Water Quality Monitoring:

Lesson Plan for Exploring Time Series Data

Presenters:
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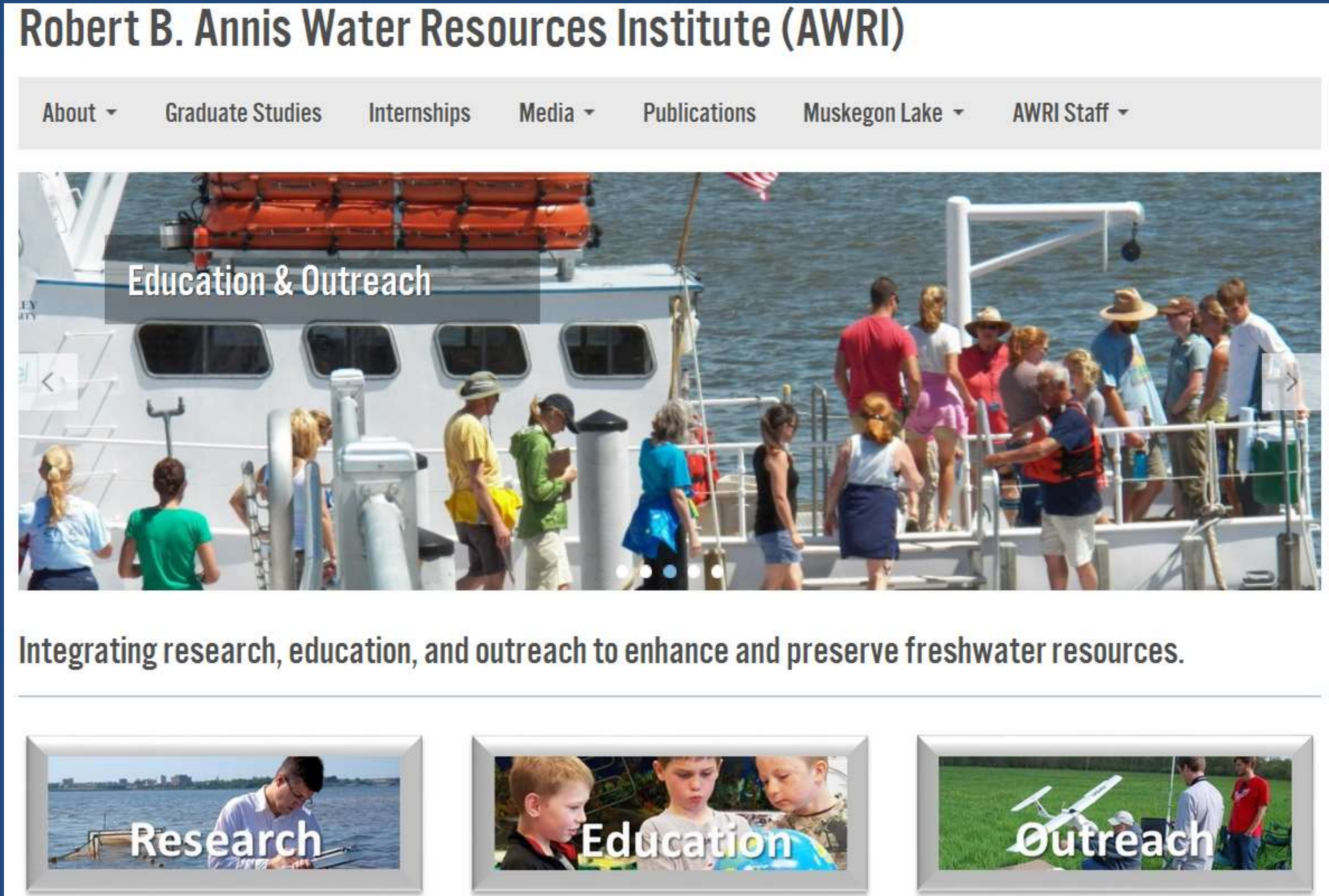
GRAND VALLEY STATE UNIVERSITY
ROBERT B. ANNIS WATER RESOURCES INSTITUTE

Lake Michigan Center in Muskegon, Michigan

Home of Annis Water Resources Institute



www.gvsu.edu/wri

What can time-series lake data tell us about seasonal ecosystem dynamics and upstream influences?

Upon completion of this lesson, students will be able to

- Explain the advantages of using times-series data sets for water monitoring versus single (one time) measurements.
- Construct and interpret graphs of real-time environmental data.
- Formulate a question about water quality and select the appropriate data to answer the question.
- Explore patterns as well as cause and effect relationships.

Engage

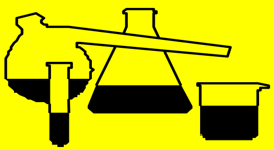
Engage

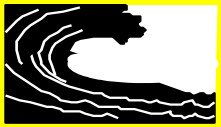
Lake Superior

Lake Erie

Water Quality Parameters

Biological
- Phytoplankton
- Zooplankton
- Benthic organisms
- Detritus
- Macrophytes
- Fish*
- Bacteria*





Chemical
- pH
- Dissolved oxygen
- Conductivity
- Phosphorus*
- Nitrogen*
- Alkalinity*
- Metals*
- Organics*

Physical
- Depth
- Water Clarity
- Turbidity
- Water Color
- Bottom materials
- Waves & Currents
- Temperature

Table 1. **Sources and associated pollutants** U.S. EPA, 2015

Source	Common Associated Pollutants
Cropland	Turbidity, phosphorus, nitrates, temperature, total solids
Forestry harvest	Turbidity, temperature, total solids
Grazing land	Fecal bacteria, turbidity, phosphorus, nitrates, temperature
Industrial discharge	Temperature, conductivity, total solids, toxics, pH
Mining	pH, alkalinity, total dissolved solids
Septic systems	Fecal bacteria (i.e., Escherichia coli), nitrates, phosphorus, dissolved oxygen/biochemical oxygen demand, conductivity, temperature
Sewage treatment plants	Dissolved oxygen and biochemical oxygen demand, turbidity, conductivity, Phosphorus, nitrates, fecal bacteria, temperature, total solids, pH
Construction	Turbidity, temperature, dissolved oxygen and biochemical oxygen demand, total solids, and toxics
Urban runoff	Turbidity, phosphorus, nitrates, temperature, conductivity, dissolved oxygen and biochemical oxygen demand

Explore

- About the Muskegon Lake Observatory

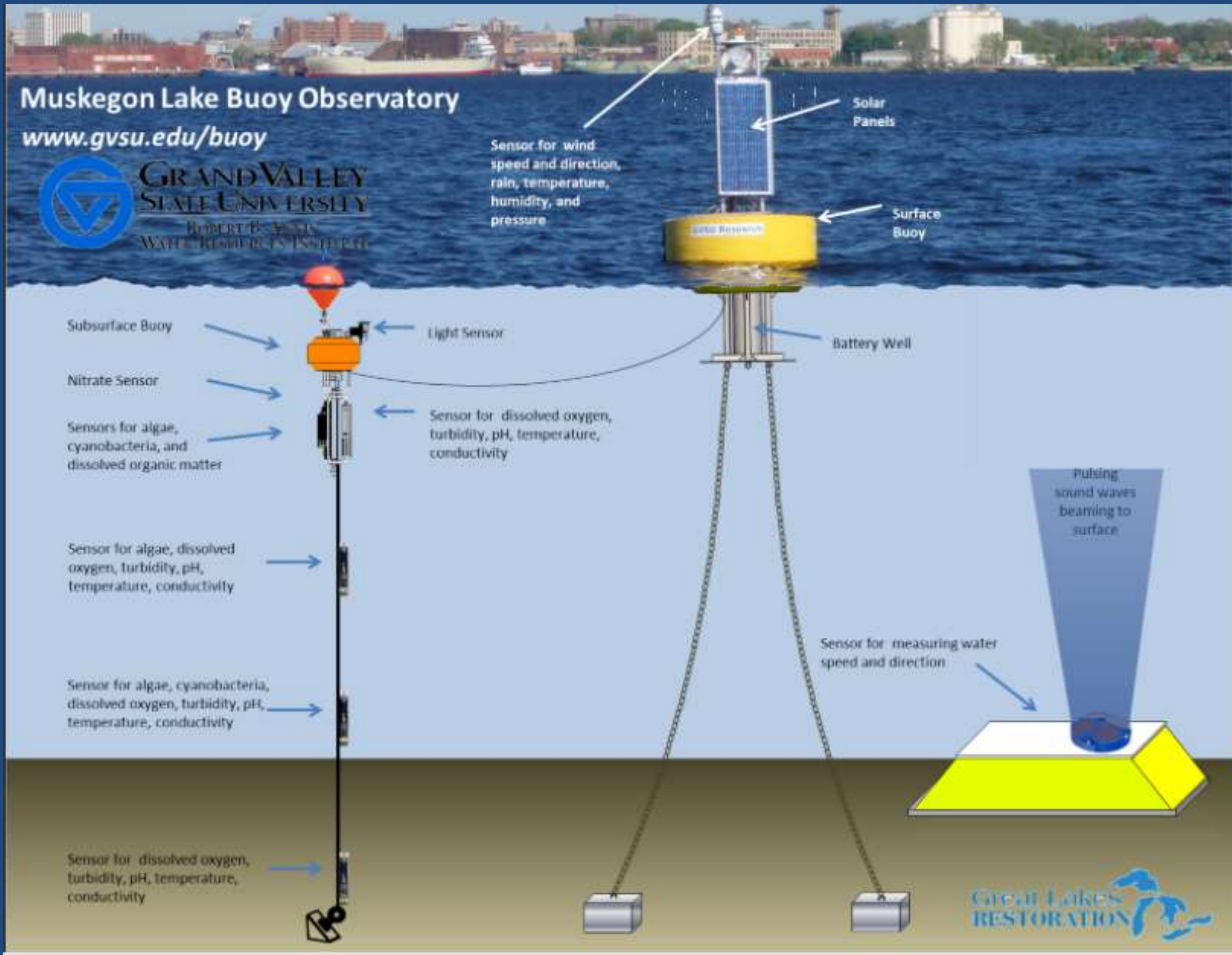
www.gvsu.edu/buoy

Location of the Muskegon Lake Observatory

Muskegon Lake Observatory

- Collects air/water data 4-12 times per hour
- Sends the data to GVSU computer, then to the internet

What's connected to the buoy?



