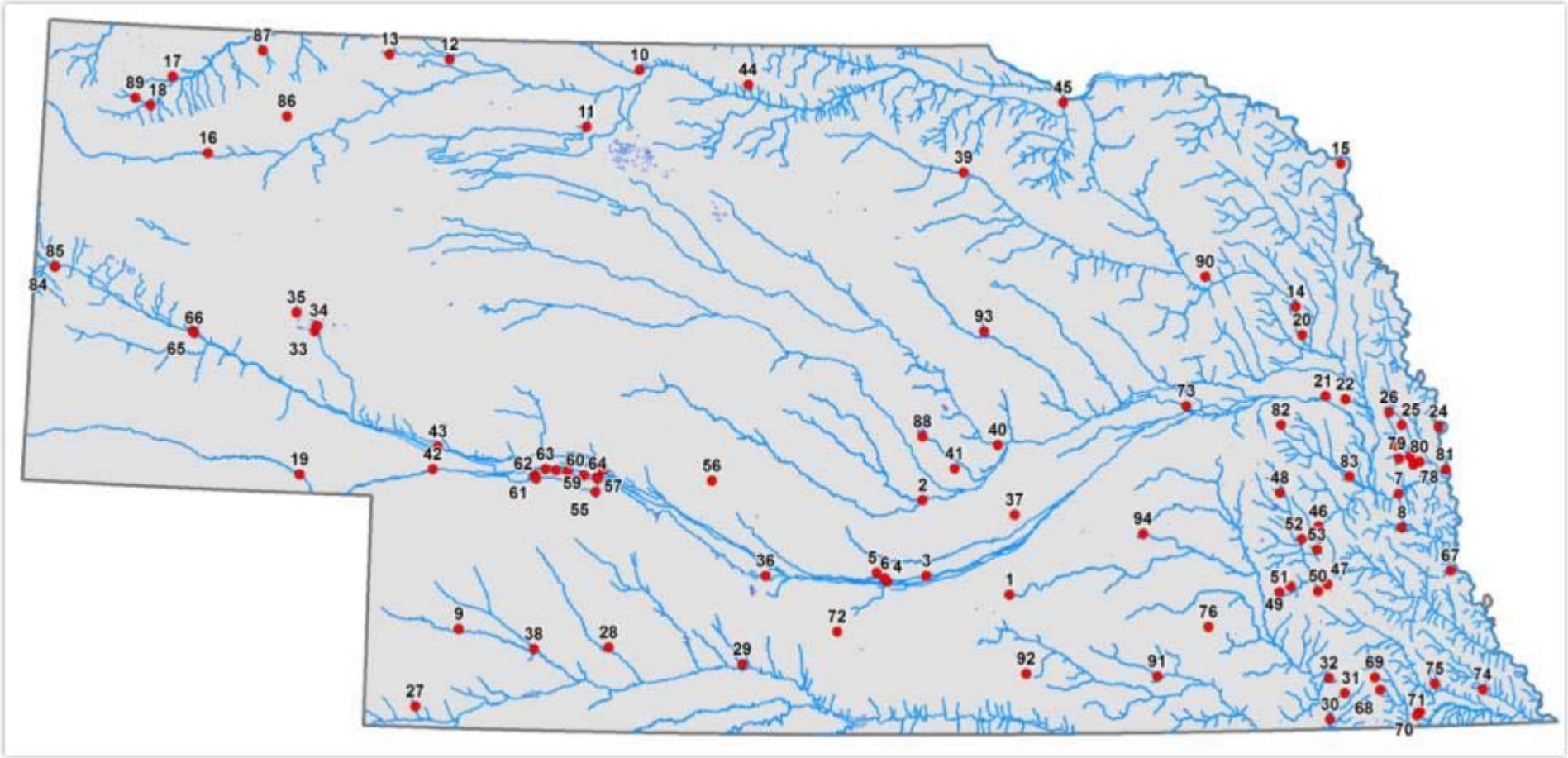
Methylmercury exposure can affect child development, particularly if exposed in-utero



Sources:

1. Dijkstra, J. A., K. L. Buckman, D. Ward, D. W. Evans, M. Dionne, and C. Y. Chen, 2013: Experimental and natural warming elevates mercury concentrations in estuarine fish.
2. Gonzalez-Estecha, M., and Coauthors, 2014: [The effects of methylmercury on health in children and adults; national and international studies].

