Ecosystem Forecasting: Bridging Science to Management

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- Data/slides generously borrowed from D. Schwab, D. Beletsky, T. Croley, C. He, G. Lang, S. Joseph, R. Sturtevant, J. Dyble, J. Wiens and others!

Oregon State University OSU

Science-Management Partnerships

The Scientist

Management Agencies

Partnerships
Community of Practice
Science-informed Decisions
Adaptive management
Stakeholder Engagement

Ecosystem Forecasting

Ecosystem forecasting predicts the effects of biological, chemical, physical and human-induced changes on ecosystems and their components

- What will happen in the future?
- When will it happen?
- At what spatial scales?

“There is no reason anyone would want a computer in their home”

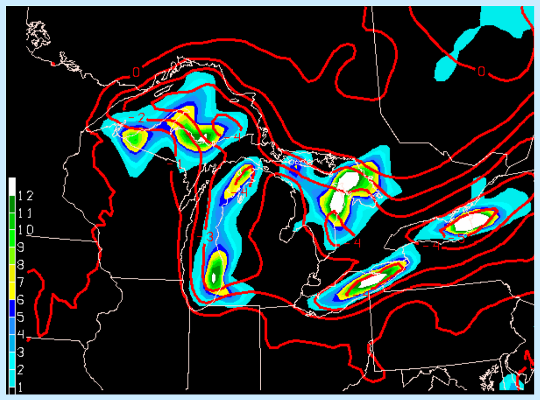
Ken Olsen, Founder,
DEC, 1977

“1930 will be a splendid employment year”

U.S. Department of Labor, 1929

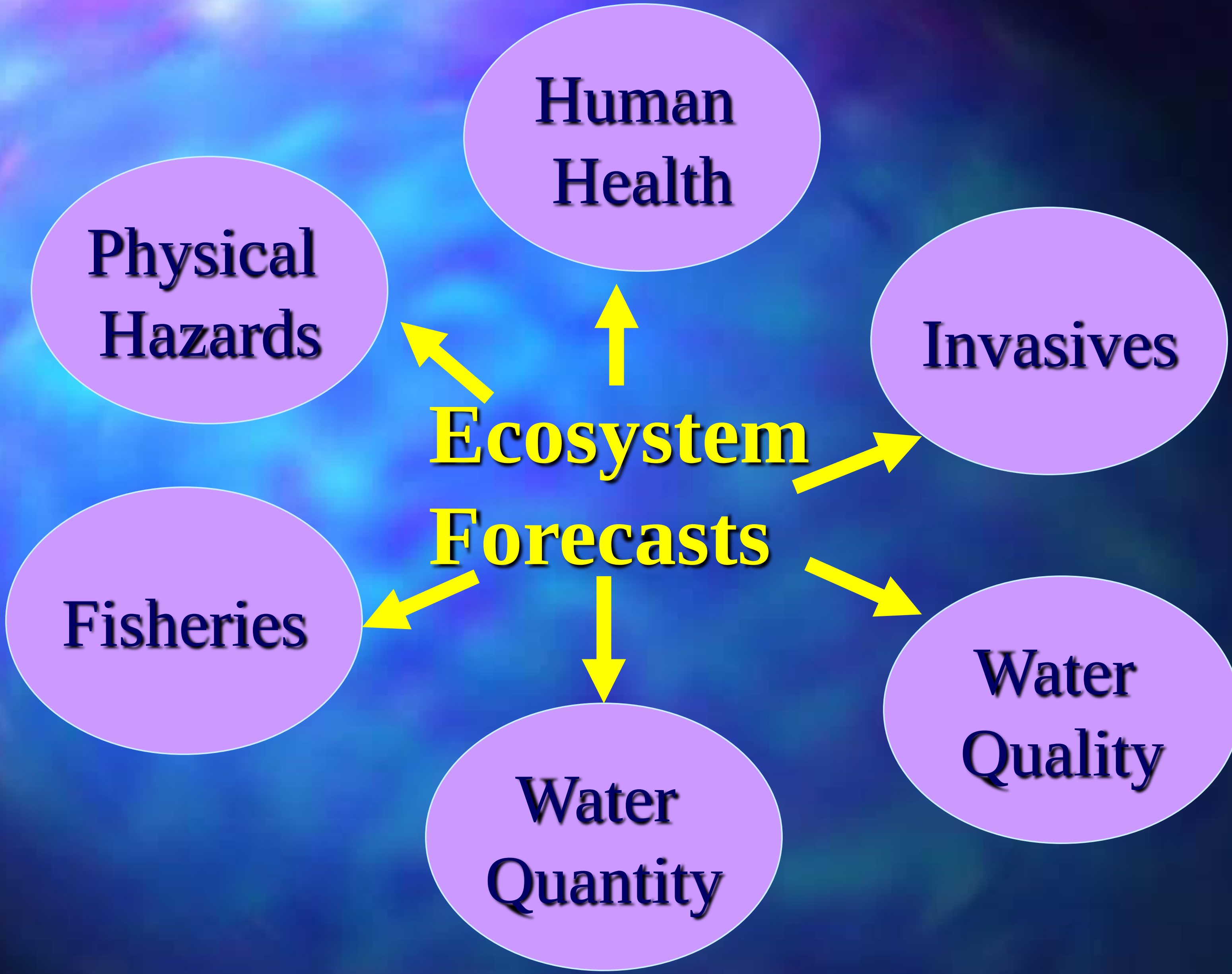
“640k [of memory] ought to be enough for anybody”

Bill Gates, Co-founder, Microsoft



Ecosystem Forecasting

- Aids in
  - Improved decision making
  - Reductions in risks
  - Focusing research on fundamental driving forces and science at disciplinary interfaces
  - Mitigation of natural events and human activities – Adaptive management



Times scales of a few hours for safety issues to 20 – 50 year planning horizons for coastal constructions

Ecosystem Forecasts

Physical Hazards

- Offshore Wave Heights
- Coastal Erosion
- Rip Currents
- Ice Thickness and Extent
- Fog
- Spill / Search and Rescue
- Storm Surge
- Offshore Currents
- Temperature

Water Quantity

- Levels
- Tributary Flows (floods)

Water Quality

- Turbidity / Clarity
- Anoxia
- Taste and Odor
- Near Shore Vegetation
- Bacteria Concentrations
- Chemical Concentrations

Ecosystem Forecasts

Human Health

- Beach Closings (bacteria)
- Fish Contaminants
- Harmful Algal Blooms (toxin concentrations)

Fish Recruitment and Productivity (by species)

- Numbers of Fish
- Size and growth of Fish
- Fish Distribution

Invasive Species

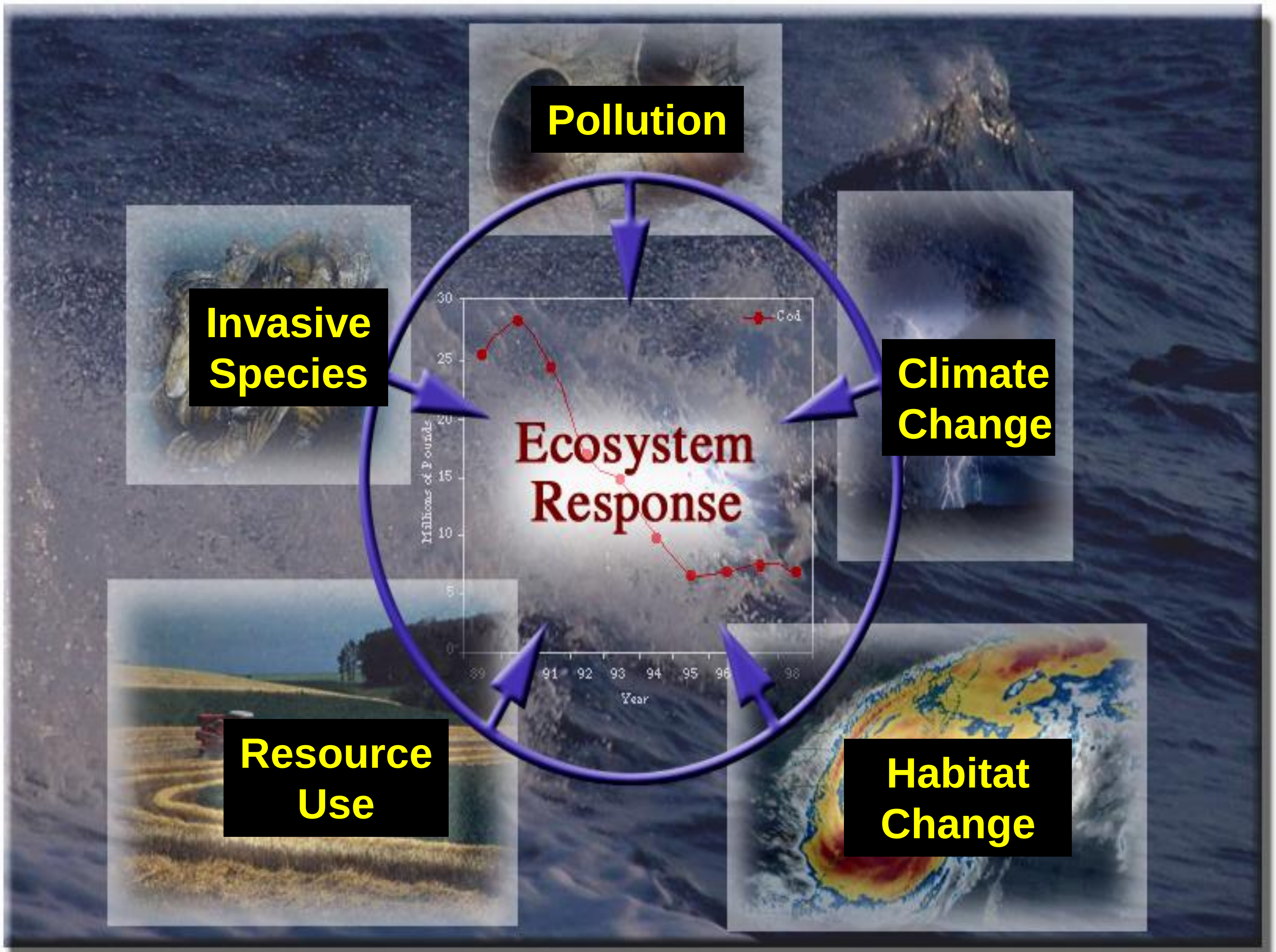
- New Non-Native Species Introductions
- Spread of Introduced Species
- Impact on Ecosystem

Drivers of Ecosystem Change

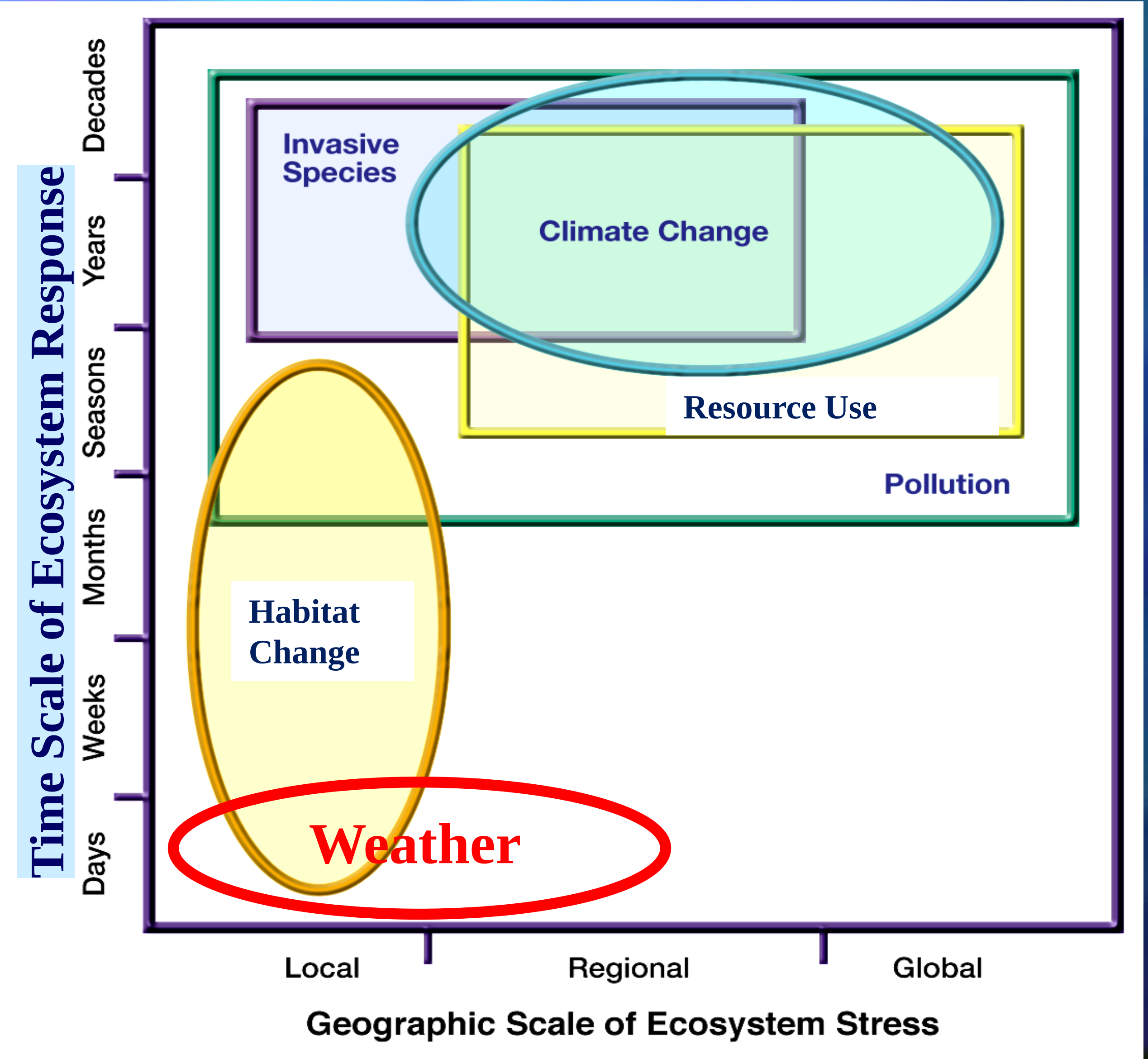
Research

Ecosystem Responses

Drivers of Ecosystem Change

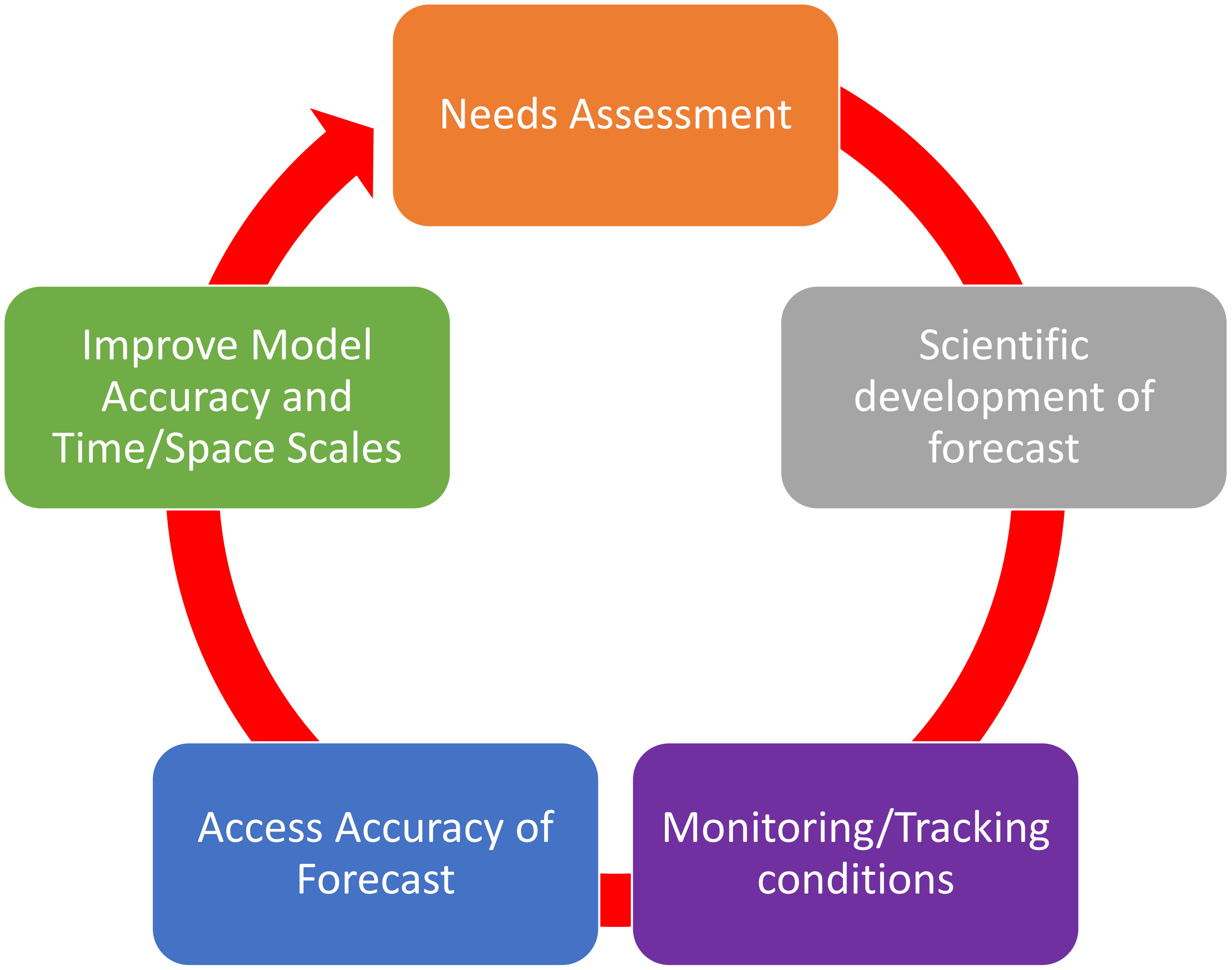


Different Time and Space scales.



From CENR

Ecosystem Forecasting



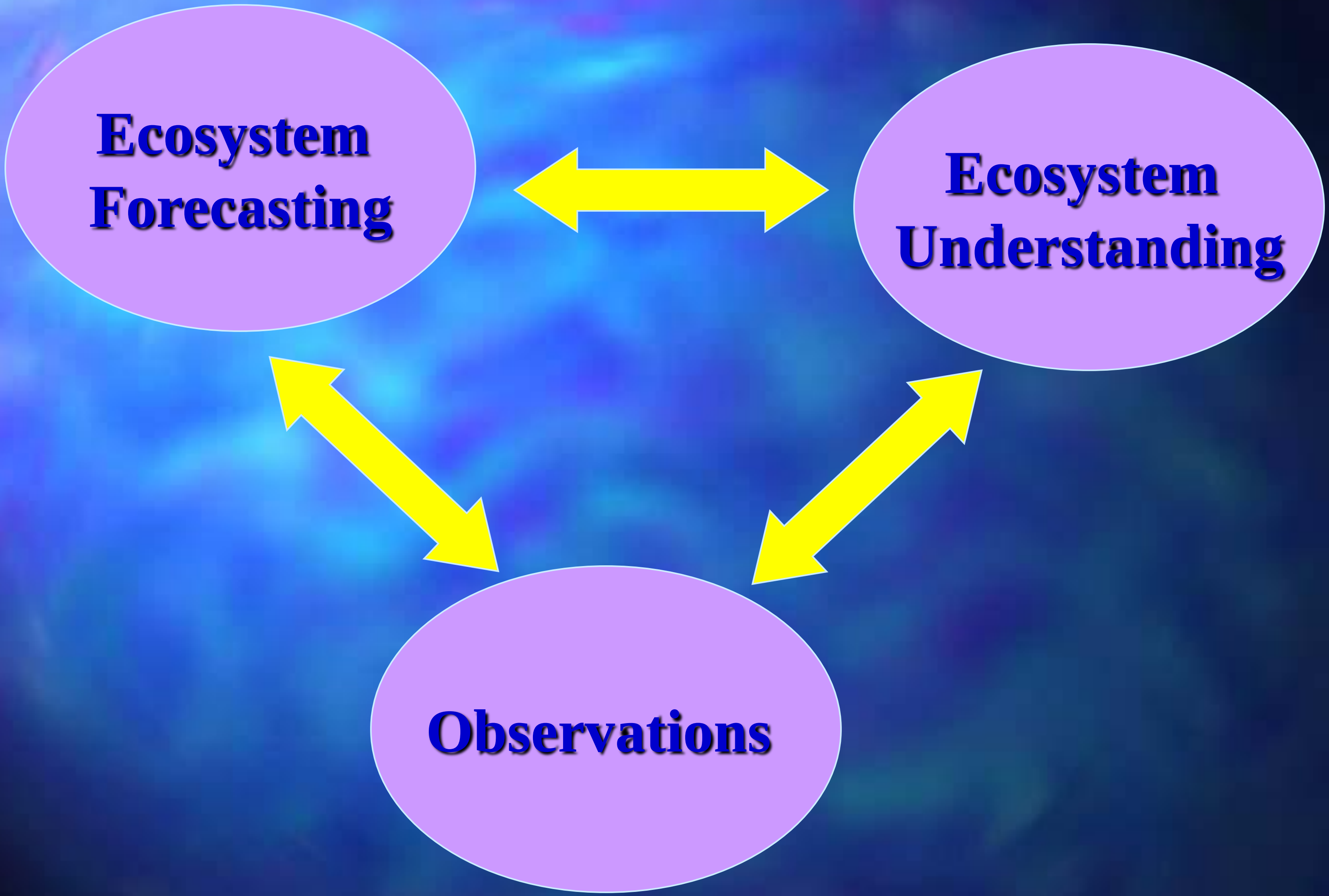
Needs Assessment:

What types of Ecological Forecasts would be useful or economically beneficial to Coastal User Groups?

