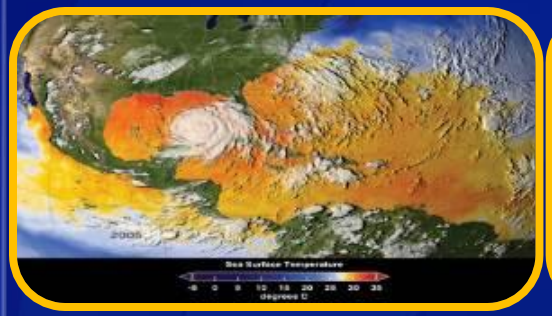
CLIMATE CHANGE:

Impacts on the Hydrologic Cycle and Waterborne disease



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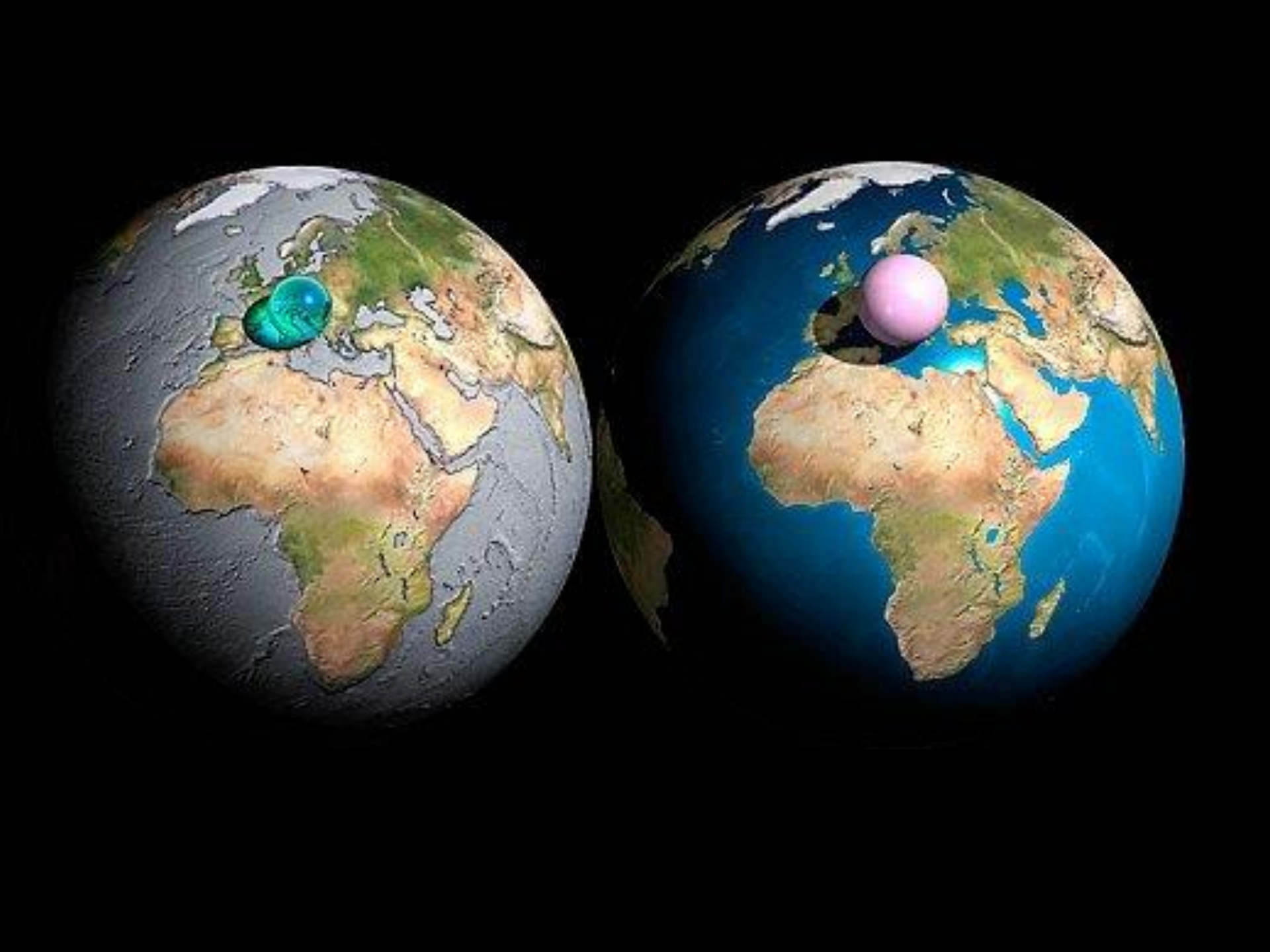
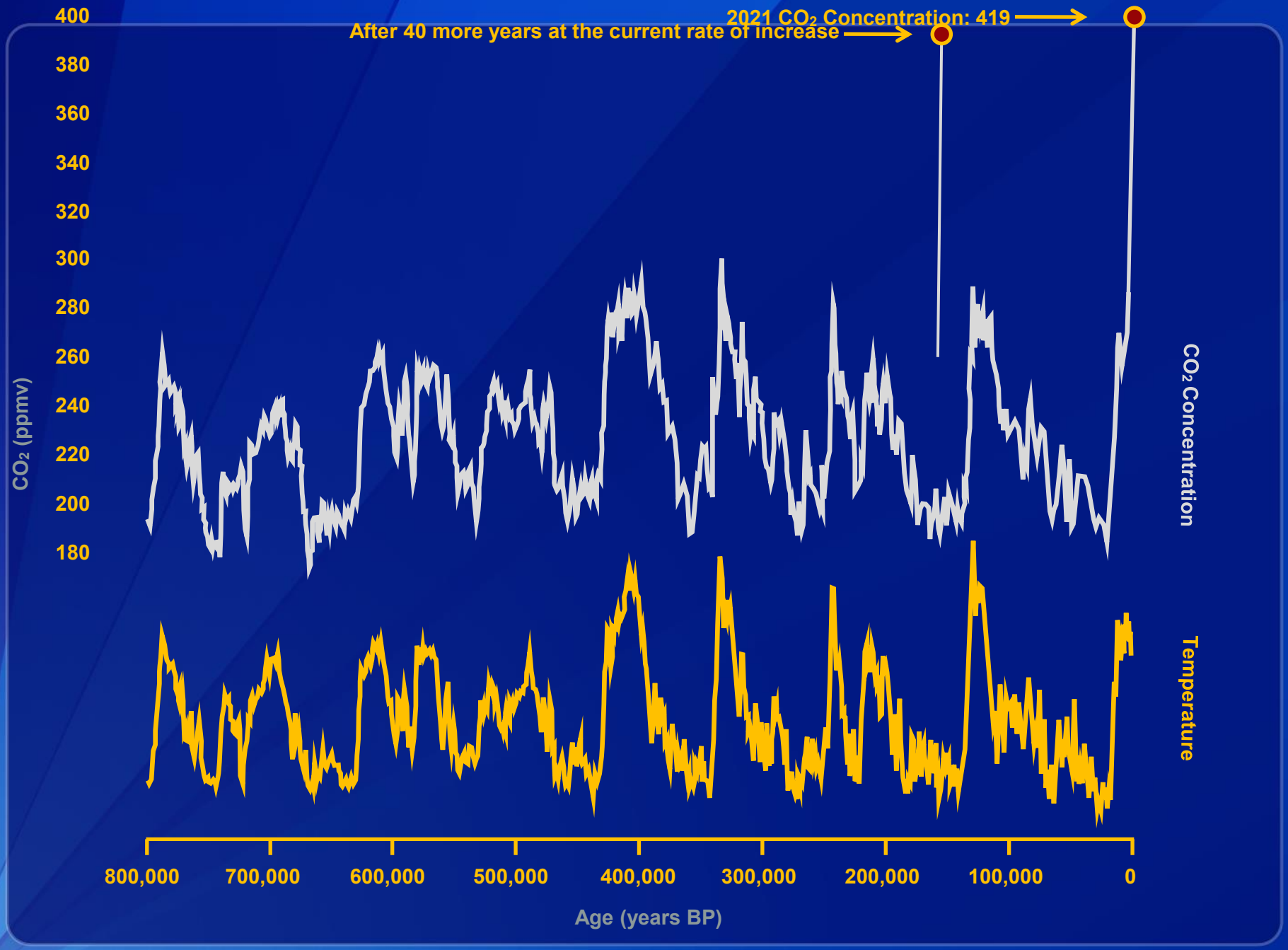
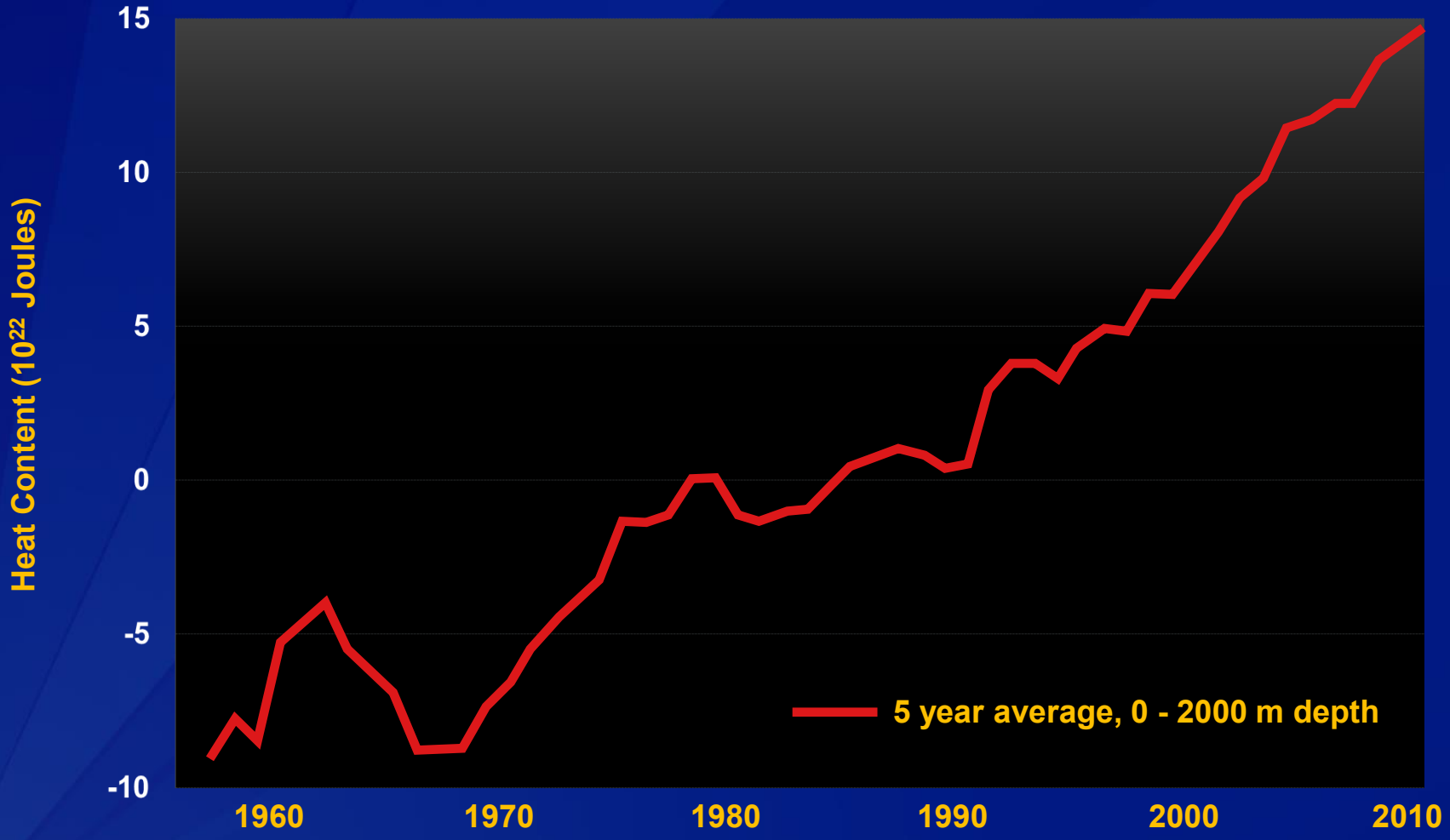
Disclaimer





