Climate and Ecological Forecasting: Predicting and Preventing Public Health Risks

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NOAA Climate Program Office

Climate Stewards Webinar
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A few summertime questions

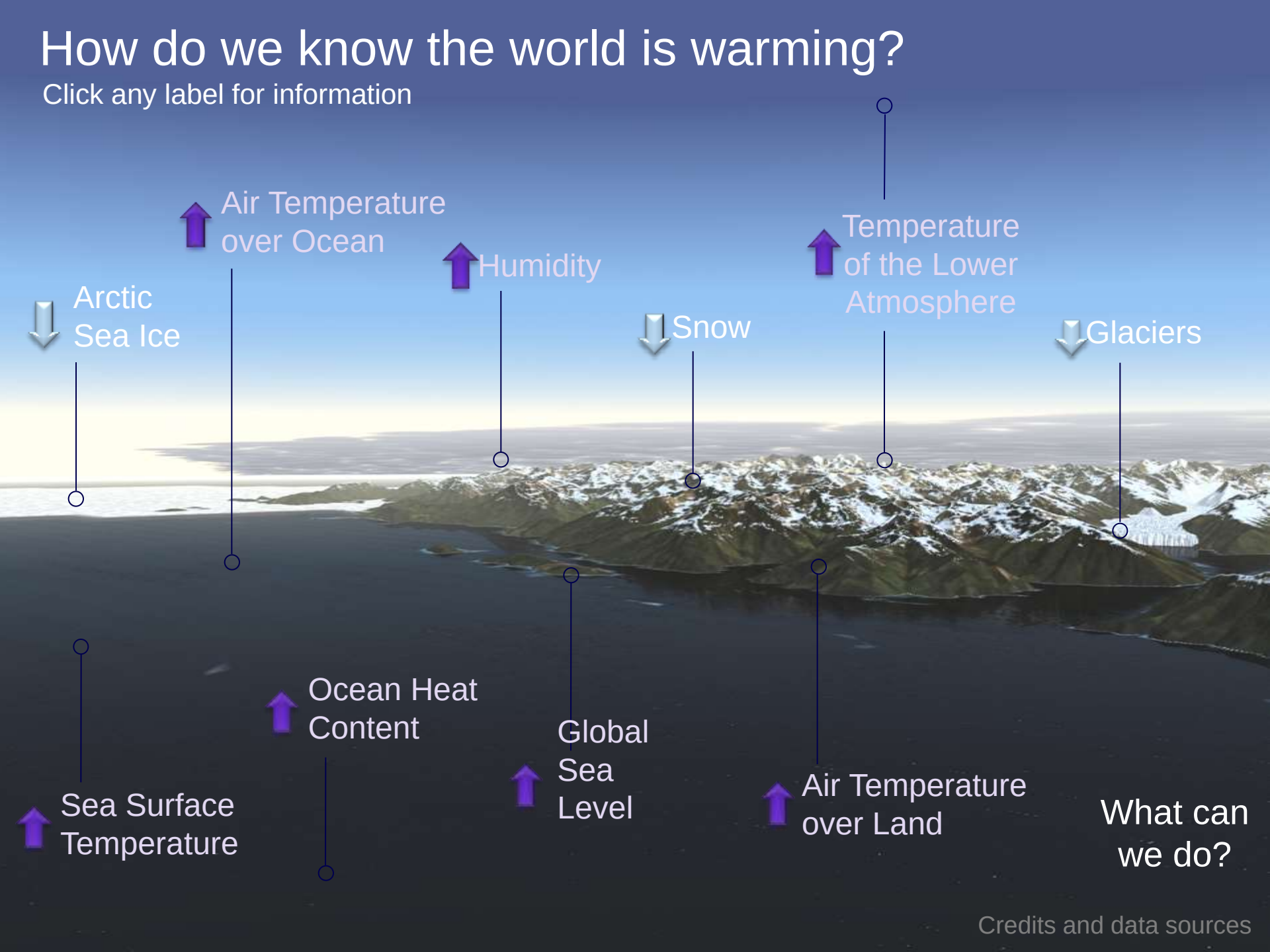
- Can I swim on that coastal beach?
- Is the seafood safe to eat?
- Why did that whale die and how does that affect me?
- Why is my drinking water green…
- Does it feel hotter, wetter, drier to you?

The Structure

- A little climate context
- A little about ecological forecasting
- A little about developing operational products
- A little about future trends and the US Climate and Health Assessment
- A lot of interaction with you about
  - how to communicate this information
  - how to stimulate interest in science and action to protect the environment

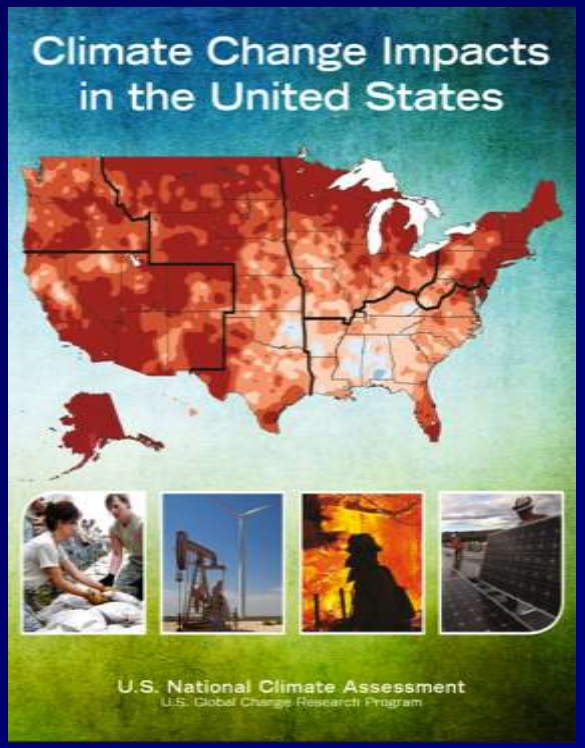
How do we know the world is warming?

Click any label for information



Credits and data sources

Third National Climate Assessment



- Released on May 6, 2014
- 30 Chapters (Sectors, Regions, and Response Strategies)
- Chapter 9: Human Health

3rd National Climate Assessment Key Findings

Increasing Strength of the Evidence

- **Average US temperature has increased by about 1.5°F since 1895 ; more than 80% of this increase has occurred since 1980.**
- **Extreme weather events, including heat waves, floods, and droughts, have become more frequent and intense.**
- **Sea level has risen by about 8 inches since 1880, projected to rise another 1 to 4 feet by 2100.**
- **Frost-free season has been increasing since 1980s.**
- **Heavy downpours have increased in most US regions.**
- **Number of Category 4 and 5 hurricanes in North Atlantic has increased since early 1980s.**

Source: National Climate Assessment Development Advisory Committee, *Third National Climate Assessment Report*, http://ncadac.globalchange.gov

Air Temp over Land - Observed

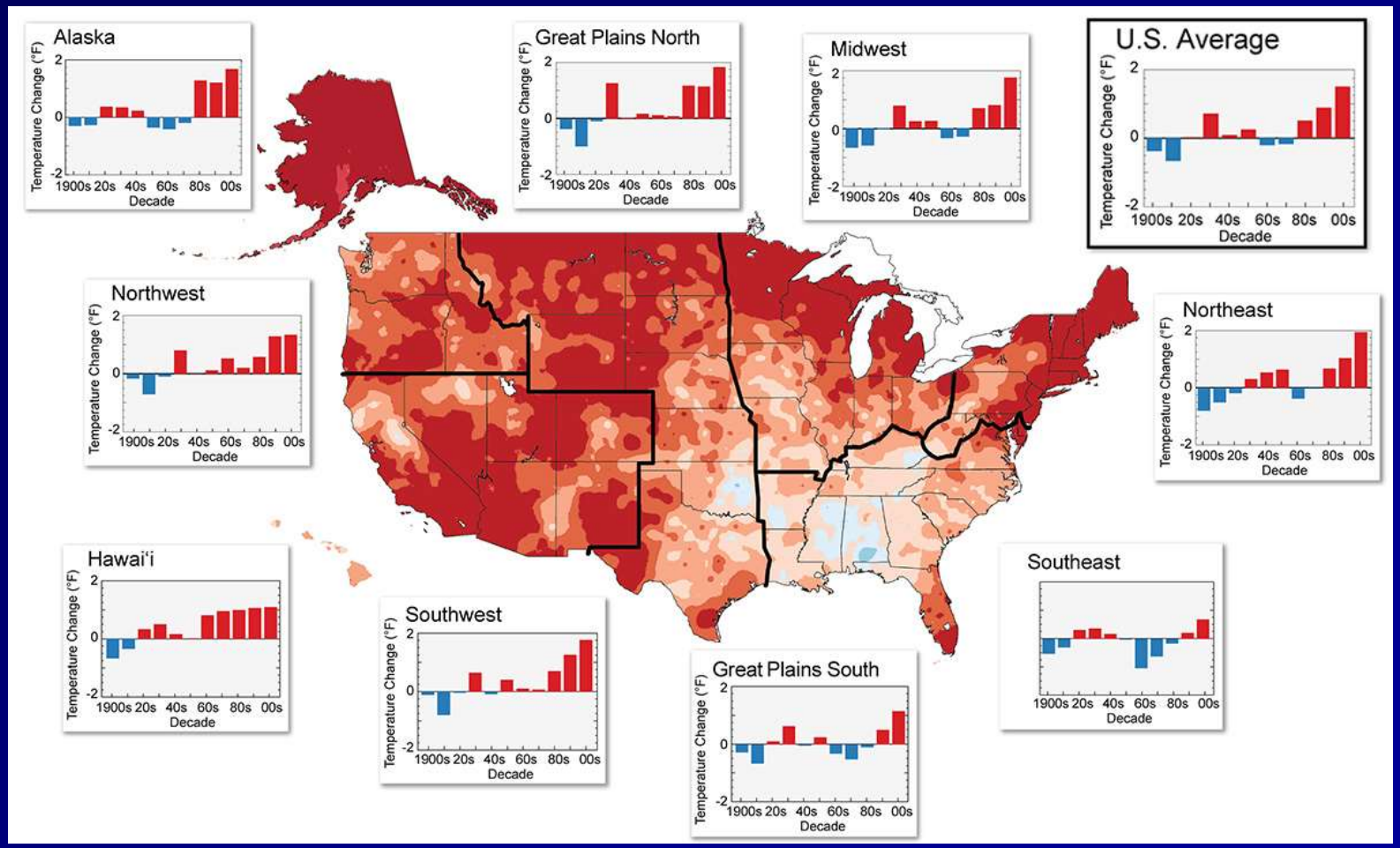


Image Source: Ken Kunkel

Projected Temperature Change of Hottest Days

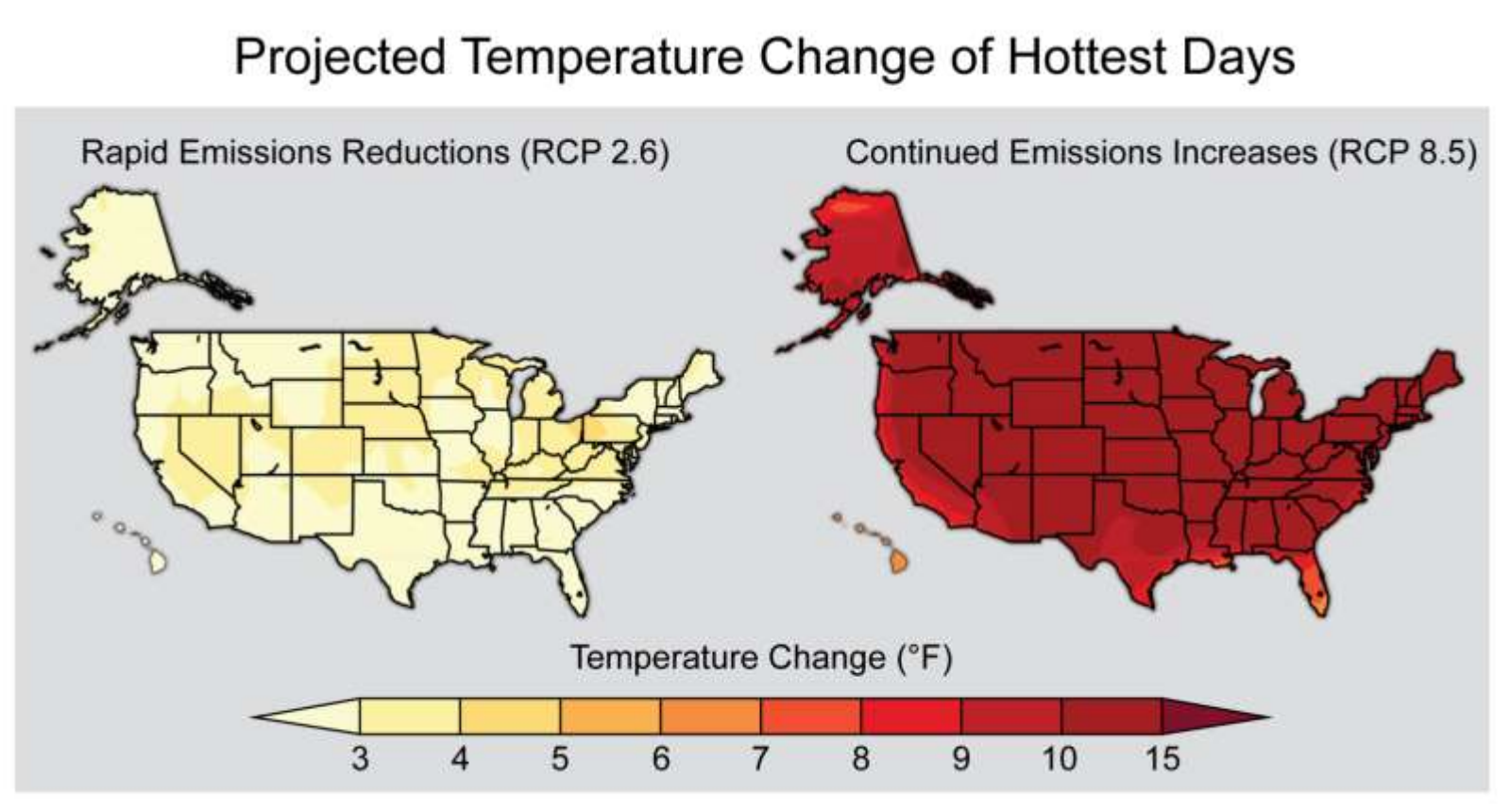
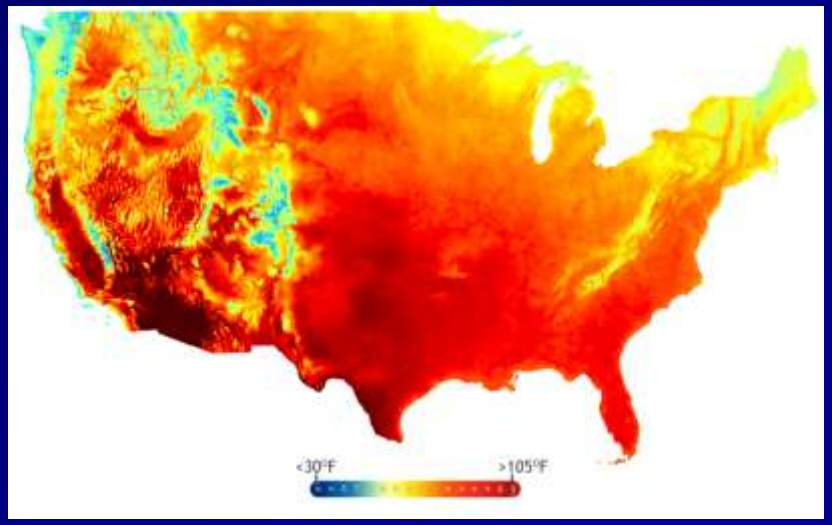


Figure source: NOAA NCDC / CICS-NC

Temperatures are on the Rise

Extreme heat events will be more frequent and more intense in the future….what now seems like an unusually hot day will become commonplace (NCA).



From 1979-2003, **excessive heat exposure caused 8,015 deaths** in the U.S. During that period, more people died from extreme heat than from hurricanes, lightning, tornadoes, floods, and earthquakes combined.