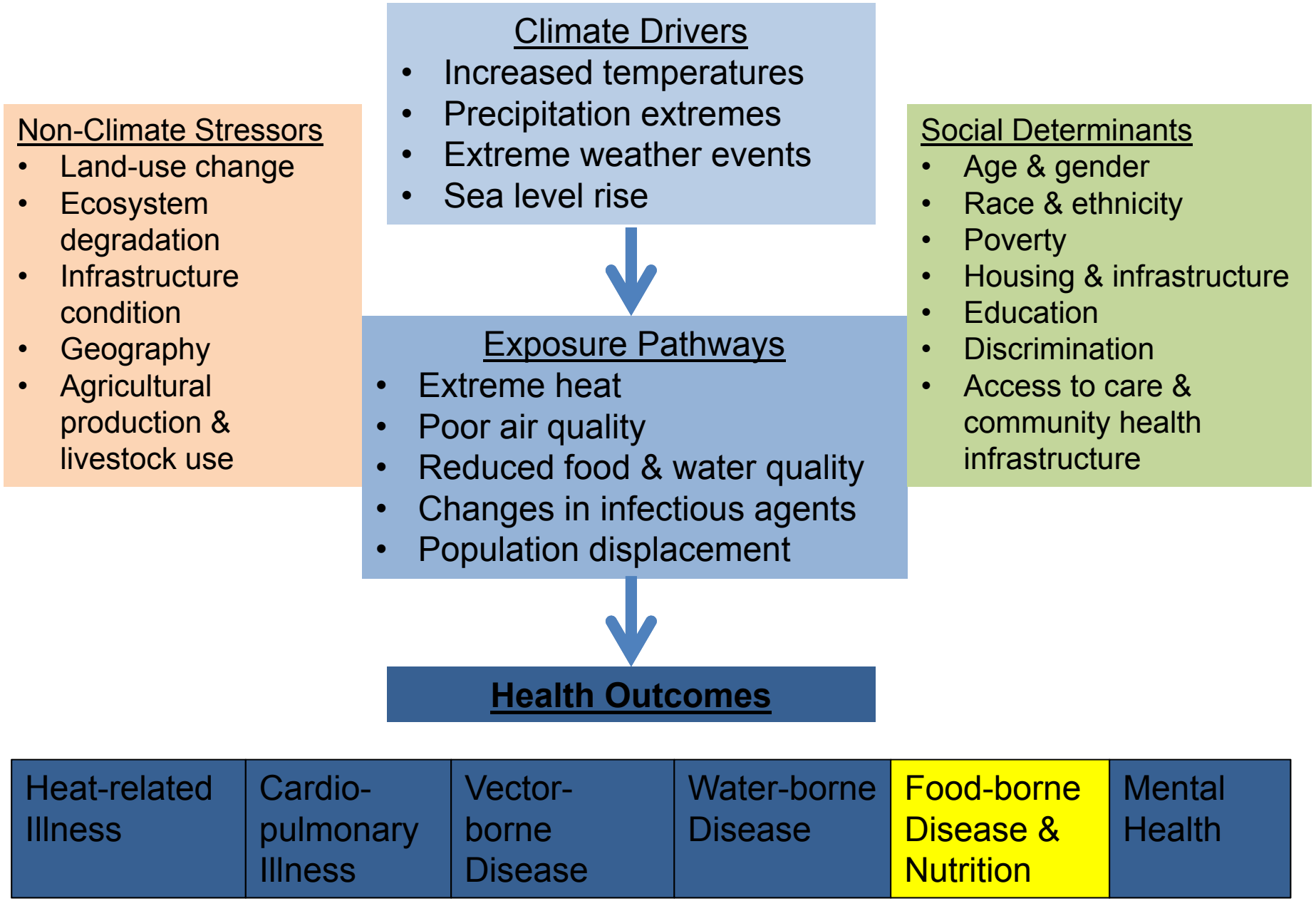
Nebraska Fish Consumption Advisories – 2013
Primarily Due to Mercury Contamination



92 Lakes and Streams in Nebraska

Source: Scott Holmes, Lincoln Lancaster County Health Department

Climate Change and Health



Rising Temperatures Can Decrease Food Safety

Rising temperatures and changes weather extremes is expected to intensify pathogen and toxin exposure, increasing the risk and incidence of foodborne illnesses.