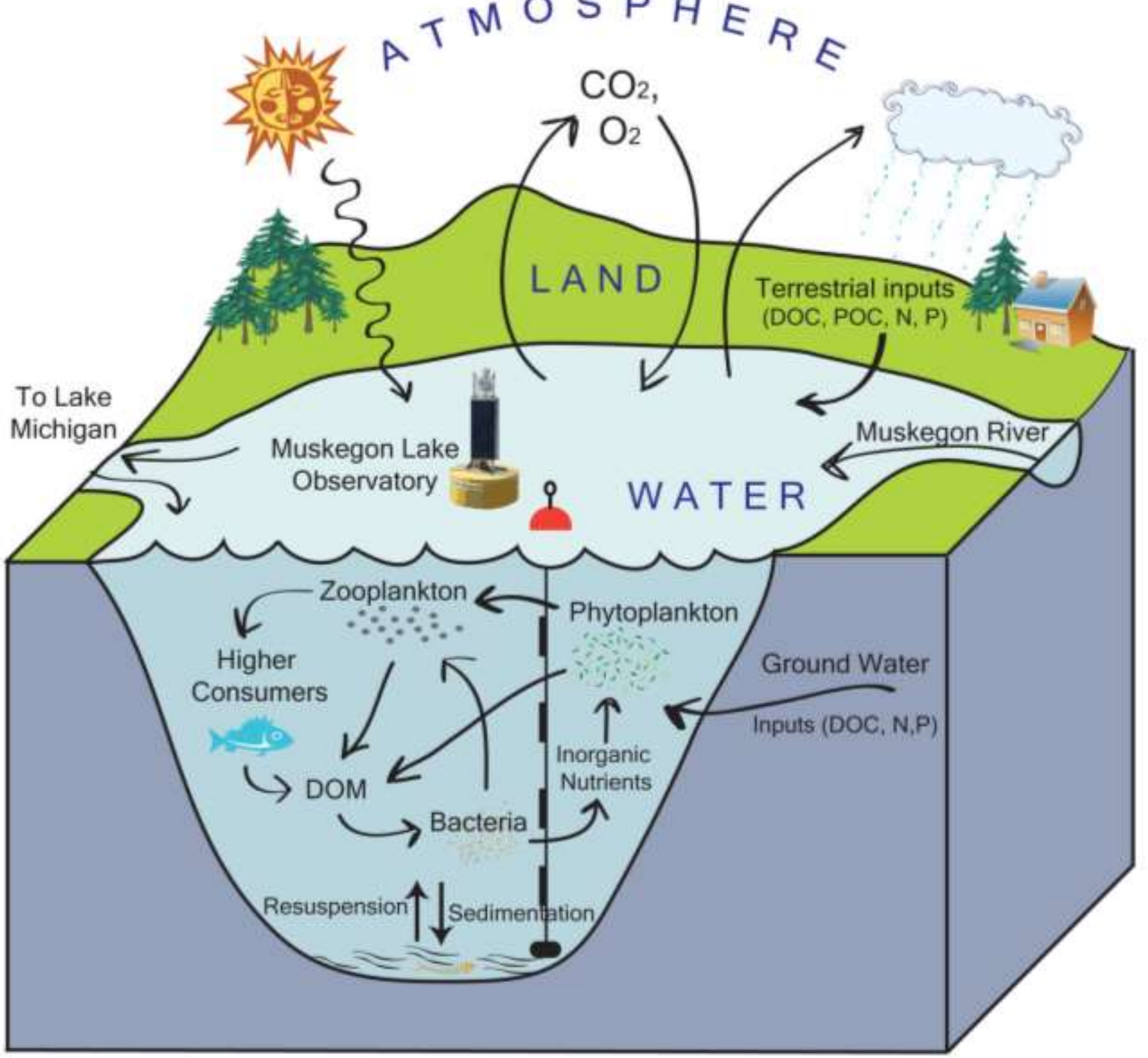
What is being measured?

- Water sensors have measured over 13 parameters including temperature, oxygen, nutrients, light, pH, conductivity, algal pigments (chlorophyll), bacterial pigments (phycocyanin), and current speed and direction.

- Air sensors measured 8 parameters including temperature, wind, humidity, and precipitation.

Sensors

- Temperature
- Oxygen
- Light
- Nutrients
- Turbidity
- Algae
- Wind
- Rain
- Water speed



http://www.gvsu.edu/buoy

Current Conditions

Annis Water Resources Institute

integrating research, education, and outreach to enhance and preserve freshwater resources

print site index

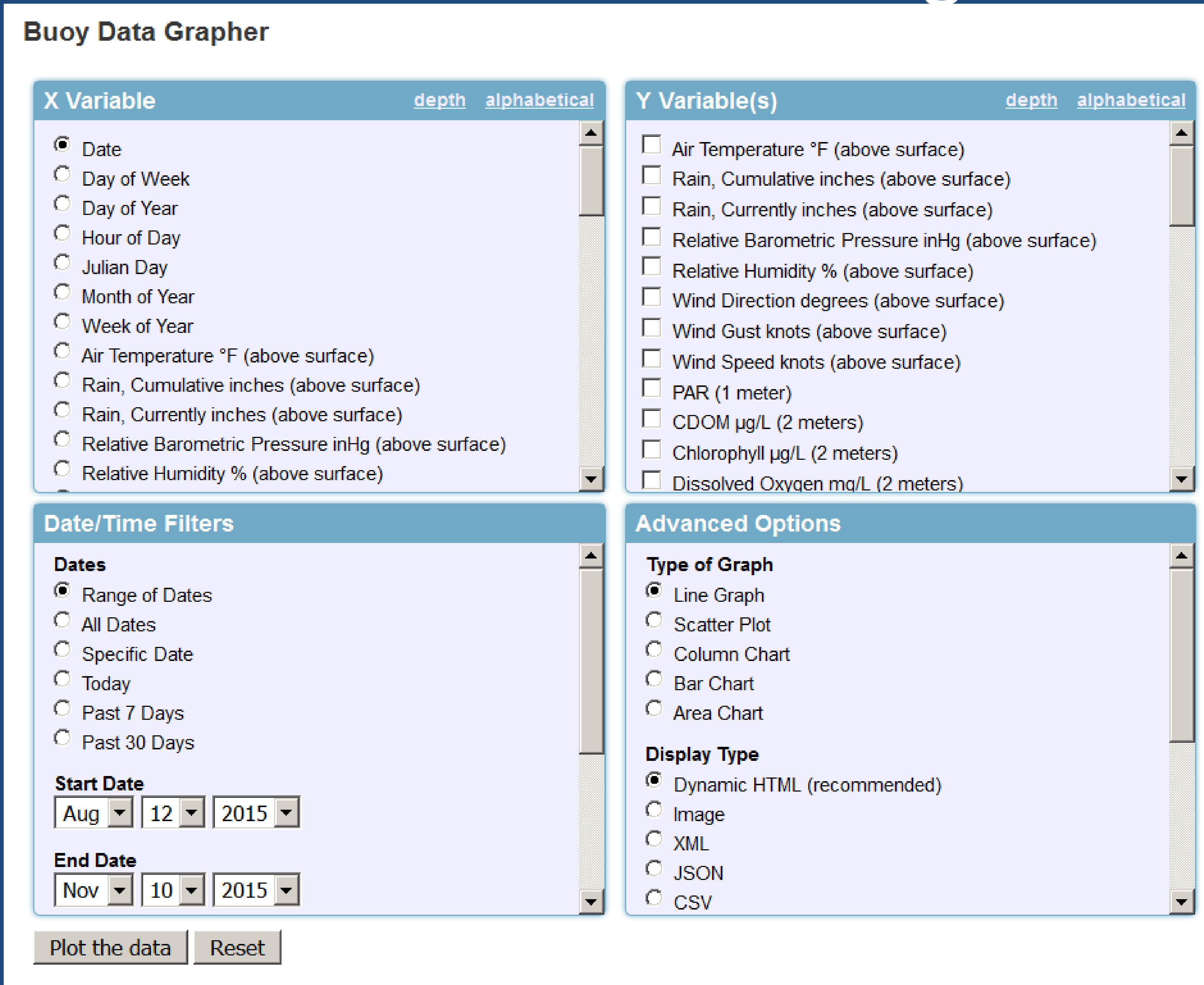
Data Grapher • Current Conditions • API

Buoy Current Conditions

Tuesday, November 17, 2015 at 8:00 AM		
Air Temperature	51.7	°F
Relative Humidity	69	%
Relative Barometric Pressure	30.15	inHg
Wind Speed	13.4	knots
Wind Gust	17.1	knots
Wind Direction	120	degrees
Rain, Cumulative	226	inches
Rain, Currently	0	inches