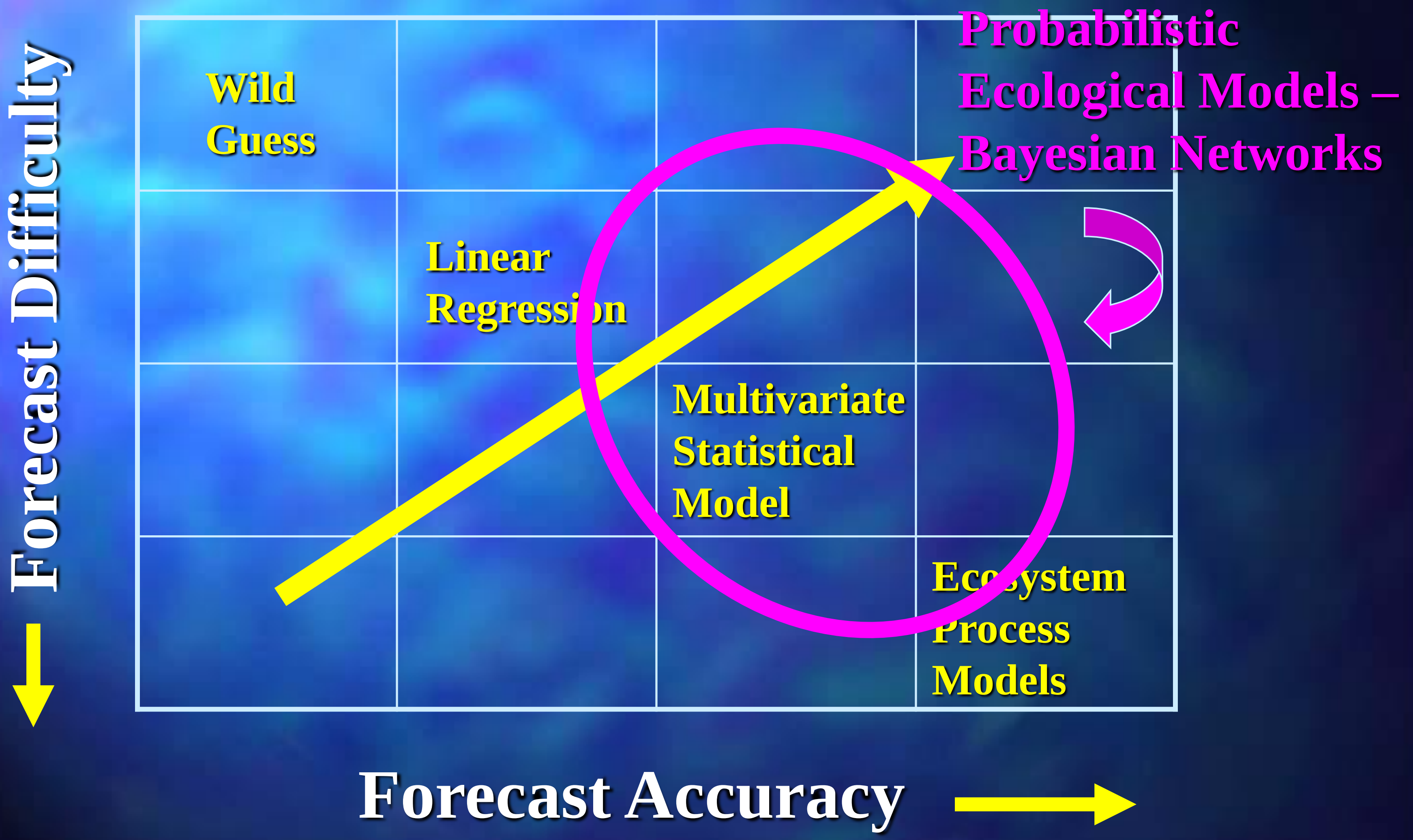
- **Who are the specific users?**
- **What use would be made of the forecasts?**
- **What level of accuracy is required?**
- **What are the required time and space scales?**
- **Any suggestions about how one might approach this goal?**

Strategic Matrix

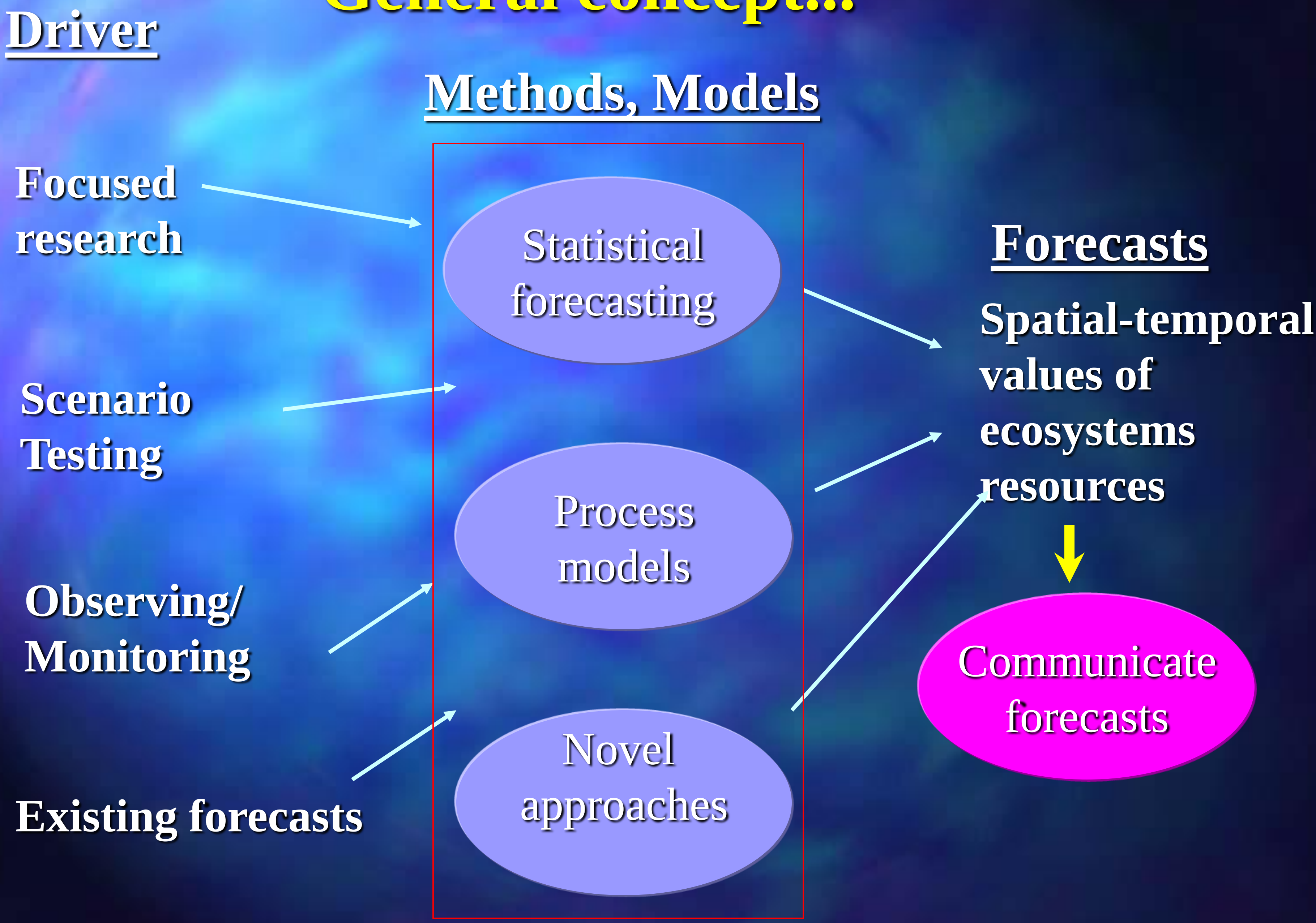
Forecast	Identify Target Parameters & Users	Identify Time and Space Scales	Identify Key Processes	First level Predictions & Data Comparison	Refine Methods & Further Study	Quasi-level Operation & Testing	Transition to Operation
Wave Forecasts	X	X	X	X	X	X	■
Beach Closing	X	X	X	■			
Water Quality	X	X	■				
Microcystin Levels	X	X	X	X	X	■	
Fish Production	X	X	X	■			


Ecosystem Forecasting
Ecosystem Understanding
Observations

Ecosystem Forecast Tools



General concept...

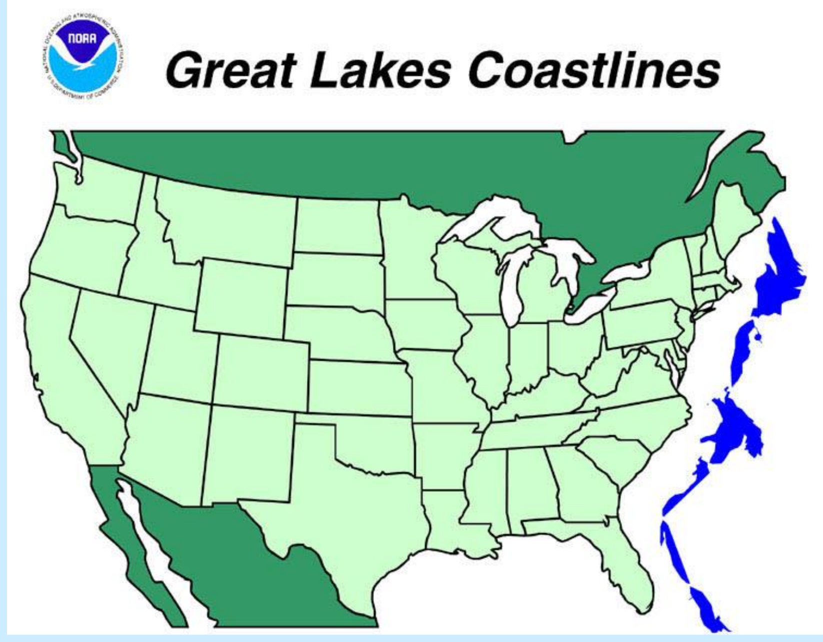


Ecosystem Forecasting

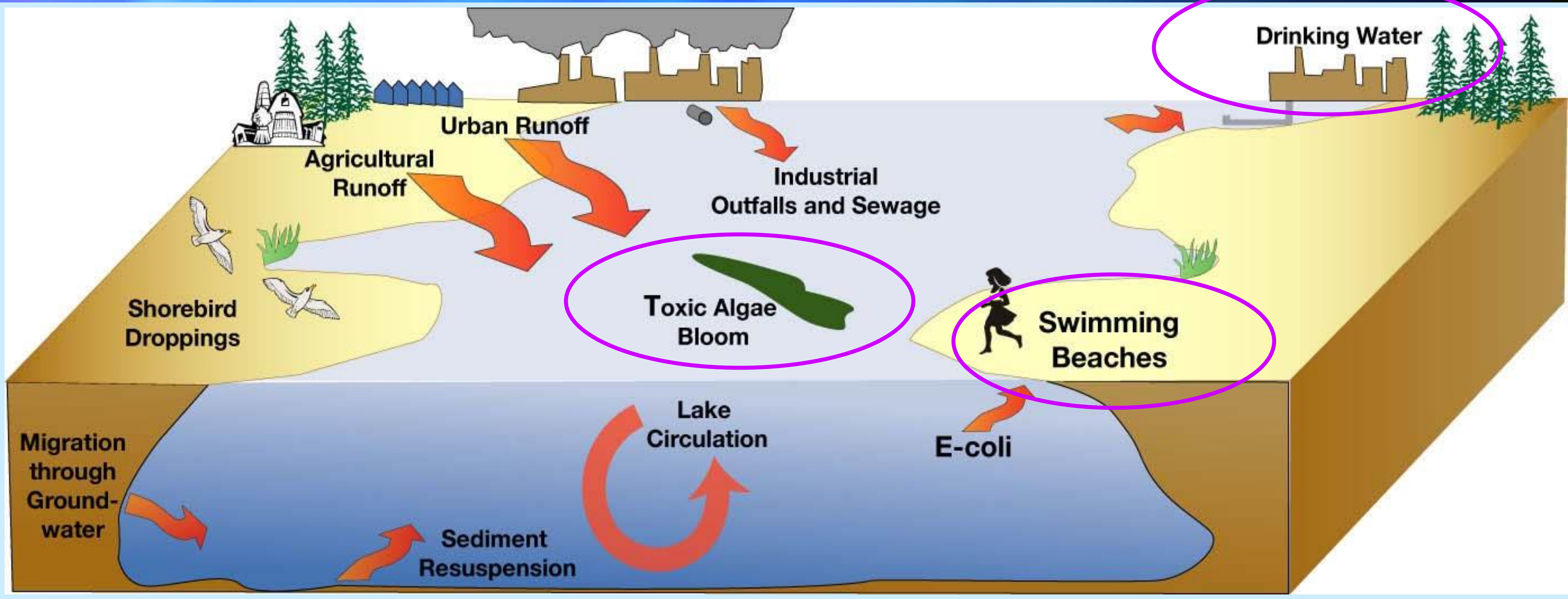
Climate – Meteorology – Hydrology – Hydrodynamics – Physical/Chemical Oceanography – Biology/Ecology

Great Lakes Facts

- 95,000 Square miles of water
- 250 Species of fish
- Drinking Water for 40 Million People
- $4 Billion Sports Fishery
- 1/3 of U.S. registered boaters.
- Commercial Shipping—200 Million Tons—1270 Mile Transportation Route
- Largest surface freshwater supply in the world (90% of surface U.S. supply)
- 56 Billion Gallons per day for Municipal, Agricultural, Industrial
- 1,000 mile international border
- Over 500 Recreational beaches



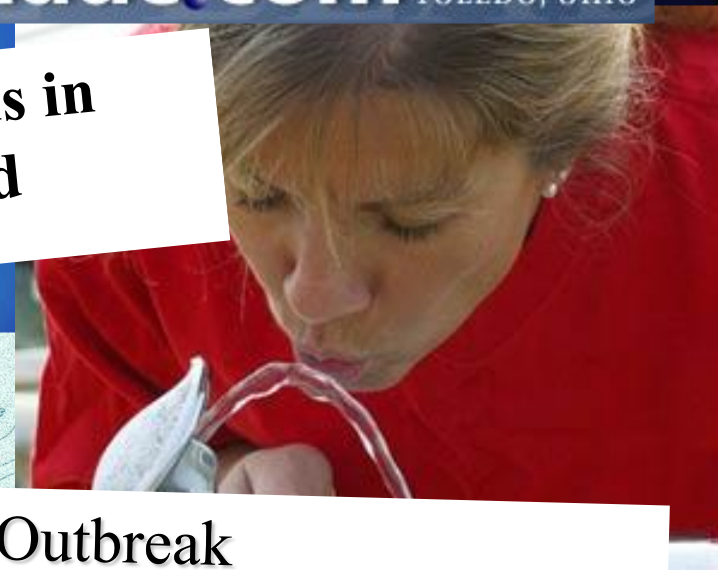
Factors Contributing to Nearshore Water Quality in the Great Lakes



Climate – Meteorology – Hydrology – Hydrodynamics – Biology/Chemistry

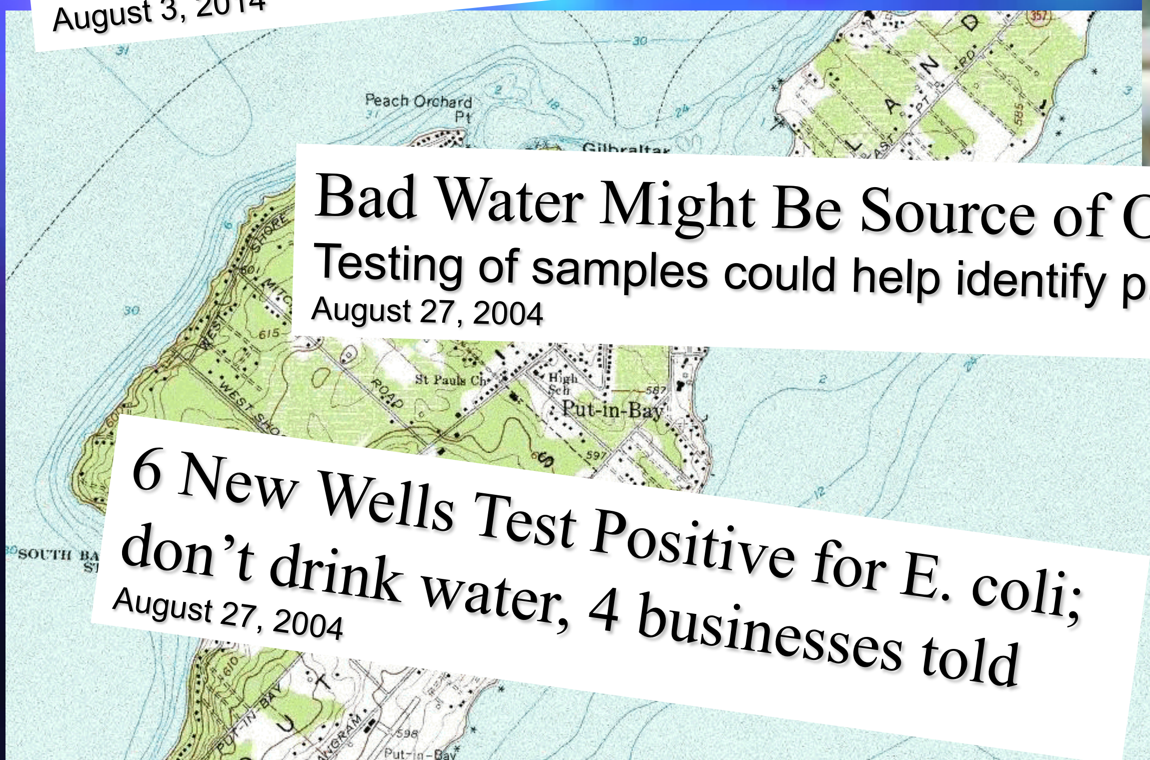
The Columbus Dispatch
Ohio's Greatest Online Newspaper

toledoblade.com TOLEDO, OHIO



Water crisis grips hundreds of thousands in Toledo area, state of emergency declared