Some pathogens thrive in warm, humid conditions

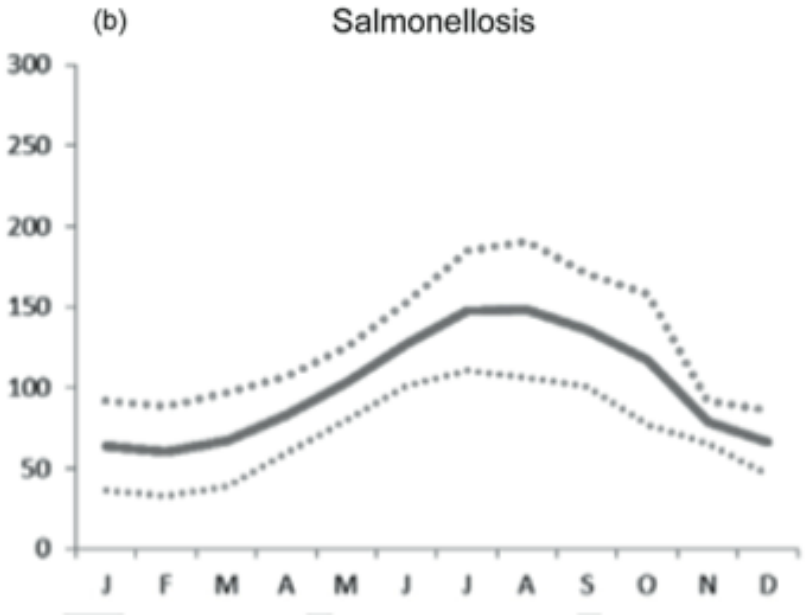
- *Salmonella*
- *Escherichia coli (E. coli)*
- *Campylobacter*

Foodborne illnesses peak in the summer

- Warmer weather
- Food preparation outdoors
- Leaving food outside at picnics and BBQs

Salmonella on raw chicken will double in number approximately every hour at 70°F, every 30 minutes at 80°F, and every 22 minutes at 90°F.

Seasonality of *Salmonella*

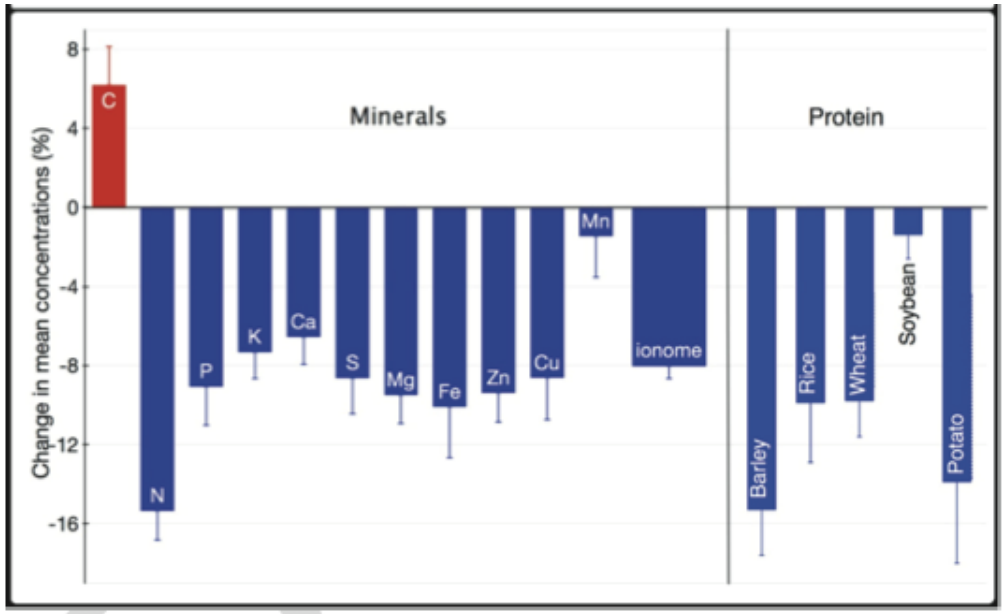


Sources:
1. Baranyi, J., and M. L. Tamplin, 2004: ComBase: a common database on microbial responses to food environments. *Journal of Food Protection*
2. Oscar, T., 2009: Predictive model for survival and growth of Salmonella Typhimurium DT104 on chicken skin during temperature abuse. *Journal of Food Protection*