Source: National Climatic Data Center, NOAA

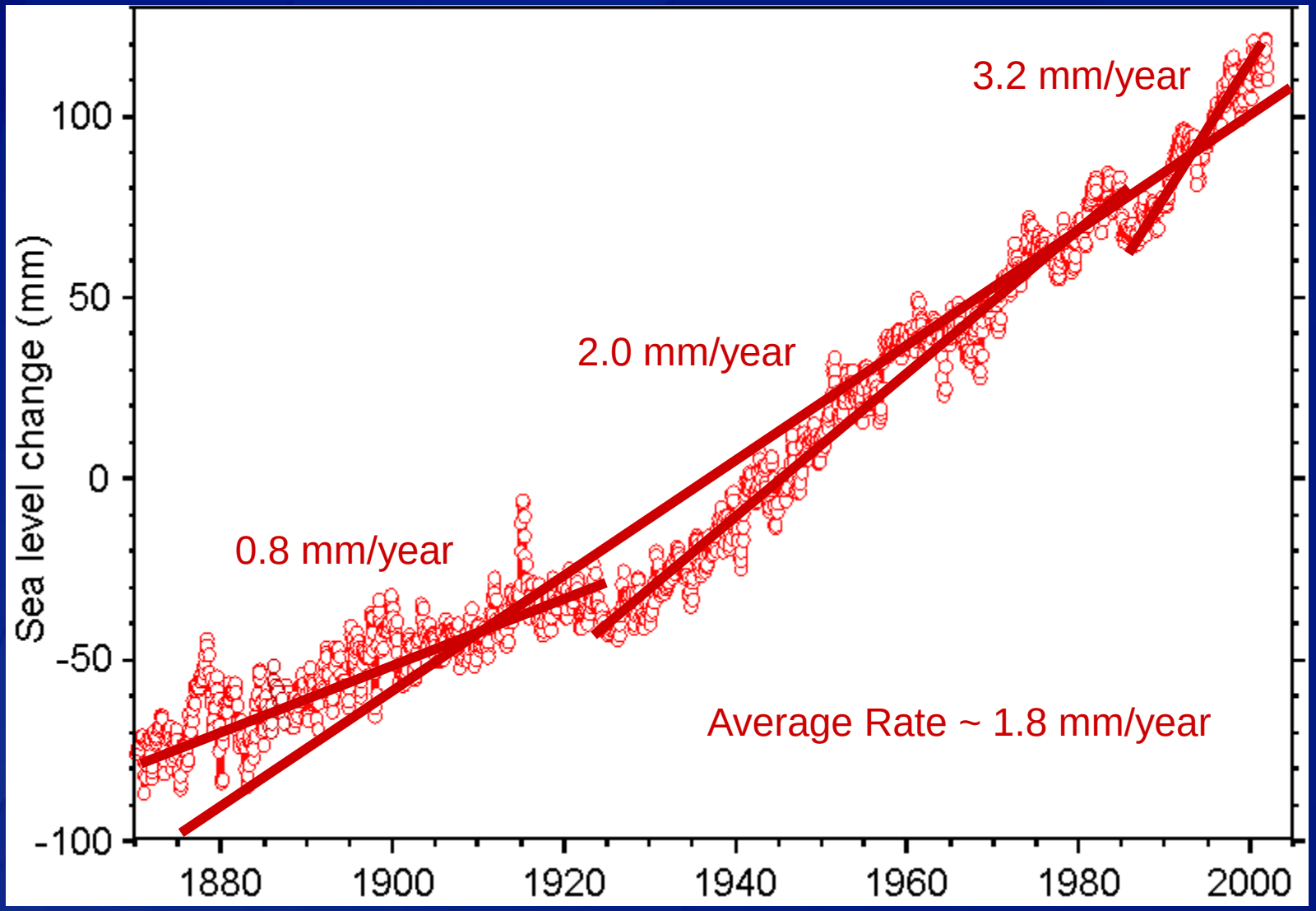
Global Ocean Heat Content
1955 – 2010



Source: NOAA/NESDIS/NODC Ocean Climate Laboratory, updated from Levitus, S., et al., "World ocean heat content and thermosteric sea level change (0-2000), 1955-2010," *Geophys. Res. Lett.* 39, doi:10.1029/2012GL051106, 2012.