Tuesday, November 17, 2015 at 8:00 AM		
Water Temperature 2m	48.63	°F
Water Temperature 4m	48.63	°F
Water Temperature 6m	48.49	°F
Water Temperature 7m	48.47	°F
Water Temperature 9m	48.38	°F
Water Temperature 11m	48.61	°F
PAR 1m	3	
Nitrate 2m	0.513	mg/L
Specific Conductivity 2m	404	us/cm

Interactive Data Plotting Tool



☐ Turbidity NTU (2 meters)

☐ Turbidity NTU (5 meters)

☐ Turbidity NTU (8 meters)

☐ Turbidity NTU (11 meters)

☐ Water Temperature °F (2 meters)

☐ Water Temperature °F (4 meters)

☐ Water Temperature °F (6 meters)

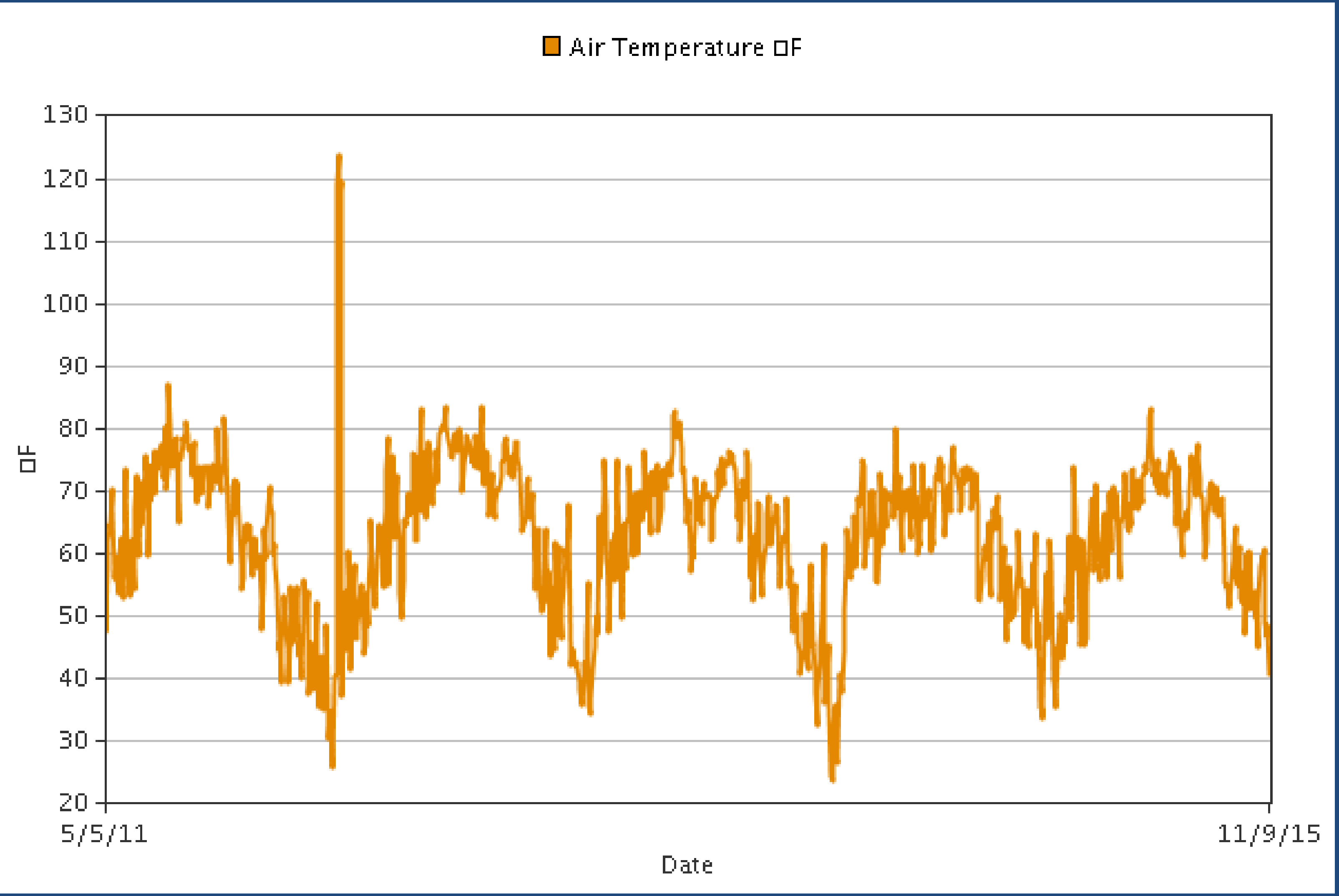
☐ Water Temperature °F (7 meters)

☐ Water Temperature °F (9 meters)

☐ Water Temperature °F (11 meters)

Interactive Data Plotting Tool

Air Temperature at the Muskegon Lake Observatory

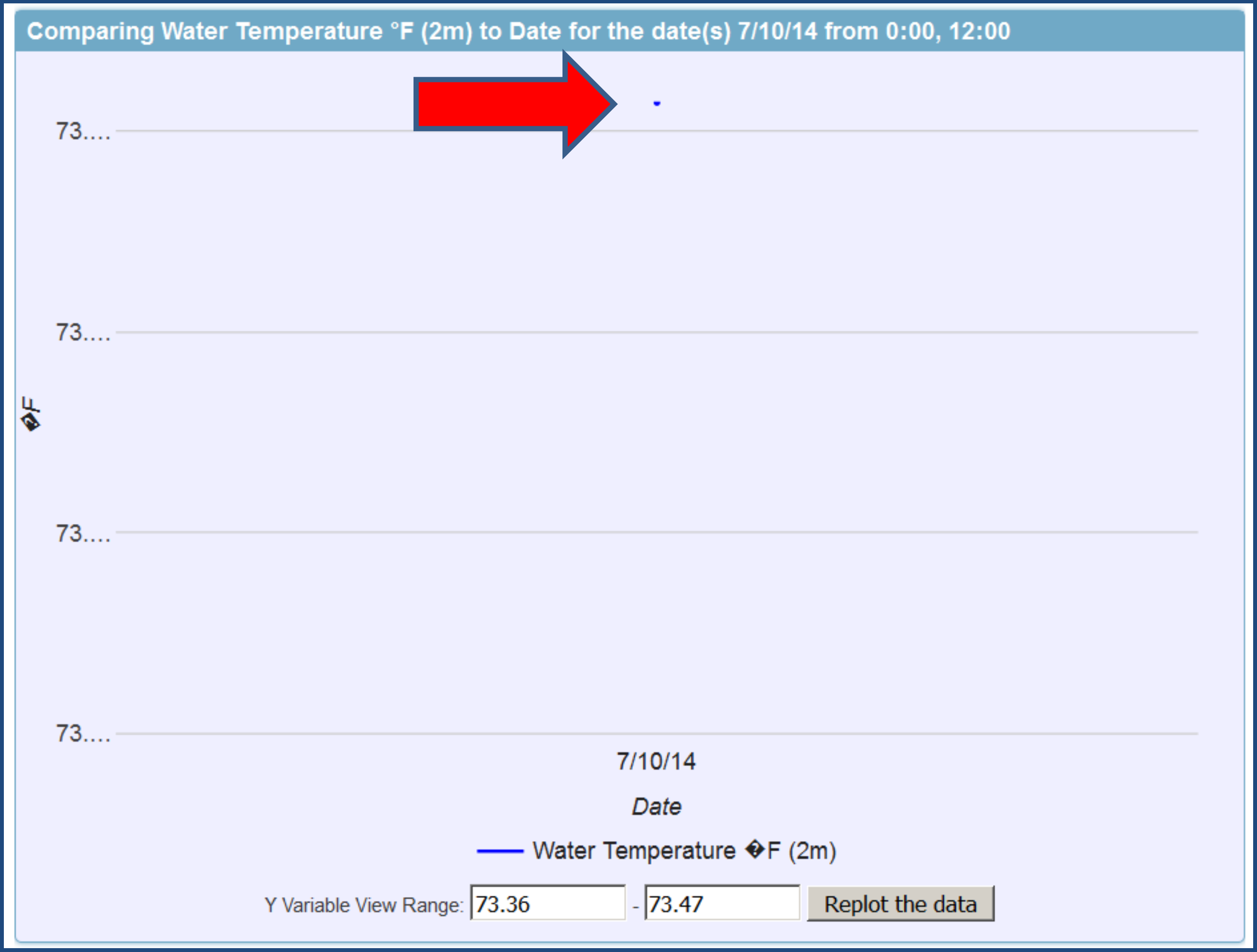


Let’s Explore!