Food Nutrition

- Increases in CO2 will likely increase carbohydrate content in food, while as the same time decreasing the protein and essential mineral content.
- “Hidden Hunger” is the sufficient or excessive intake of calories but insufficient intake of one or more micronutrients, such as vitamin A, iron, iodine, and zinc.
- Micronutrient deficiencies adversely affect metabolism, the immune system, cognitive development and maturation, and can be a factor in the prevalence of obesity.
- Aquaculture
  - Climate change is altering fish distribution and productivity of marine and fresh water species

Effects of Carbon Dioxide on Protein and Minerals



Pest Distribution

- Climate change will also alter the distribution of pests, parasites, and microbes, which will lead to increases in the use of pesticides
- Increased human exposure to chemical contaminants in the food chain.

Extreme Weather Can Decrease Food Security

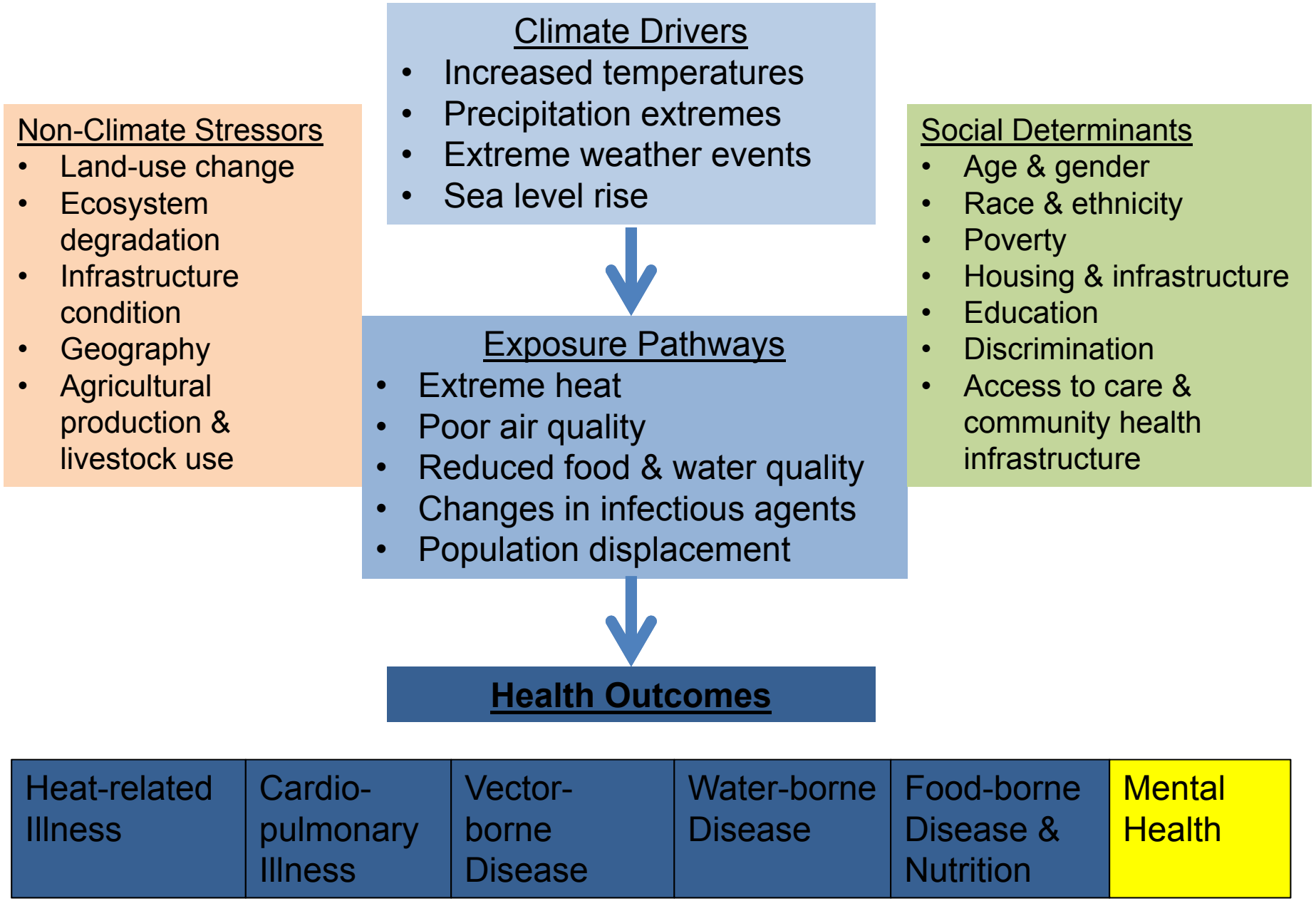
Extreme weather events can contribute to pathogen transmission, multiplication, survivability, and growth, increasing risk of food contamination