Accelerating Sea Level Rise

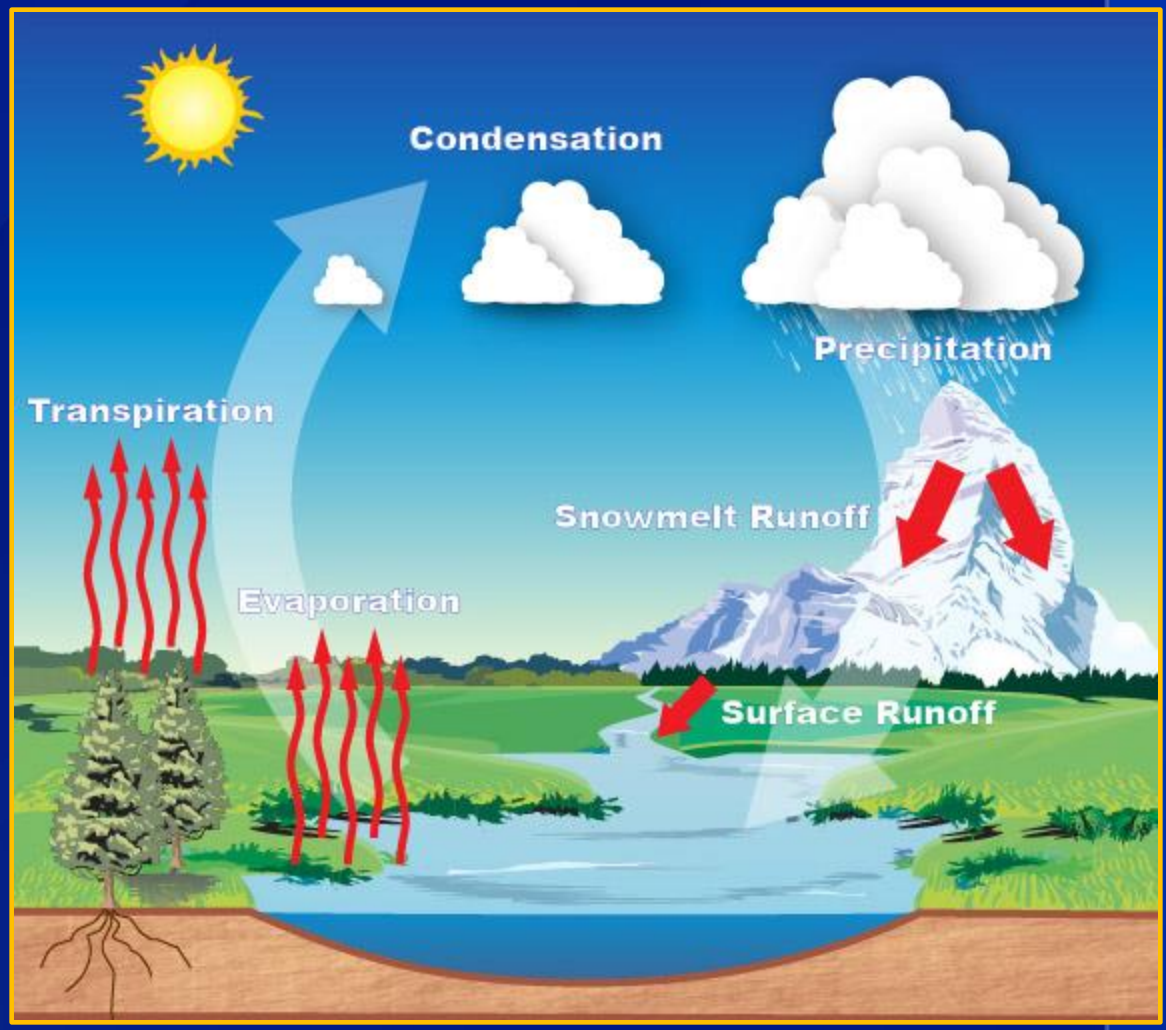
Primarily due to thermal expansion



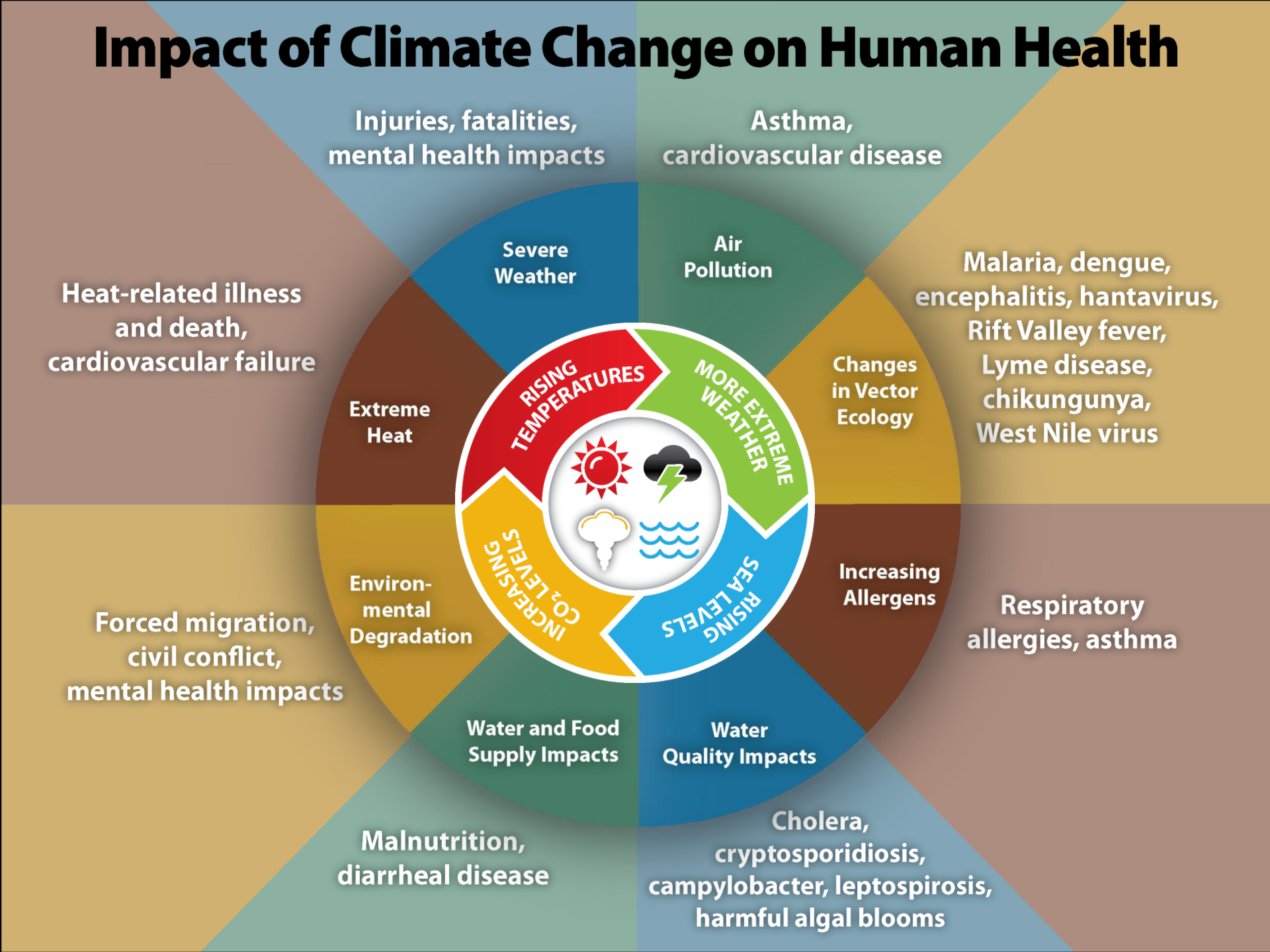
Source: Church and White 2006, GRL 33:L01602
Courtesy R.S. Nerem

Changes in Hydrology Due To CC

- Increase in Water Temp
- Increase in Heavy Precip
- Increase in Droughts
- Increase in Flooding



Impact of Climate Change on Human Health



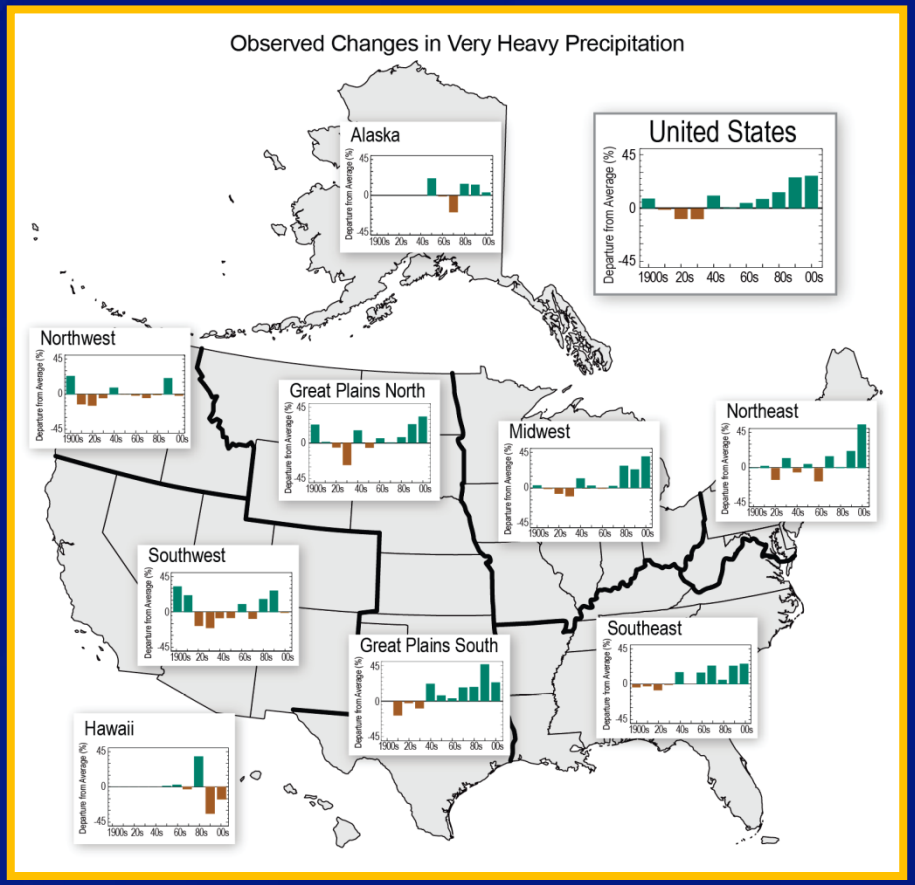
WaterBorne Diseases

- **What is a Waterborne Disease?**
  - Diseases that are spread by the consumption of contaminated water (WHO).
  - Include pathogens from a wide range of taxa
    - viruses, bacteria, protozoa, and helminths

- **Statistics**
  - 7.15 million domestically acquired waterborne illnesses occur in the US annually (CDC)
  - Responsible for of 1.5 million deaths globally (2012).
  - 58% of that burden in low- and middle-income countries – 842 000 deaths per year
  - Attributable to unsafe water supply, inadequate sanitation and lack of hygiene

Extreme Precipitation Events Impact Human Health: Waterborne Disease

- 67% of waterborne disease outbreaks preceded by precipitation above 80th percentile (across 50 year climate record)
- Heavy precipitation events projected to occur more frequently

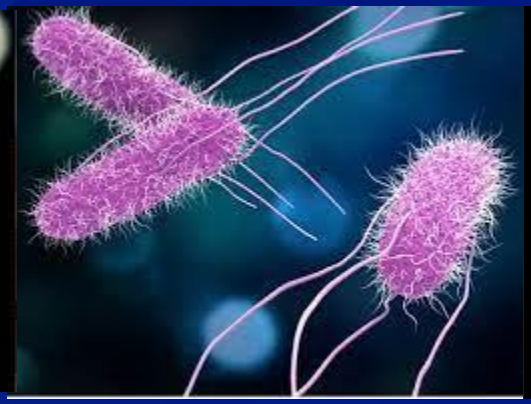


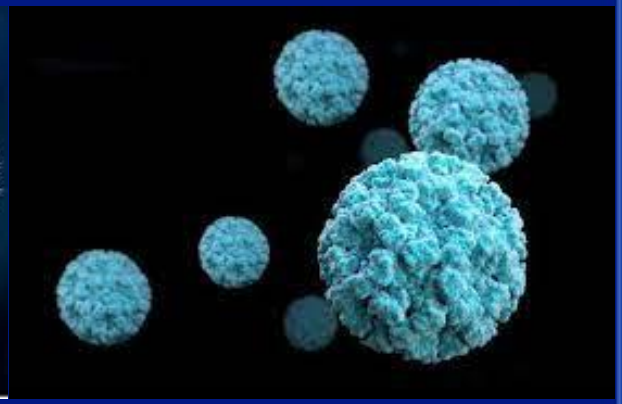
Observed Increases in Very Heavy Precipitation (heaviest 1% of all events) 1901 to 2011

Curriero, Patz, et al, 2001.