August 3, 2014



Bad Water Might Be Source of Outbreak

Testing of samples could help identify problem on South Bass Island

August 27, 2004

6 New Wells Test Positive for E. coli; don't drink water, 4 businesses told

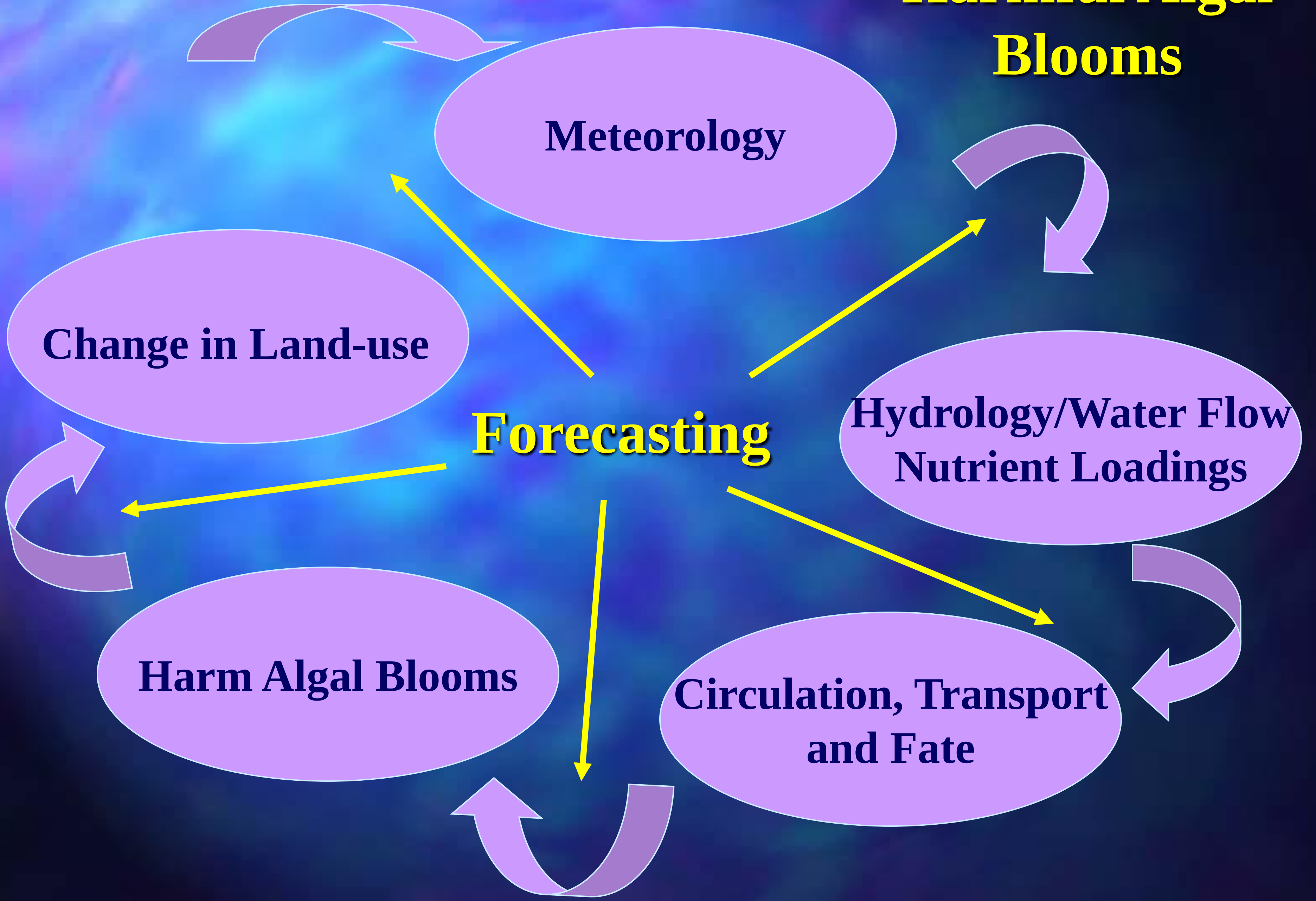
August 27, 2004

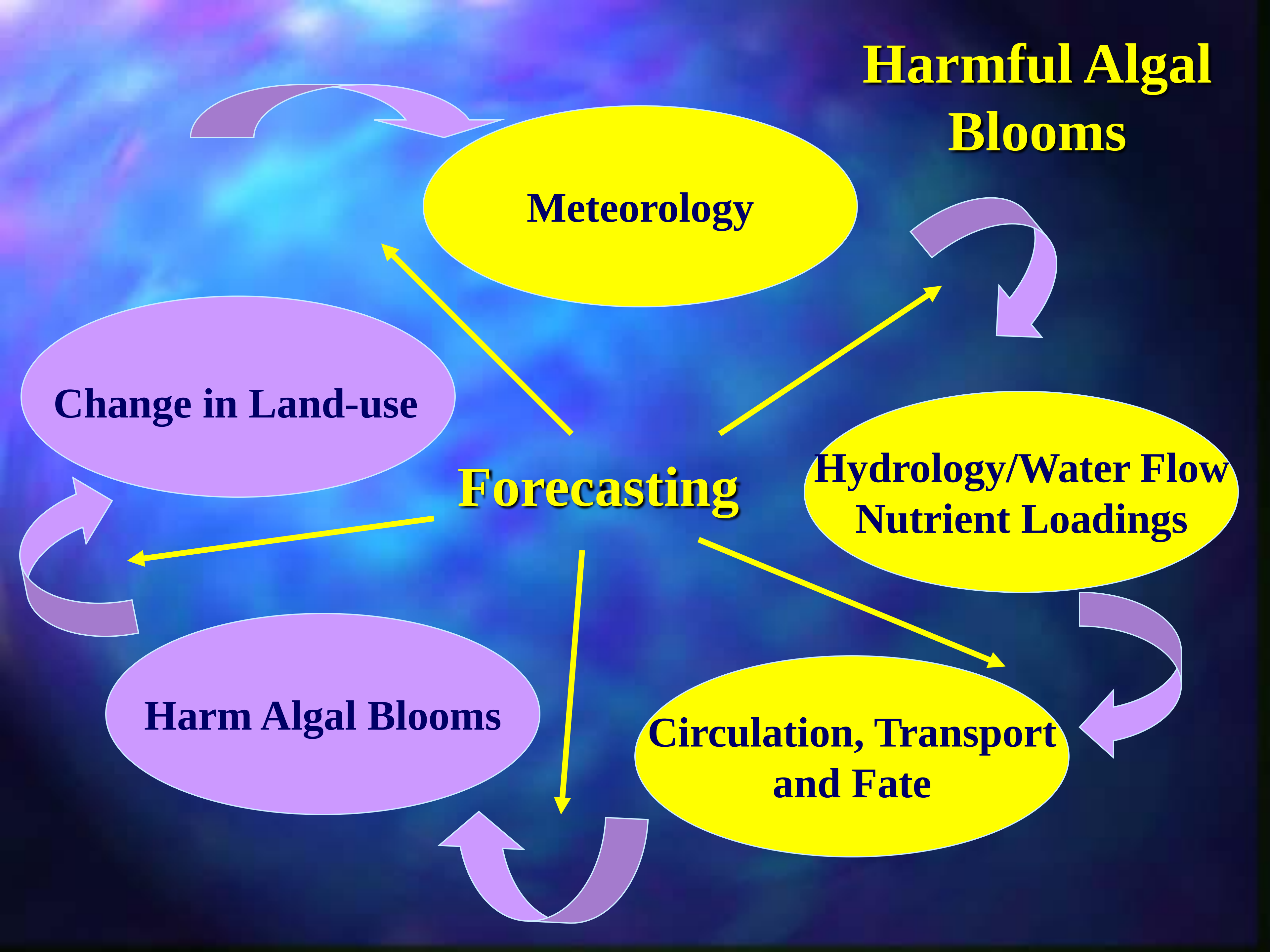
Harmful Algal Blooms

- Bloom-forming toxic cyanobacteria occur worldwide in nutrient-enriched freshwater
- Cyanobacteria contaminate drinking water and can produce toxins

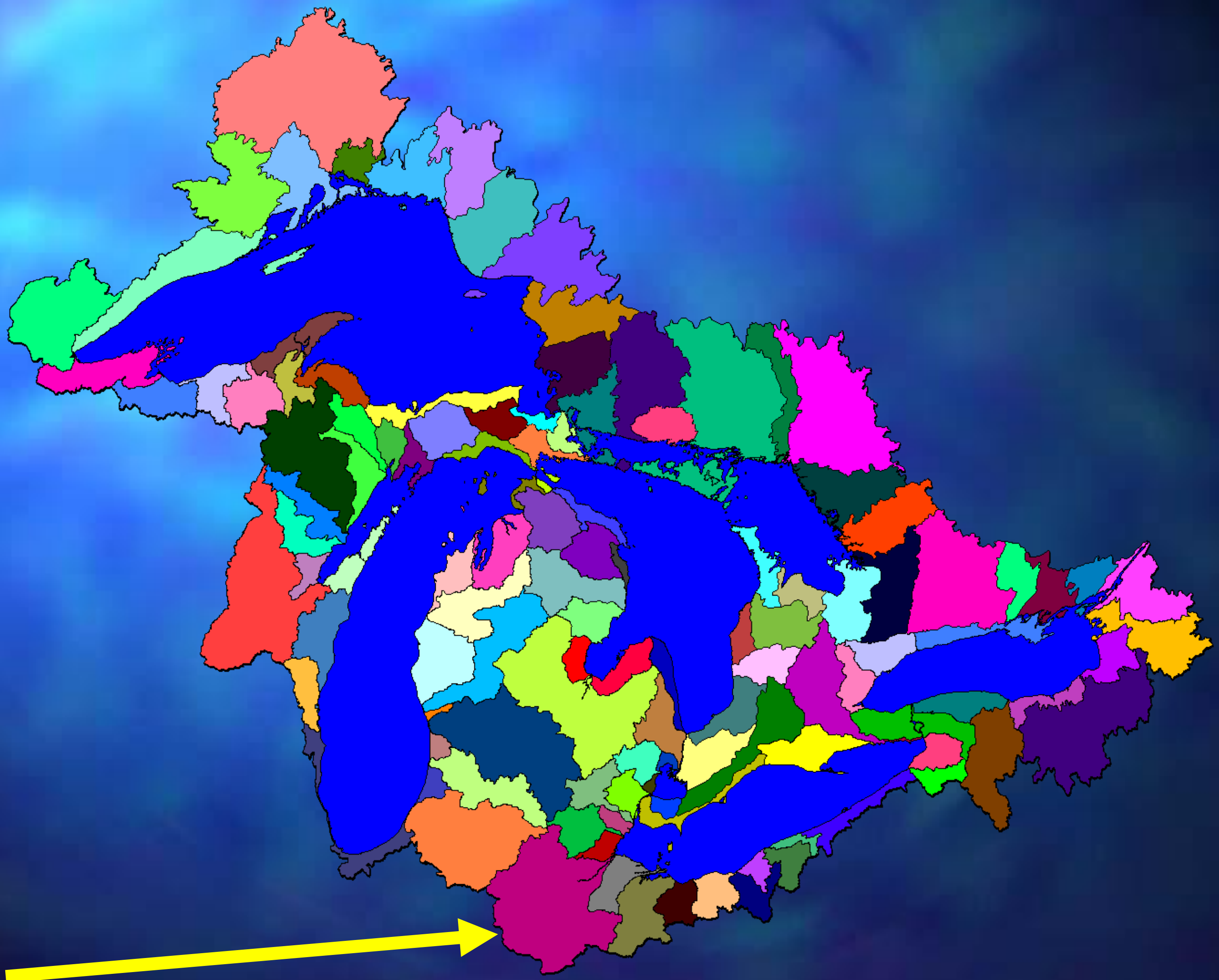
- Concentrations of microcystin (the dominant form of cyanobacteria) has exceeded World Health Organization in some Great Lakes

Harmful Algal Blooms



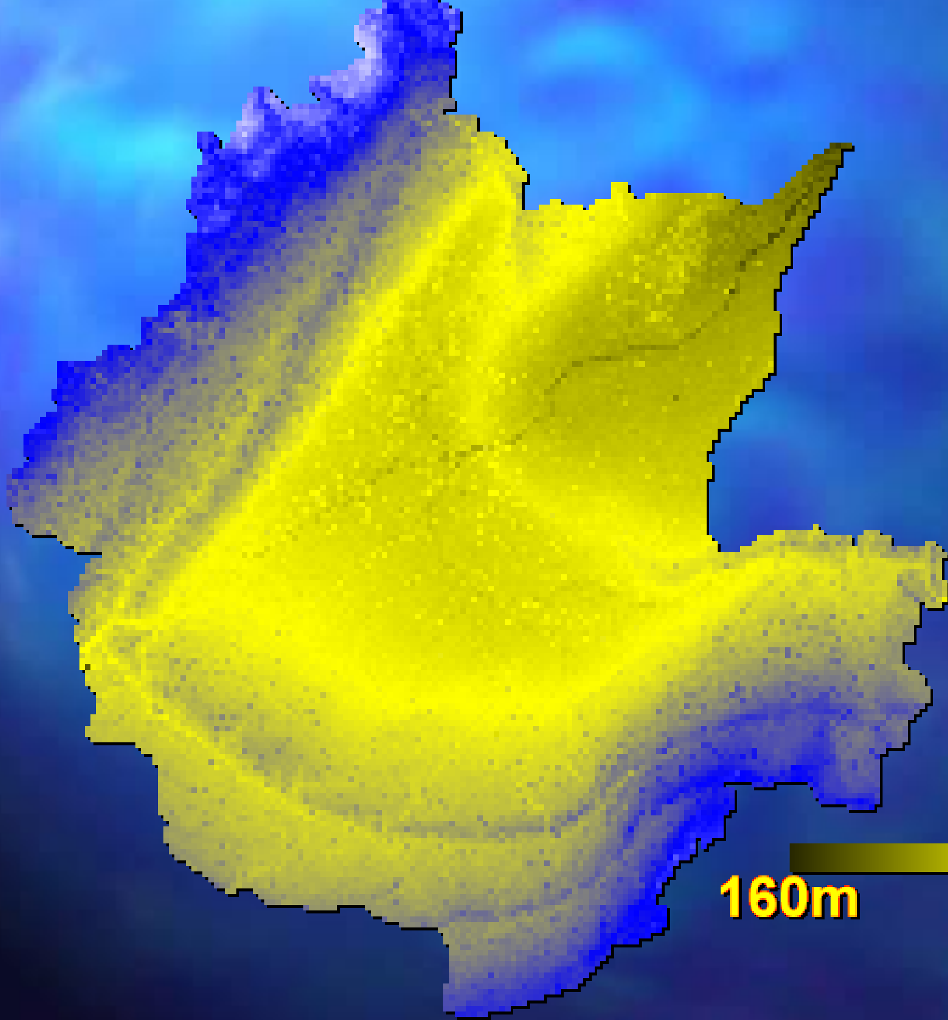

Harmful Algal Blooms
Meteorology
Change in Land-use
Forecasting
Hydrology/Water Flow
Nutrient Loadings
Harm Algal Blooms
Circulation, Transport
and Fate