Example: Runoff or flood water that may carry partially untreated sewage or other wastes can contaminate ground water and surface water used for irrigation, harvesting and washing of food.

Chemical contaminants in floodwater following Hurricane Katrina included spilled oil, pesticides, heavy metals, and hazardous waste.

Source: Manuel, J., 2006: In Katrina's Wake. *Environ Health Perspectives*

Climate Change and Health



Mental Health and Well-Being

Mental health consequences of exposure to disasters

- Post-traumatic stress disorder (PTSD)
- Depression
- General anxiety

Virtually everyone is exposed to the threats of climate change and to events attributed to climate change through frequent media coverage.

High risk groups

- Children
- Elderly
- Pregnant and post-partum women
- People with pre-existing mental illness,
- Low-income persons and homeless
- First-responders

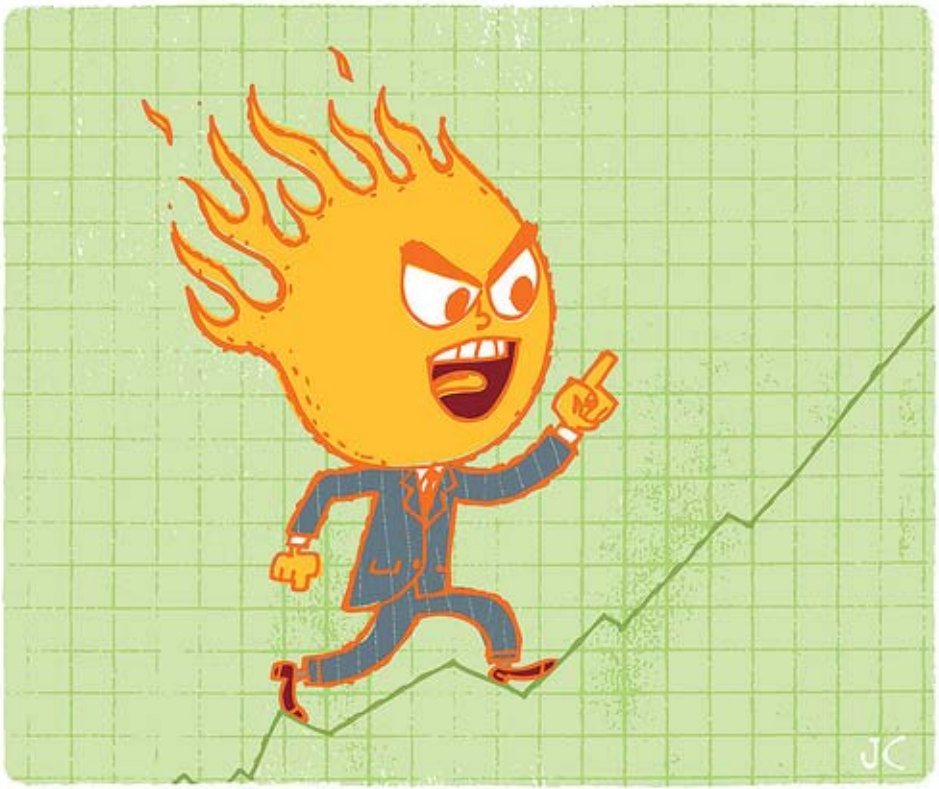
The Impact of Climate Change on Physical, Mental, and Community Health