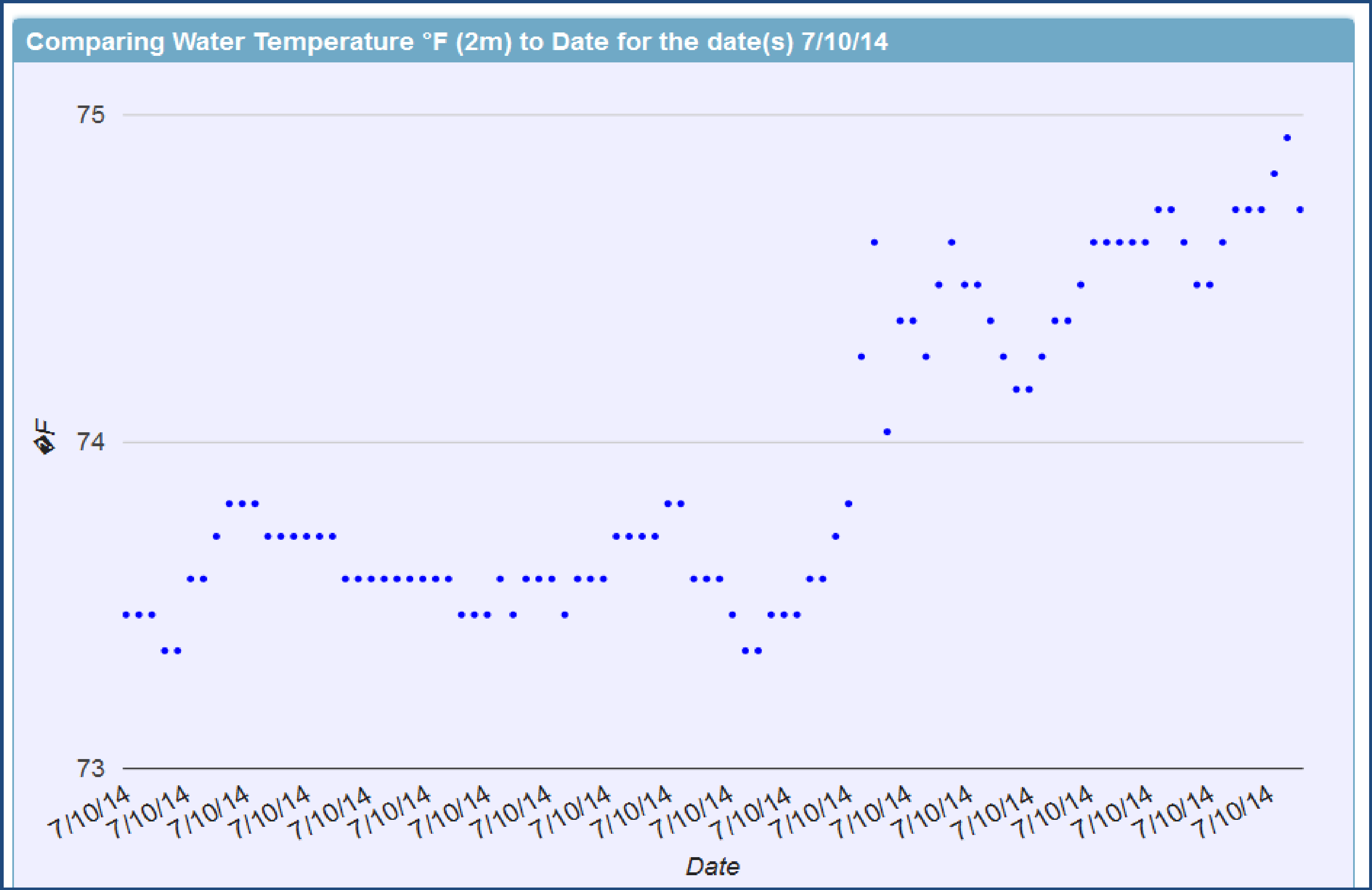
- www.gvsu.edu/buoy

a. Water temperature at 2 M (specific date, every X minutes)

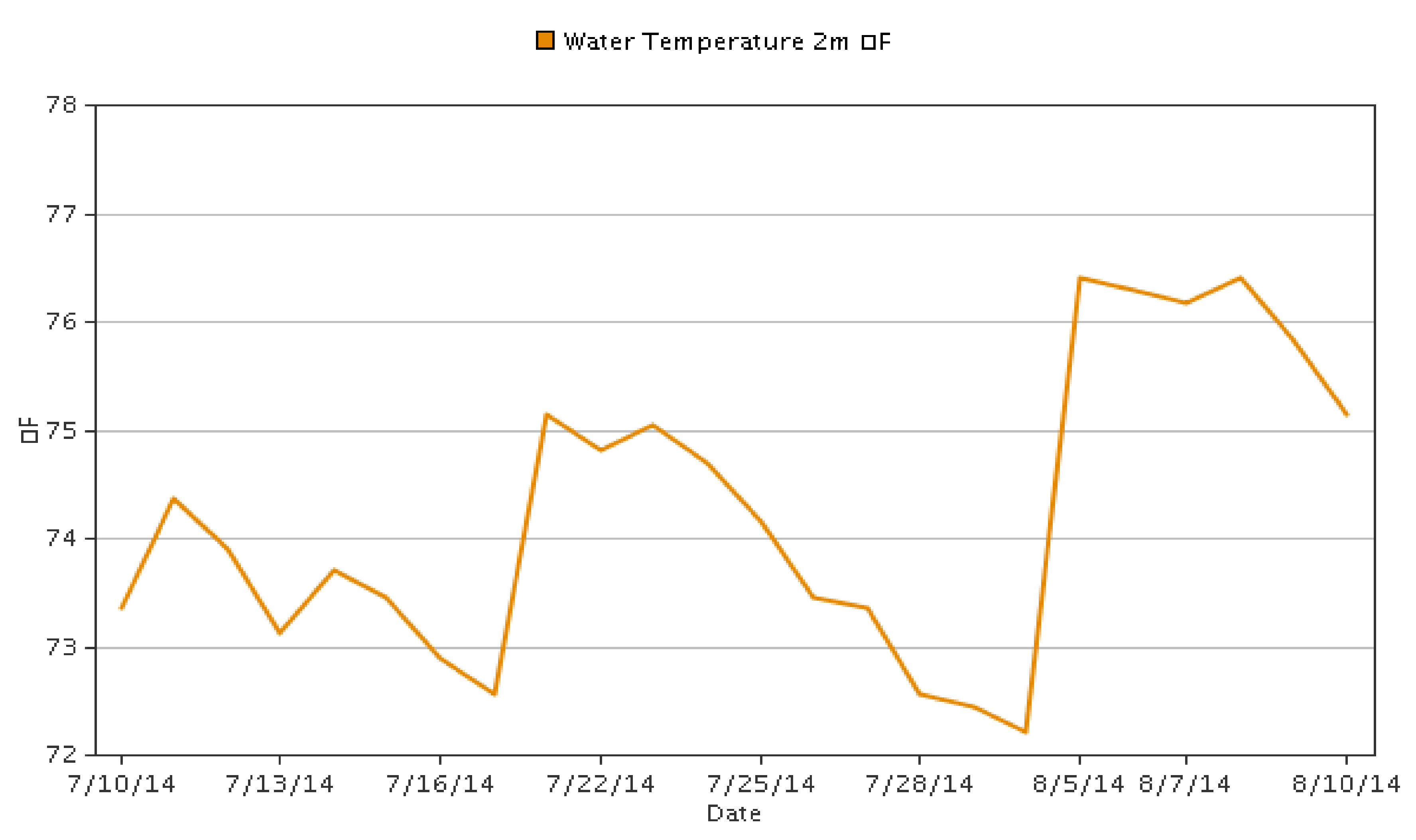
There is a single point on the graph, which is the mean temperature, about 73.4 F.