Climate Change:
Impacts on the Hydrologic Cycle

Warmer air can hold a lot more water vapor

With each additional 1° (C) of temperature, the atmosphere's capacity to hold water vapor increases by 7%

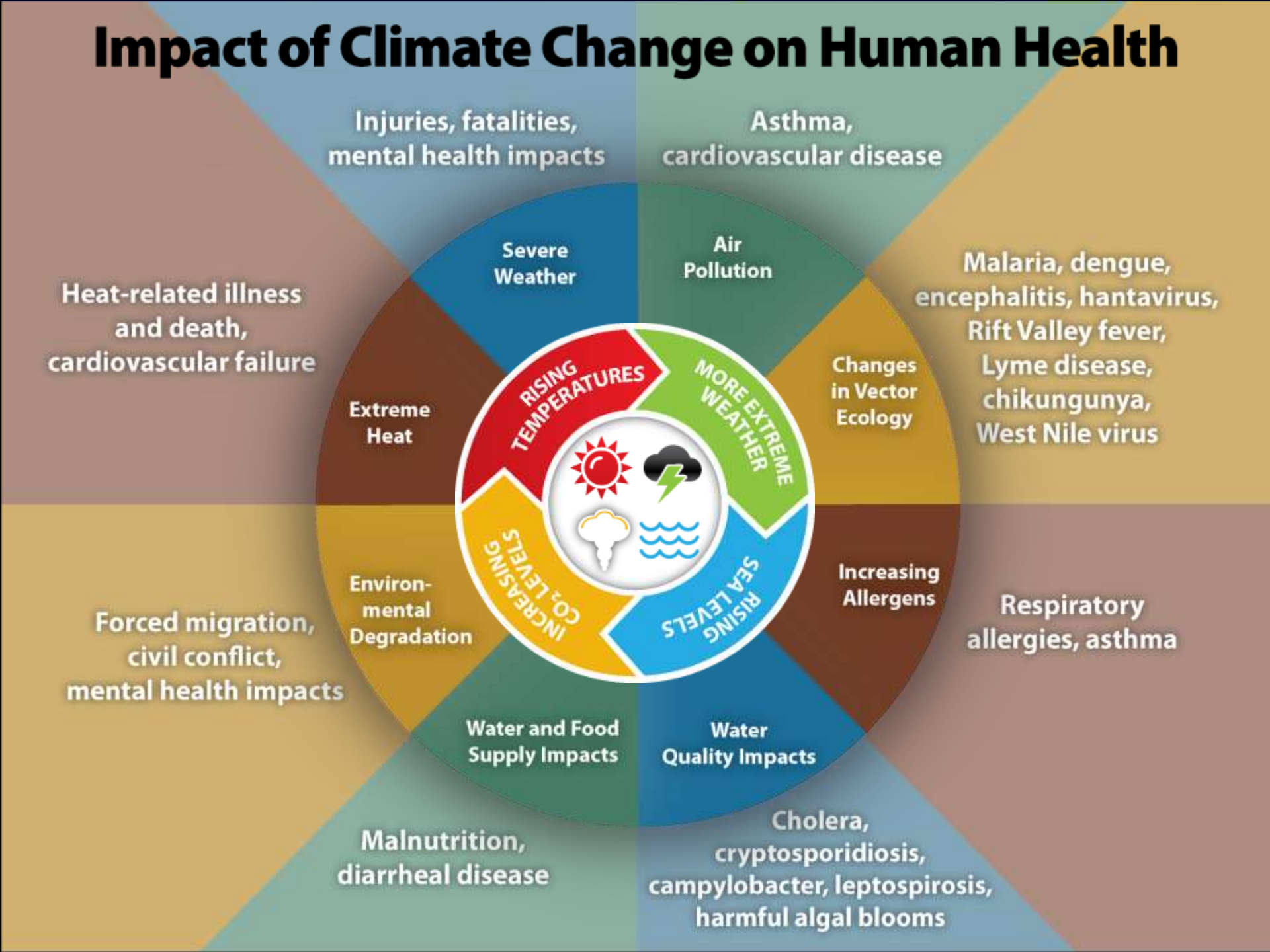
There is already 4% more water vapor over the oceans than there was only 30 years ago

So What are the Impacts?

Wide-ranging Health Impacts

Climate change threatens human health and well-being in many ways, including impacts from increased extreme weather events, wildfire, decreased air quality, threats to mental health, and illnesses transmitted by food, water, and disease-carriers such as mosquitoes and ticks. Some of these health impacts are already underway in the United States. (NCA)

Impact of Climate Change on Human Health



Climate is a Continuum

- Starting with weather (minutes, hours, days)
- To sub-seasonal (weeks to months)
- To seasonal (….well, seaonal!)
- To interannual (el nino, la nina)
- To decadal
- To century

Potential Health Effects of Climate Change

Climate Change:

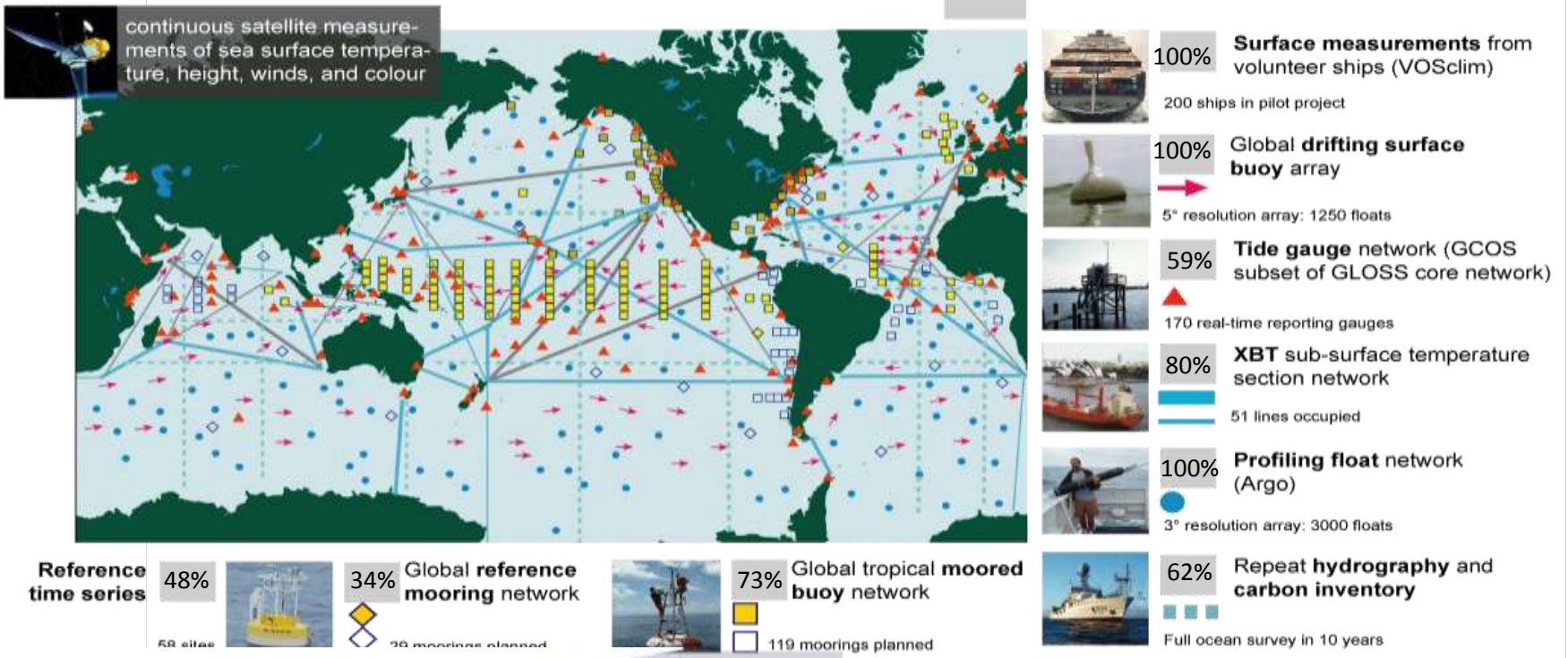
- Temperature Extremes
- Hydrologic extremes
- Sea level rise
- Ocean currents
- Ocean acidification

HEAT	Heat stress, cardiovascular failure
SEVERE WEATHER	Injuries, fatalities
AIR POLLUTION	Asthma, cardiovascular disease
ALLERGIES	Respiratory allergies, poison ivy
VECTOR-BORNE DISEASES	Malaria, dengue, encephalitis, hantavirus, Rift Valley fever, zoonotics, microbial contamination
WATER-BORNE DISEASES	Cholera, cryptosporidiosis, campylobacter, leptospirosis
WATER AND FOOD SUPPLY	Malnutrition, diarrhea, harmful algal blooms
MENTAL HEALTH	Anxiety, despair, depression, post-traumatic stress
ENVIRONMENTAL REFUGEES	Forced migration, civil conflict

Adapted from J. Patz

Climate Observations Division: both embedded in and key to the international framework

Total *in situ* networks **62%**

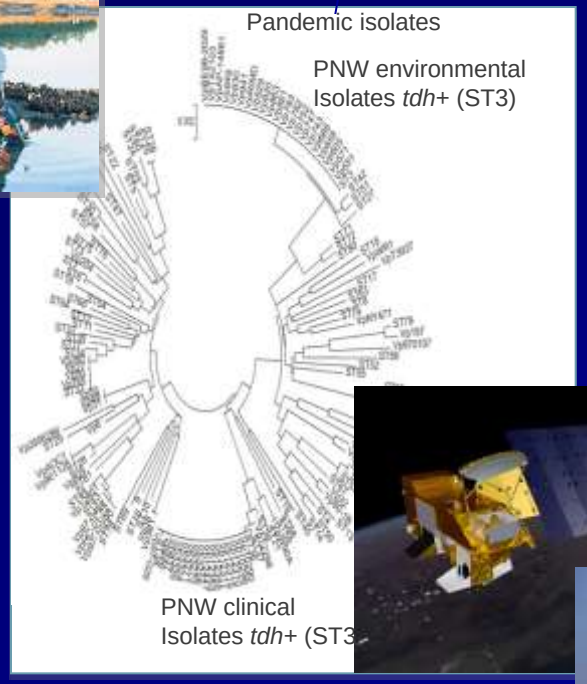


System % complete

A heritage summary slide – now looking at new system goals and ways to convey the benefits of the system

From Genes to Satellites to in situ: Tools for Tracking and Health Early Warning Systems

Oceanographic measurements and biogeographical linkages of pathogen to human illness

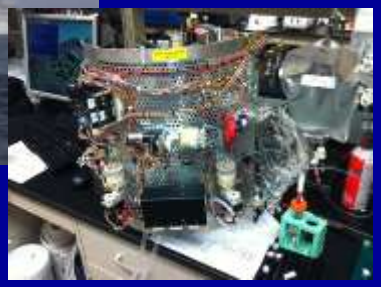


Virulent strains rare and less diverse

Genome sequencing of multiple strains to identify

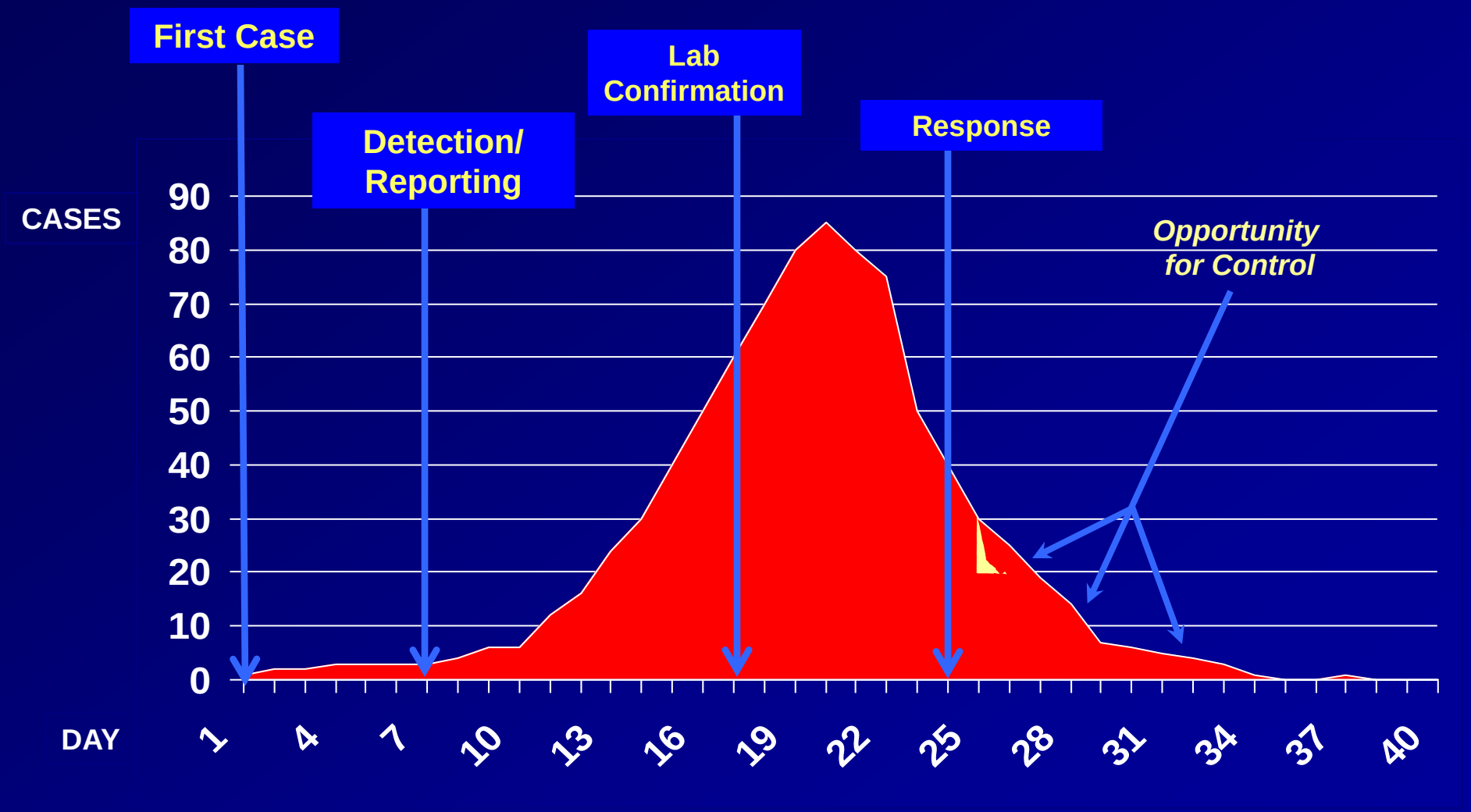
NASA Aqua w
MODIS

Appropriate genetic markers on biosensors, linked to ocean observing



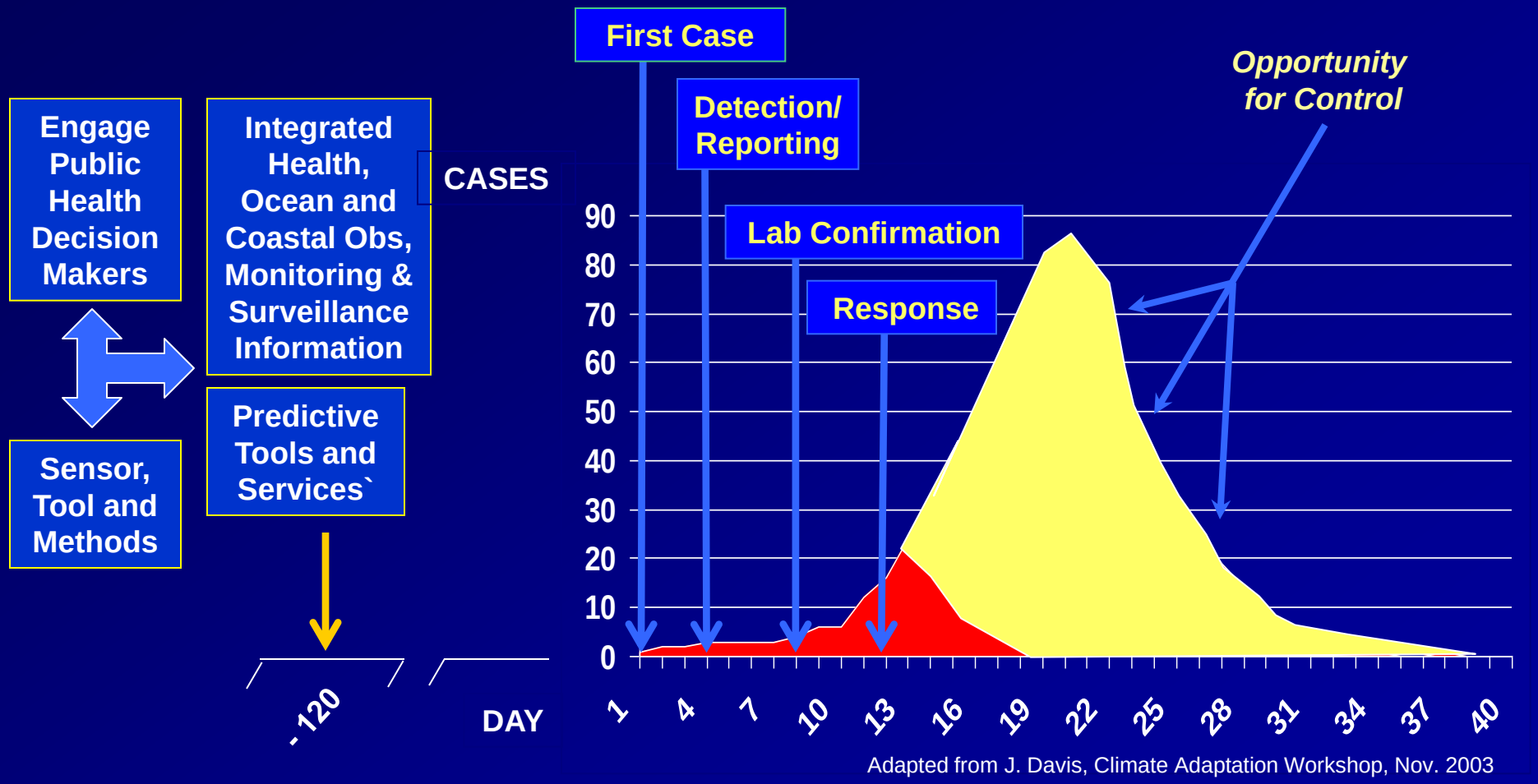
for *Vibrios*

Current Epidemic Detection and Response Curve



Adapted from J. Davis, Climate Adaptation Workshop, Nov. 2003

Getting ahead of the Curve: Integrating Ocean, Climate and Public Health Information



Enhancing Public Health Engagement, Outreach, and Feedback throughout

So Now What?
Enter…..
Ecological Forecasting

What are Ecological Forecasts?