Great Lakes Watersheds

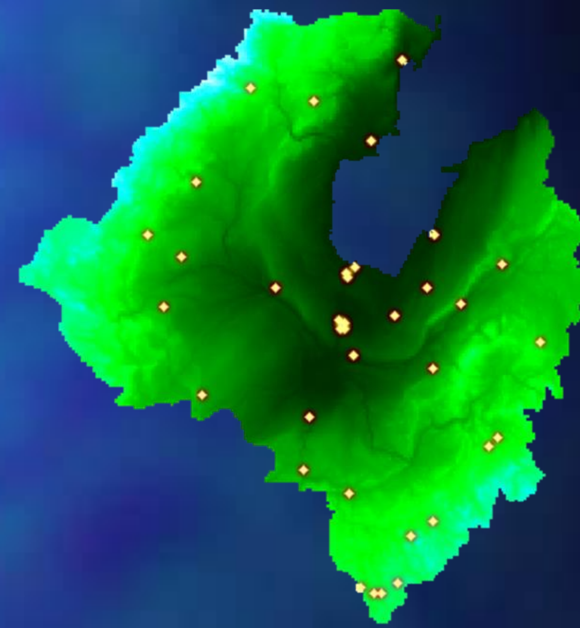


Discretized Watersheds to 1 km^2 Resolution

Maumee River watershed in Ohio on Lake Erie: 17,541 km^2

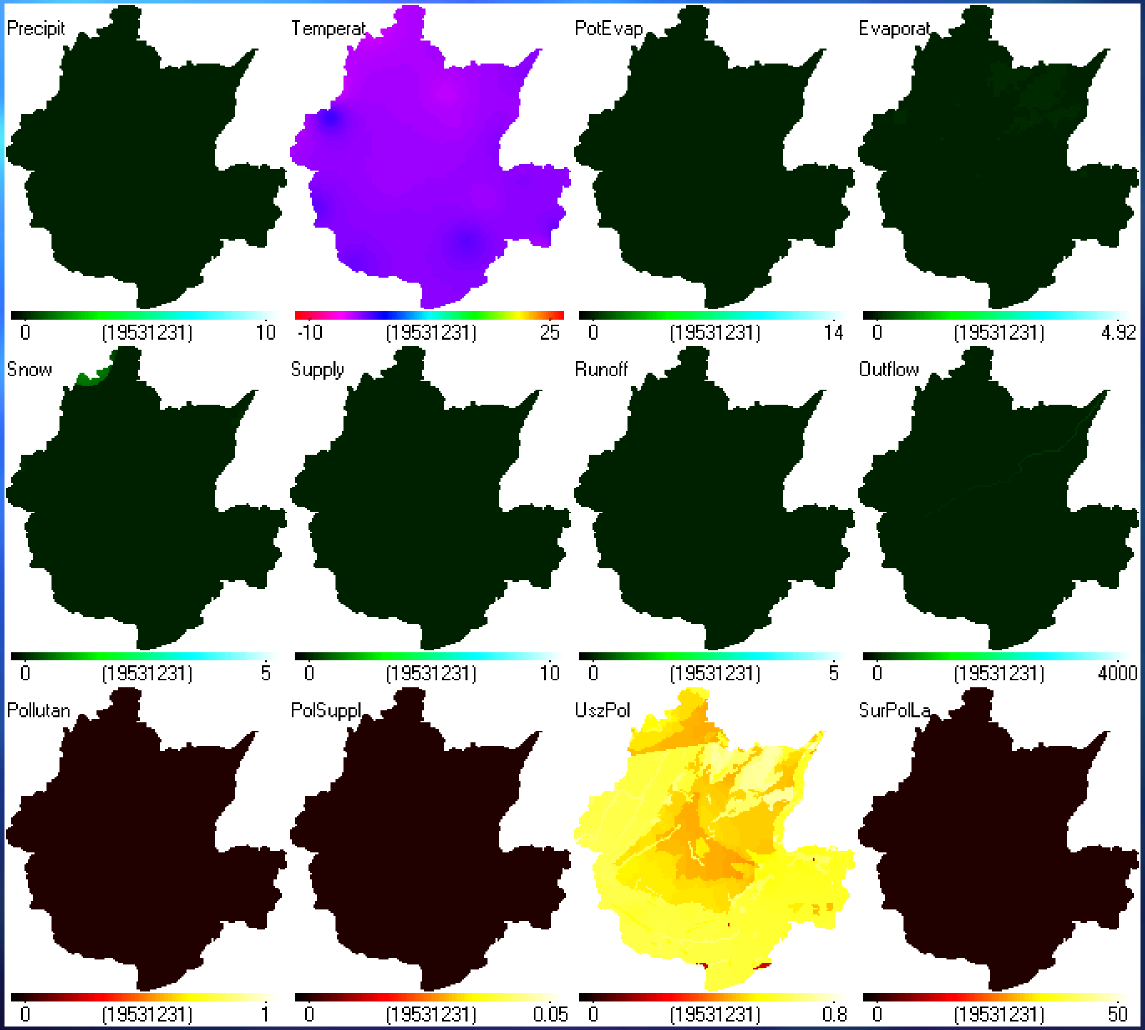


Point-Sources CSO's and SSO's

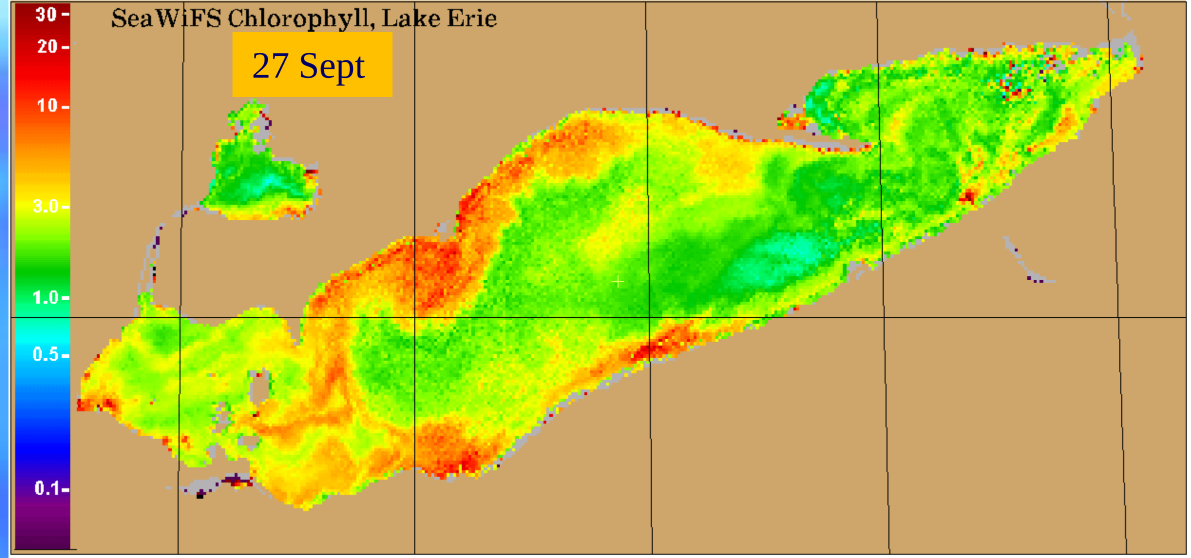


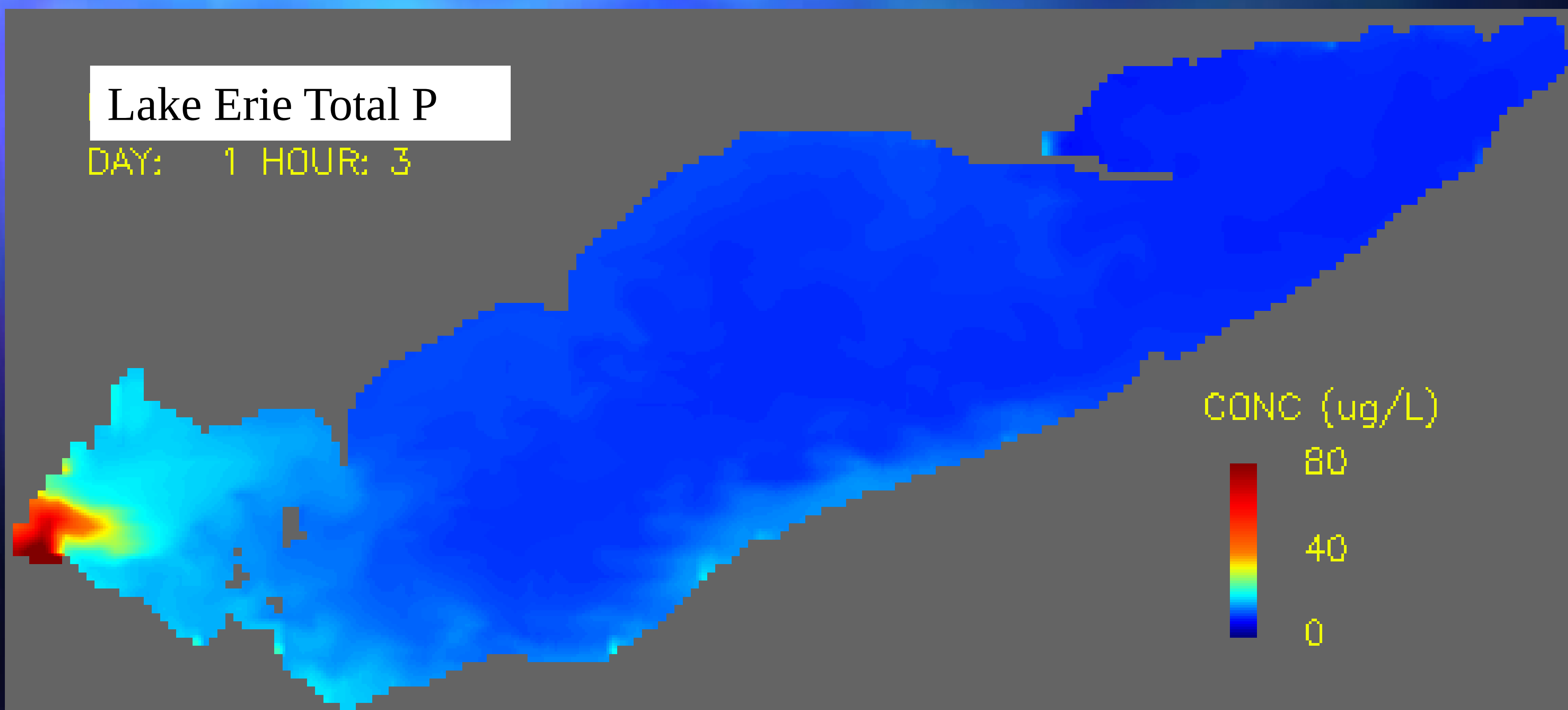
Distributed Surface Subsurface Hydrology

Maumee River Distributed LBRM with Pollutant Movement

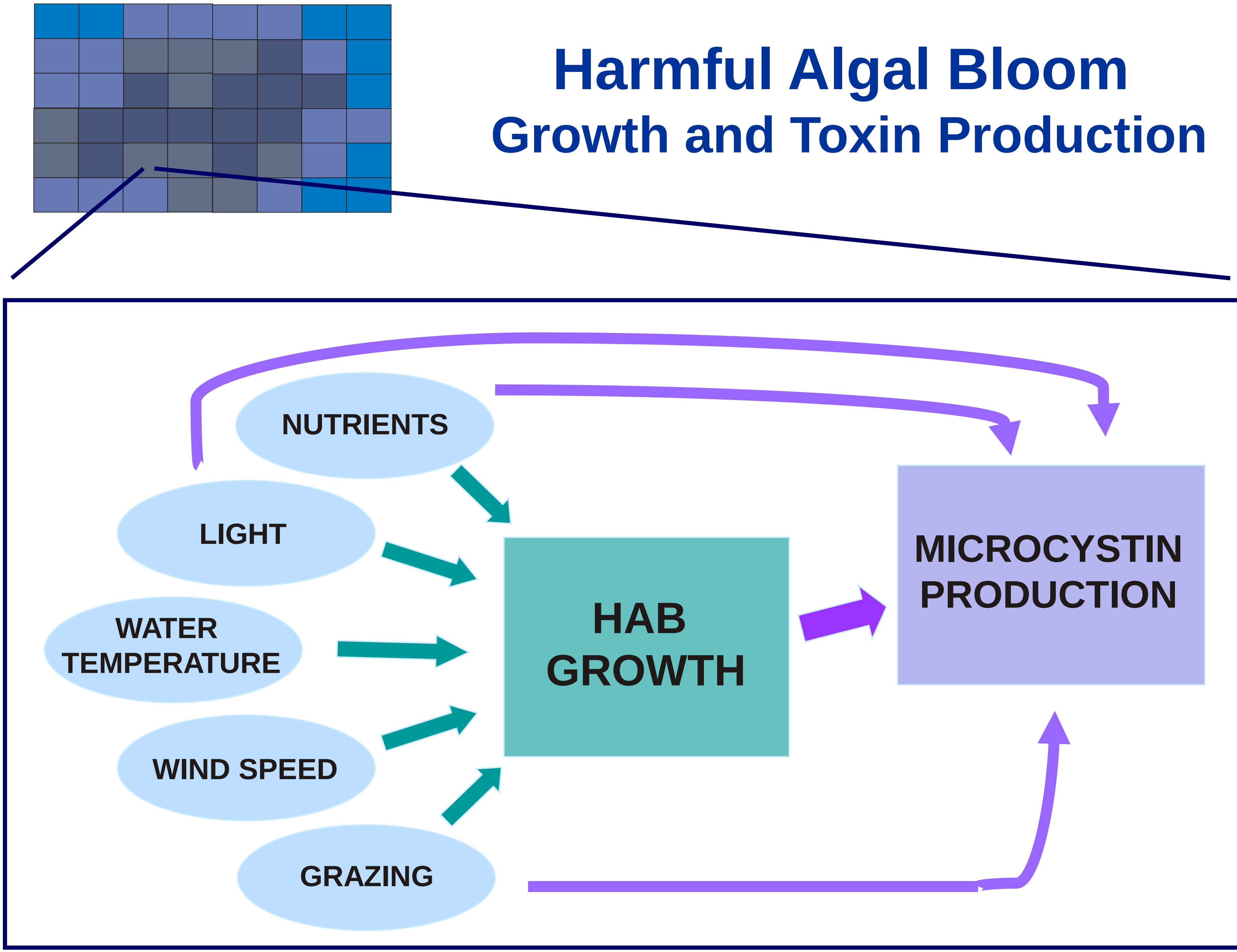


4fps (1024x768)


SeaWiFS Chlorophyll, Lake Erie
27 Sept
30
20
10
3.0
1.0
0.5
0.1


Lake Erie Total P
DAY: 1 HOUR: 3
CONC (ug/L)
80
40
0

Harmful Algal Bloom
Growth and Toxin Production



An operational HAB bulletin has been developed to provide bi-weekly forecasts for *Microcystis* blooms in western Lake Erie. The bulletin depicts the HABs' current location and forecasted movement of bloom 3 days later, as well as graphs the winds and currents.

Experimental Lake Erie Harmful Algal Bloom Bulletin

1 November, 2016, Bulletin 30

2016 Bloom Analysis. The *Microcystis* cyanobacteria bloom in 2016 was mild compared to the last few years, with a severity index of 3.2, much lower than the 10.5 record observed in 2015. In the western Lake Erie basin, the bloom biomass was more toxic than in 2015, but less than half the toxicity of 2014. In contrast, because of the relatively mild bloom, areas of scum were fewer, less dense, and less toxic in 2016 than in either 2014 or 2015.

This bloom had a "double peak", one in August, followed by a decrease in biomass, then a brief reappearance in late September. This differs from the typical year in which the bloom grows through August to a peak in early September and then gradually decreases through September. Isolated pockets of *Microcystis* also persisted into October.

The bloom was milder than the forecast severity of 5.5, but within the range of uncertainty of all the models (3-7). The models primarily use the phosphorus load from the Maumee River. However, the models also included residual internal load of phosphorus in the lake, particularly a residual from the Maumee River's record spring phosphorus load in 2015. This additional phosphorus used in the models was greater than the apparent residual internal load, leading to model forecasts of greater bloom severity than were observed.
–Stumpf, Wynne, Davis, Dupuy

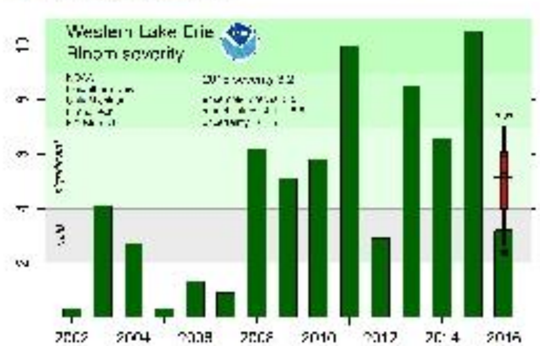


Figure 1. Bloom severity index for 2002-2016, and the forecast for 2016. 2011 is 10, 2015 is 10.5. The index is based on the amount of biomass over the peak 30-days. The 2016 bloom had a severity of 3.2, between 2003 and 2004.

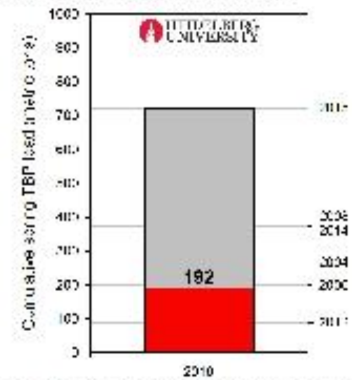
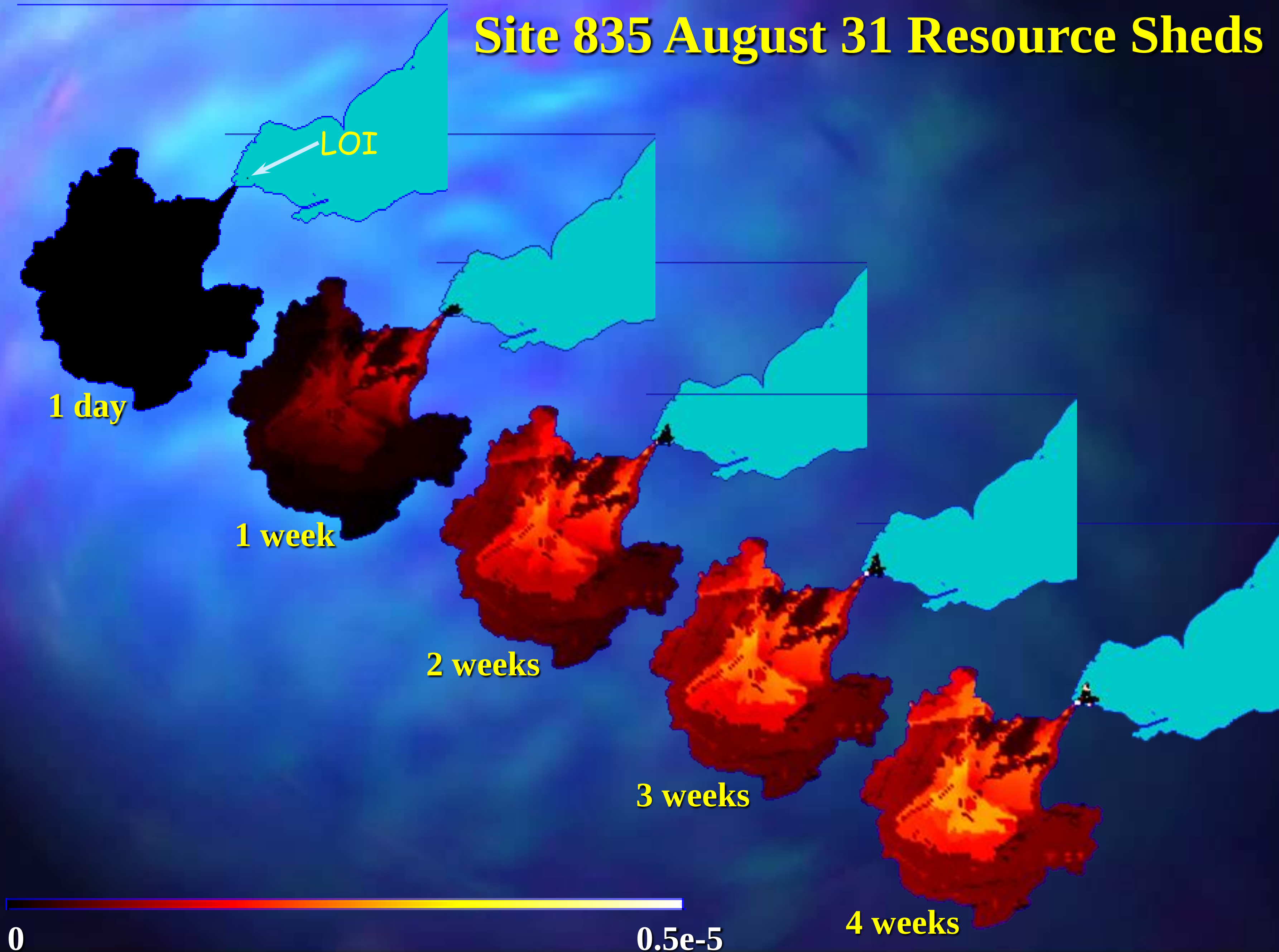


Figure 2. Total bioavailable phosphorus from the Maumee River for 2016 compared to some other years. Data collected by Heidelberg University.

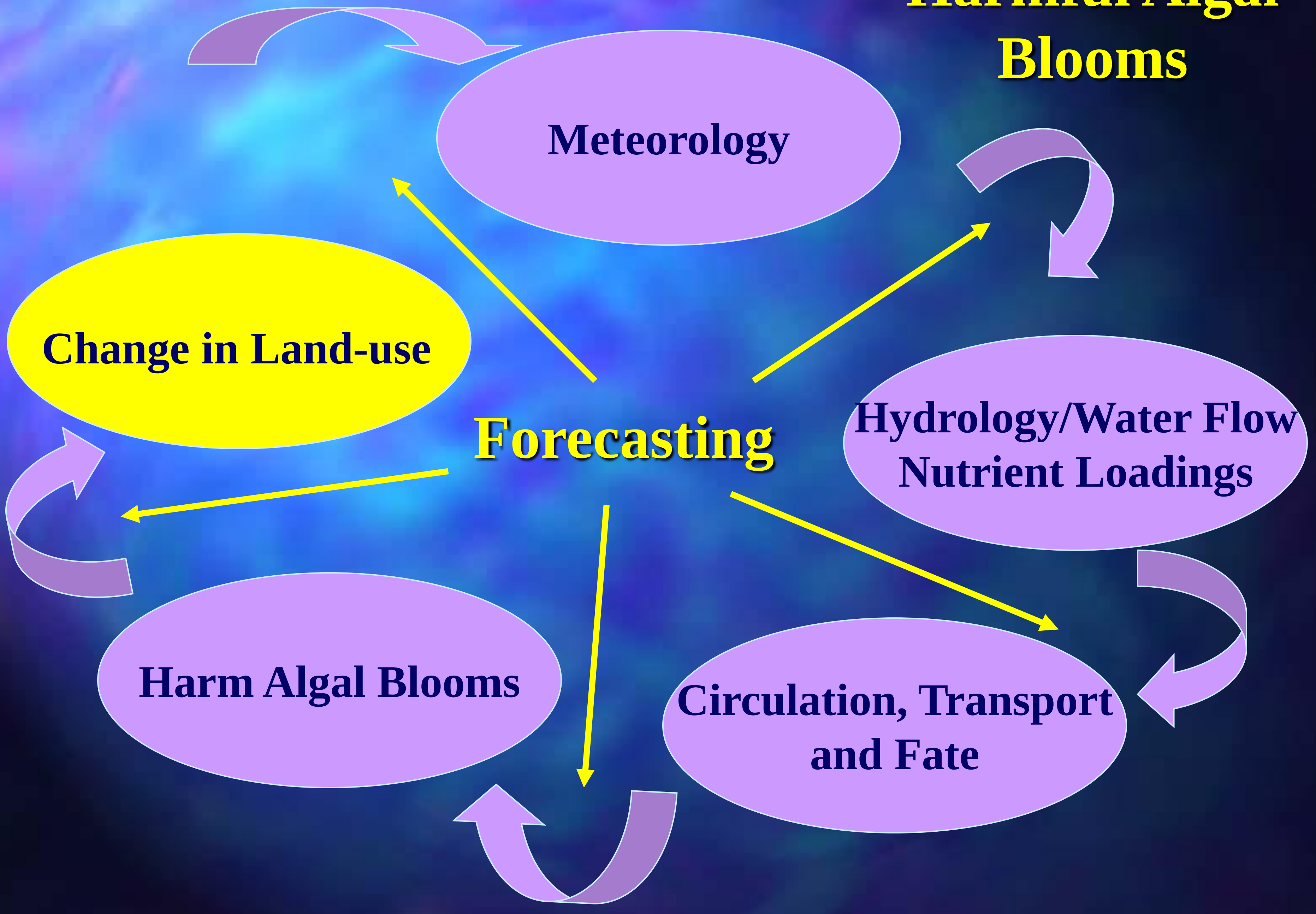
Figure 3. The *Microcystis* cyanobacteria bloom in western Lake Erie on 20 September 2016 taken by the MODIS sensor on NASA's Terra satellite. Scum areas were found mostly in the green colored water through the center of the western basin and around Pelee Point. Patches of scum were also present within the greenish white area closer to Ohio. Sediment (gray blue) from Lake St Clair is seen entering the lake from the Detroit River. Sandusky Bay is green with predominately *Plantothrix* cyanobacteria. Resuspended sediment is bright white on the Ontario coast near Long Point.