Source: Walsh et al. 2013: *Draft NCA Report*, Chapter 2

Overview of Select Waterborne Diseases



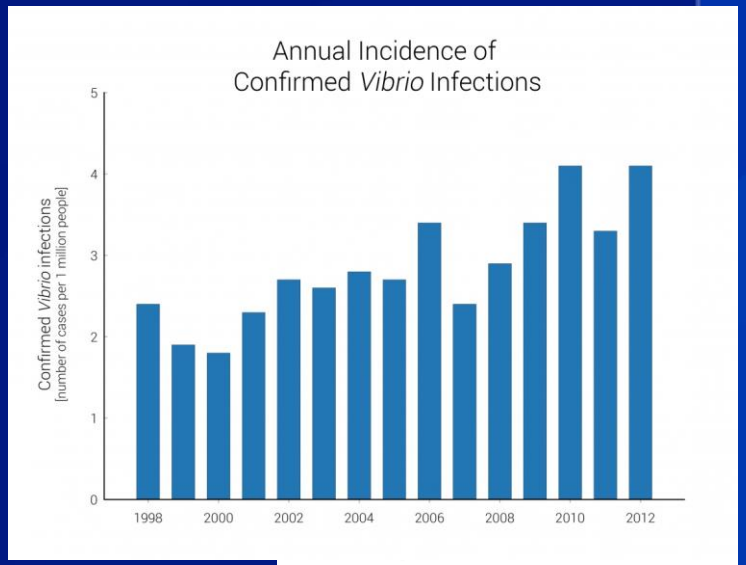


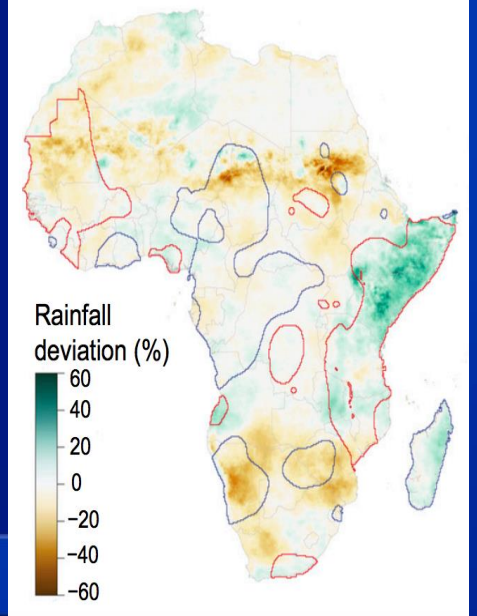
Waterborne Pathogens: Salmonella

- Symptoms include:
  - Causes gastroenteritis
  - Nausea/vomiting
  - Diarrhea
- Water can become contaminated through faecal pollution by infected humans but also by other vertebrates
- Incidence could increase with warming waters

Waterborne Pathogens: *Vibrio* (cholera)

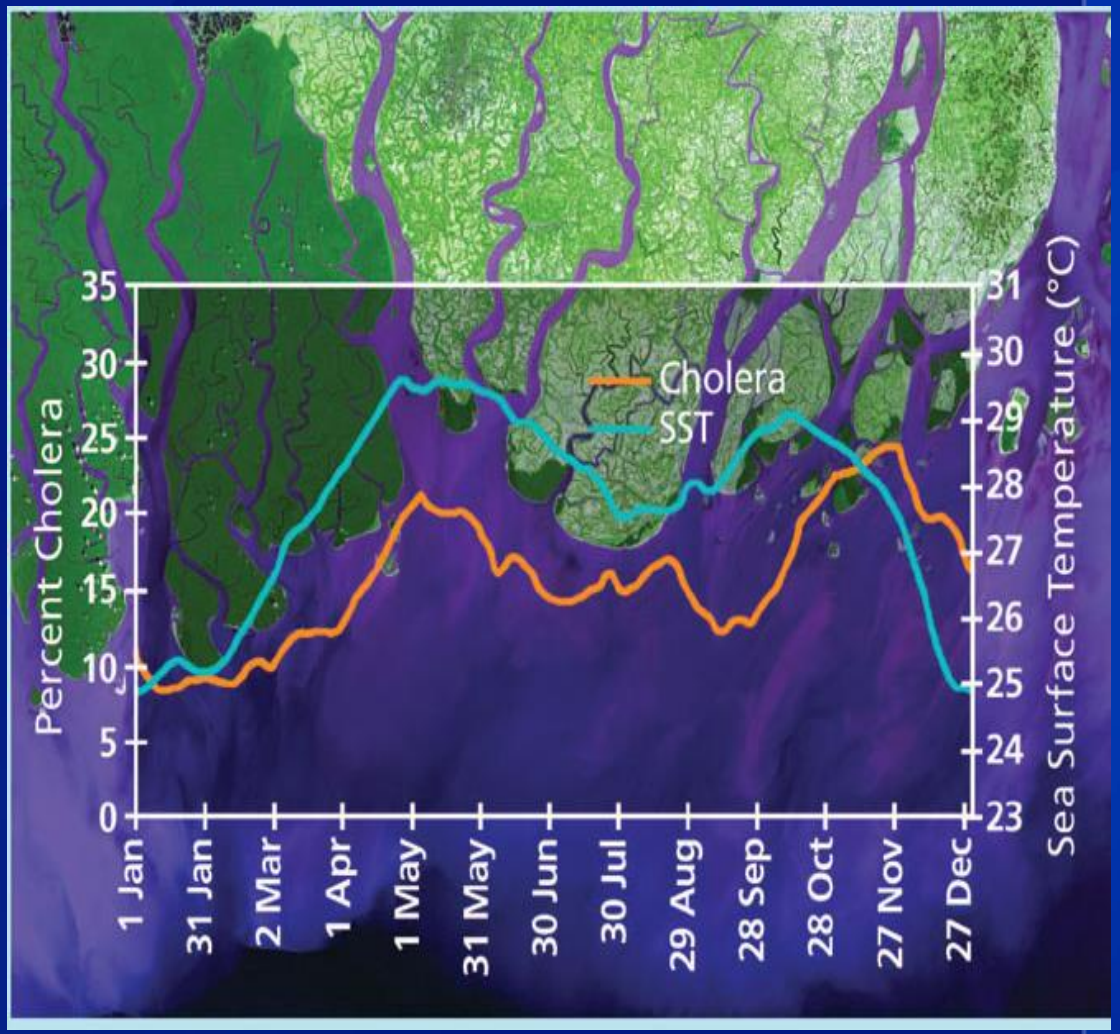
- **Pathology and Human Health**
  - Acute diarrhea that can kill within hours
  - Highly contagious
  - Most pressing in Africa and Asia + poor infrastructure
- **Consequences of Climate Change**
  - El Niño→ wetter in East Africa→ higher incidence
  - Complicated
    - Less rain in dry areas→ unsafe drinking water
    - More rain in dry areas→ flooding of sewer system
    - Less rain in wet areas→ decrease flooding
    - More rain in wet areas→ decrease pathogen conc but increase flooding





Water Borne Pathogens: Cholera

- ↑ SST → ↑ phytoplankton blooms, which provide good habitat for the survival and spread of cholera

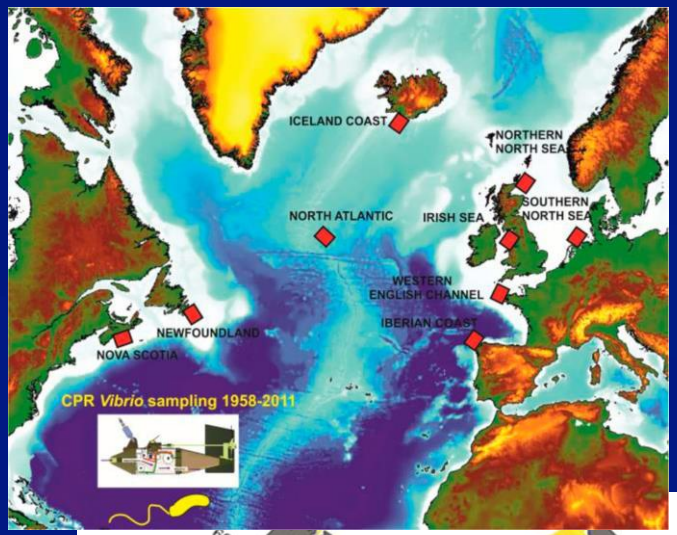


Source:Pascual et al., 2002; Image: www.nature.com

Waterborne Pathogens:

Vibrio vulnificus & parahaemolyticus

- **Microbial Characteristics**
  - Bacterium
  - Warm coastal waters
    - + salt tolerant
  - Summer and early autumn
- **Consequences of Climate Change**
  - Increase ocean temp→ increase range
  - Increase algal blooms→ increase concentration
  - Higher minimum temps→ uninterrupted growth
- **Pathology and Human Health**
  - Septicemia of wounds (*V. vulnificus*)
  - Gastrointestinal (*V. parahaemolyticus*)



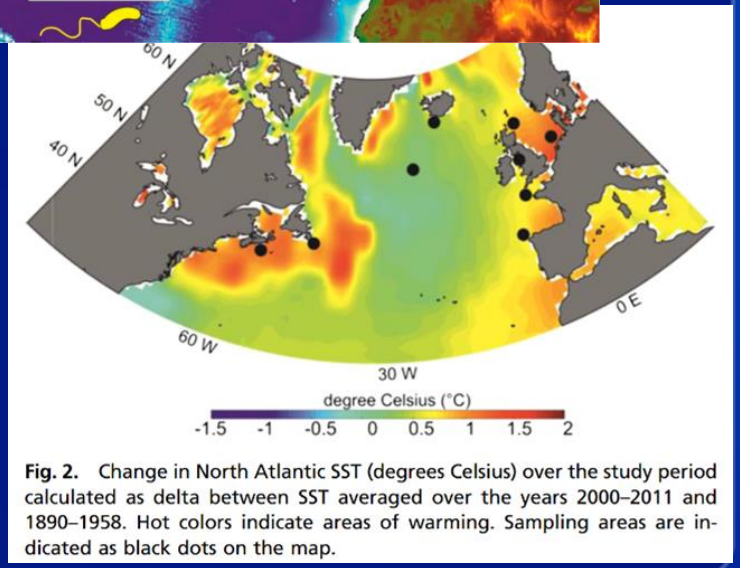
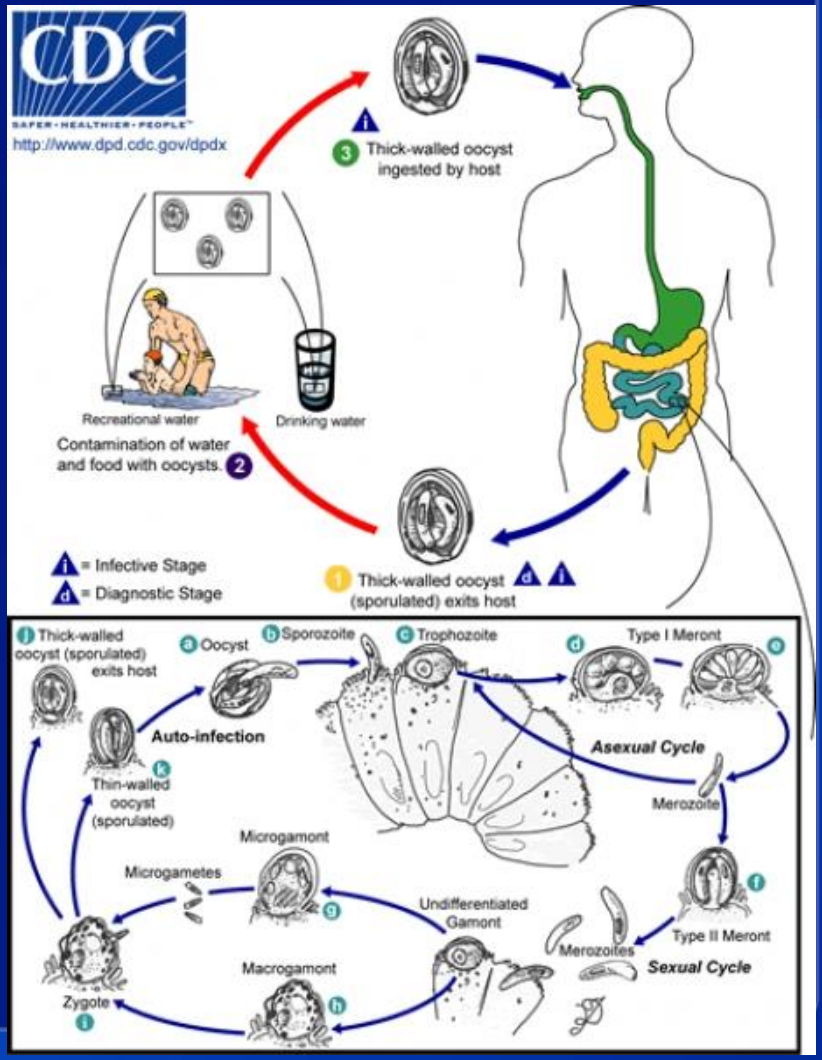


Fig. 2. Change in North Atlantic SST (degrees Celsius) over the study period calculated as delta between SST averaged over the years 2000–2011 and 1890–1958. Hot colors indicate areas of warming. Sampling areas are indicated as black dots on the map.

Waterborne Pathogens: *Cryptosporidium*

- Watery diarrhea that can be severe and even life threatening
- Sturdy oocysts: Chlorination ineffective
- Small size: Filtration ineffective
- Heavy rainfall causes mobilization of oocysts leading to outbreaks



Heavy Precipitation and Water-borne Disease:

Milwaukee 1993

Cryptosporidiosis epidemic

405,000 cases, 54 deaths

Preceded by heaviest rainfall in 50 years (Curriero et al., 2001)

$31.7 million in medical costs

$64.6 million in lost productivity

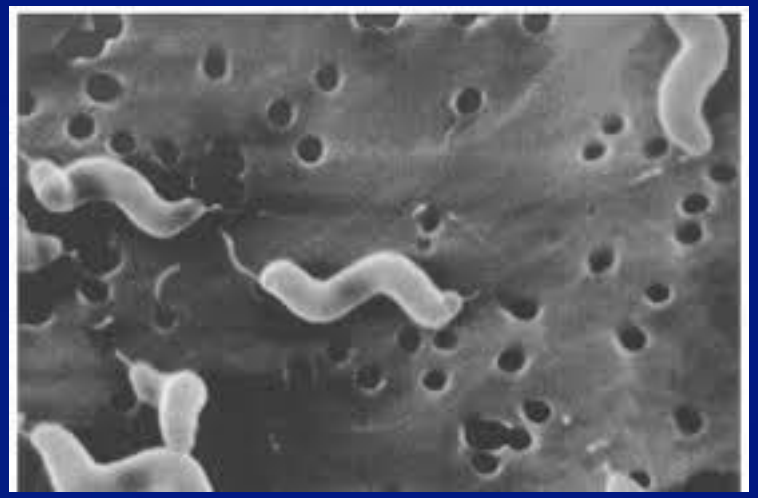
(Corso et al., 2003).

Waterborne Pathogens: Norovirus

- Causes acute gastroenteritis in humans
- Symptoms
  - Projectile vomiting
  - Watery non-bloody diarrhea
  - Abdominal cramps
  - Myalgia
- Heavy rainfalls/flooding increases infections

Waterborne Pathogens: *Campylobacter*

- Symptoms include:
  - Watery, bloody diarrhoea
  - Abdominal pain
  - Fever
  - Headache
  - Nausea
- Associated with increased air and water temp and heavy precipitation



Waterborne Pathogens: *Naeglaria fowlerii*

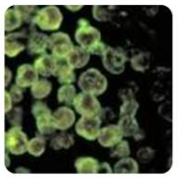
- **Pathology and Human Health**
  - Fatal brain infection
  - "Brain-eating amoeba"
- **Microbial Characteristics**
  - Amoeba
  - Warm freshwater lakes and rivers
  - Infects brain via nasal passage and olfactory nerves
- **Consequences of Climate Change**
  - Typically found in southern US
  - Warmer temps→ range moving northward (presumption)

CBS News

Child dies of brain-eating amoeba likely contracted at Texas splash pad, officials say

On Friday, the CDC confirmed the presence of active Naegleria fowleri amoeba in water samples from the splash pad and from the system that...