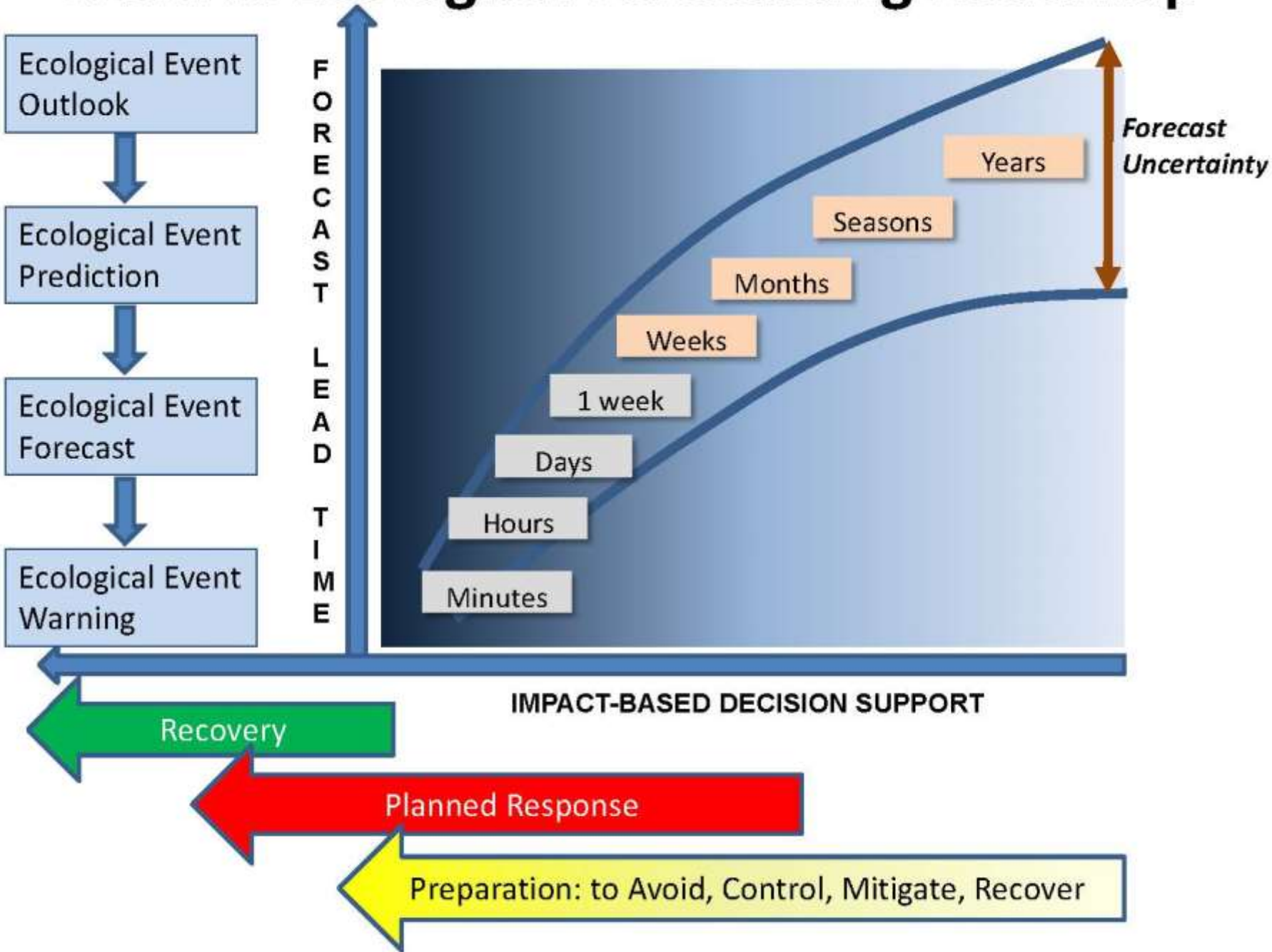
- Ecological forecasts predict likely changes in ecosystems in response to environmental drivers and resulting impacts to people, economies and communities.

- Ecological forecasts provide early warnings of the possible effects of ecosystem changes (e.g., harmful algal blooms, hypoxia, etc.) on coastal systems and human well-being with sufficient lead time to allow for corrective or mitigative actions.

NOAA's Ecological Forecasting Roadmap: What We Will Achieve

- Strong science to enable delivery of forecasts
- Delivery of more products and services building on existing NOAA and partner capacity
- Delivery of more consistent, efficient, reliable, and national forecasts (tailored to region-specific needs)

NOAA's Ecological Forecasting Roadmap



Forecasts Under Development

Harmful Algal Blooms:

- West Florida Shelf (operational)
- Texas (operational)
- Lake Erie (demo/experimental)
- Gulf of Maine (demo/experimental)
- Puget Sound (demo/experimental)
- Washington Coast (demo/experimental)
- California (future)
- Chesapeake Bay (future)

Hypoxia:

- Gulf of Mexico (demo/experimental)
- Chesapeake Bay (demo/experimental)
- Pacific Northwest (future)

Pathogens:

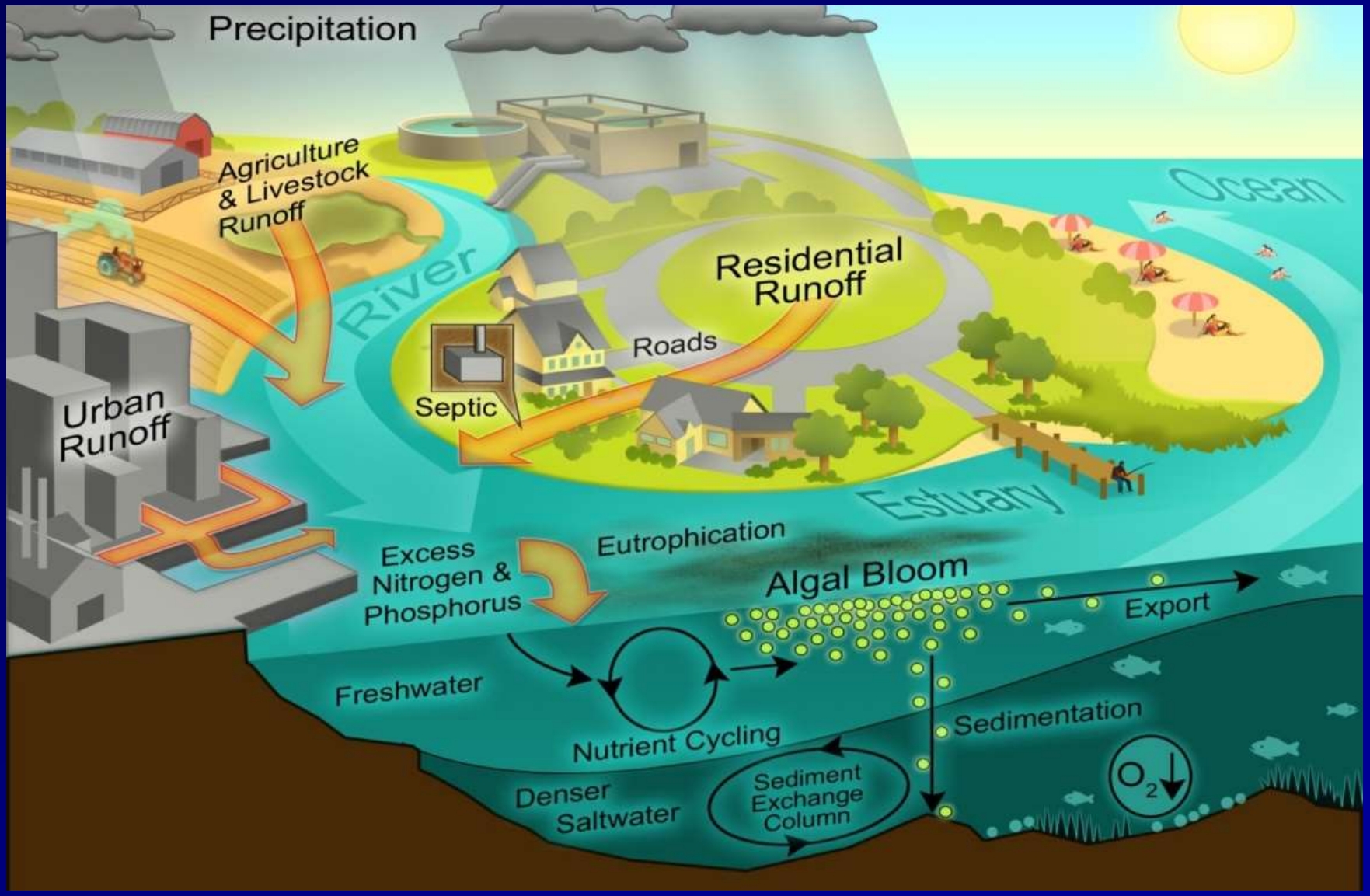
- Chesapeake Bay (demo/experimental)
- Delaware Bay (demo/experimental)
- Tampa Bay (demo/experimental)
- Gulf of Mexico (future, location may change)

Sentinel Habitat:

A Few Examples

- Water-related Illness
  - Vibrios
- Harmful Algae Blooms

Water-borne disease pathways freshwater-marine continuum



Waterborne Disease and Water Related Illness

- Waterborne disease are bacteria, virus, parasites transmitted through
  - drinking water
  - recreational water/occupational exposure
  - food contaminated with fecal pollution, or other bacteria or viruses
- Marine and Freshwater
- Chemical Contaminants
- Marine Zoonotics

- Diarrhea, cryptosporidiosis, campylobacter, leptospirosis, Cholera, Vibriosis, Salmonella , Brucella
- Harmful Algal Bloom related
- Chemical Exposure
- Malnutrition

Climate Pathways for Water-Related Illness

Climate Drivers

- Temperature rise
- Hydrologic extremes
- Sea level rise
- Ocean currents
- Ocean acidification

Contaminant Source

- Urban
- Rural
- Agricultural
- Wildlife
  - Marine
  - Terrestrial

Routes of Exposure

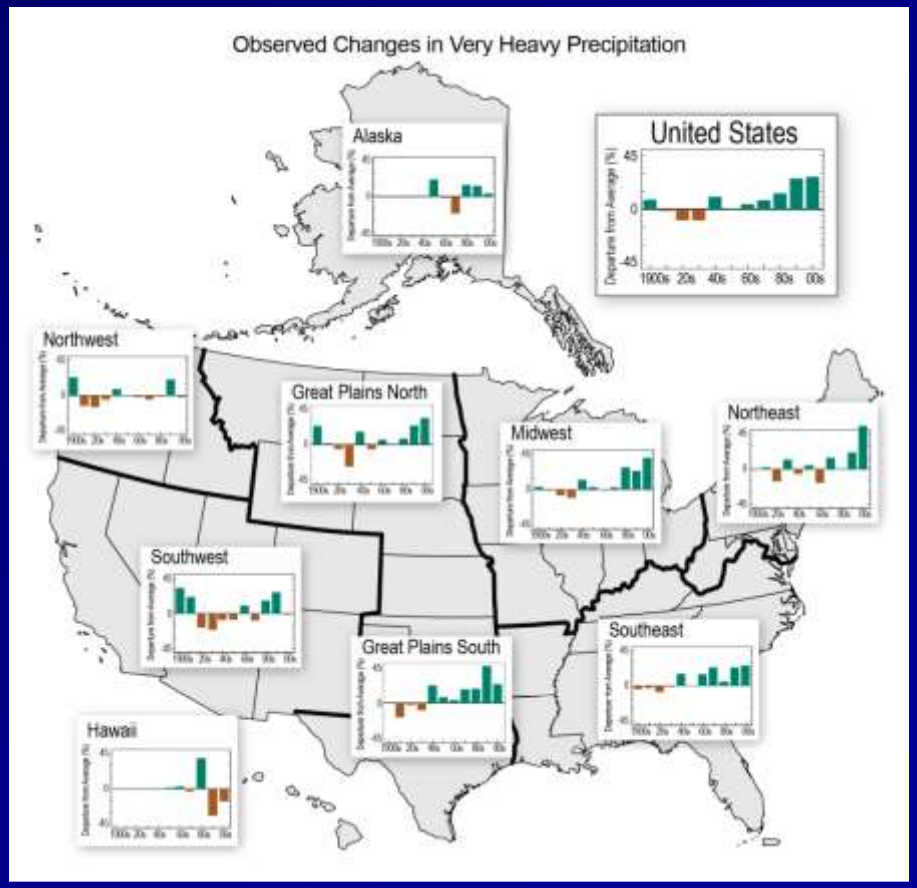
- Drinking Water
- Recreational or Occupational
- Ingestion

Health Outcome

- Diarrheal Disease
- Neurologic
- Respiratory
- Illness from Chemical Exposure
- Other (ear, MRSA etc)

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

Impacts on Great Lakes

- Increases of combined sewage overflow flow volumes by 20%
- Changing wind fields will change distribution of contamination
- Runoff from stormwater will also impact the nearshore

Cryptosporidiosis

Milwaukee 1993

Cryptosporidiosis epidemic
405,000 cases, 54 deaths

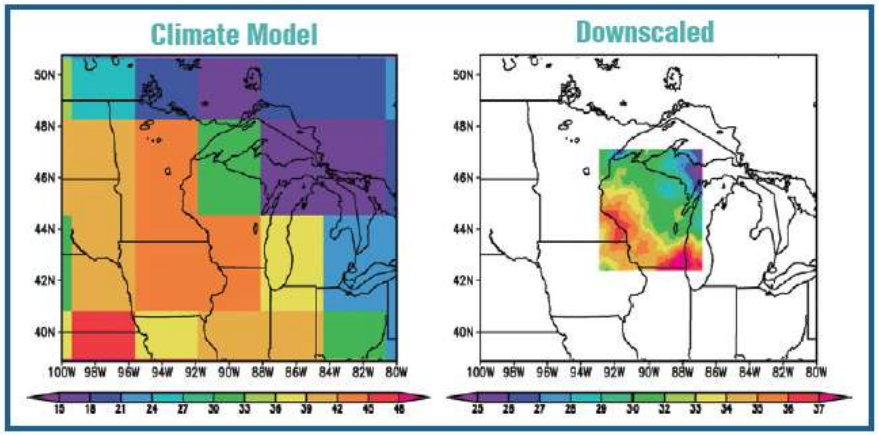
Preceded by heaviest rainfall in 50 years (Curriero et al., 2001)

$31.7 million in medical costs
$64.6 million in lost productivity
(Corso et al., 2003).