For more information and to subscribe to this bulletin, go to: http://coastalscience.noaa.gov/research/habs/forecasting

Linked Maumee & Western Basin Site 835 August 31 Resource Sheds



Harmful Algal Blooms



Beach Closures

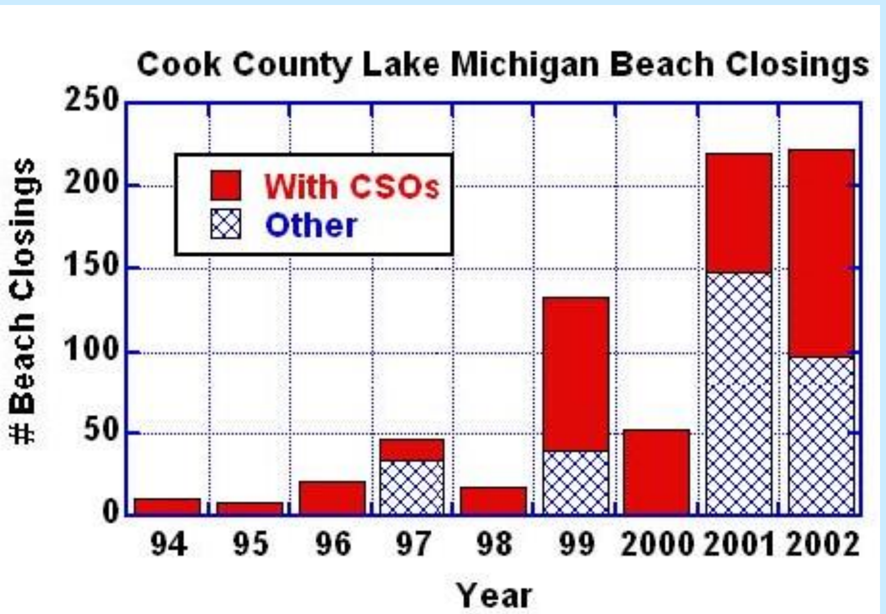
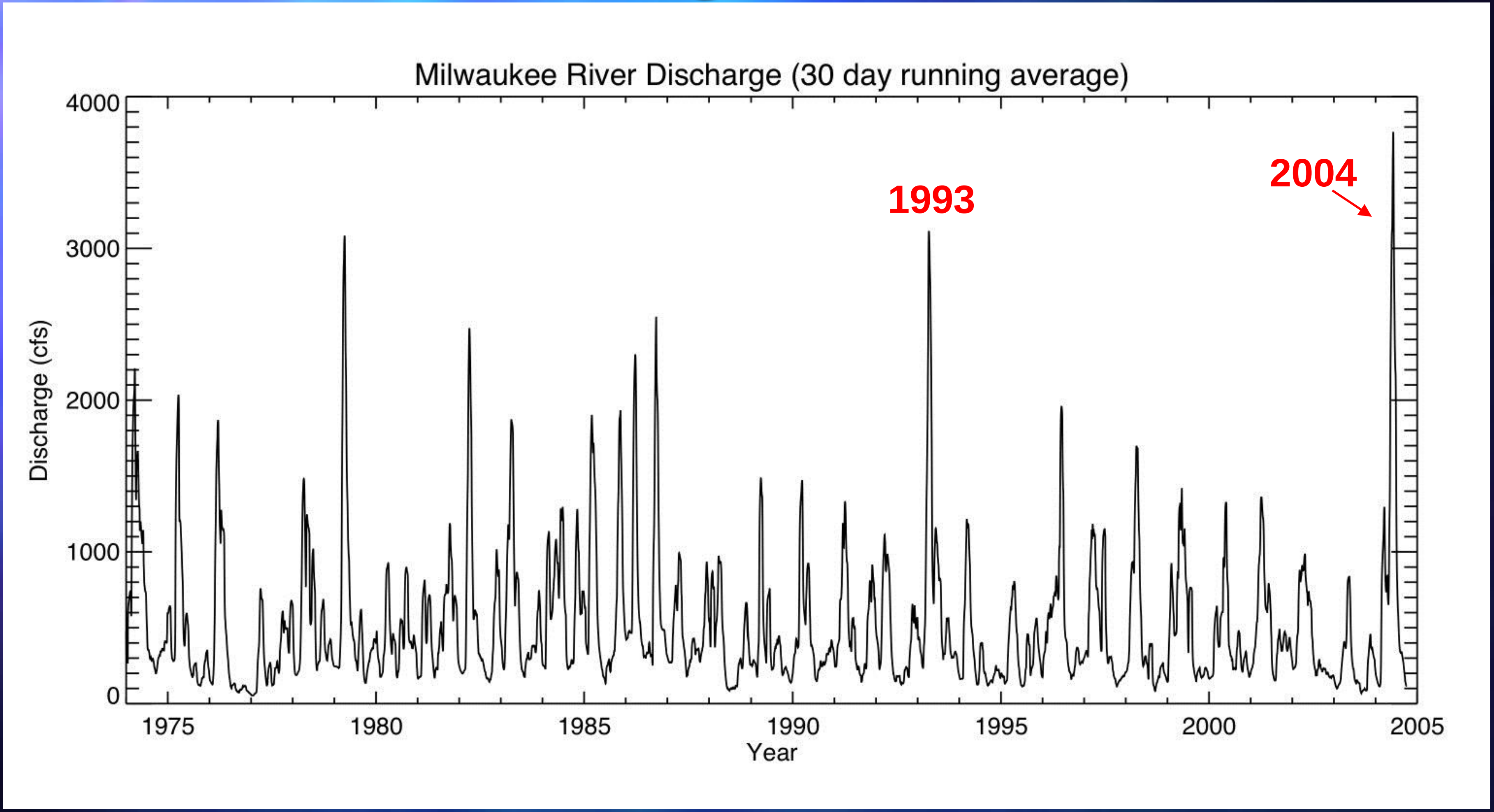


Figure 3. Cook County Lake Michigan Beach Closings.

- **Major health risk of microbial contamination by bacteria, viruses and protozoa in recreational waters**
- **E.Coli requires a 24 hour incubation period**
  - **People may unintentionally swim in contaminated water**

Long-term record of Milwaukee River discharges (1974-2005)



Over 4 billion gallons of sewer overflow released between May 10-24

chicagoist

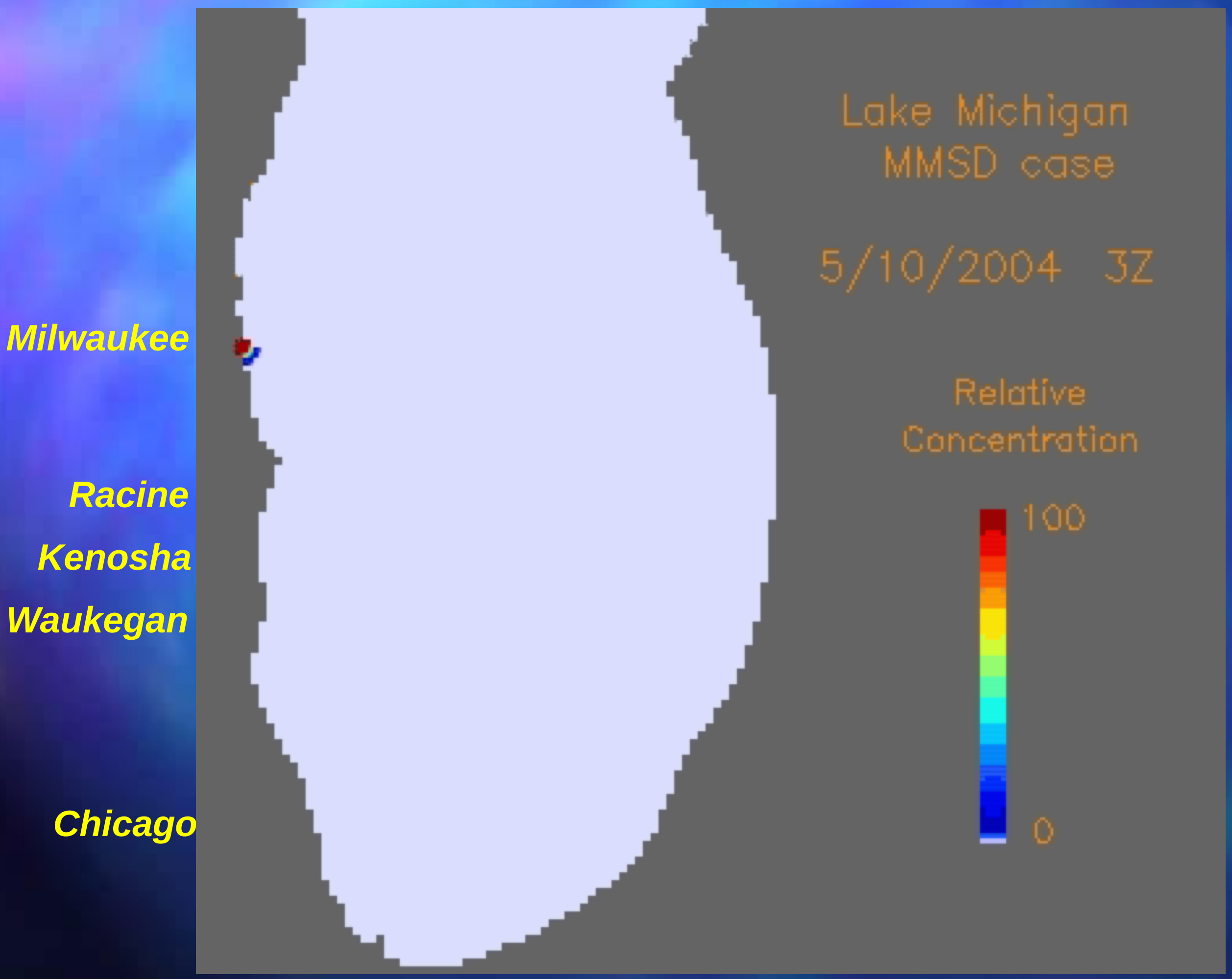
JUNE 15, 2004

Chicago's Beaches Closed

As a result of Milwaukee's dumping of raw sewage into Lake Michigan, **more** than half of the Chicago's beaches have been temporarily closed due to high bacteria levels. The beaches remain open for sunbathers and volleyball players, but lifeguards are told to keep swimmers out of the water. The Chicago Park District closed 16 of the 31 beaches to swimmers after tests of water samples showed high counts of E. coli bacteria. Officials blame the Cheeseheads.

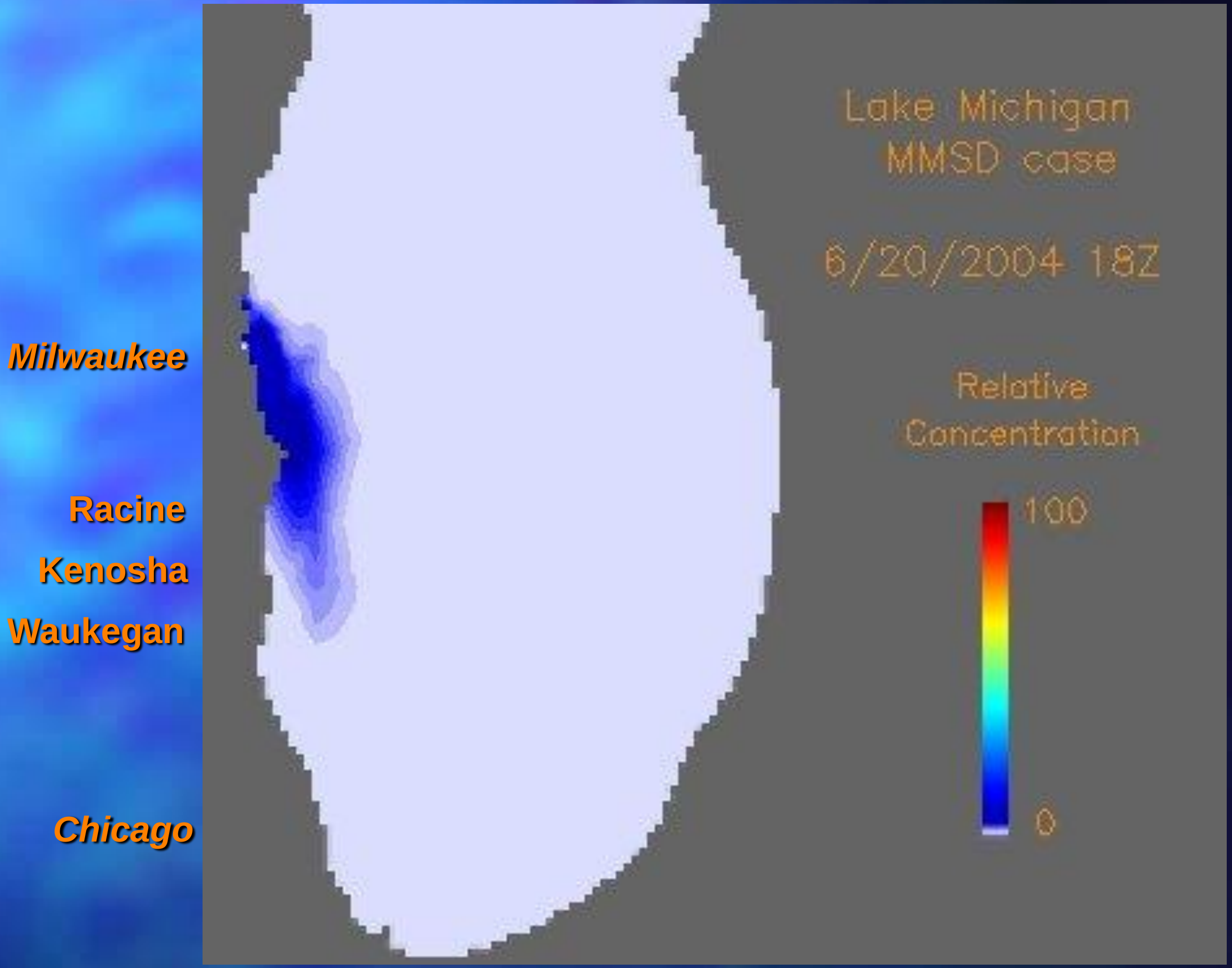
Before heading to your favorite Chicago beach and risking catching a nasty infection, you should check out the Swim Report on the Chicago Park District's site.

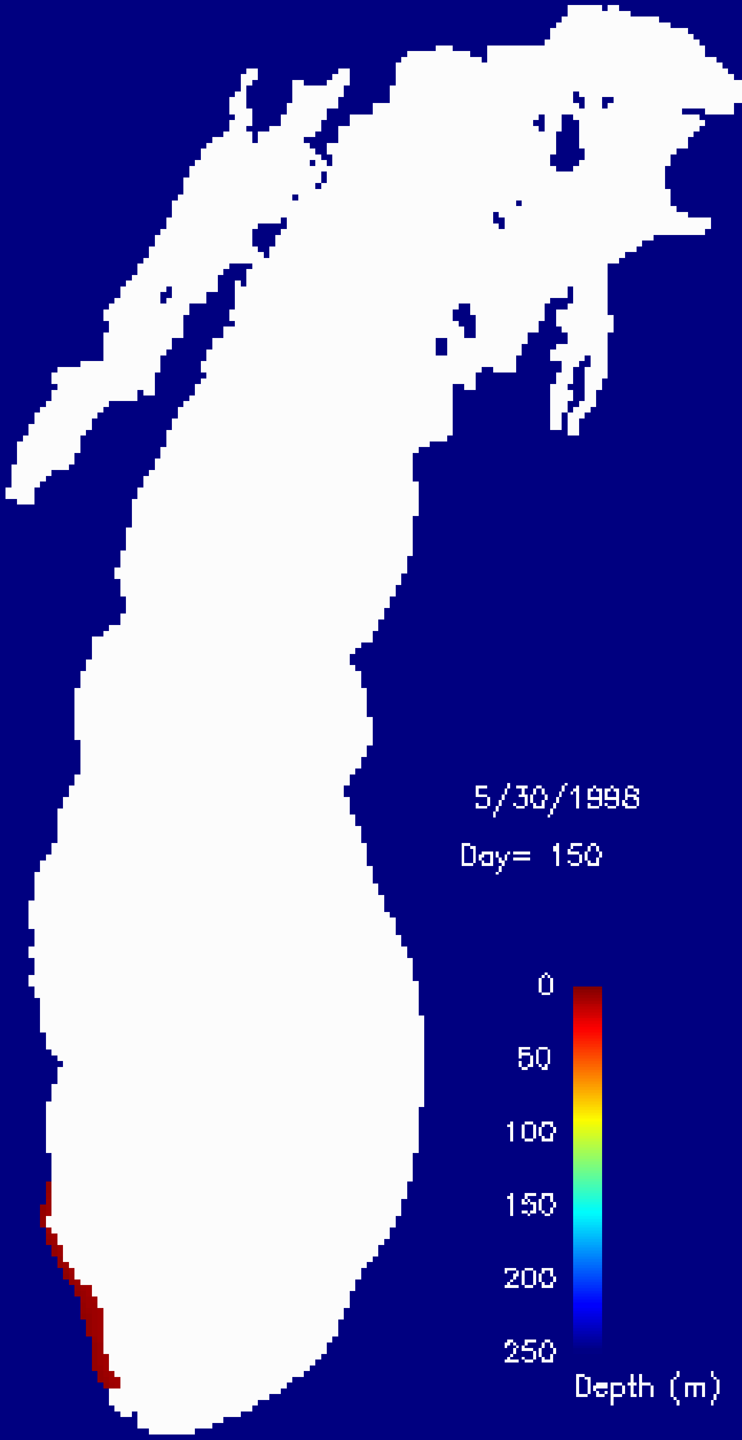
Posted by Rachelle Bowden in News: Chicago



The lake circulation model was used to simulate the dispersion of a passive tracer released continuously from the Milwaukee harbor area from 10 May – 20 June, 2004.

The final frame of the simulation shows water from the Milwaukee River released between 10 May - 25 May 2004 could not have reached Chicago area beaches by 20 June 2004.





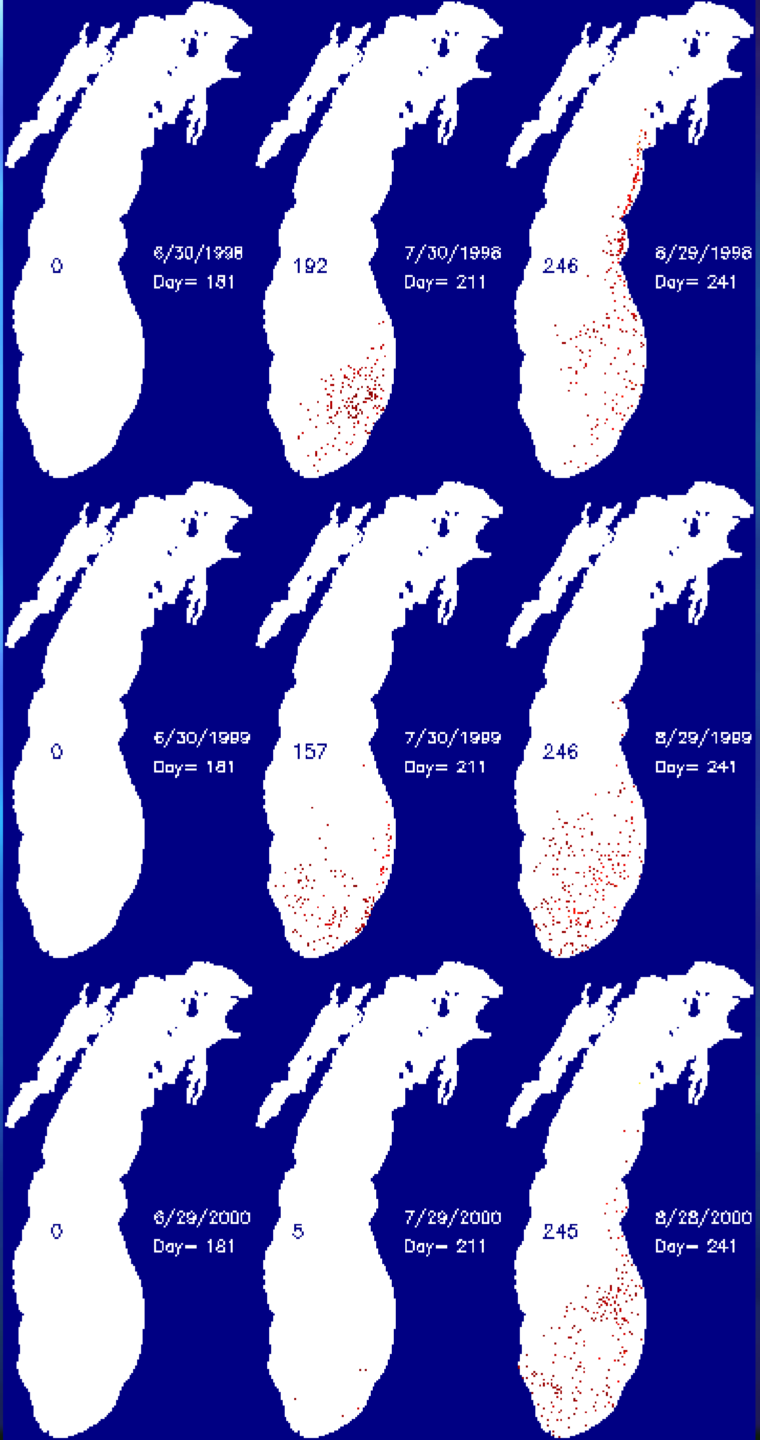
Lake Physics and Fish Recruitment

- Overall goal is to quantify the relative effects of lake physics (meso-scale circulation features, small scale turbulence, turbidity, water temperature) on distribution, survival, feeding, growth, and potential recruitment of alewife and yellow perch

Larval transport: physical-biological model.

Reduced consumption scenario.