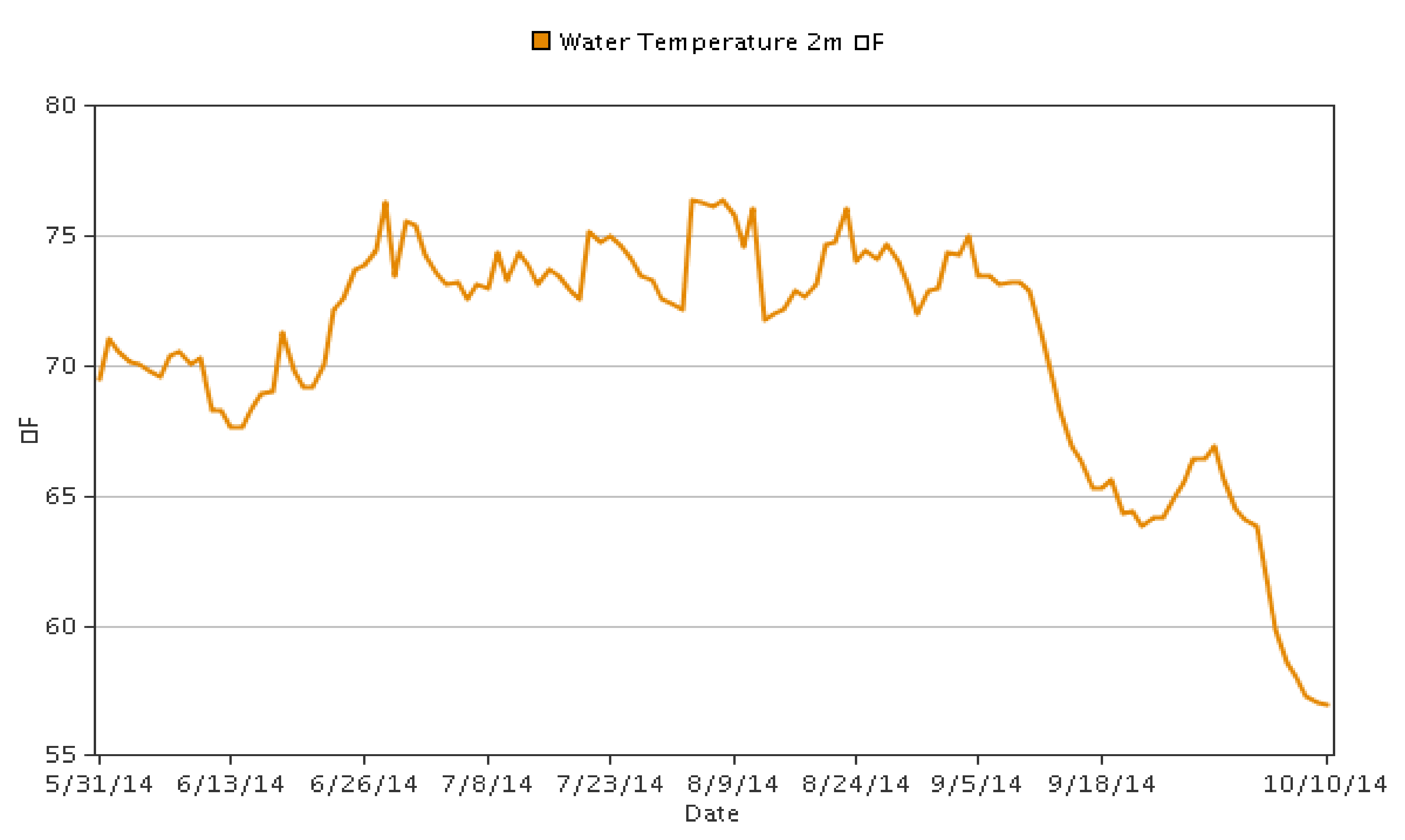
b. Water temperature at 2 M (specific date, all day)



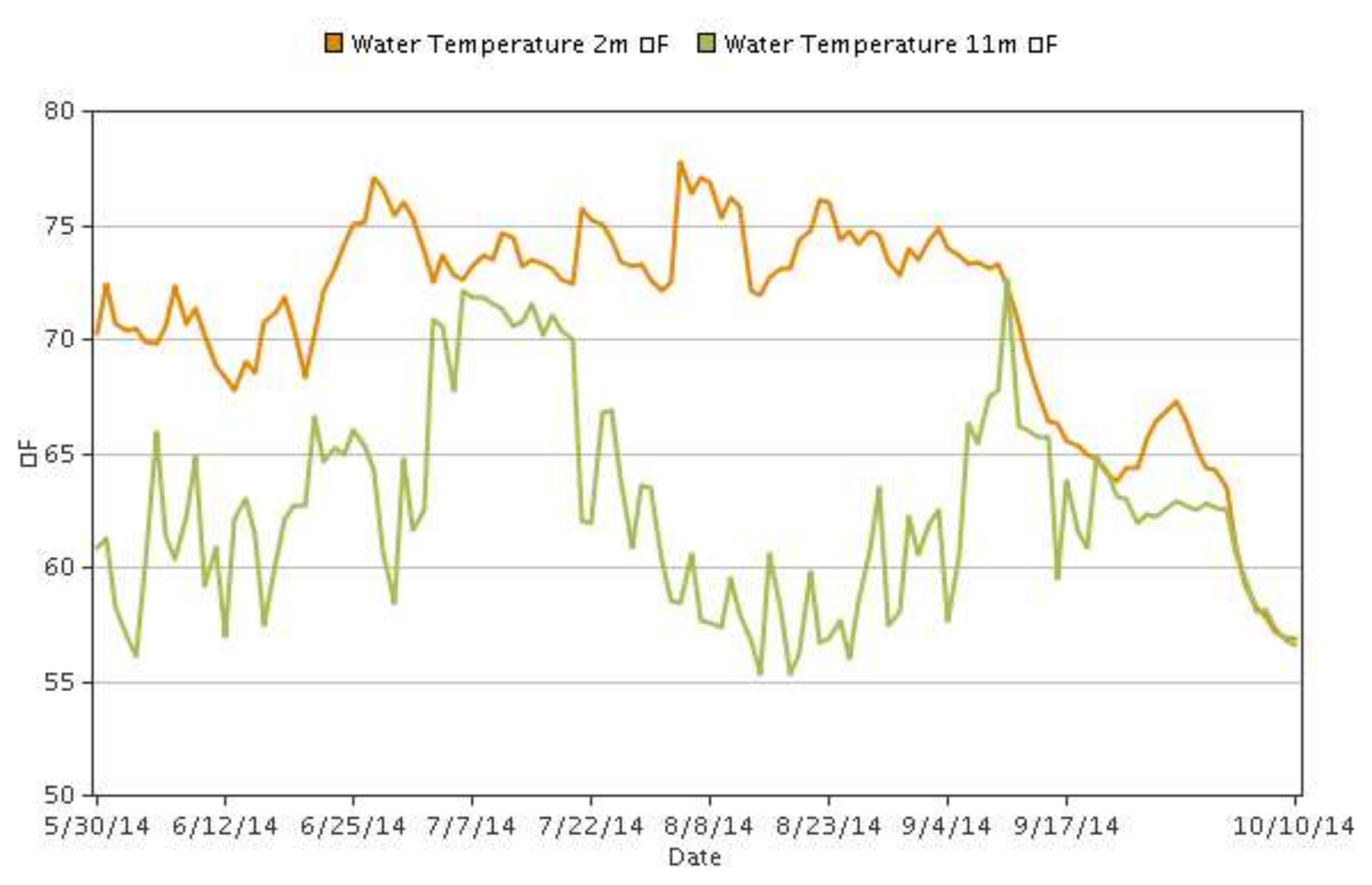
c. Water temperature at 2 M (range of dates for 1 month)



d. Water temperature at 2 M (range of dates for 5 months)



e. Water temperature at 2 M and Water temperature at 11 M (range of dates for 5 months)



Predict - Explain - Plot – Explain Again

- What trends do the data show?
- Why do the data show those trends?
- Is the trend different or the same than you predicted? If it’s the same, justify. If it’s different, justify why?

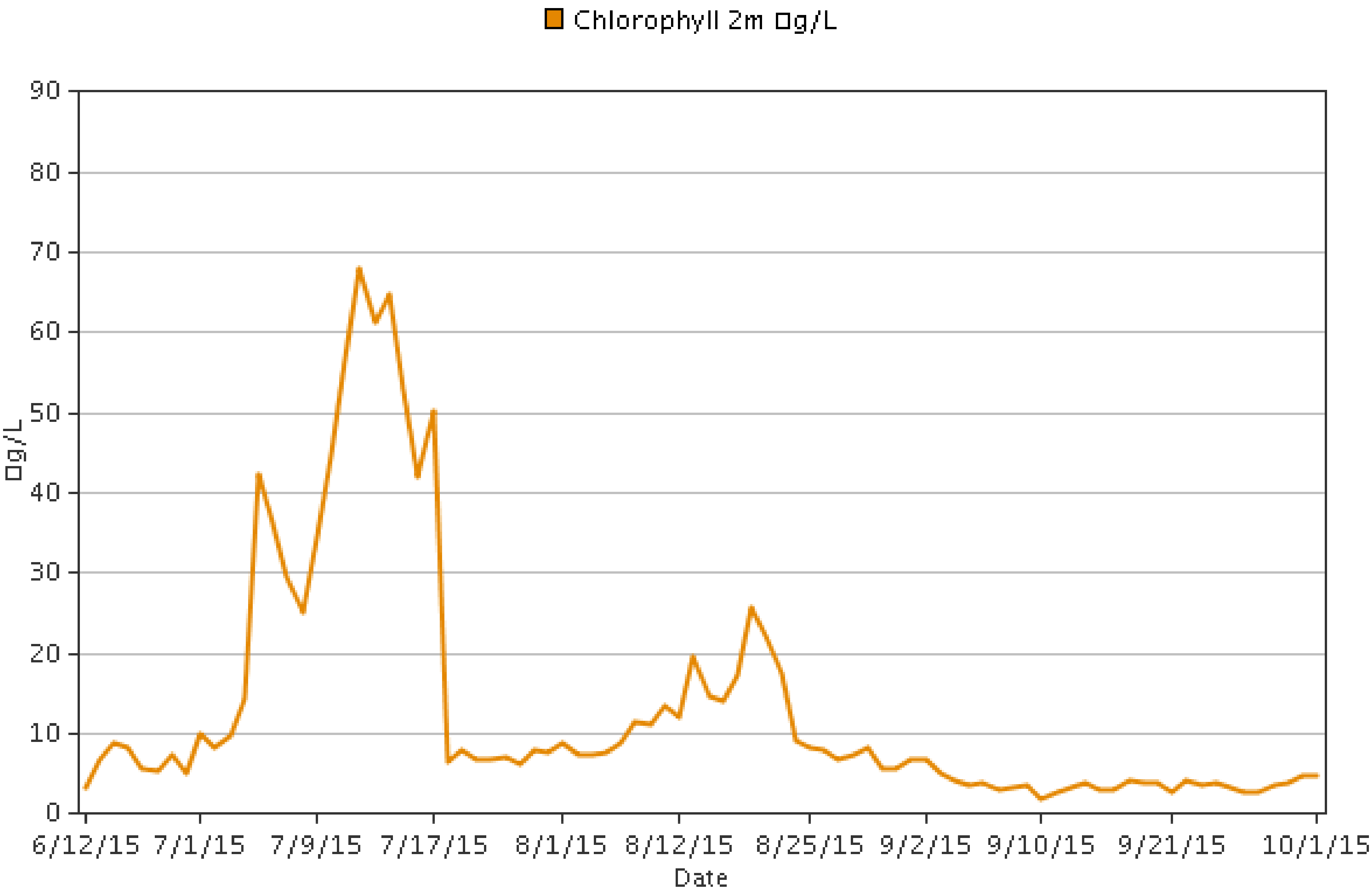
When do algal blooms happen in Muskegon Lake?