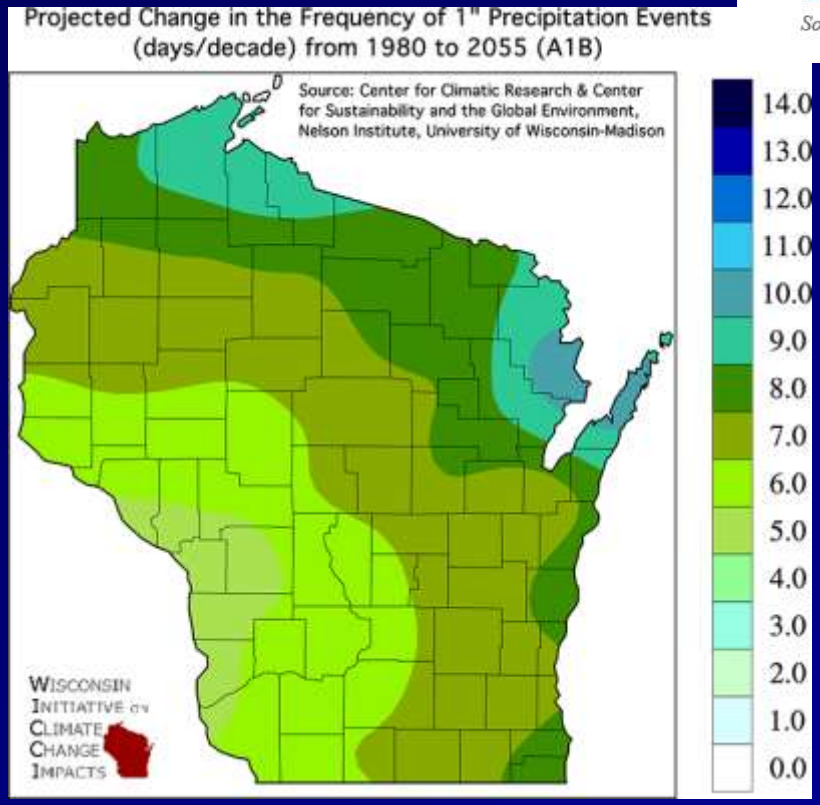
Brisbane-Weekly temps over 31C, relative humidity < 63%, 13.64 increase in risk

(Hu et al., 2010)

Climate Change in the US Great Lakes



Source: David Lorenz, Nelson Institute Center for Climatic Research, University of Wisconsin-Madison



Increases of rainfall frequency and intensities projected for the Great Lakes

Intense rainfall or extreme rainfall inundates urban wastewater infrastructure

http://www.wicci.wisc.edu/climate-change.php

Ecological Forecasting in Action: Toledo

Over a half million people impacted by "Do Not Drink Advisories" in Northwest Ohio and Southeast Michigan.
(August 1--3, 2014)

Harmful Algal Blooms (HABs)

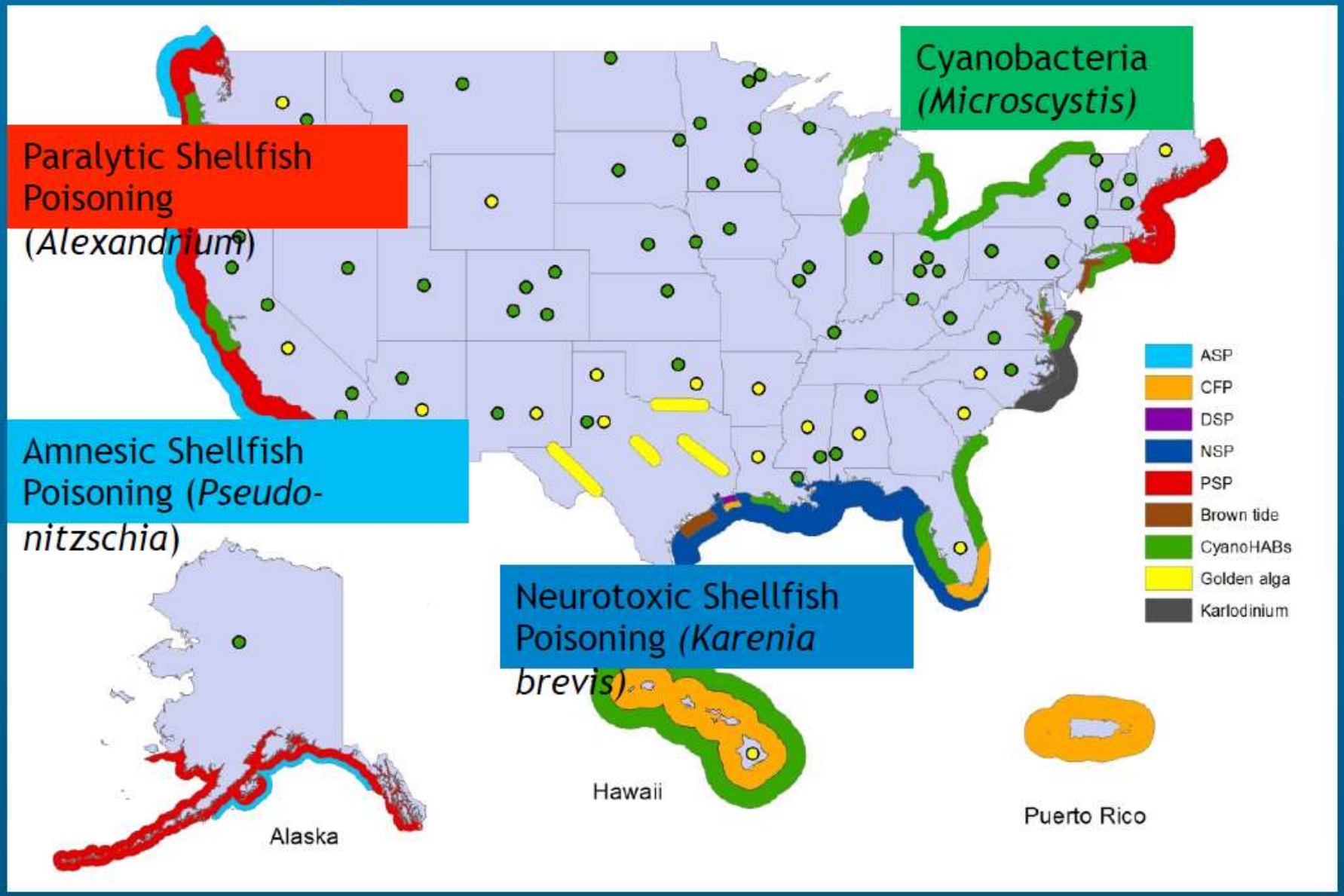
- Natural phenomena caused by the proliferation of algae, resulting in damage to the environment and/or risk to human health

"Florida red tide"

- Many produce toxins that accumulate in fish and shellfish and cause illness or death in humans if consumed

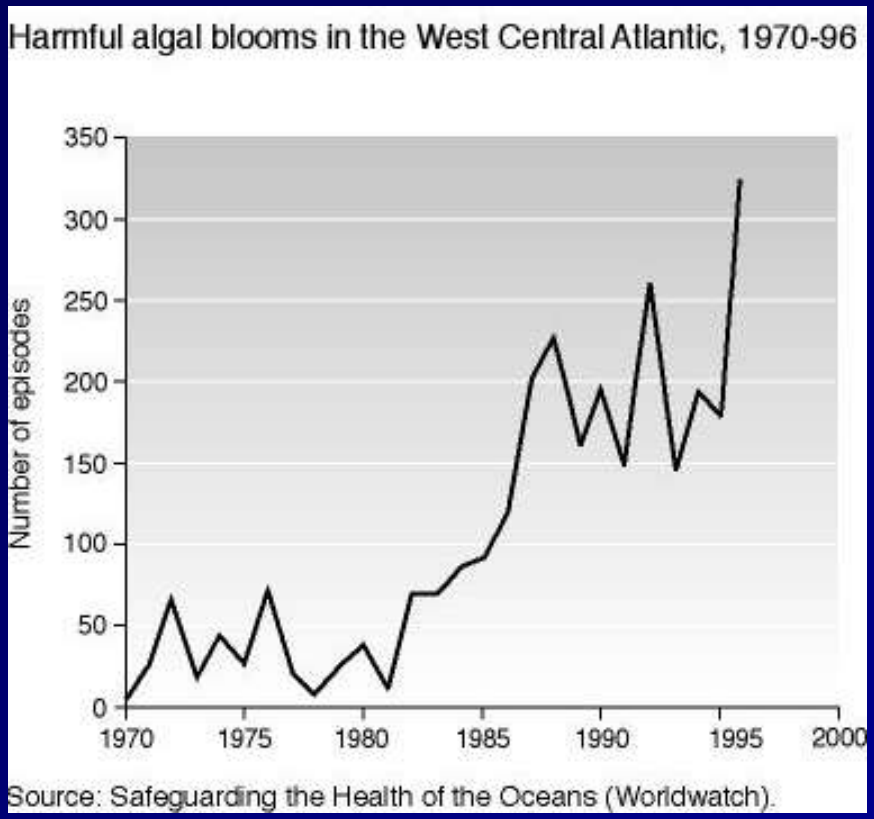
Erdner *et al.* (2008): Environmental Health

Harmful Algal Blooms in the U.S.



Economic cost of HABs over the last decade is conservatively ~$1billion.

Worldwide Increase In Frequency, Duration, And Geographic Scope Of Harmful Algal Blooms (HABs)



Outbreaks of harmful algal blooms in Chinese coastal waters increased 10-fold from 1975 to 1993 (redrawn from Zhang 1994).

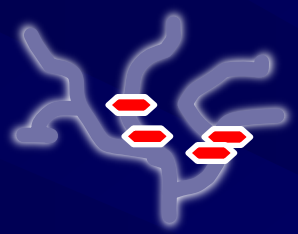
SOURCES:

Harmful algal blooms in the West Central Atlantic, 1970-96. (2001). In *UNEP/GRID-Arendal Maps and Graphics Library*. Retrieved 19:42, June 16, 2009 from http://maps.grida.no/go/graphic/harmful_algal_blooms_in_the_west_central_atlantic_1970_96.

GEOHAB, 2001. Global Ecology and Oceanography of Harmful Algal Blooms, Science Plan. P. Glibert and G. Pitcher (eds). SCOR and IOC, Baltimore and Paris. 87 pp.

S. Moore, NOAA West Coast Center for OHH and North West Fisheries Science Center

Fish Poisoning

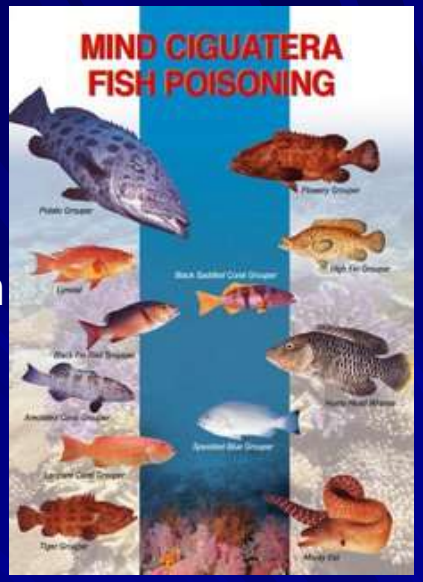


Epi-benthic toxic algae

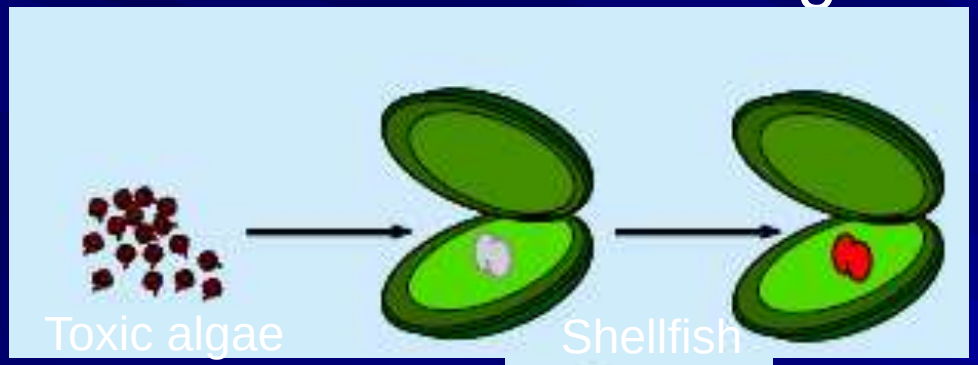
Herbivorous fish

Piscivorous fish

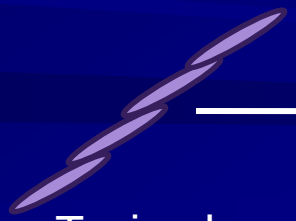
Human consumption



Shellfish Poisoning



Human consumption



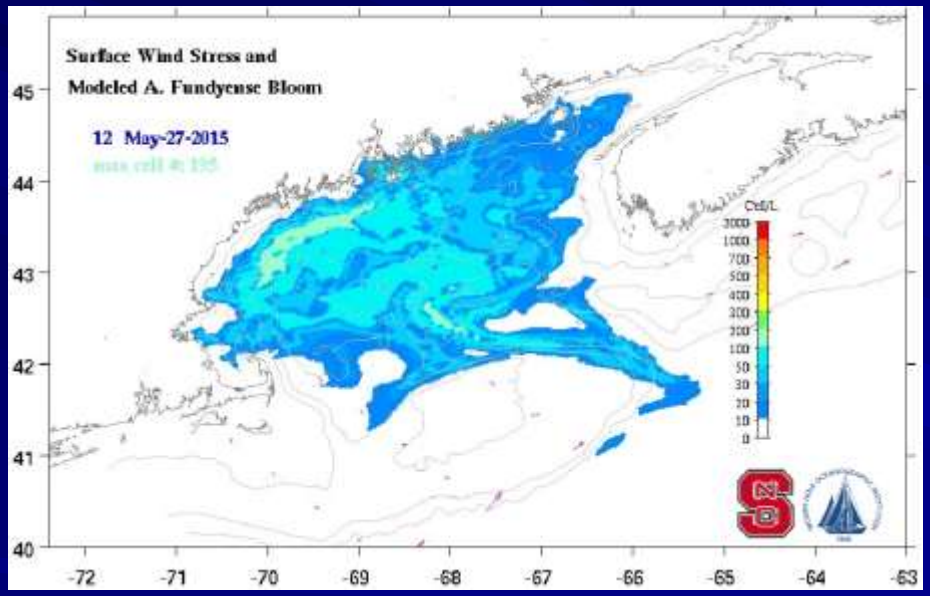
Toxic algae

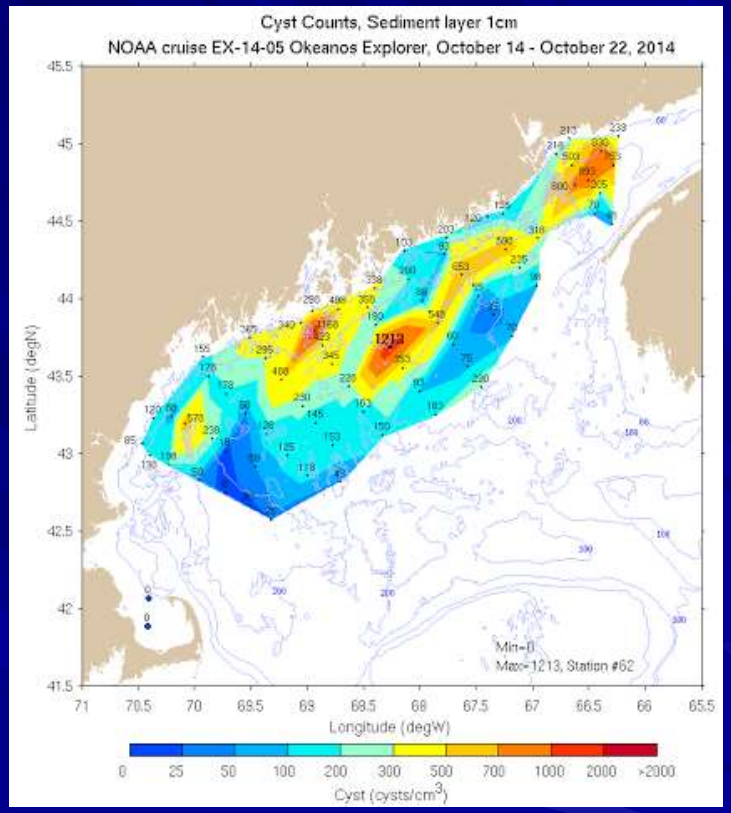
Razor clams

Human consumptio

Gulf of Maine Season HAB forecast

Forecast: New England's spring and summer red tides will be similar in extent to those of the past three years.