3 weeks ago

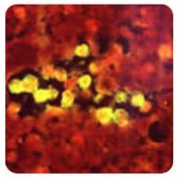


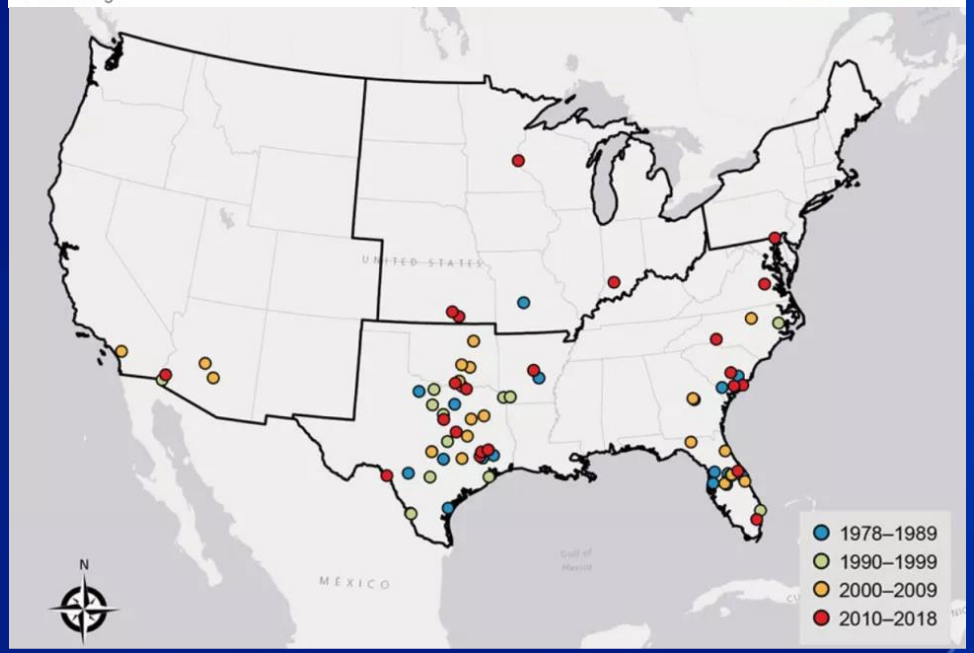
Infectious Disease Special Edition

Recent Death in California Spotlights Rare Brain Infection

The recent death of a 7-year-old California boy has called attention to the risks associated with the rare organism Naegleria fowleri,...

3 weeks ago



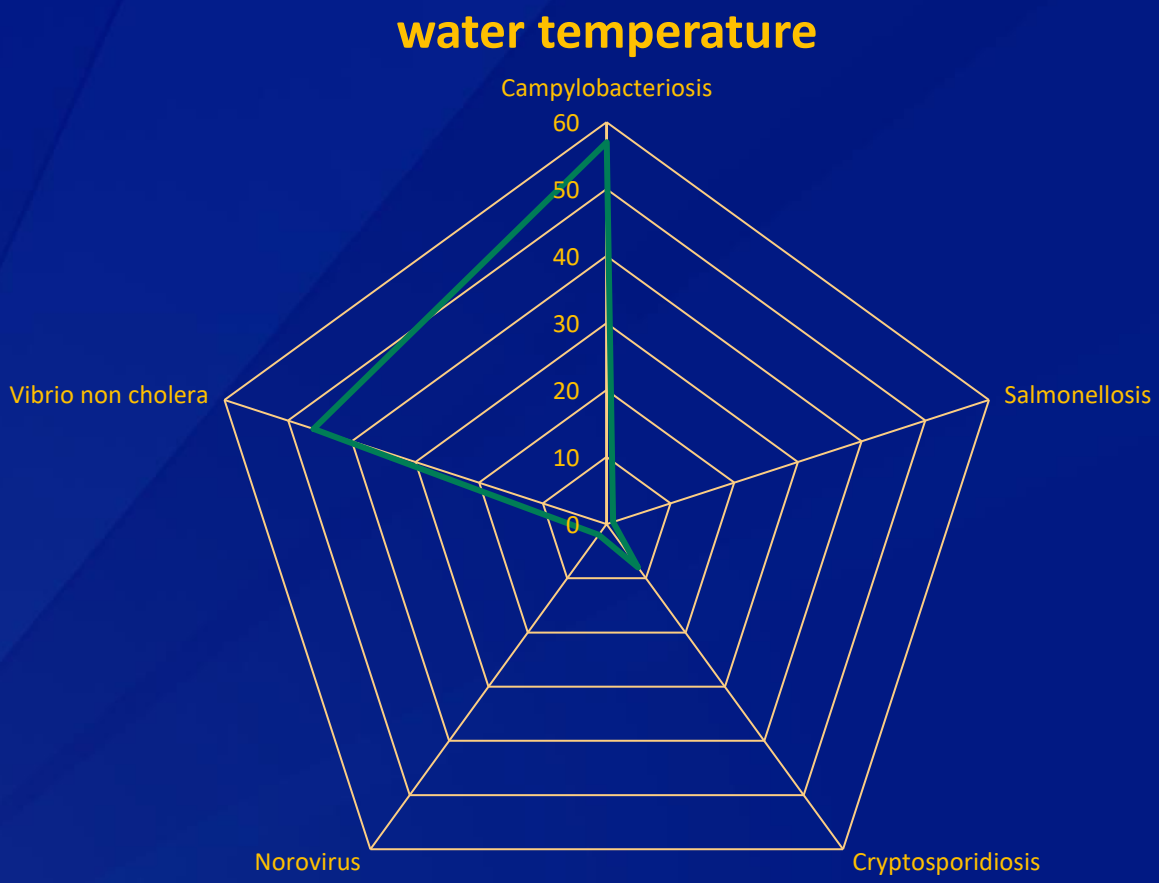


Climate Change and Waterborne Diseases: Environmental Effects, Pathogen Fate, and Microbial Risk

Climate Change	Effects	Consequences	Microbial Risk
Water temperature increase	Replication of marine bacteria (*Vibrio*)	Bacterial blooms in marine environments	Increased risk
	Die-off of enteric pathogens (e.g., *Norovirus*, *Campylobacter*)	Lower concentrations of pathogens in surface water	Decreased risk
	Organic matter and nutrients dissolve better	Challenges for water treatment: less efficient	Increased risk
Precipitation increase	Runoff, sediments, organic matter, nutrients	Challenges for water treatment: less efficient	Increased risk
	Peak concentrations of pathogens in surface water	Challenges for water treatment: less efficient	Increased risk
	Flooding of wells or water treatment plants	Water treatment at risk	Increased risk
	Storm water runoff and combined sewage overflow	Water treatment at risk Recreational water contamination	Increased risk
	Groundwater contamination with fecal pathogens	Water treatment insufficient	Increased risk
Drought	Changes in water sources	Insufficient treatment options	Increased risk
	Concentration of pathogens	Challenges for water treatment: less efficient	Increased risk