- What parameter(s) would measure that?
- Make a prediction for the levels of your parameter between April and November.

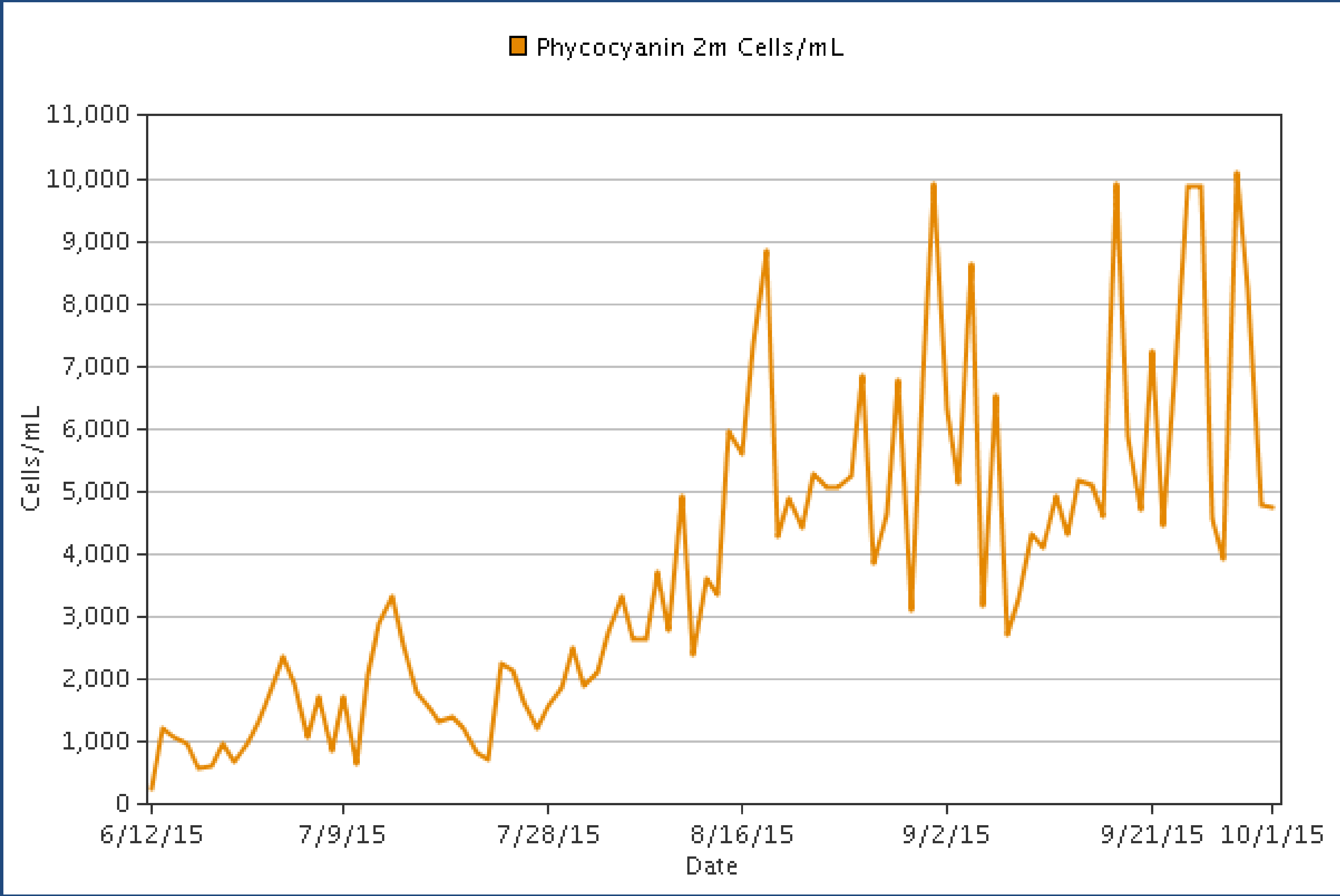
Parameter Amount

April November

Chlorophyll



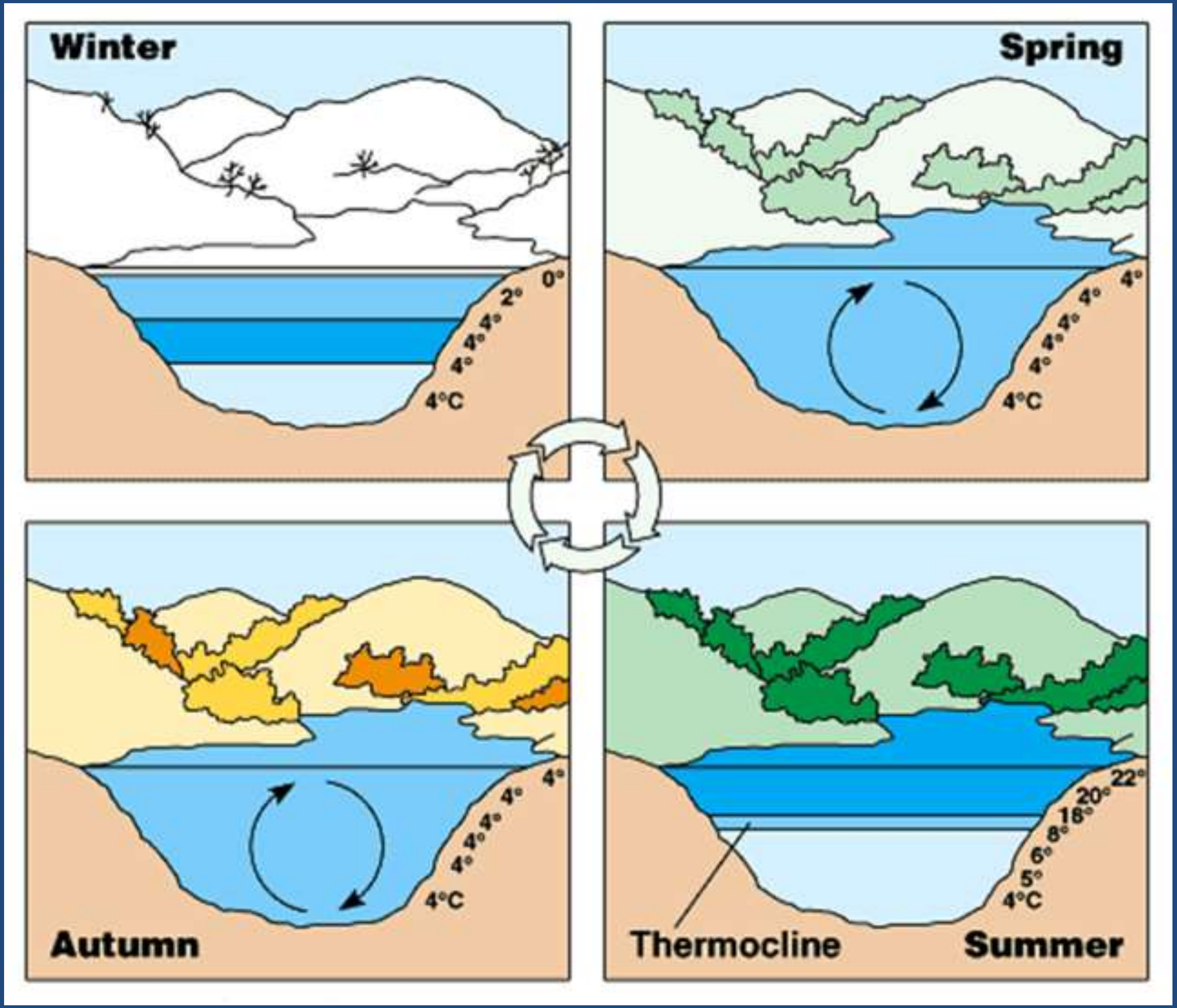
Phycocyanin



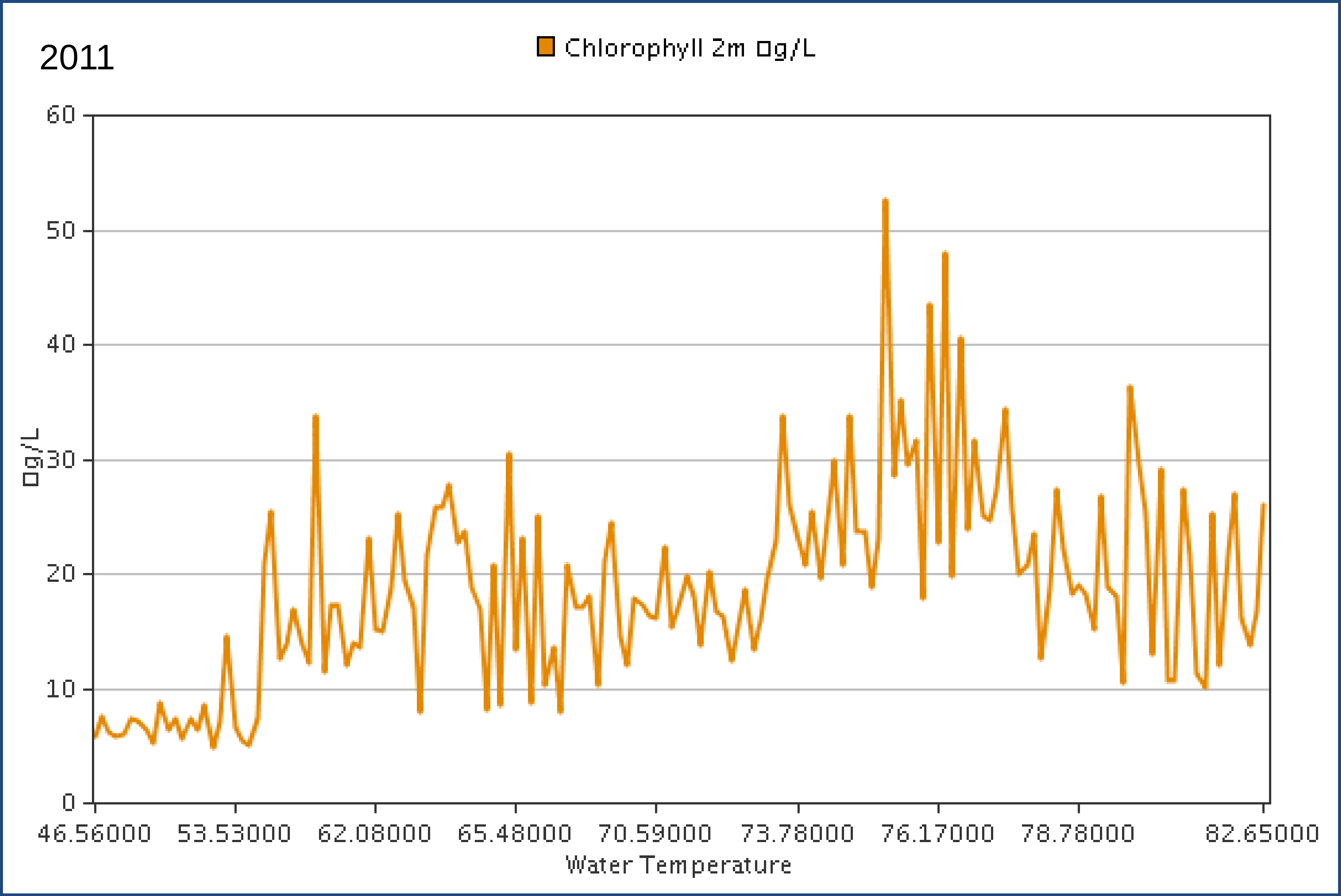
Muskegon Lake, September 2015

Elaborate

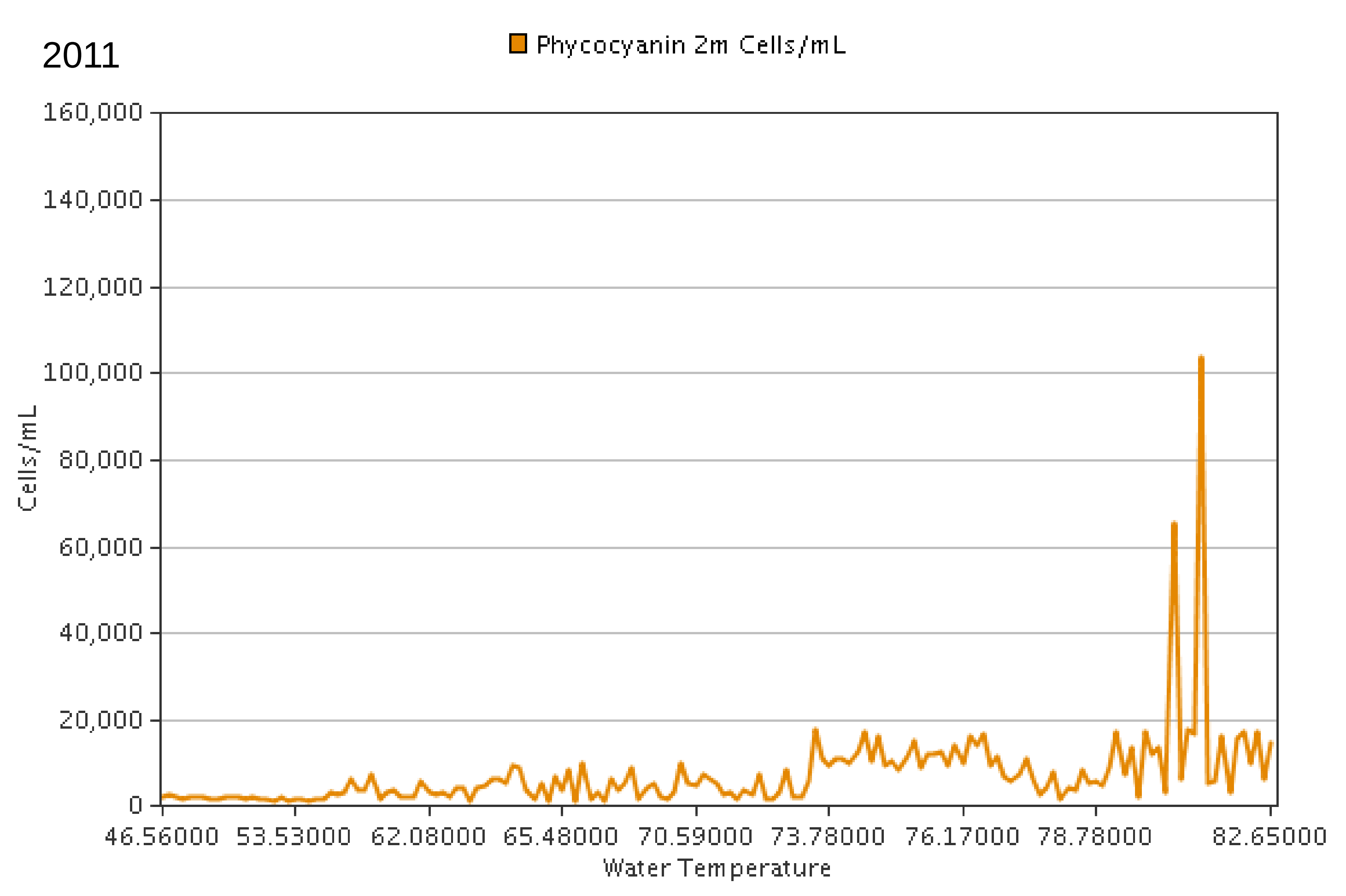
> Patterns > Cause and effect



Water Temperature and Chlorophyll



Water Temperature and Phycocyanin



Evaluate

- Suppose each year a class can do one day of water monitoring. When should the monitoring be done?
- If we compare the data from one year to the next, how can we know that any trends are meaningful?
- How will we know if things have changed or remained the same?
- How can human activities impact the aquatic environment and what evidence do we have (or require) to evaluate and mitigate that impact?

Resources

Table 4. Online Great Lakes and water quality data sets

Data Source	Description
Great Lakes Observing System (GLOS) Data Portal (www.glos.us/)	Near-real-time and archived observations including lake conditions, water levels, wave heights, air and water temperatures, and forecasts.
Integrated Ocean Observing System (www.ioos.noaa.gov/)	Students can explore and track conditions over different parts of the world ocean, coastal waters and the Great Lakes
United States Geological Survey (USGS) (waterdata.usgs.gov/mi/nwis/rt)	Real-time data for stream flow and other parameters. Time-series graphs and data sets can be generated online
Teaching Great Lakes Science (www.miseagrant.umich.edu/lessons/	This website features a suite of lessons, activities and data sets focused on the Great Lakes.