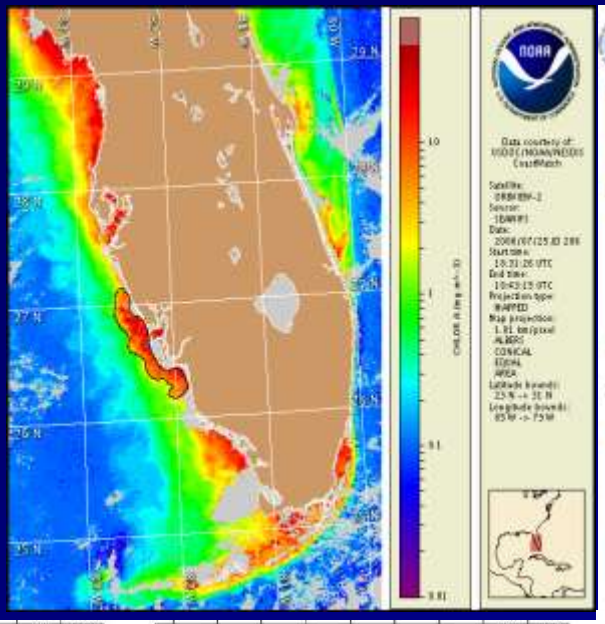


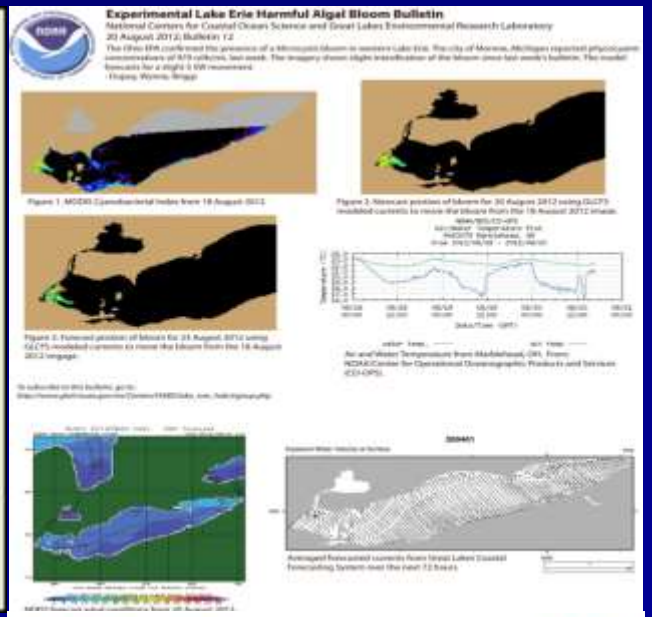
"This partnership on the Gulf of Maine seasonal HAB forecast and use of ESPs to detect toxic red tide offshore are examples of NOAA's role in improving ecological forecasting capabilities along our coasts,"
- Holly Bamford, Ph.D., Acting Assistant Secretary of Commerce for Conservation and Management

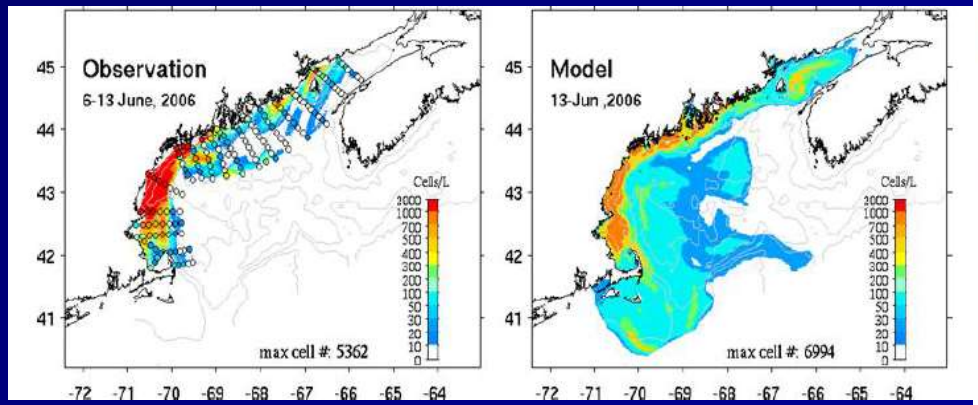
HAB Operational Forecast System

- Within 5 years:

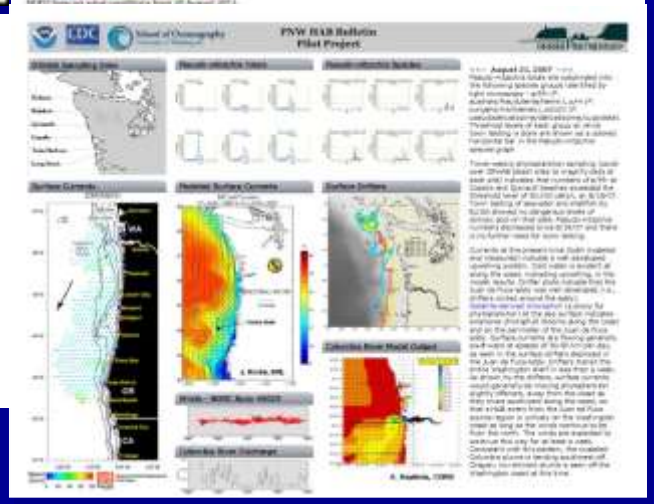
Gulf of Maine, Gulf of Mexico (FL, TX), Chesapeake Bay, Lake Erie, PNW, CA







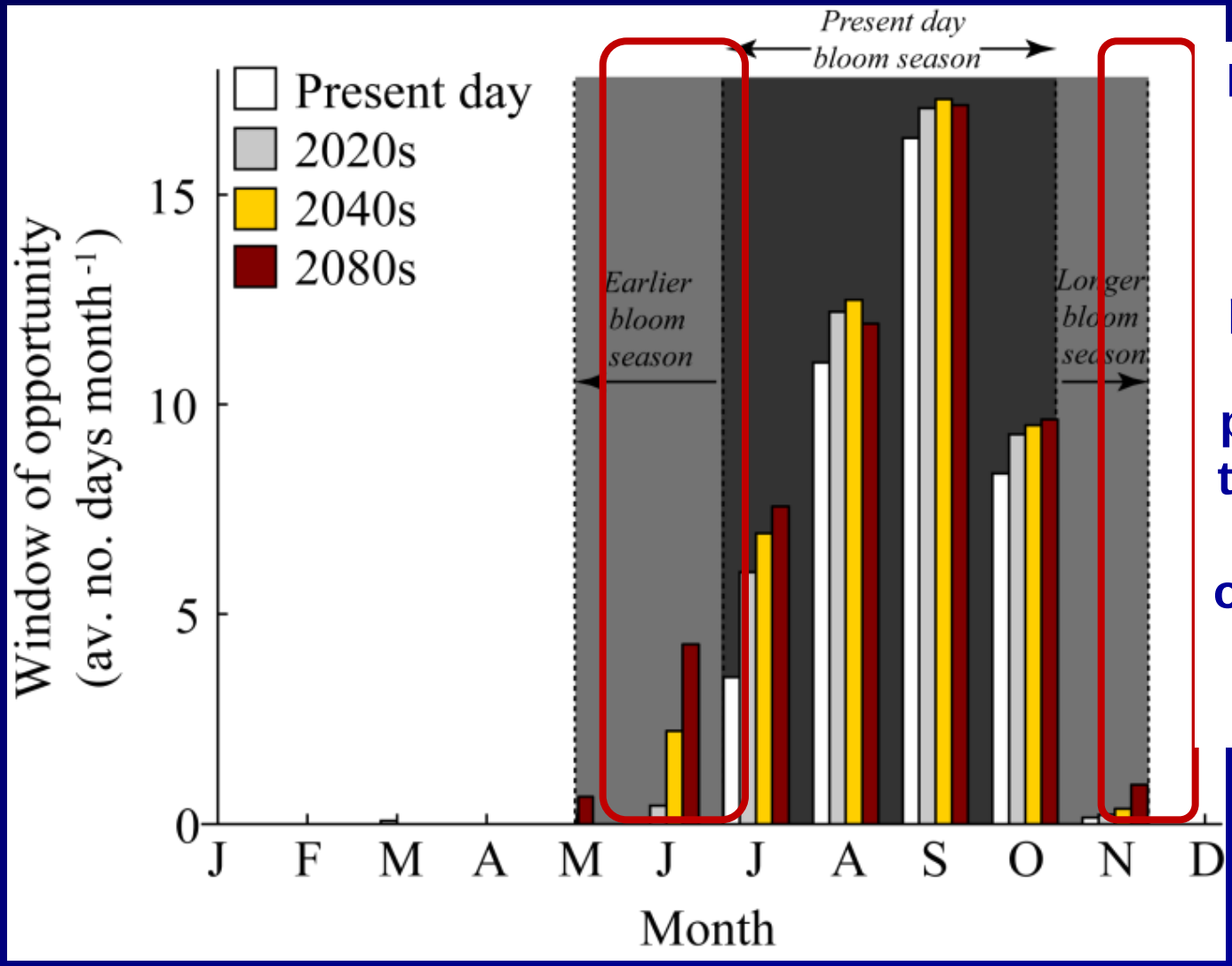
Courtesy of Don Anderson



http://tidesandcurrents.noaa.gov/hab

http://www.glerl.noaa.gov/res/Centers/HABS/lake_erie_hab/lake_erie_hab.html

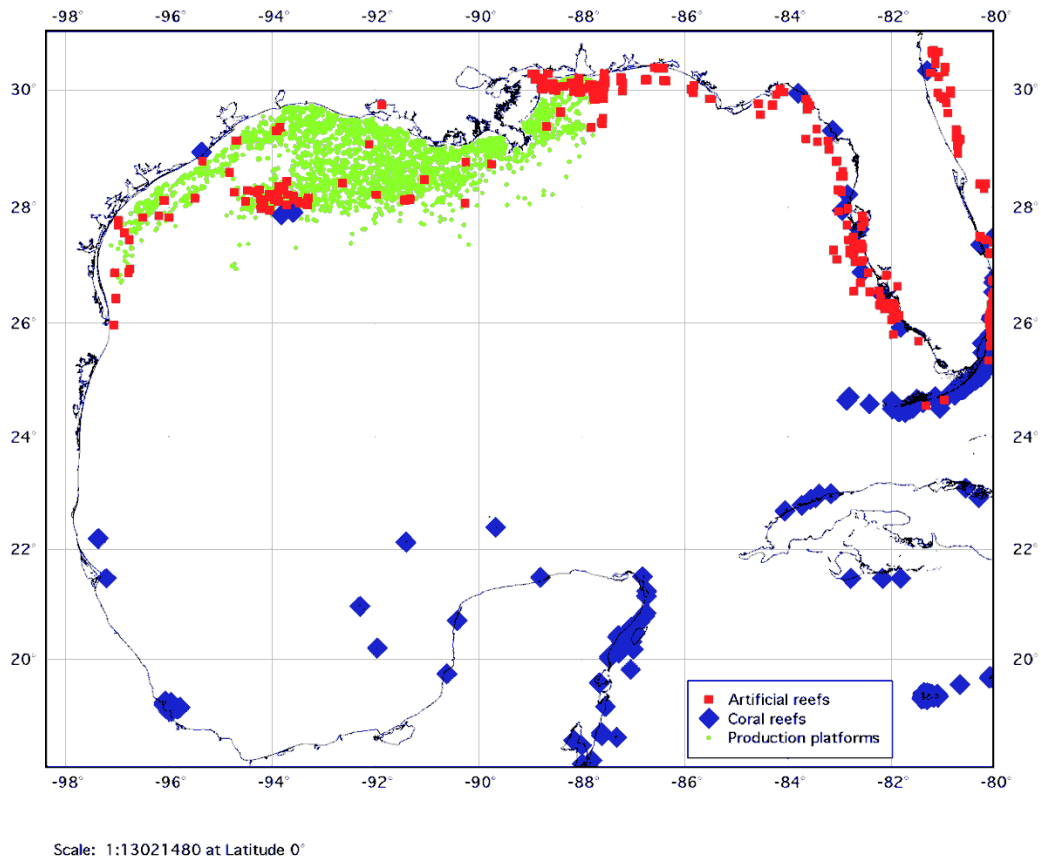
Projected window of opportunity for *Alexandrium* spp. in Puget Sound



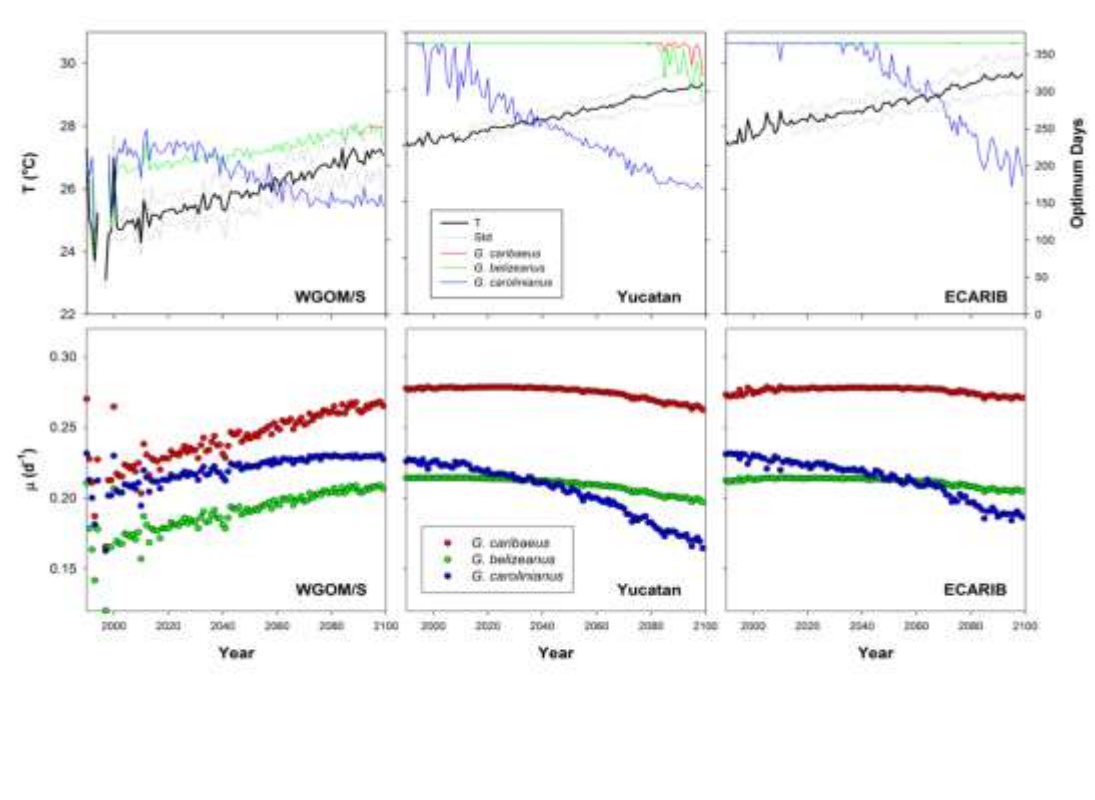
Managers can watch these months more closely and put mitigation measures in place ahead of time instead of being caught off guard by an unexpected bloom