Larval positions on 6/30, 7/30, and 8/29



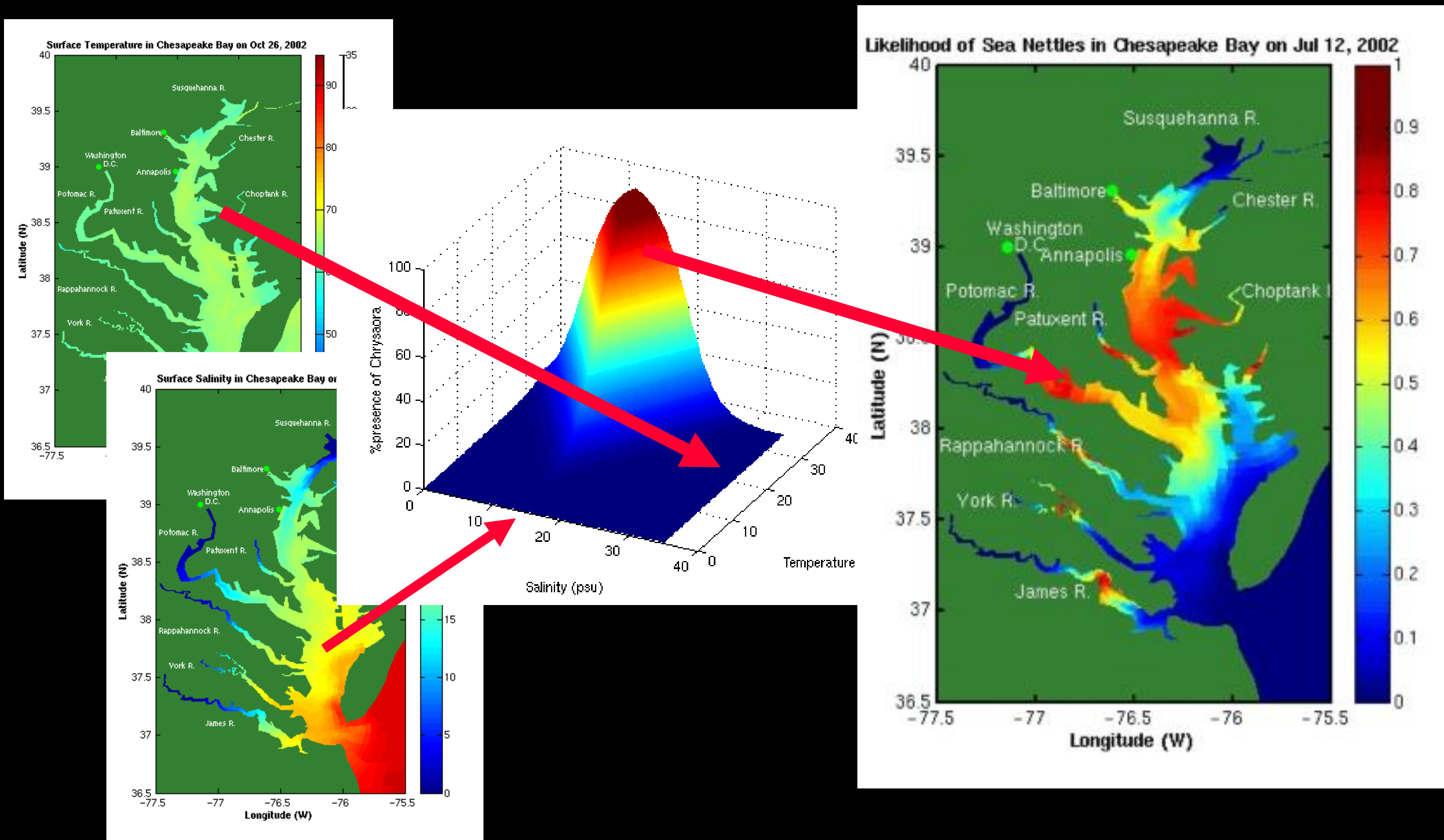
1998

1999

2000

Sea Nettle Nowcasts

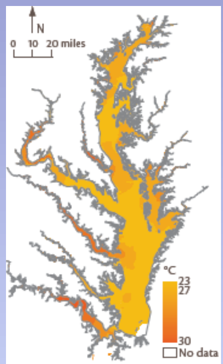
Developed by NESDIS, NOS, UMd, and VIMS



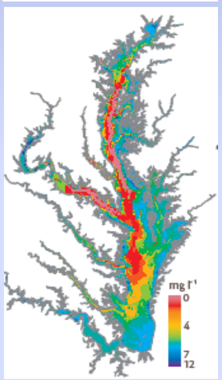
Bay Anchovy growth rate potential

Monitoring Data

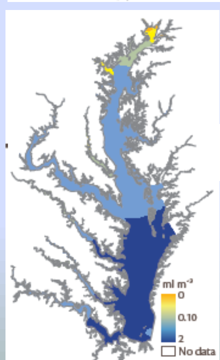
Temperature



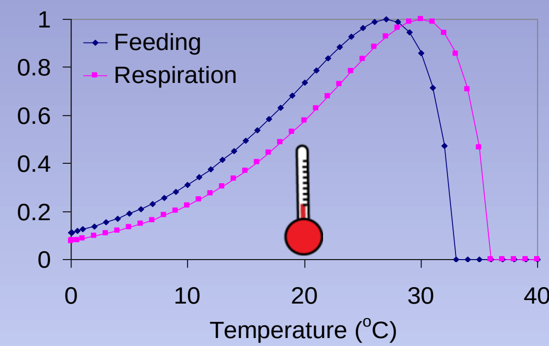
Dissolved Oxygen

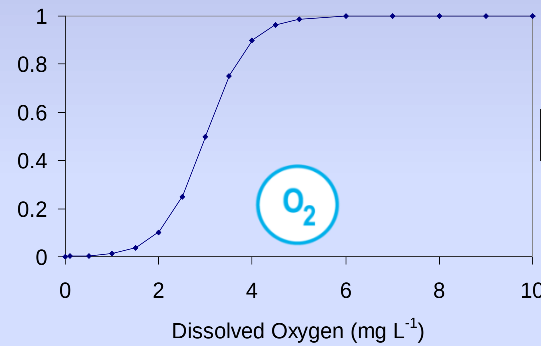


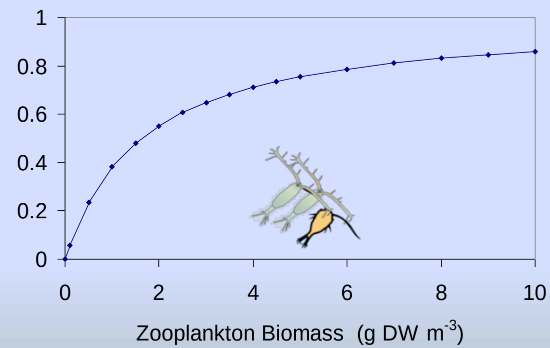
Zooplankton



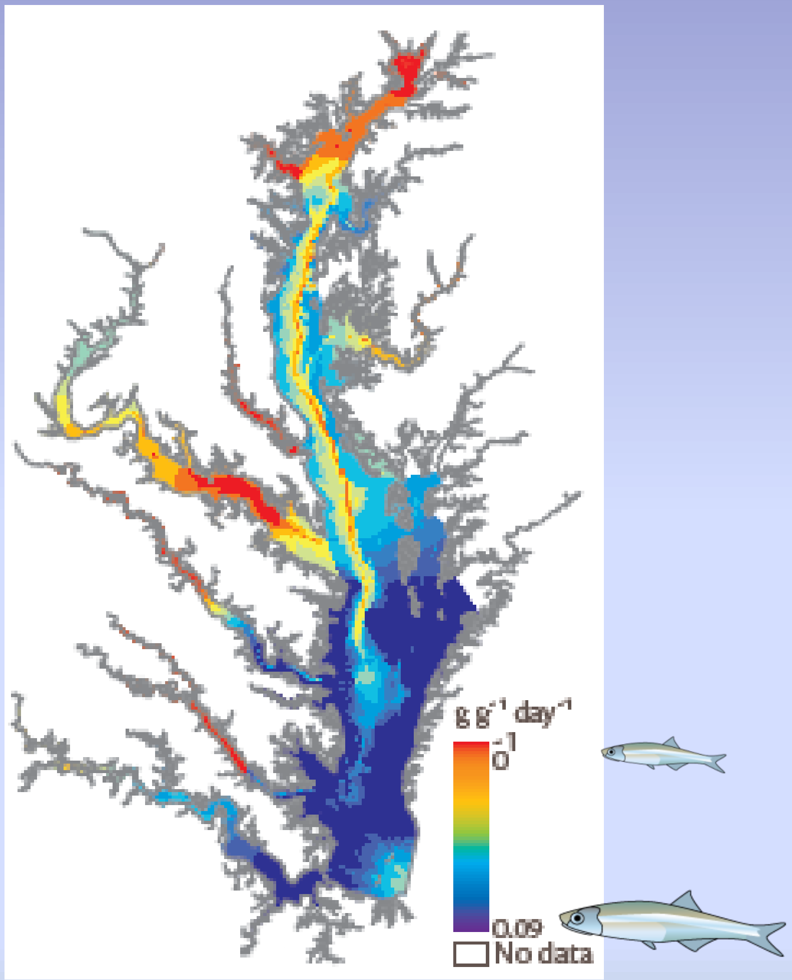
Response Scale Functions





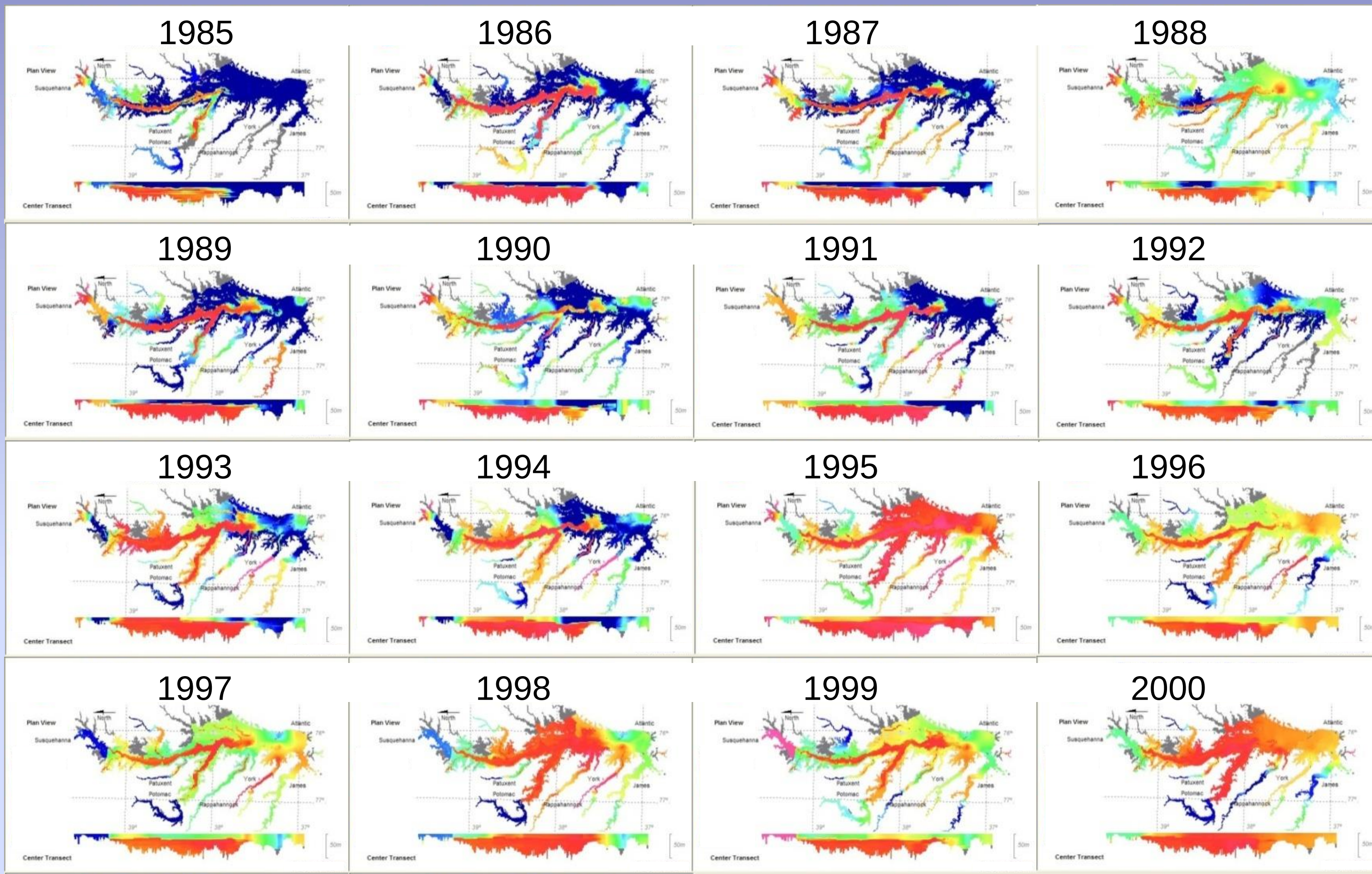


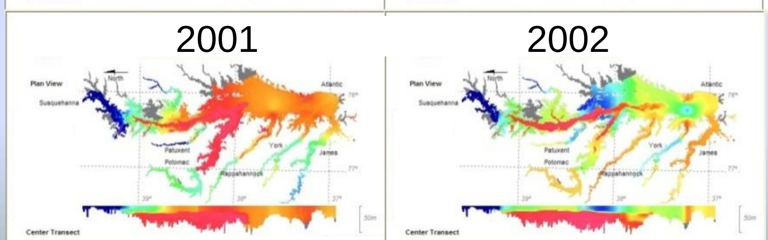
Growth Rate Potential

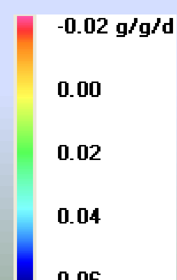


Response scale functions are based on Brandt et al. 1992; Luo & Brandt 1993

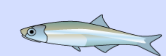
Significant long-term decline in modeled anchovy GRP