Great Lakes Monitoring (greatlakesmonitoring.org/)	Easy access to long-term, environmental monitoring data collected throughout the Great Lakes. There are a range of environmental parameters to choose from such as nutrients, contaminants and physical properties of water.
Michigan Surface Water Information Management System (MiSWIMS) (www.mcgi.state.mi.us/miswims/)	The application on the website is an interactive map-based system that allows users to view information about Michigan's surface water.
Cooperative Lakes Monitoring Program (MI Corps) (www.micorps.net/lakeoverview.html)	An online data set is searchable for lakes and streams in Michigan.
Wastewater and Water Treatment Plants Example: Grand Rapids (grcity.us/enterprise-services/Water-System/).	The City of Grand Rapids has monitored the Grand River and selected tributaries with data going back several decades
World Water Monitoring Challenge™ (WWMC) (www.worldwatermonitoringday.org)	WWMC provides a venue for students to use simple test kits to monitor water quality and their results can be posted online.
Global Learning and Observations to Benefit the Environment (GLOBE) (www.globe.gov)	A world-wide environmental monitoring program where students at GLOBE schools follow standardized monitoring protocols and post their results online. Data sets can be retrieved and analyzed with graphical visualization capability.
Great Lakes Fieldscope (greatlakes.fieldscope.org)	Students can explore maps and graphs and contribute water quality data from across the Great Lakes watershed region.