Moore *et al.*, 2011

Ciguatera Fish Poisoning on Texas Coast Oil Rigs



Projected Changes in Caribbean *Gambierdiscus* Species

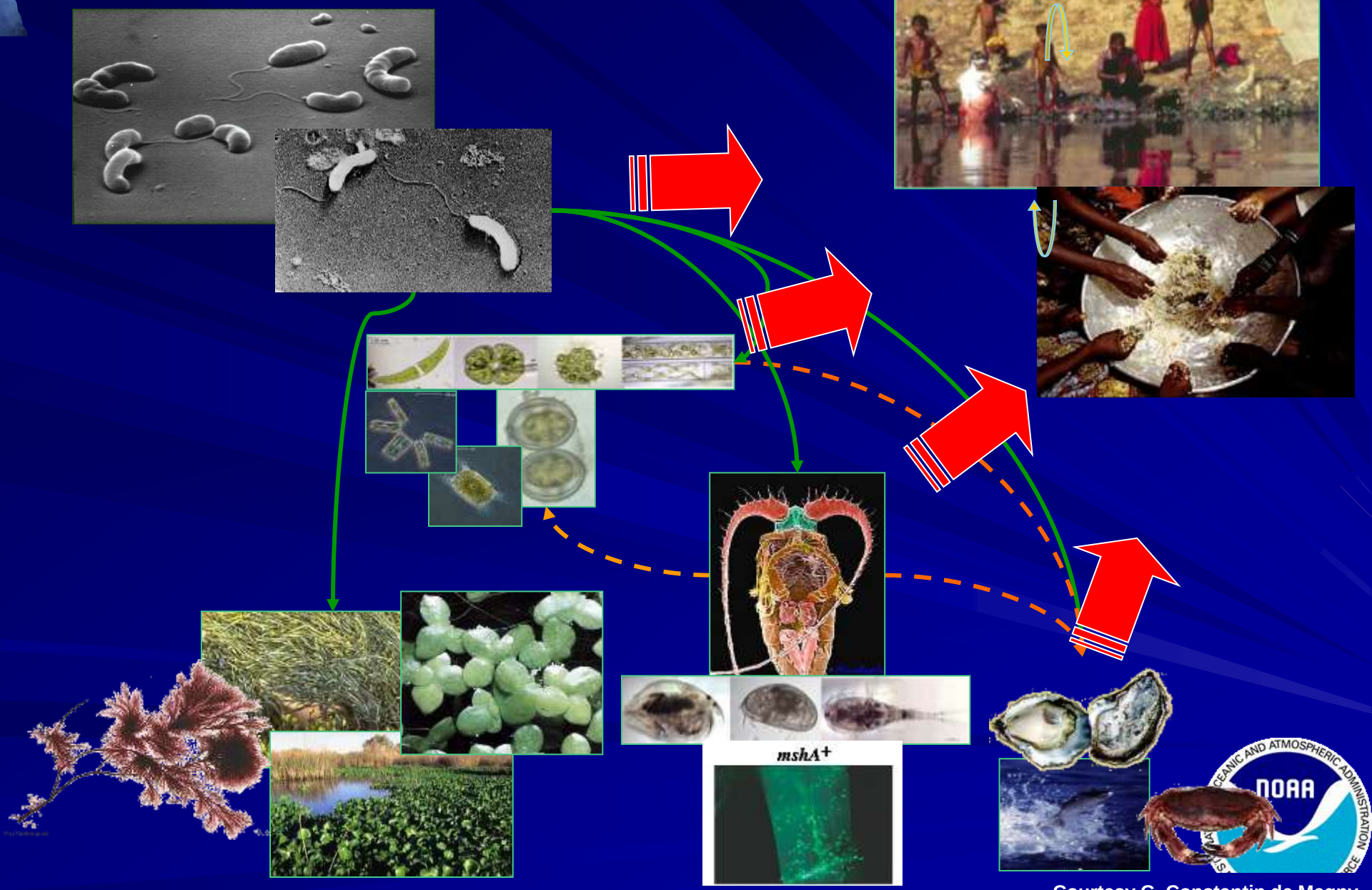


Caption: Projected average annual water temperature (T,°C), yearly number of optimum growth days, and mean projected growth rates (μ, d^{-1}) for three Caribbean *Gambierdiscus* species (*G. caribaeus*, *G. belizeanus*, *G. carolinianus*) at buoy sites in the western Gulf of Mexico (WGOM), Yucatan channel (YUCT), and eastern Caribbean Sea (ECAR) through 2099. Figure source: Kibler et al. (accepted)

Climate, Vibrio Cholera and its Bacterial Cousins

- ***Vibrio parahaemolyticus***
  - **main cause of seafood poisoning**
  - **under reported, misdiagnosed, increasing-8000 cases per year**
- ***Vibrio vulnificus***
  - **95% fatality rate from consumption**
  - **causes wound infections**
- ***Vibrio* infection rates have increased 115% over the last decade.**
- ***Vibrio Cholera***
  - 3–5 million cases, 100,000–120,000 deaths

Ecology of Cholera

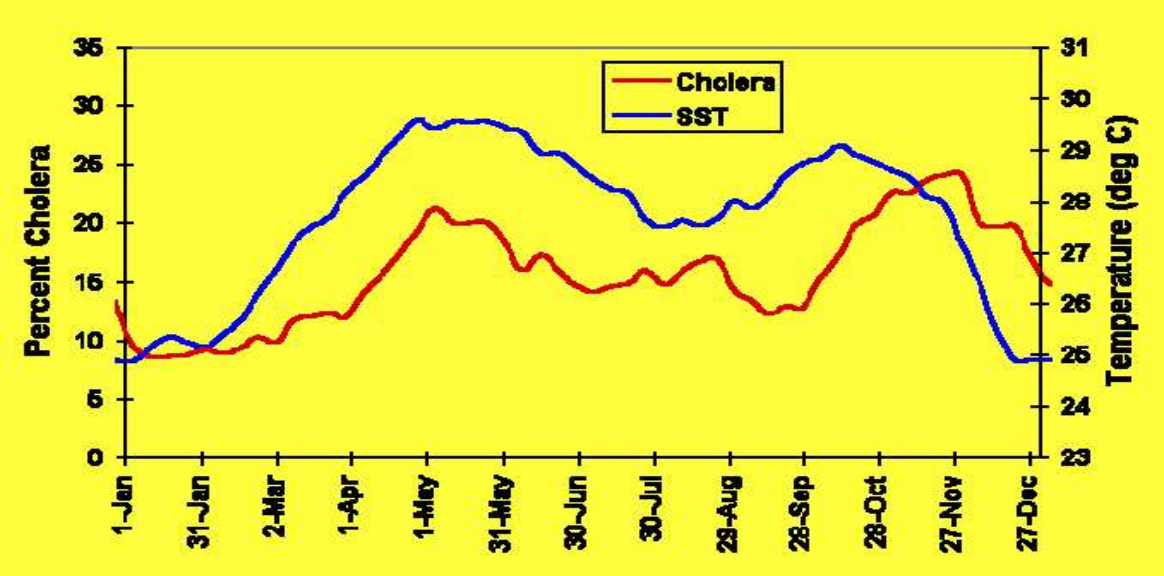


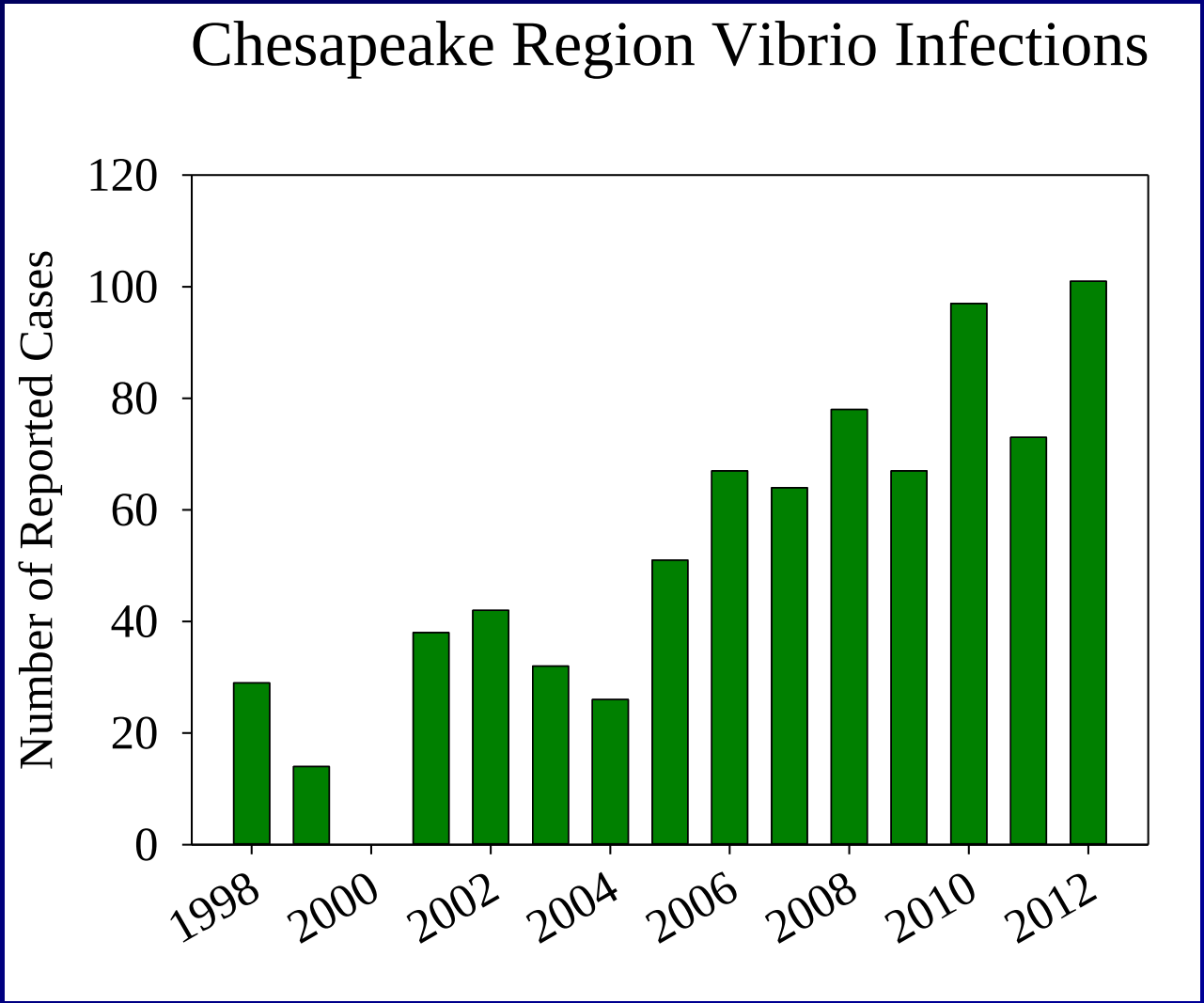
Courtesy G. Constantin de Magny

What are the environmental drivers?

- Sea Surface Temperature
- Salinity
- Chlorophyll
- Temperature

- Soil Moisture
- Precipitation
- Soil Type

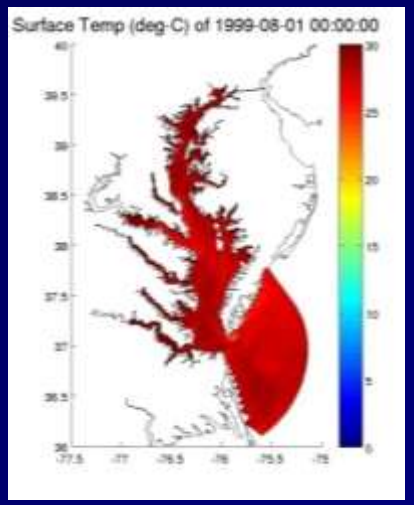




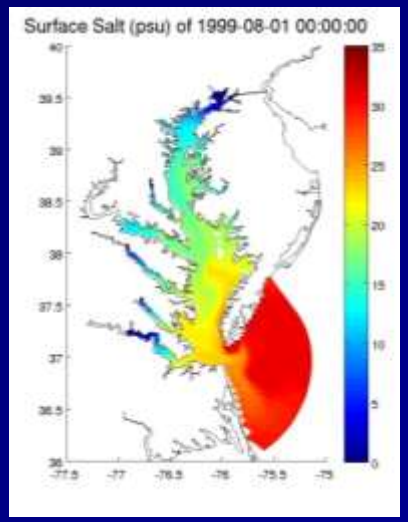
CDC, COVIS Surveillance Program (MD, VA, PA)

Pathogen Forecasting System

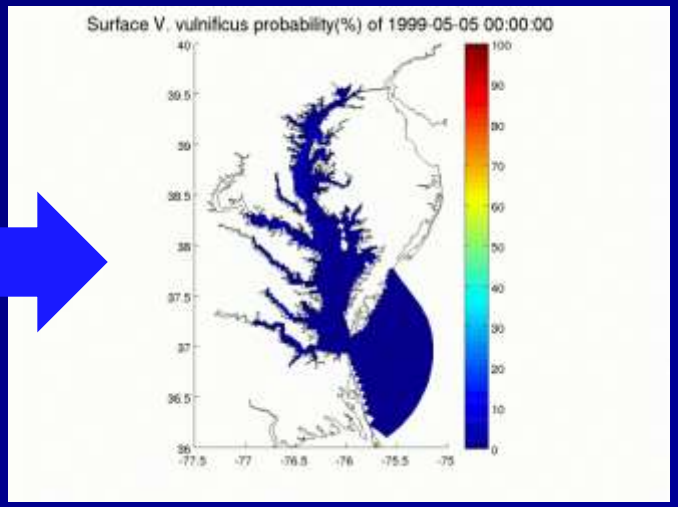
Sea Surface Temperature



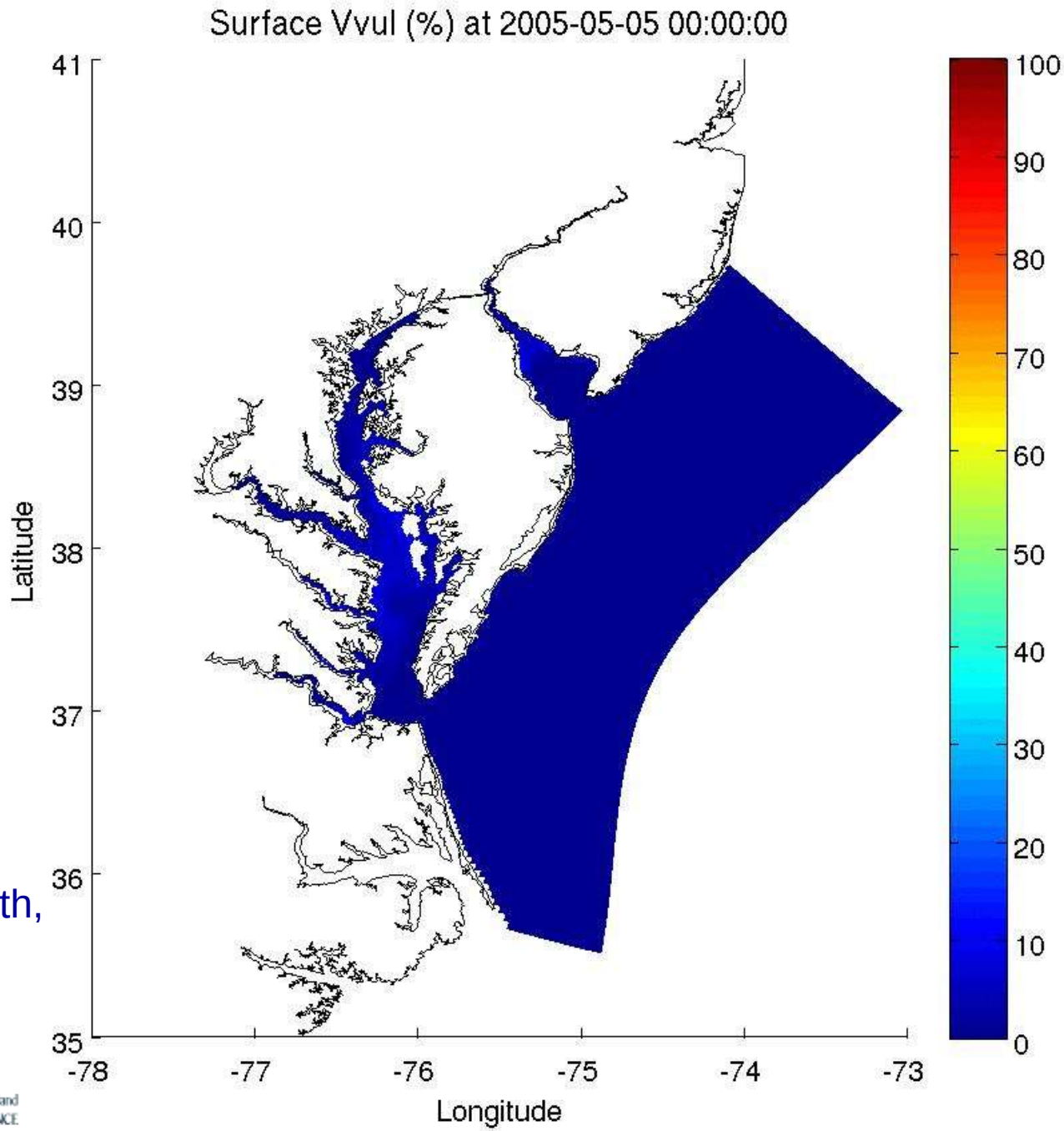
Salinity



Vibrio empirical models



Brown, C.W., R. R. Hood, W. Long, J. Jacobs, D. L. Ramers, C. Wazniak, J. D. Wiggert, R. Wood, and J. Xu. (2013). Ecological Forecasting in Chesapeake Bay: Using a Mechanistic-Empirical Modeling Approach. Journal of Marine Systems
http://www.sciencedirect.com/science/journal/aip/09247963