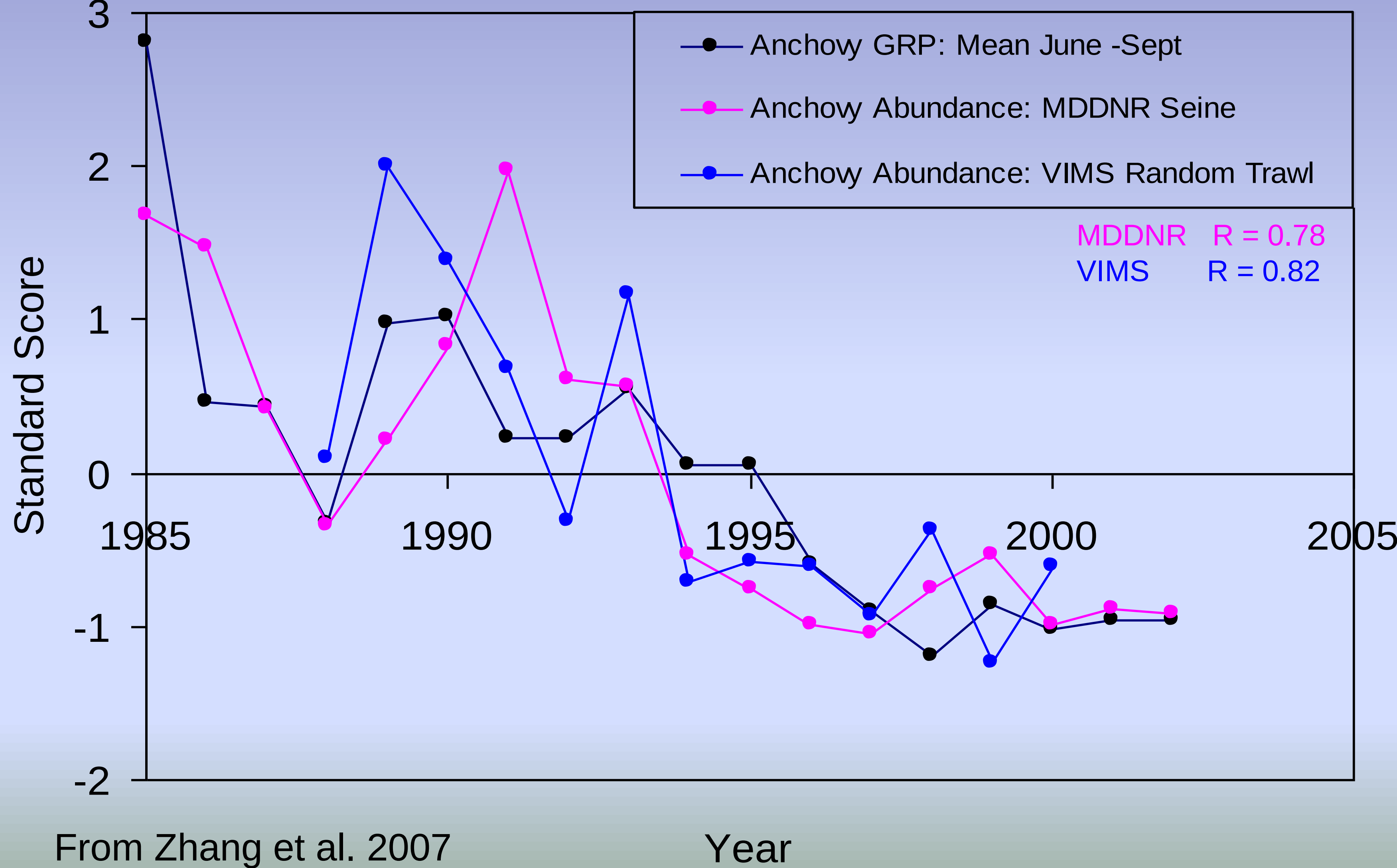
Red = low GRP



Blue = high GRP

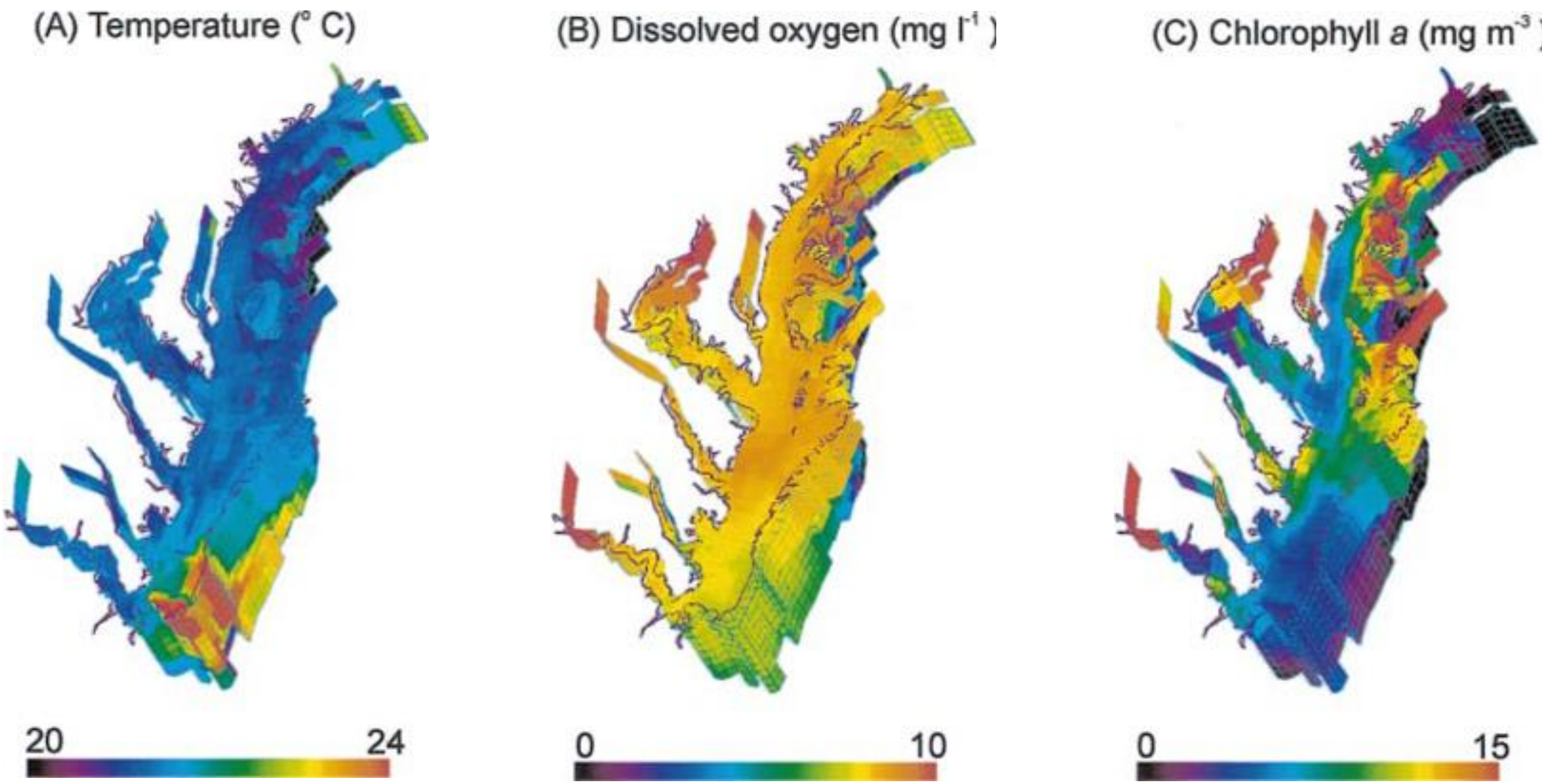
From Zhang et al. 2007

Anchovy growth rate potential is correlated with abundance



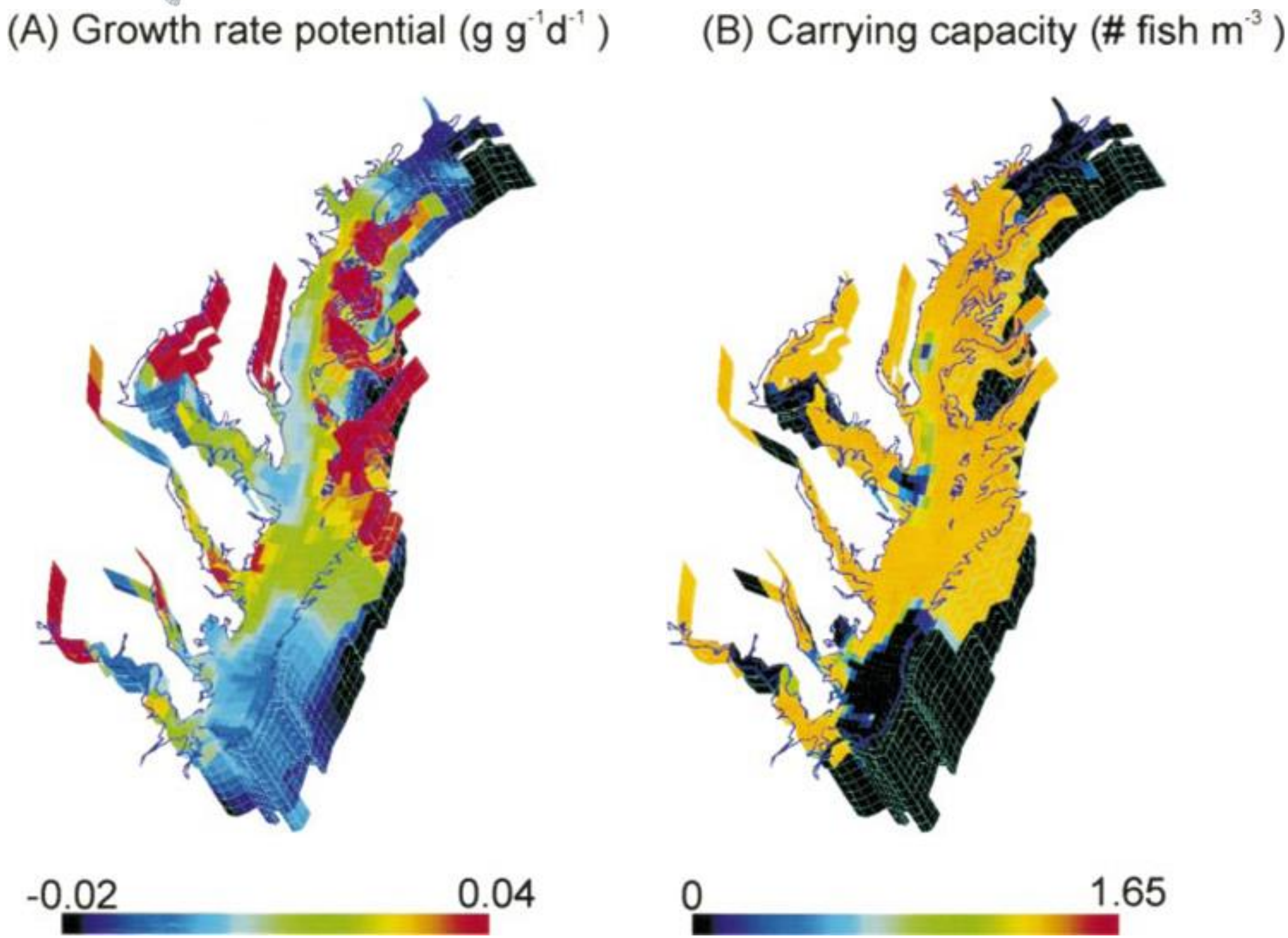
From Zhang et al. 2007

Menhaden Growth Rate Potential predicted from 3-D Water Quality Model of Chesapeake Bay July 1



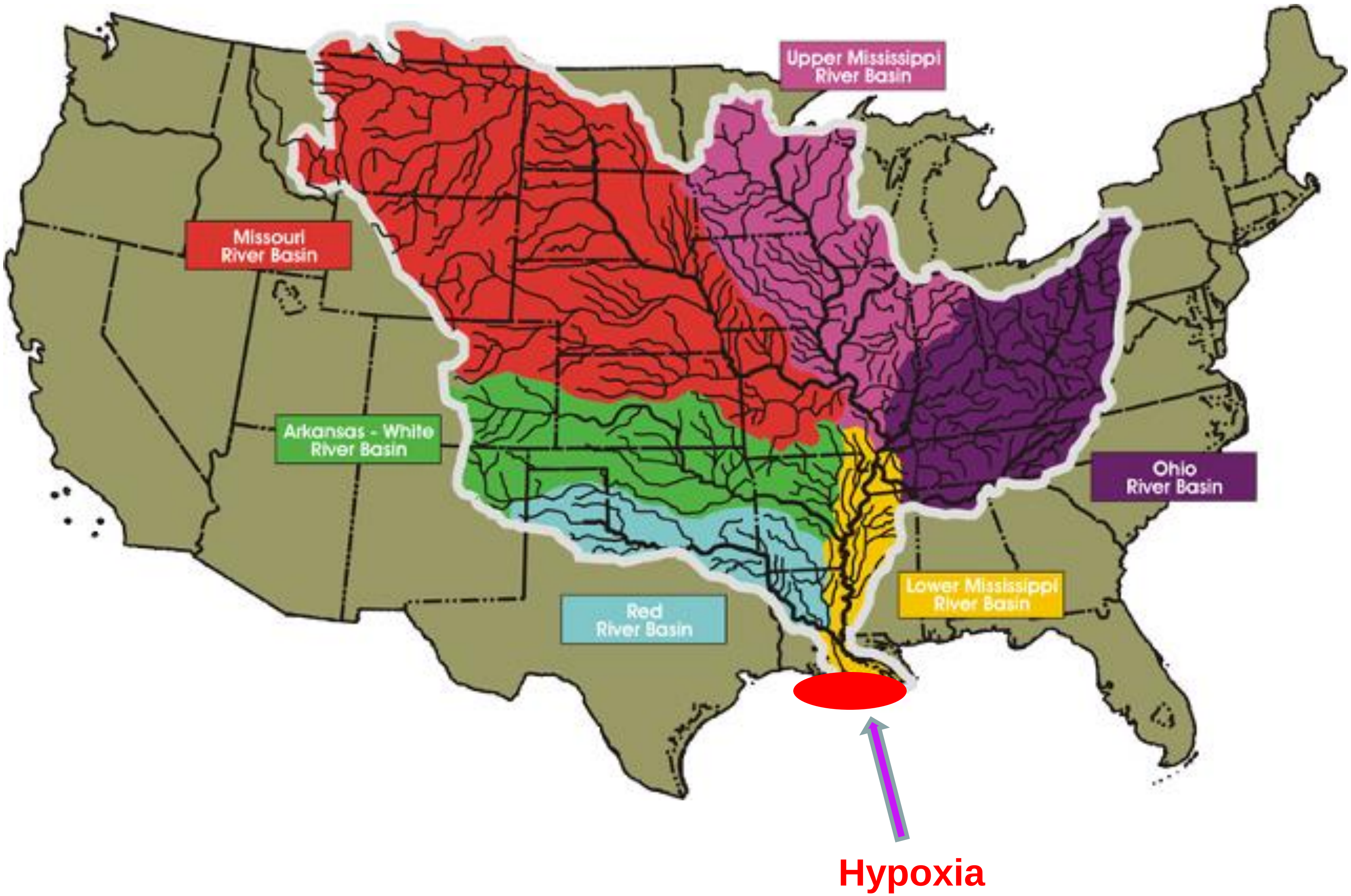
from Luo et al. 2001

Atlantic Menhaden



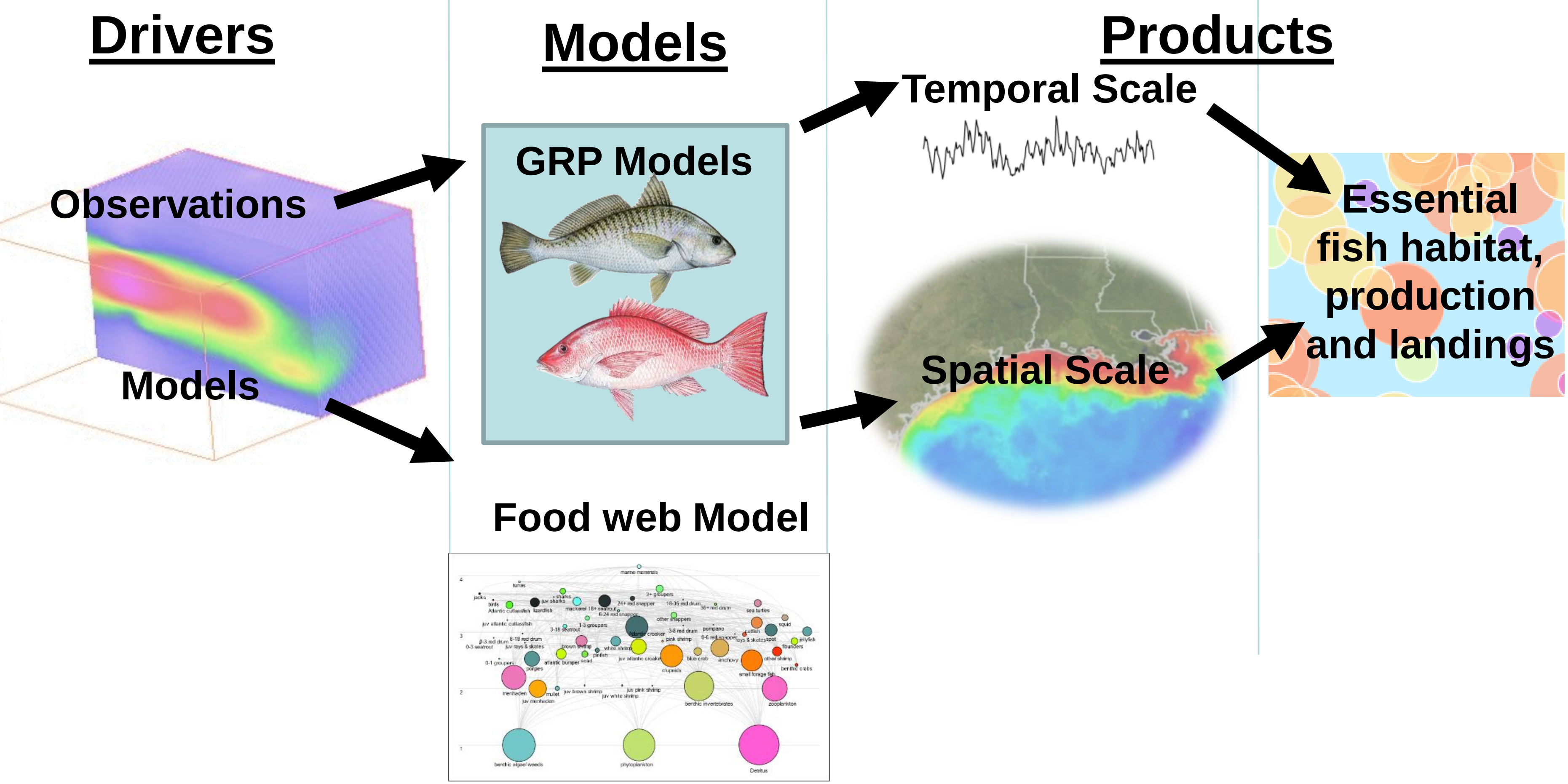
from Luo et al. 2001

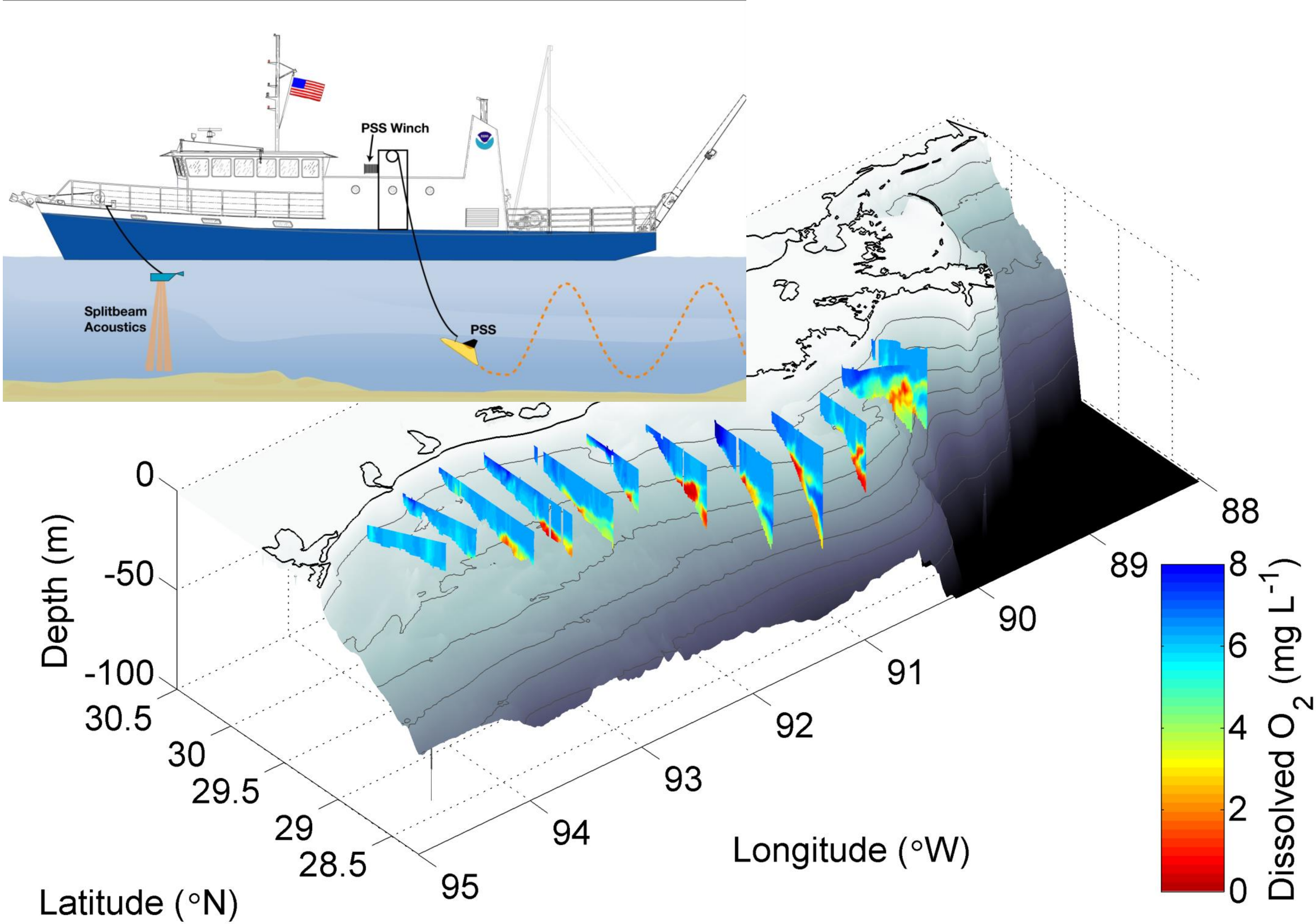
– Drainage Area 60% of U.S. Surface Area



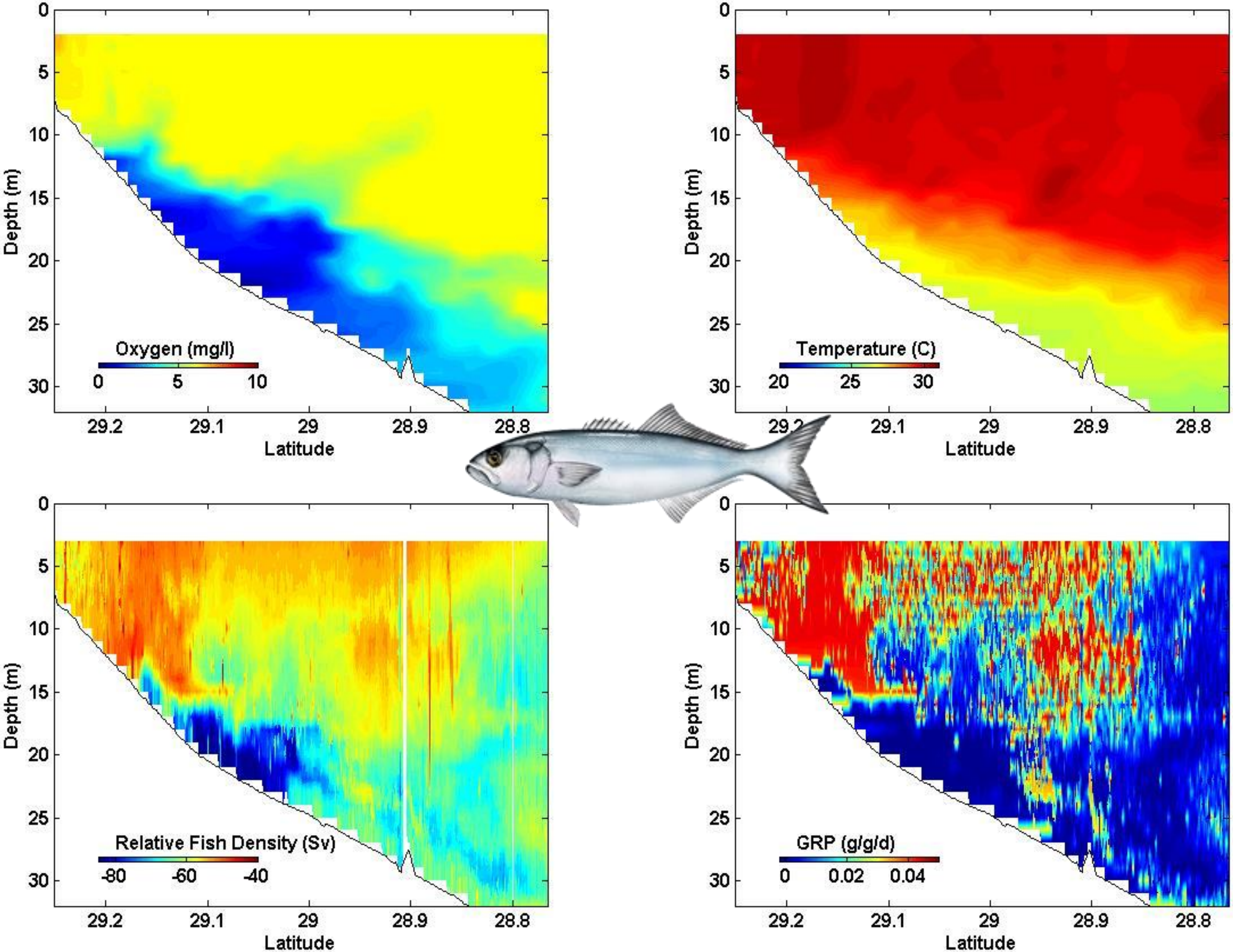
USER-DRIVEN TOOLS TO PREDICT AND ASSESS EFFECTS OF REDUCED NUTRIENTS AND HYPOXIA ON LIVING RESOURCES IN THE GULF OF MEXICO