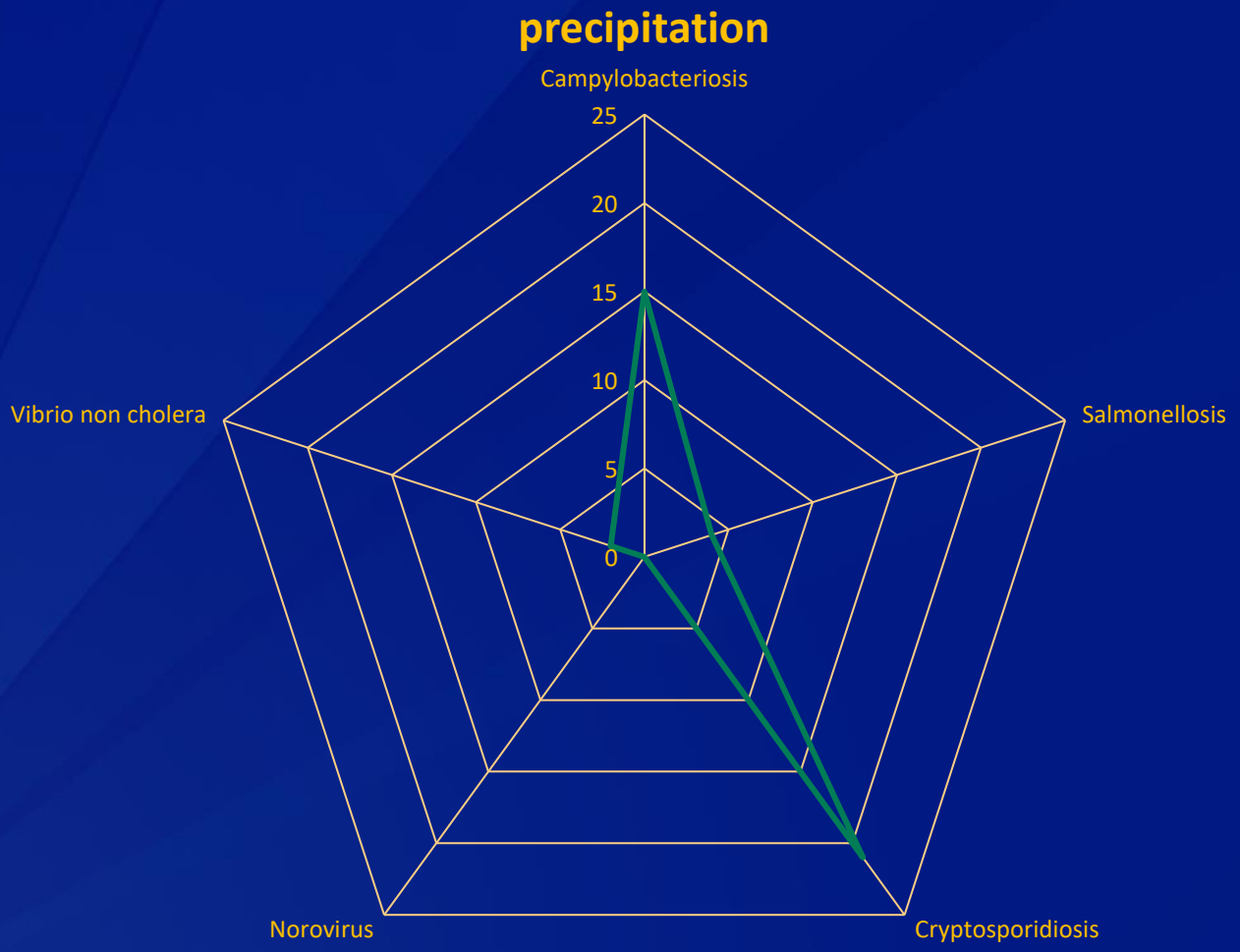
From: Smenza, 2015

Radar Diagram: Water Temperature



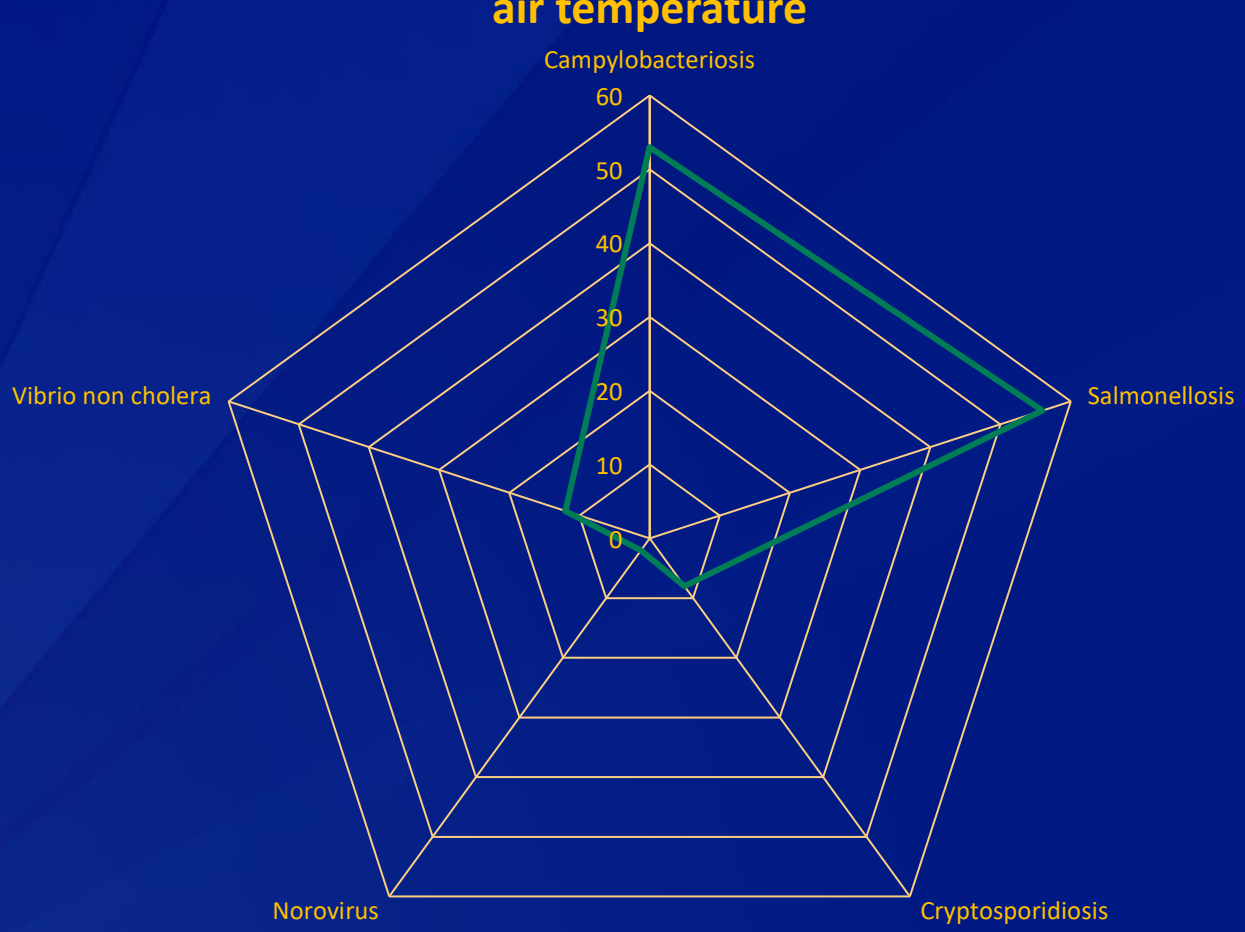
From: Smenza, 2015

Radar Diagram: Precipitation



From: Smenza, 2015

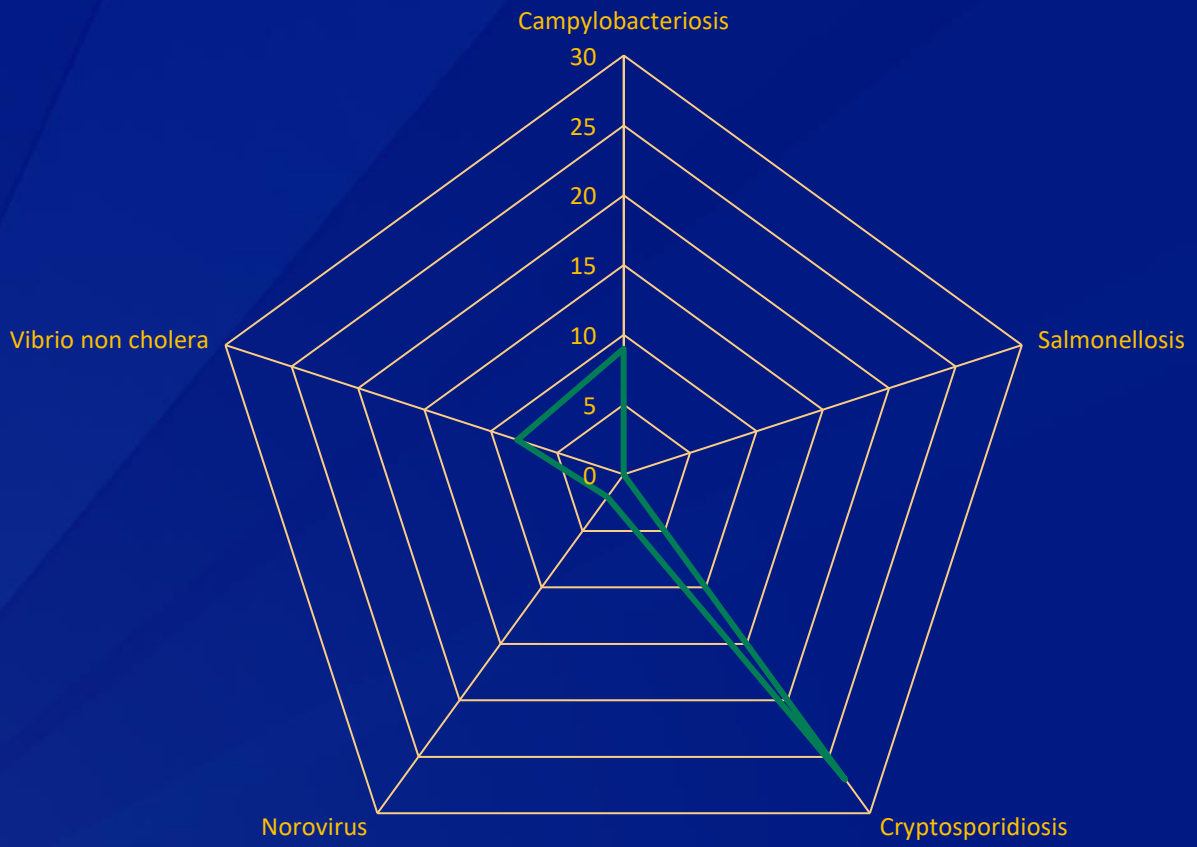
Radar Diagram: Droughts



From: Smenza, 2015

Radar Diagram: Flooding

heavy rainfall event



From: Smenza, 2015

Summary

Hydrological Cycle and Climate Change

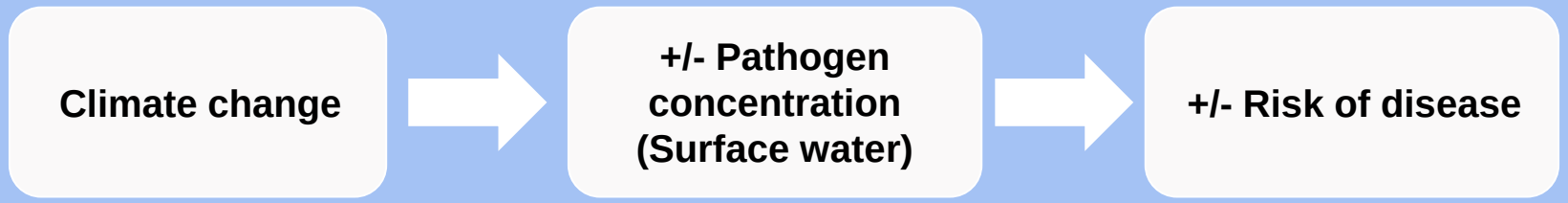
Water temp +/-
Agricultural seasons
Recreation
Precipitation +/-
Drought

Waterborne Pathogens

Norovirus
Cryptosporidium + Giardiasis
Vibrio (cholera and non cholera)
Brain-eating amoeba
Vector-borne disease