Medical and Physical Health
- Changes in fitness and activity level
- Heat-related illness
- Allergies
- Increased exposure to waterborne and vectorborne illness

Mental Health
- Stress, anxiety, depression, grief, sense of loss
- Strains on social relationships
- Substance abuse
- Post-traumatic stress disorder

Community Health
- Increased interpersonal aggression
- Increased violence and crime
- Increased social instability
- Decreased community cohesion

A 2°C Temperature Increase Can Make People Angrier



- Spikes in temperature and precipitation can increase the risk of personal violence and social upheaval
- While climate is not the sole or primary cause of violence, it undeniably exacerbates existing social and interpersonal tension in all societies, regardless of wealth or stability.

http://wattsupwiththat.com/2013/08/01/claim-2c-temperature-increase-will-make-people-angry/

"Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen."

"Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the last 800,000 years. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-20th century."

- IPCC Climate Change 2014 Synthesis Report Summary for Policymakers

The Report:

- 1 scoping meeting to outline 30 chapters
- 217 author nominations representing 92 nationalities
- 242 lead authors and 66 review editors from 70 countries
- 436 contributing authors from 54 countries
- Over 12,000 scientific references cited

Total Reviews:

- 50,492 comments
- 1729 expert reviewers from 84 countries
- 49 governments

The WGII Approval Session

- 25-29 March 2014, Yokohama, Japan
- The Summary for Policymakers was approved line-by-line and accepted by the Panel, which has 195 member Governments

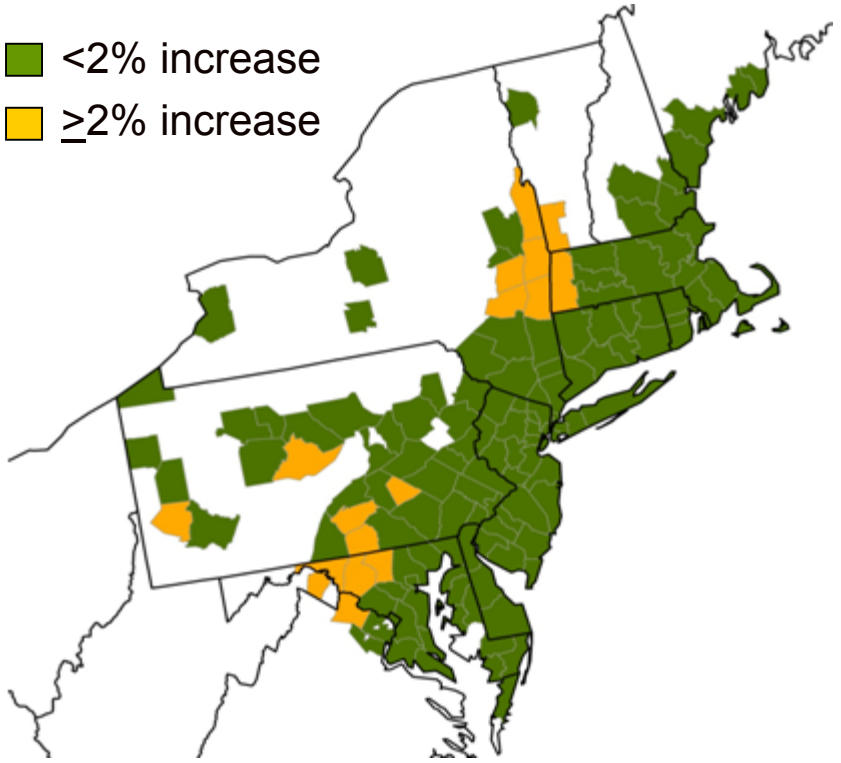
“Climate change is a problem which can no longer be left to future generations.”