NOAA – 2016 - 2020

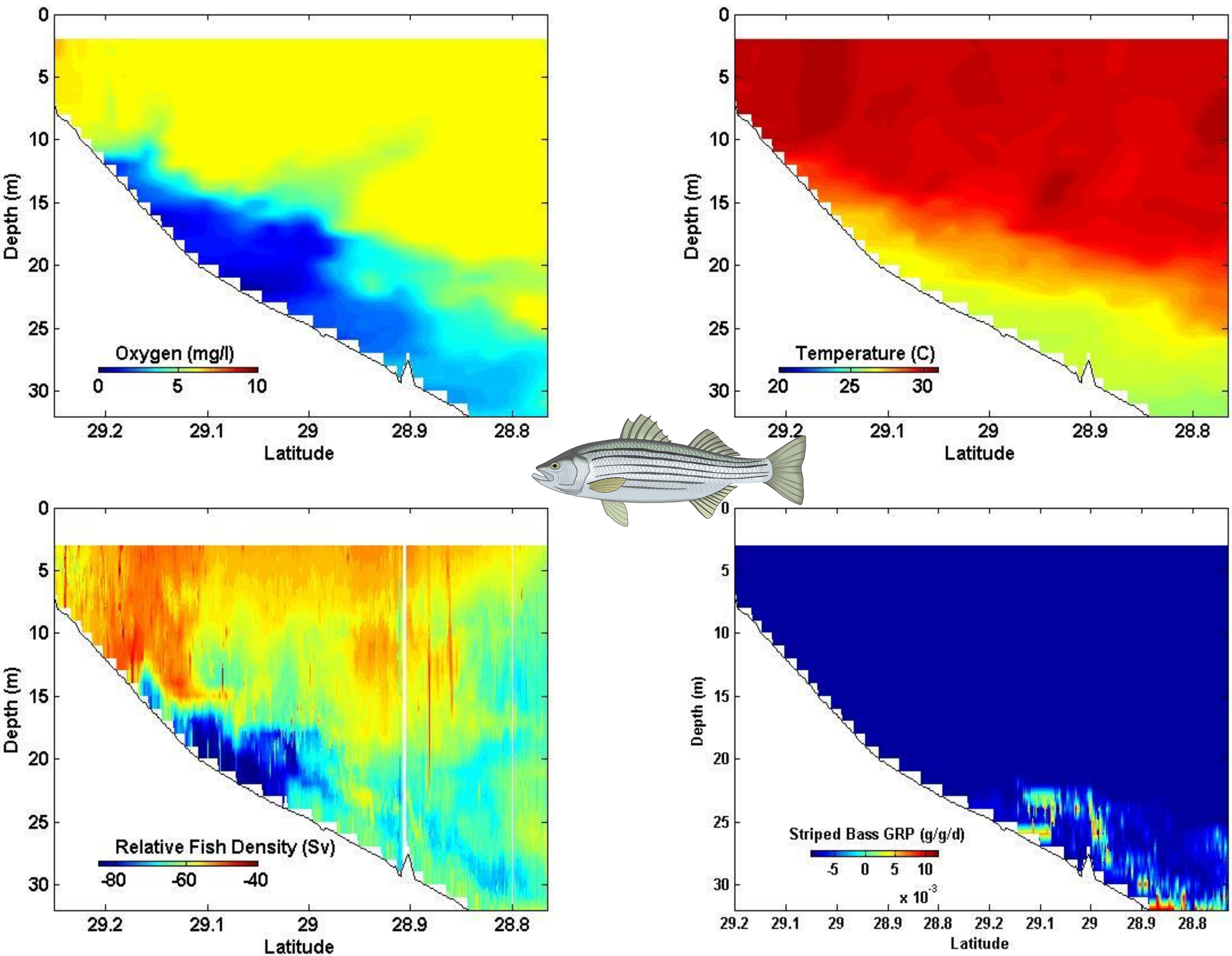




PSS Winch
Splitbeam
Acoustics
PSS
Depth (m)
0
-50
-100
Latitude (°N)
30.5
30
29.5
29
28.5
Longitude (°W)
95
94
93
92
91
90
89
88
Dissolved O_2 (mg L^{-1})
0
2
4
6
8

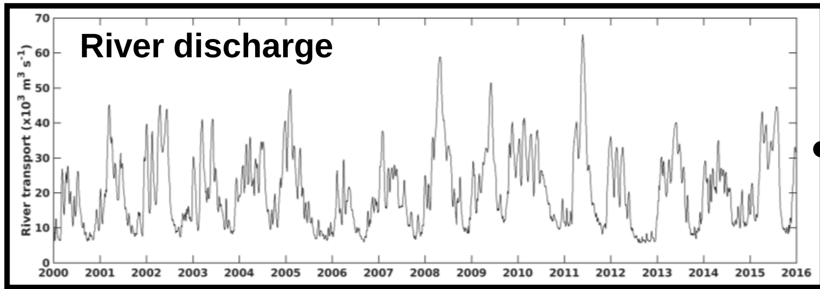


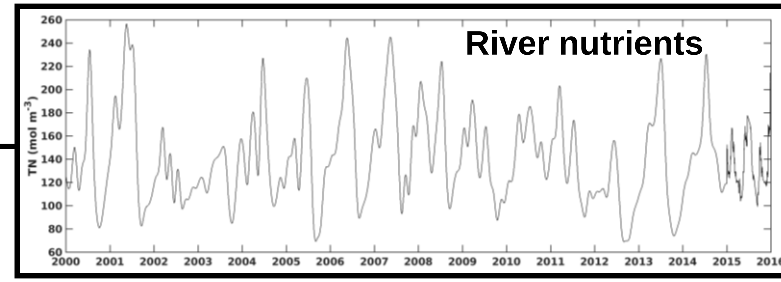
Oxygen (mg/l)
0 5 10
Temperature (C)
20 25 30
Relative Fish Density (Sv)
-80 -60 -40
GRP (g/g/d)
0 0.02 0.04
Depth (m)
0 5 10 15 20 25 30
Latitude
29.2 29.1 29 28.9 28.8

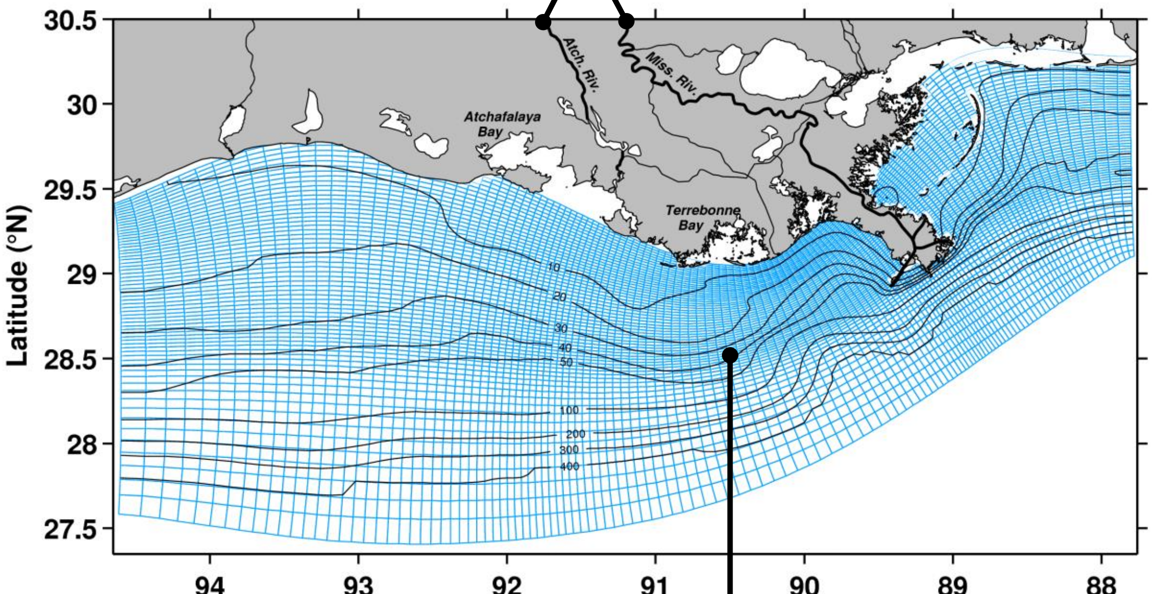


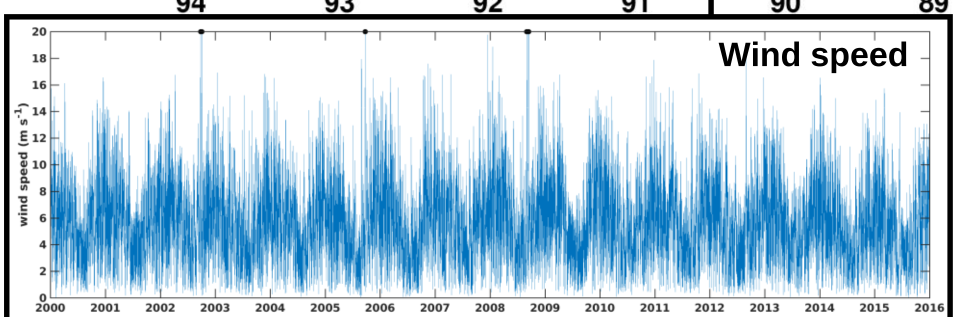
Oxygen (mg/l)
0 5 10
Temperature (C)
20 25 30
Relative Fish Density (Sv)
-80 -60 -40
Striped Bass GRP (g/g/d)
-5 0 5 10
x 10^-3
Depth (m)
0 5 10 15 20 25 30
Latitude
29.2 29.1 29 28.9 28.8
29.2 29.1 29 28.9 28.8 29.2 29.1 29 28.9 28.8

Circulation Model (ROMS)









Location: Northern GoM shelf

Resolution: 3-5 km in horizontal
20 vertical layers

Forcing: 3-hourly winds (spatially-resolved); climatological surface heat and freshwater fluxes

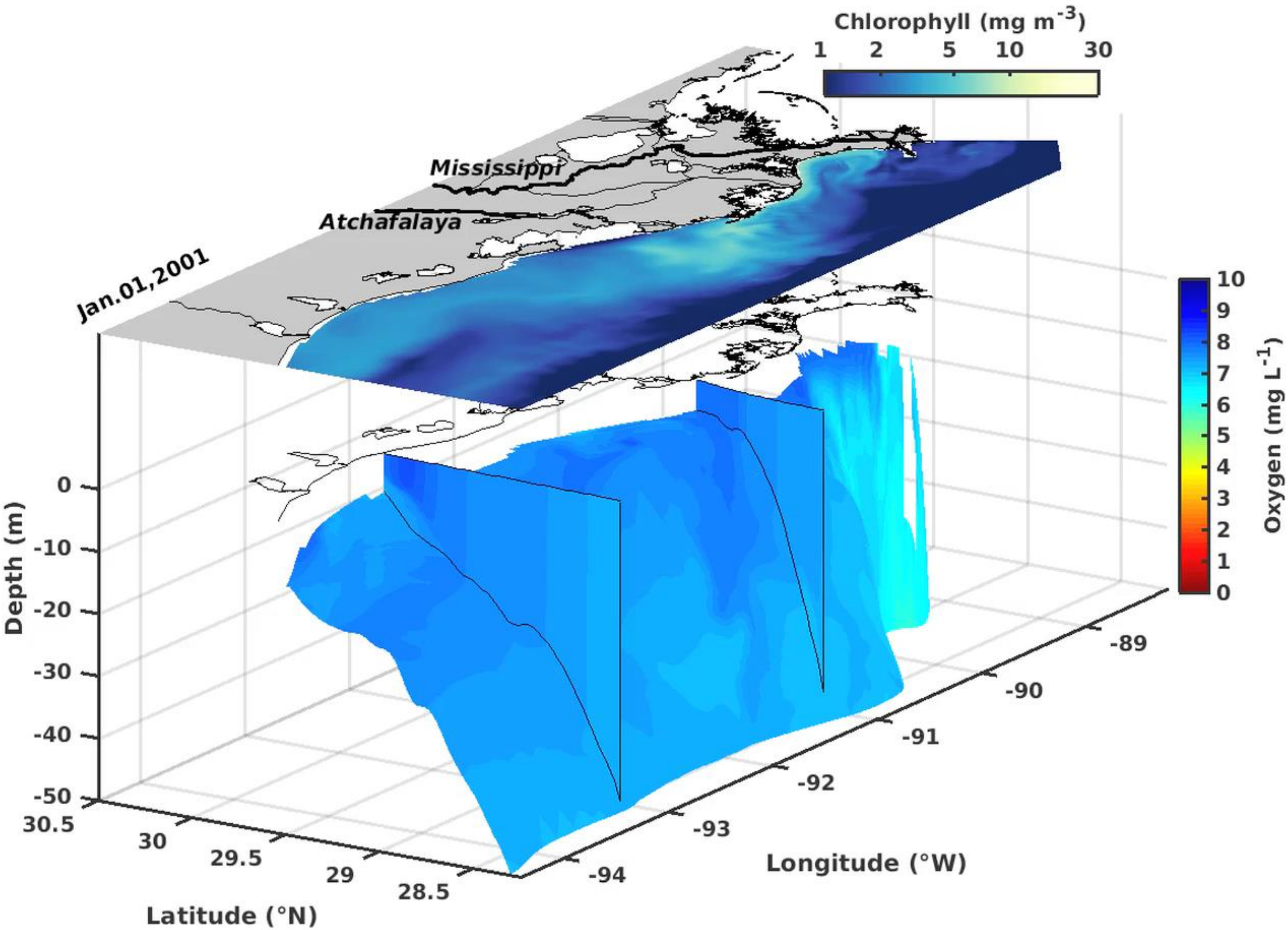
River inputs: daily freshwater input (U.S. Army Corps of Engineers); monthly nutrient and particulate matter loads (USGS)

Boundary conditions: climatology

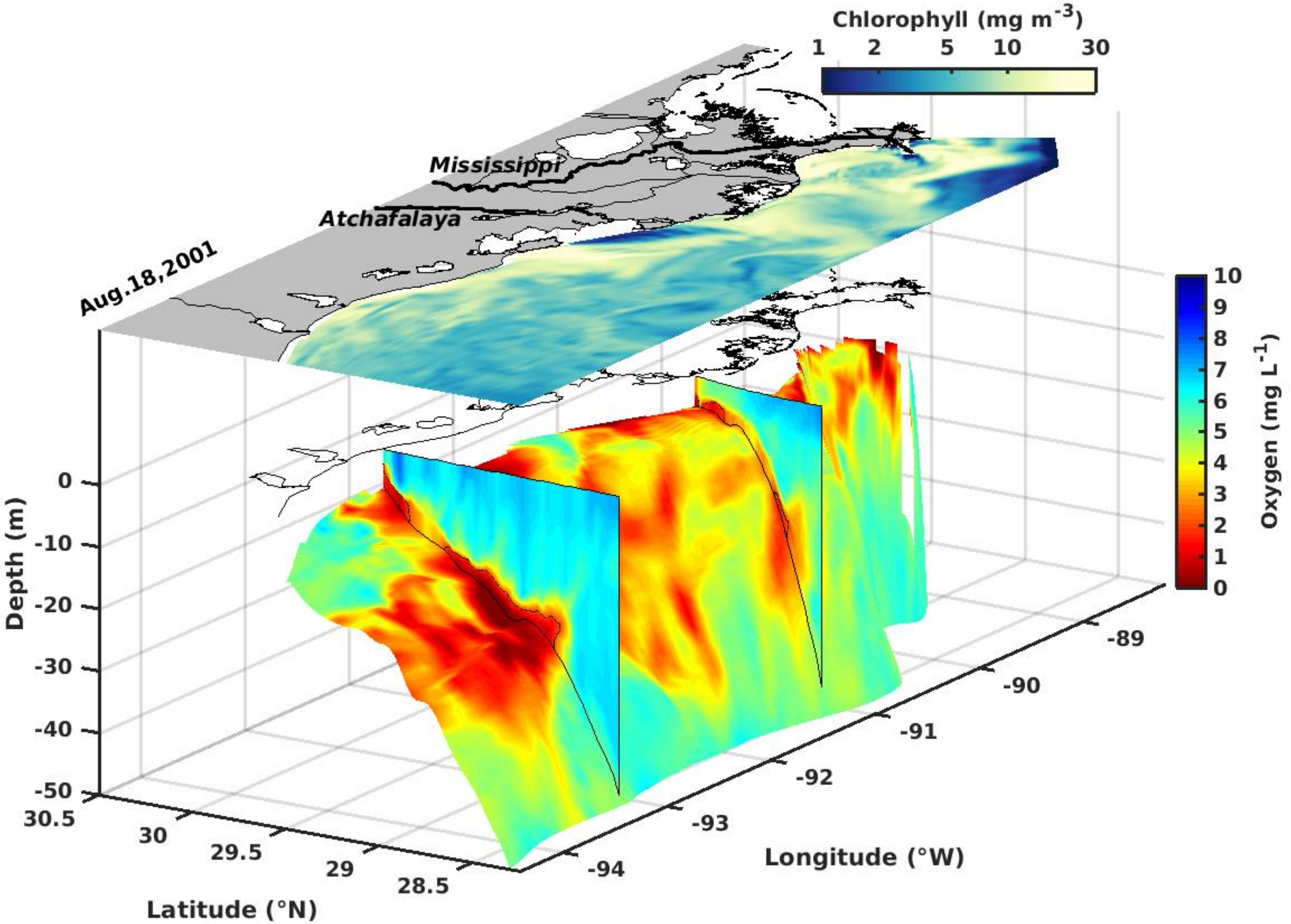
Simulation period: 2000 – 2016

Output: Daily 3D field of state variables (T, S, currents + biological variables)

Results for baseline simulation



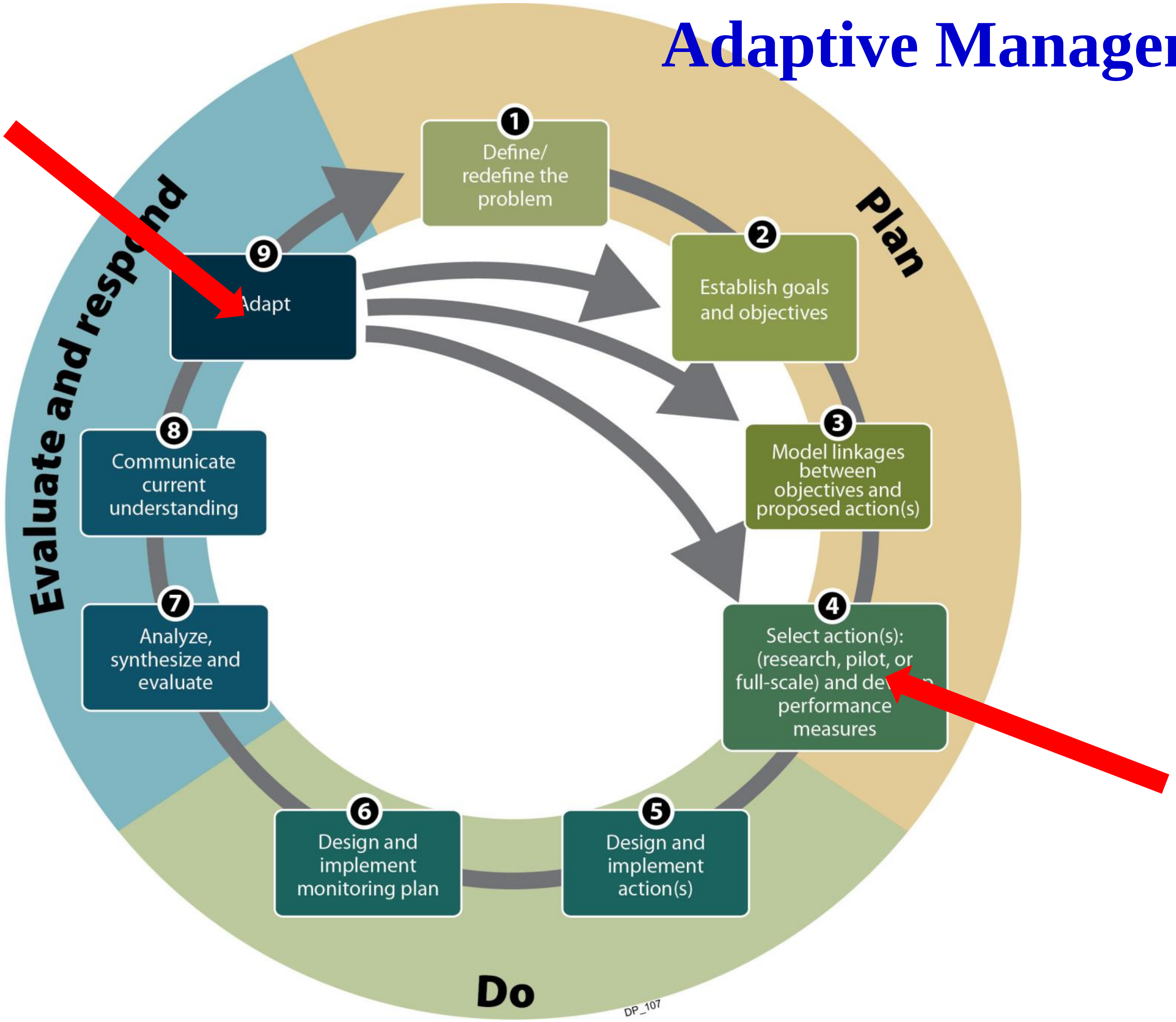
Results for baseline simulation



Major Points: Ecosystem Forecasting

- Real and can be done now.
- Provides a broad framework for prioritizing science multi-disciplinary approaches and scientific collaboration.
- This framework can help focus research to aid management and decision-making.
- Communicating the Value of Science

Adaptive Managemen



From Wiens et al. In Press

This will require ;

- Research that is more focused on **Forcing** rather than Impacts
- Research that is focused on **Prediction** rather than explanation
- New breakthroughs in our understanding at the boundaries between disciplines (including physical-chemical-biological-societal interfaces),
- Improved technologies to expand the time, space and parameter scales that we observe the ecosystem
- Changes in training the next generation of scientists

"We didn't lose the game, we just ran out of time."

Vince Lombardi
(Green Bay Packer Football Coach)

Questions?

Support from;

NOAA-CSCOR NGOMEX

NSF

National Academy of Sciences