Adaptations and Interventions

Ecological + public health
WaSH

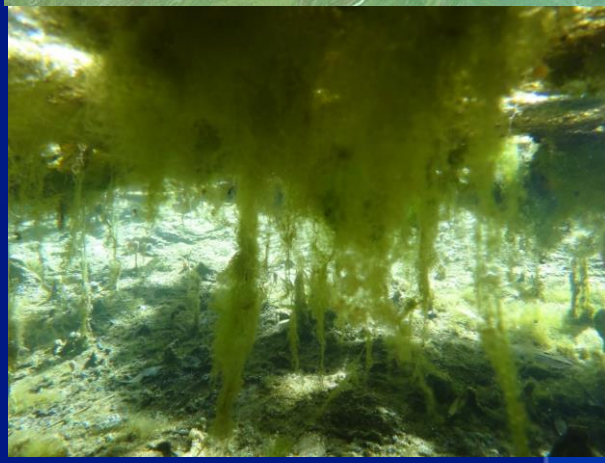


Non-infectious Water-Borne Disease Threats



Harmful Algal Blooms (HABS)

- HAB
  - The proliferation of cyanobacteria or algae to concentrations that can threaten human, animal and environmental health
- Exposure includes
  - Inhaling contaminated aerosols
  - Drinking contaminated water
  - Eating contaminated seafood
- Causes
  - Slow-moving water, Nutrients (Nitrogen & Phosphorus), Sunlight
- Environmental Degradation
  - Increasing **biological oxygen demand**
  - Creating dense algal mats
- Negative effects on fisheries, economies & coastal communities

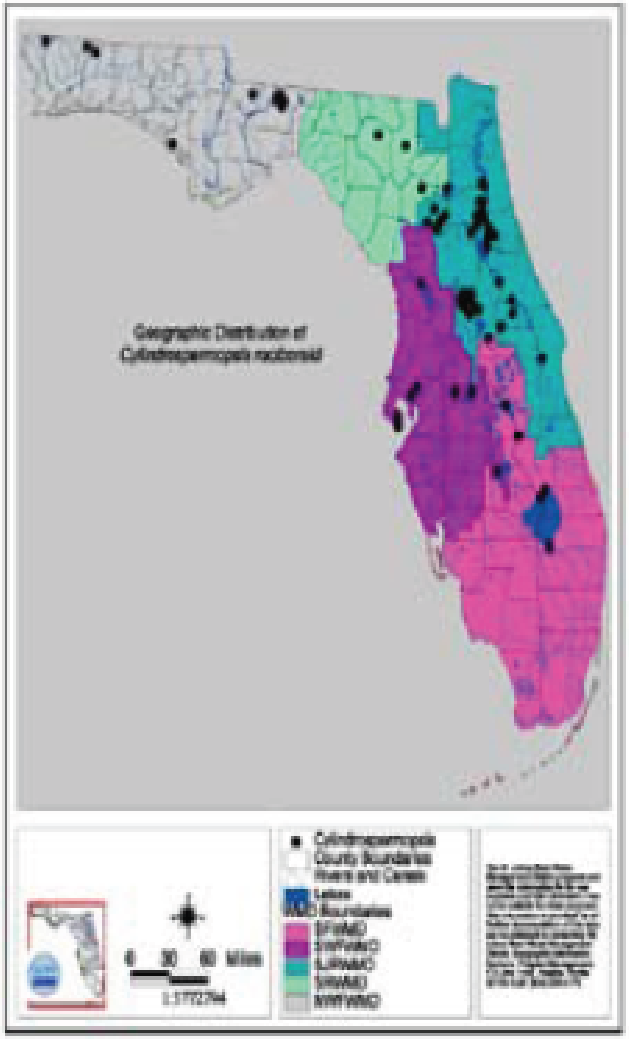


Harmful Algal Blooms (HABS)

Enhanced by:

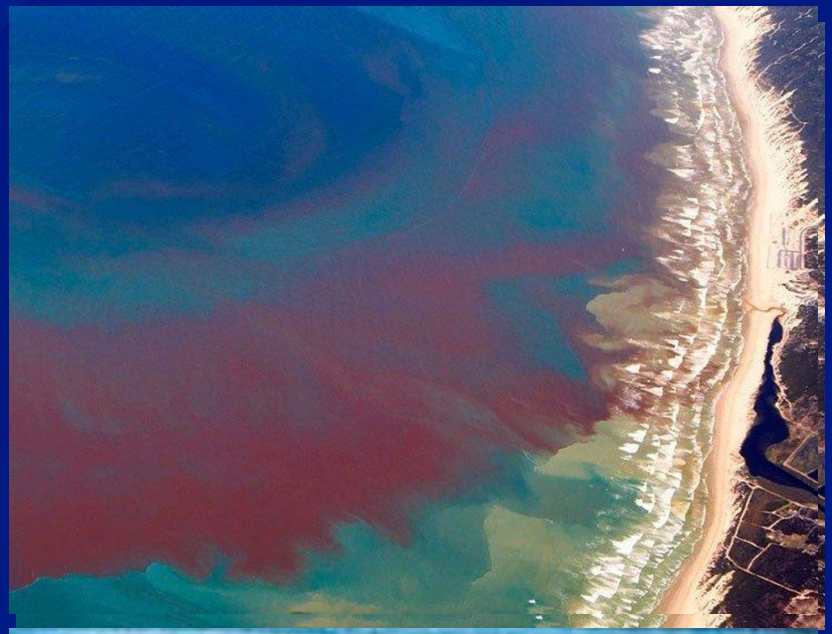
- Increased water temps
- Nutrient runoff (heavy precip events)
- Ocean upwelling events

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.

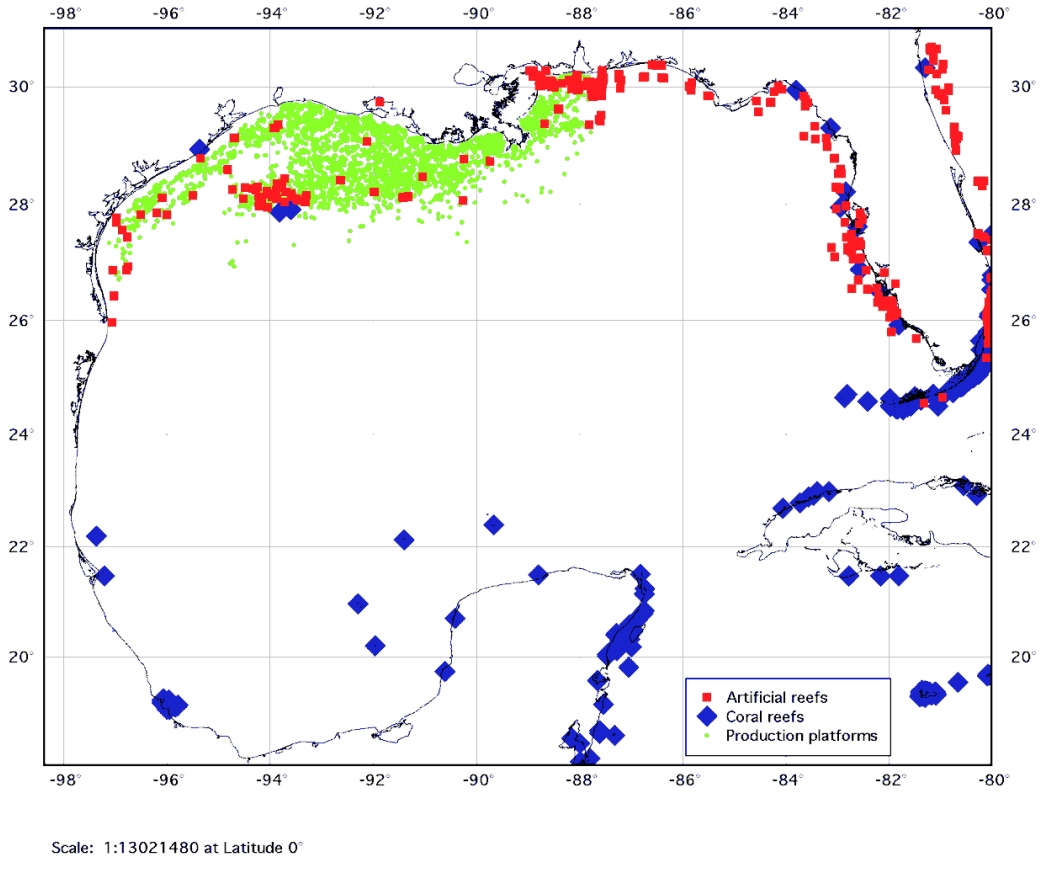


Red Tides

- One of the most prominently known HABs in the US occurs annually every summer along Florida's Gulf Coast
  - Colloquially known as "Red Tide" (*Karenia brevis)*
  - Microscopic toxic cyanobacteria that kill fish, poison shellfish.
  - In 2021, contaminated wastewater was released from the Piney Point phosphate retention pond into Tampa Bay
  - Hundreds of millions of gallons were released
  - Extraordinarily high in phosphate and nitrogen
  - Good for HABs — bad for humans



Ciguatera Fish Poisoning on Texas Coast Oil Rigs



Waterborne Pathogens

- Waterborne disease risk will increase as the hydrological cycle is effected by Climate Change

- Precipitation patterns, floods and droughts are all important determinants of these diseases, but their influence will be place specific and path-dependent

Adaptation Strategies

- Vulnerability, impact, and adaptation assessments can help prepare society for changes in the hydrological cycle
- Other strategies include augmenting sewer system storage capacity to minimize wet weather discharges
- All water storage measures need to be re-considered under the changing circumstances of CC

Conclusion

- Climate Change adaptation strategies should:
  - Be designed to enhance public health preparedness
  - Facilitate the response emerging threats from waterborne diseases
  - And thereby help contain human and economic costs

Thank You

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- The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.