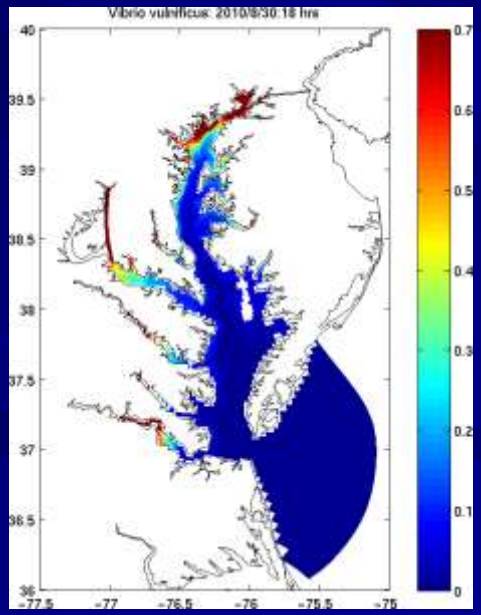


Wen Long,
Elizabeth North,
Raleigh Hood

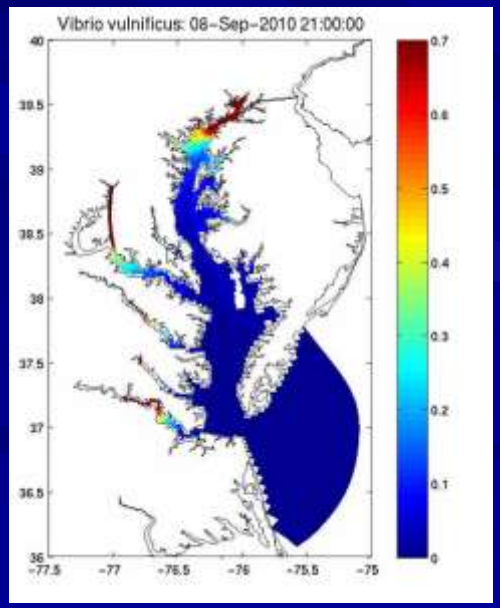
University of Maryland
Center for Environmental Science
Horn Point Laboratory

Current Experimental Products

- Nowcasts and 2-3 day forecast – UMCES and NOAA
- 14 and monthly forecasts - UMD ESSIC

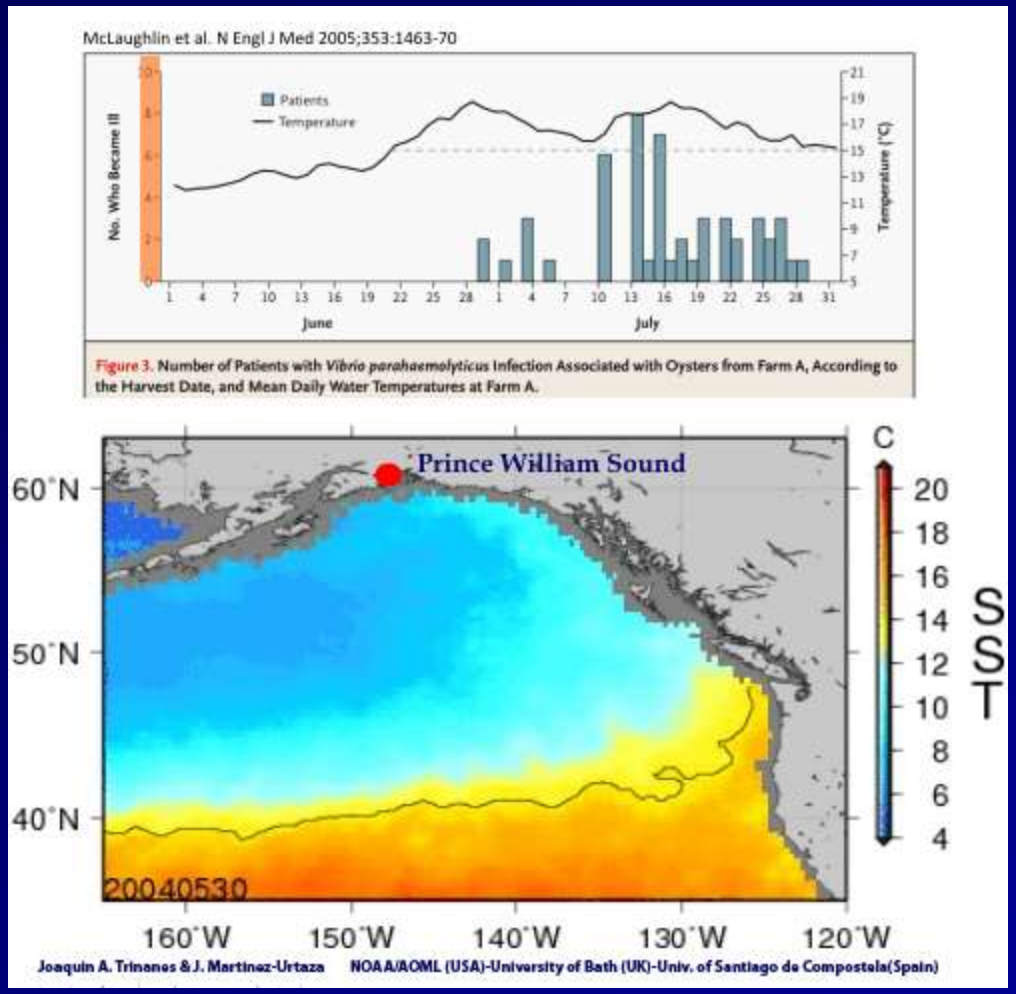


14 day



Monthly

Alaska Vibrio Outbreak

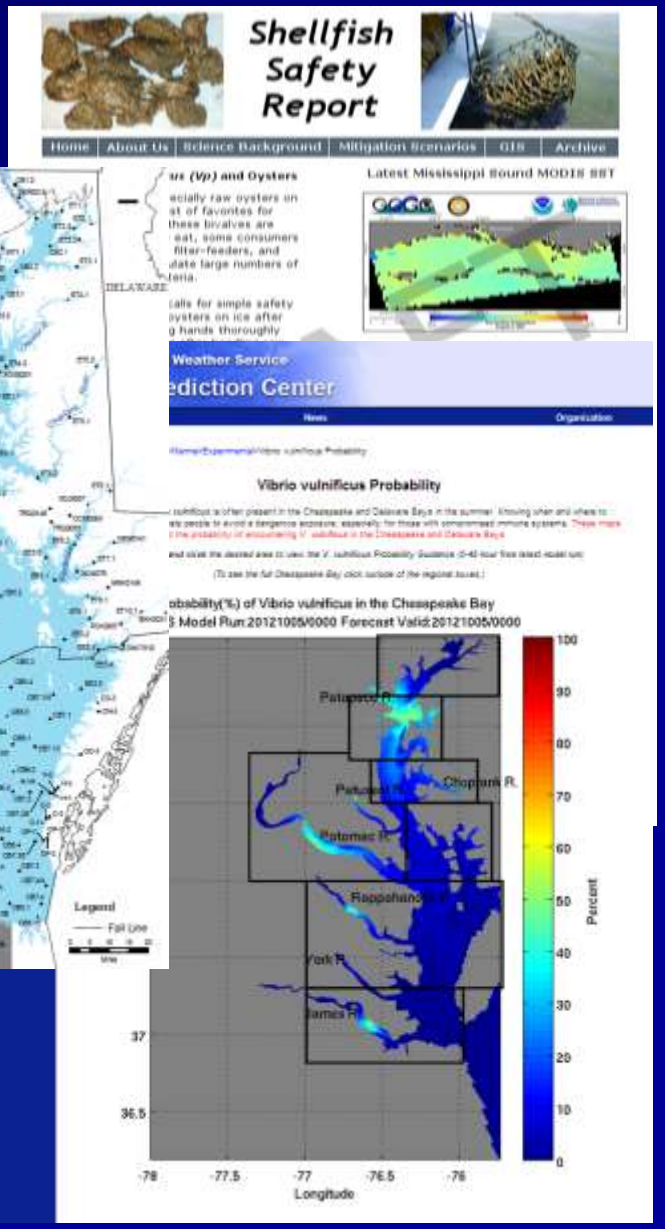


- 2004 – 62 cases associated with shellfish consumption.
- *Vp* O:4 K:12 – transported from Puget Sound
- High proportion tdh+

Martinez-Urtaza, Bowers, Trinanes, and Depaola (2010) Food Research Int.

Developing a Vibrio Operational Forecasting System

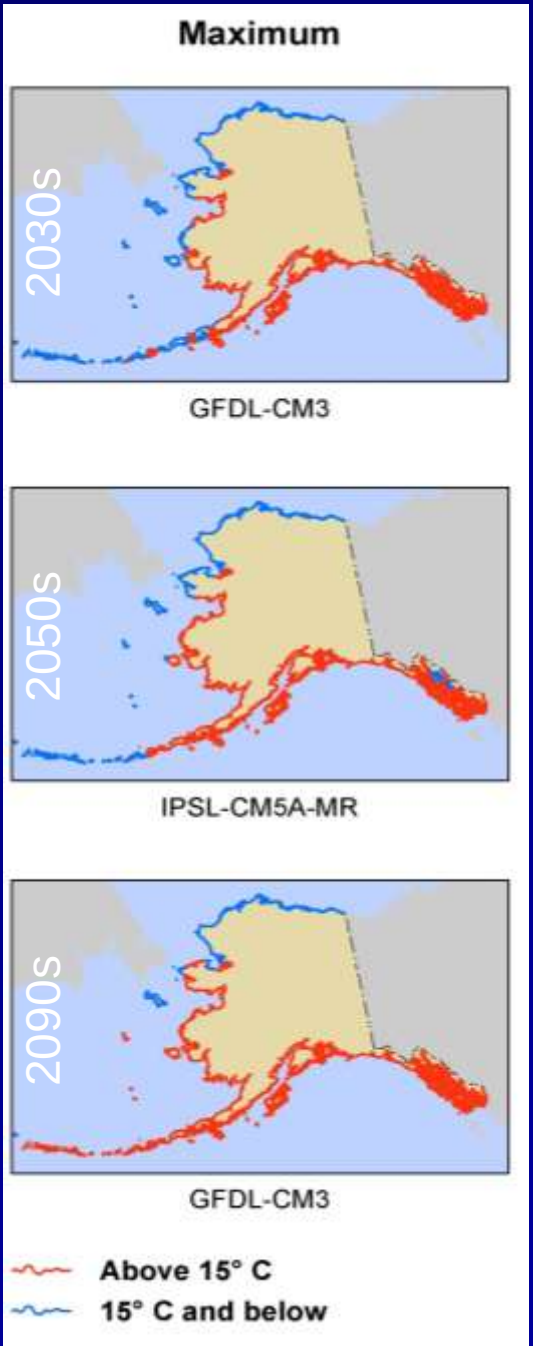
- Fully operational regional ocean model
- 48 hour predictions
- Pathogen and Water Quality monitoring~ 150 tidal stations
- Surface water samples
- Full physical and chemical water quality profiles
- Validation with CDC and State Health data
- Test and Validate other models—satellite based SST, salinity



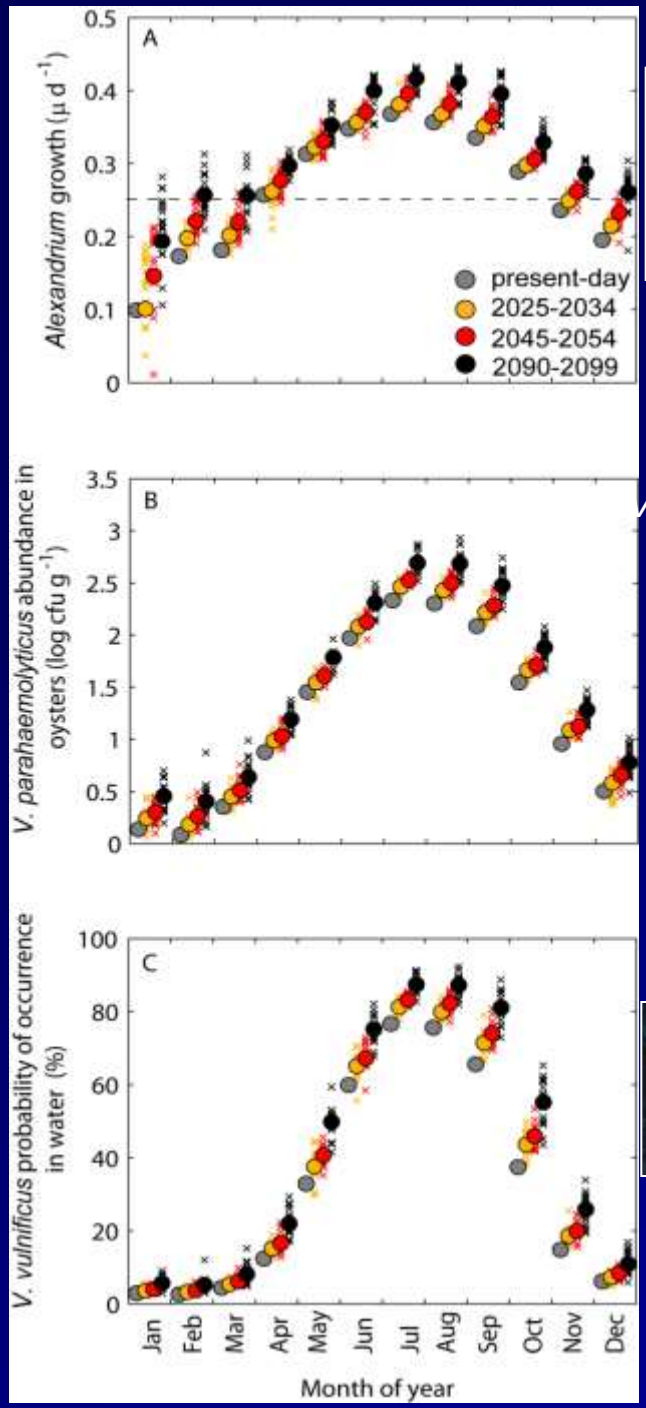
Changing Geographic Range for Vibrios

- Potential for extensive **geographic range shifts** based on the temperature niche (SST>15°C) for *Vibrio*

Climate models	Projected % of Alaskan shoreline with SST > 15°C during August (Average)		
	2030s	2050s	2090s
GFDL	22.0%	39.2%	79.6%
IPSL	30.7%	30.2%	62.1%
Nor_ESM1_M	13.1%	33.6%	51.5%
Nor_ESM1_ME	20.7%	28.0%	38.9%



Climate change impacts on coastal pathogens



Alexandrium

V. parahaemolyticus in oysters

V. vulnificus in water

- Statistically downscaled climate projections for the 2030s, 2050s, and 2100 from 21 CMIP5 models using RCP6.0
- Progressive **expansion of the seasonal window** for harmful algal blooms and pathogenic bacteria in U.S. coastal waters (Puget Sound and Chesapeake Bay)
- Managers will need to adapt monitoring and mitigation strategies to be prepared for human health risks outside of the typical season (Jacobs et. al, submitted)