- Pope Francis

Public Health Response to Climate Change

- Enhanced surveillance
  - Human cases in previously disease-free areas
  - Introduction of new vectors, hosts, or pathogens
  - Changing transmission patterns recognition and response
  - Identify potential vulnerable populations
- Strengthen public health infrastructure to improve measures to reduce the spread of disease or disease vectors and hosts

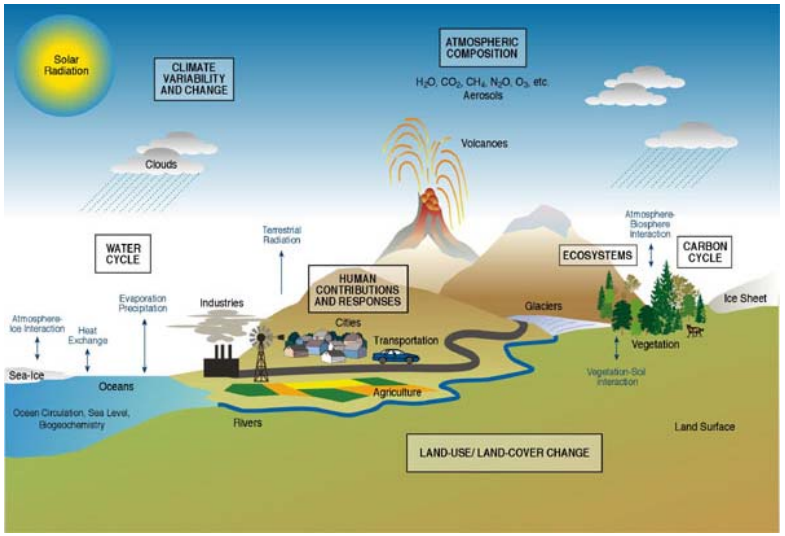
Average annual increase in Lyme disease, selected U.S. counties, 1992-2006

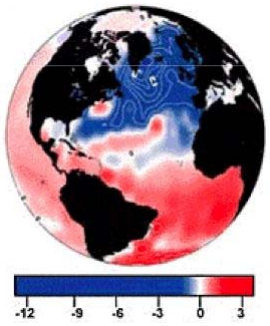


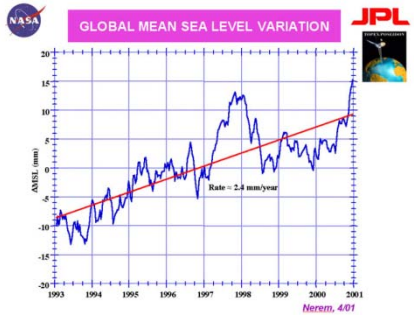
*Counties reporting average of ≥5 cases annually

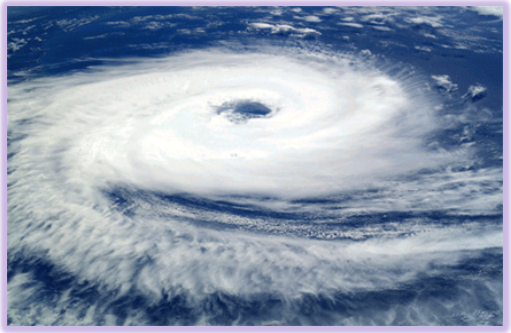
Public Health Response to Climate Change

- Modeling and long-term ecological and epidemiological research on influence of environmental changes on disease cycles
- Preparedness: Review, evaluate and prepare adaptive countermeasures (tempertaaure triggers, vaccines, therapeutic agents, insecticides, etc.)
- Training & Education: PH workforce









Challenges

- Communicating uncertainty
- Climate change must be framed as a public health issue
- The costs of not taking action are high
- Linking meteorlogic science with health – “new demands on science and services”


CLIMATE
SUMMIT
WHAT IF IT'S A BIG HOAX AND WE CREATE A BETTER WORLD FOR NOTHING?
• ENERGY INDEPENDENCE
• PRESERVE RAINFORESTS
• SUSTAINABILITY
• GREEN JOBS
• LIVABLE CITIES
• RENEWABLES
• CLEAN WATER, AIR
• HEALTHY CHILDREN
• ETC. ETC.
JOEL PETT

Acknowledgements

Kathleen Lovgren, MPH
Matthew Bosley, MD
Aleta Evans Gaertner, MPH

UNIVERSITY OF NEBRASKA MEDICAL CENTER℠

COLLEGE OF PUBLIC HEALTH

University of Nebraska Medical Center