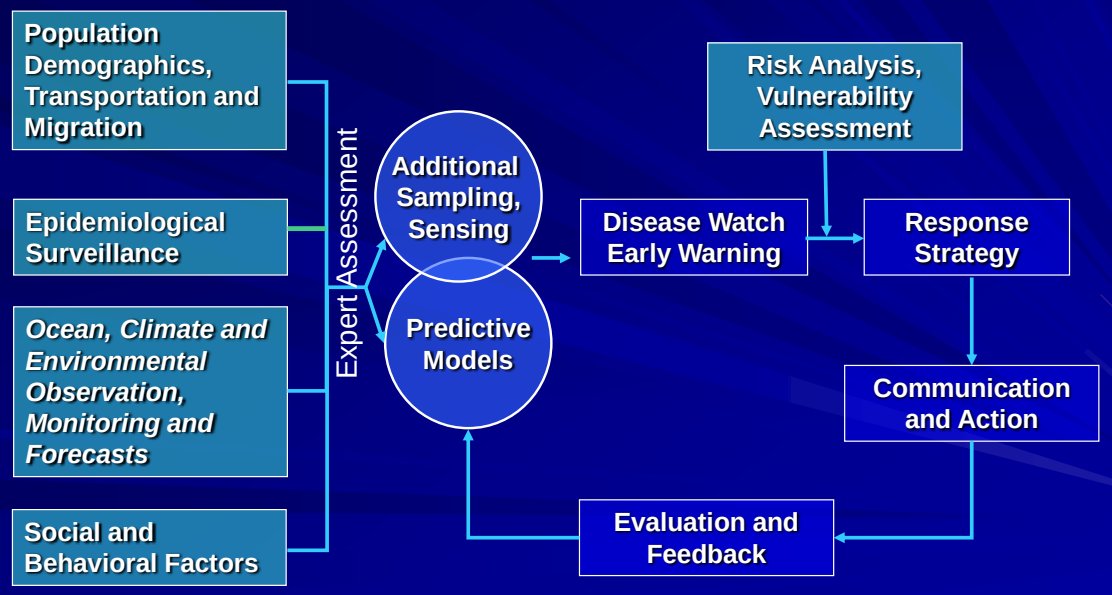
Building a Cholera Early Warning System

To stop mortalities and morbidities related to environmental diseases, with a special focus on diarrhoeal diseases, in particular of cholera

To provide an integrated system of systems

- **Linking water, sanitation, environmental and public health information**
- **at seasonal and longer time scale**
- **Problem-oriented and place based**

Components of a Health Early Warning System

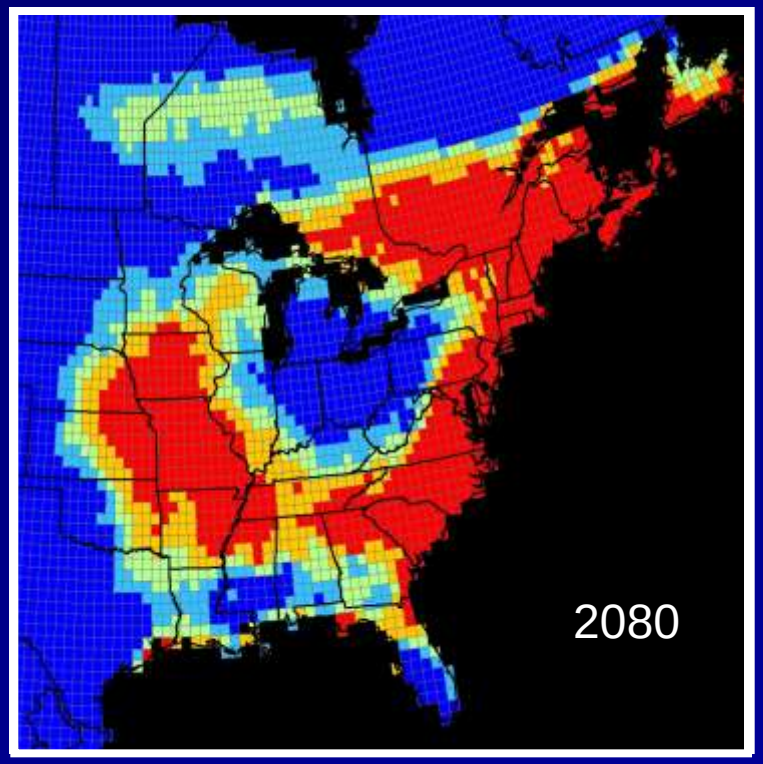


Trtanj, J., J Davis and T. Collier 2013

Precipitation, Humidity, and Temperature Changes Impact Human Health: Lyme Disease

- **Spread of Lyme disease factors**
  - Climate
  - Ecological
  - Social

Range of suitable conditions for *Ixodes scapularis*, the Lyme disease tick



Constant suitability Expanded suitability

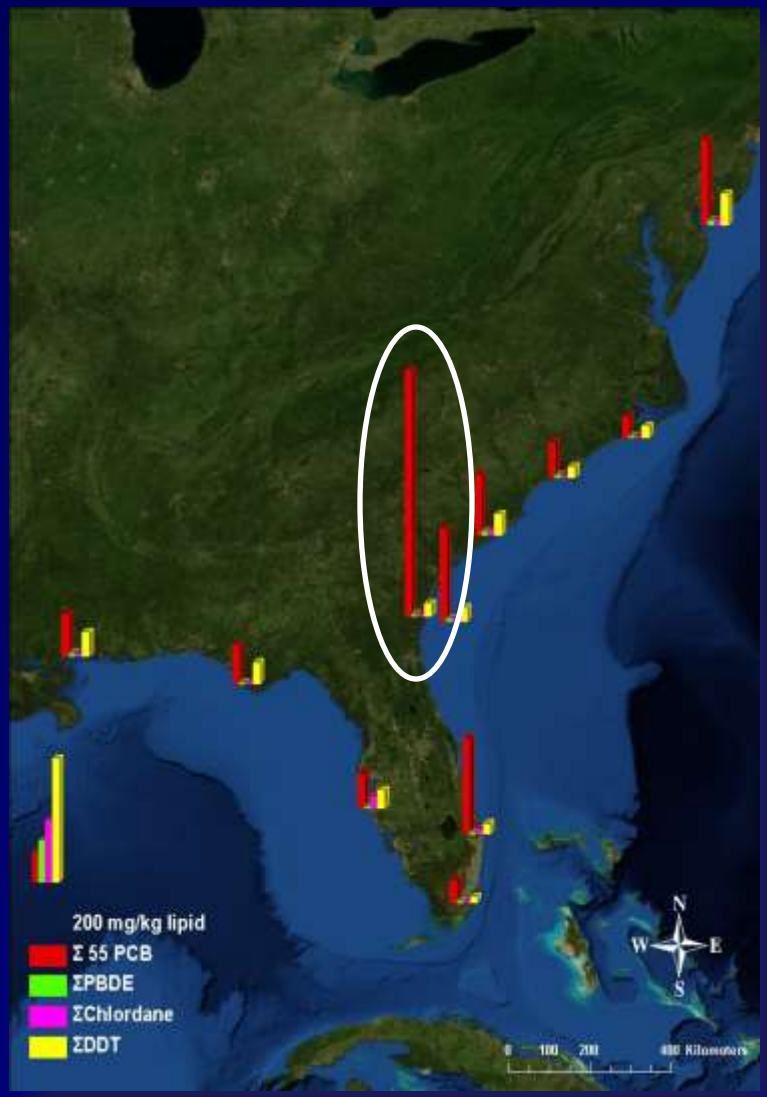
Source: Brownstein JS, Holford TR, Fish D. A climate-based model predicts the spatial distribution of the Lyme Disease vector *Ixodes scapularis* in the United States. *Environ Health Persp* 2003;111(9):1152-57.

What Sentinels Species and Habitats Are Telling us?

Ken Weiss

- 60% of emerging infectious disease events in humans caused by zoonotic pathogens and 71% of those are from wildlife
- Unexplained mortalities of marine mammals and sea turtles increasing
- HABs kill manatees; 50% of sea otter mortality related to exposure to run-off of land-based pathogens; 15% of CA sea lions have cancer
- Degraded coastal habitats provide early warning of large-scale aquatic ecosystem impairment that can impact human health
- Links to El Nino Southern Oscillation and Pacific Decadal Oscillation

Dolphins Provide Early Warning of Chemicals in Coastal Food Web



news
jacksonville.com

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Home News

Chemical causes high contamination levels in Atlantic dolphins

It brings back old questions about food safety for humans.

BY STEVE PATTERSON | STORY UPDATED AT 7:45 AM ON MONDAY, MAR. 1, 2010

Video Photos

Photo 2 of 2

Todd Speakman/NOAA
During an exam of dolphins' health off the Georgia coast, a dolphin placed on a boat has suction cups attached to it for a hearing test and electrocardiogram.

A closed chemical factory on a Brunswick marsh has caused record-high PCB (polychlorinated biphenyl) contamination in Atlantic bottlenose dolphins that ate polluted fish, scientists have concluded.

The damage tied to LCP Chemicals, including the highest ever recorded in a marine mammal, is refocusing old questions about people's risks of eating contaminated seafood.

The presence of the industrial chemical, a possible carcinogen, is also sparking questions about effects on other communities including Jacksonville, if fish that are polluted in one place travel somewhere else before they're eaten.

The contamination from the federal Superfund pollution site "may be mobilized and move up and down the coast ... as the prey move around," said Teri Rowles, who directs a marine mammal office at the National Oceanic and Atmospheric Administration.

Biologists want to check PCB levels in dolphins in Jacksonville and elsewhere.

The Centers for Disease Control and Prevention will begin a small study this year of people on Georgia's coast who regularly eat local seafood.

"There is potential for people to be exposed to these PCBs. Whether the levels are high enough to warrant concerns for people's health ... that is still to be determined," said Lori Schwacke, a NOAA researcher with the Hollings Marine Laboratory in Charleston, S.C., who has led the dolphin study.

The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment

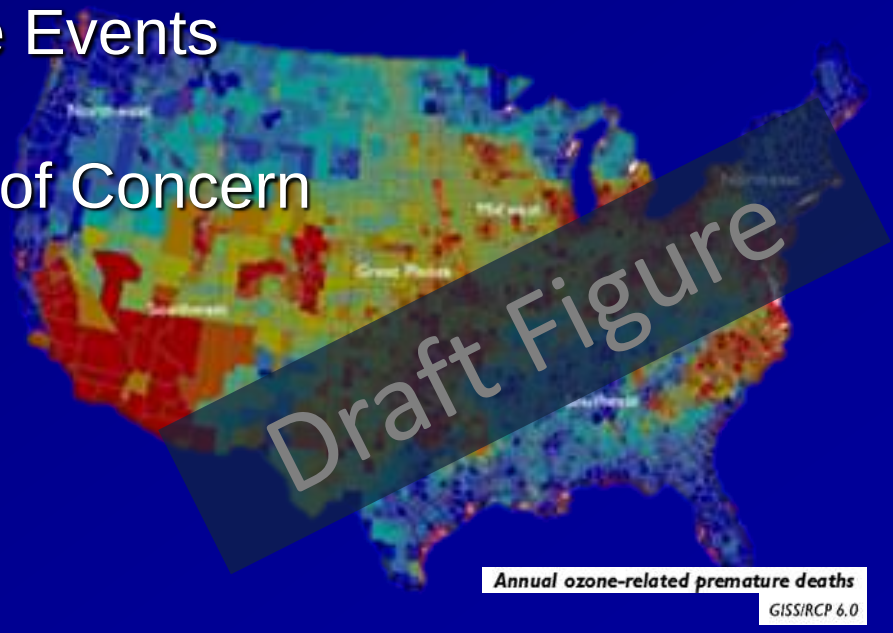
- The Interagency Group on Climate Change and Human Health (CCHHG) is driving the development of the USGCRP Climate and Health Assessment
  - As part of the ongoing (sustained) efforts of the USGCRP's National Climate Assessment
  - As called for under the President's Climate Action Plan
  - Because multiple USGCRP agencies identified climate impacts on human health as a high priority topic for an interim assessment (between the 3rd and 4th NCA)
  - To leverage ongoing analytical efforts at several agencies focused on climate and health

- The purpose of this interagency 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.

Outline of the USGCRP Climate and Health Assessment

1. Introduction
2. Thermal Extremes
3. Air Quality Impacts
4. Vectorborne and Zoonotic Disease
5. Water-Related Illness
6. Food Safety, Nutrition, and Distribution
7. Extreme Weather and Climate Events
8. Mental Health and Well-Being
9. Risk Factors and Populations of Concern

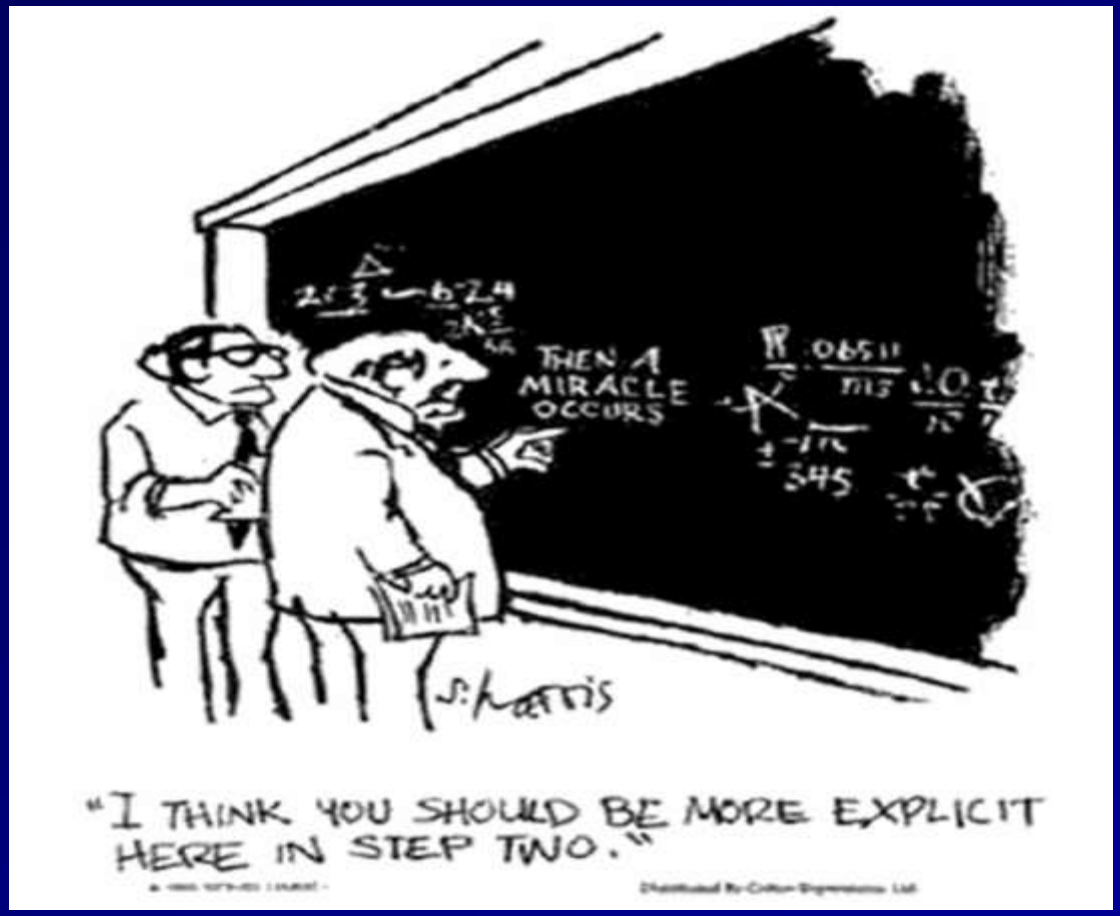
will highlight additional quantitative analyses



Draft Timeline

Internal Draft	Authors complete chapter drafts and deliver to USGCRP	January, 2015
Peer Review Draft	Public Comment (Federal Register Notice)	March – May, 2015
	NRC Peer Review	March - June, 2015
Internal Final Draft	Internal Agency Reviews and Clearance	Sept – Nov, 2015
Final Release Draft	Authors Revise and Prepare Final Release Draft	Nov 2015 – Feb 2016
	Design and Production complete- Roll Out	March, 2016

Building the next generation of scientists and communicators



- Inquisitive
- Collaborative
- Innovative
- Social
- Patient
- Bi-lingual
- Engaged in society
- Balanced

Thank you for this opportunity!

Juli.Trtanj@noaa.gov