Buoys are all over the world

Next Generation & Michigan Science Standards

- Using authentic data helps students to identify patterns, change through time, and cause and effect.
- The lesson sequence above follows the science and engineering practices of asking questions, defining problems, analyzing and interpreting data, constructing explanations, and engaging in argument from evidence.

So what do these sensors tell us about seasonal ecosystem dynamics and upstream influences?

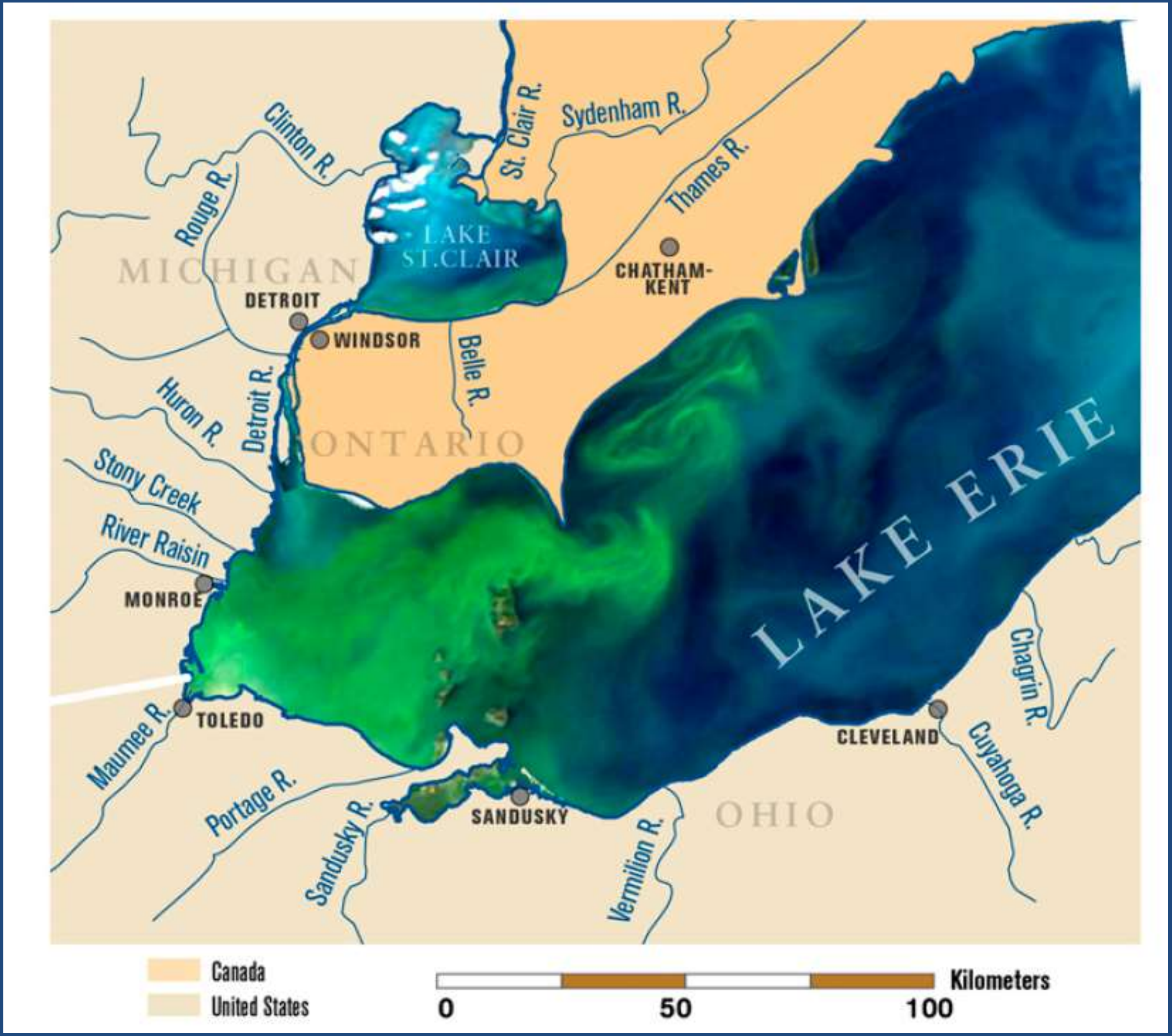
So what do these sensors tell us about seasonal ecosystem dynamics and upstream influences?

How do these sensors help make scientific discoveries?

How to make a scientific discovery

- Engage (to motivate the work ahead)
- Explore (patterns & study fundamentals)
- Explain (make guesses – hypotheses – and test them)

Engage



Michalak, 2014 *Proc. Natl. Acad. Sci.*

Engage


Clinton
Clair R.
Sydenham R.
JOURNAL SENTINEL
7
PETER ESSICK
A boat pushes its way through a pea soup-like toxic algae outbreak on Lake Erie in late summer 2011. The bloom was the largest in the lake's history and spanned nearly 2,000 square miles.
A WATERSHED MOMENT | GREAT LAKES AT A CROSSROADS
Canada
United States
Kilometers
0
50
100

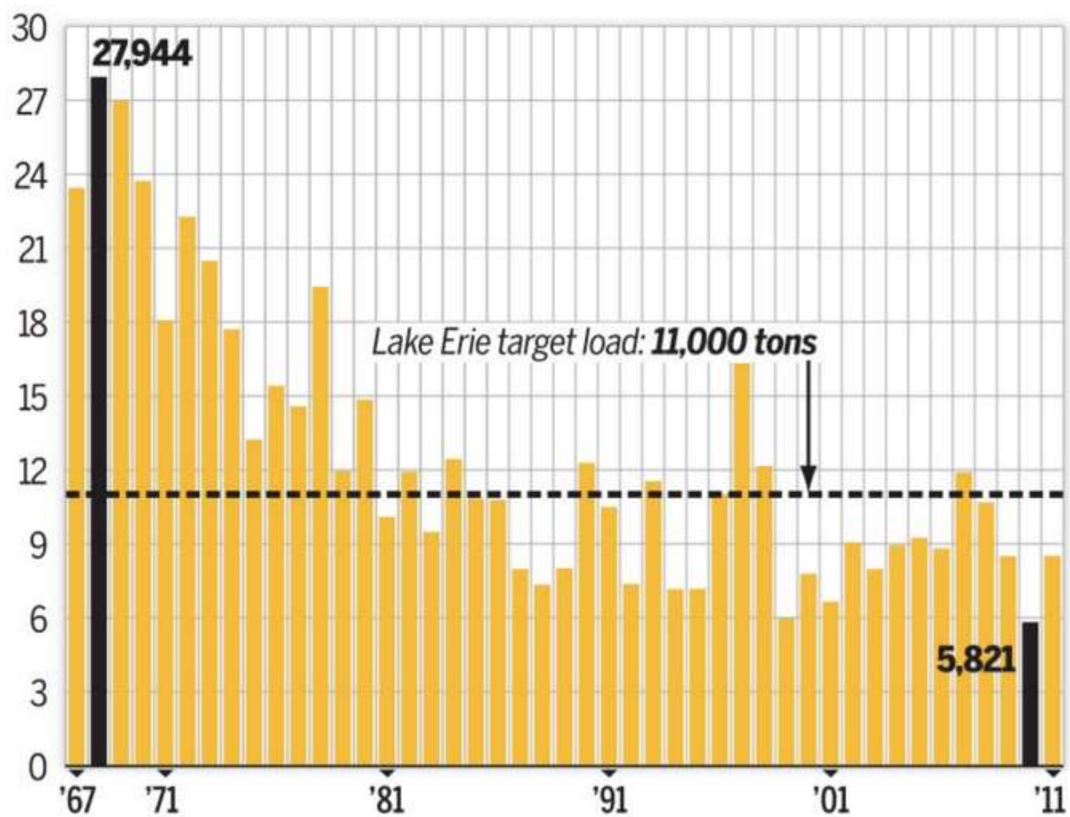
Engage

JOURNAL SENTINEL

PHOSPHORUS NUMBERS PLUMMET, ALGAE BLOOMS EXPLODE

Before the 1972 passage of the Clean Water Act and a separate phosphorus-reduction agreement between the U.S. and Canada, Lake Erie received an average of about 24,000 metric tons of phosphorus annually. The lake has typically been well under its 11,000-metric ton target since, but in the last decade the blooms have returned. The reason: changes in farming practices and more intense spring storms mean the phosphorus flowing into Lake Erie has increasingly been in its highly potent dissolved state.

Lake Erie's annual total phosphorus load by major source, in metric tons



SOURCE: OHIO DEPARTMENTS OF AGRICULTURE, AND NATURAL RESOURCES; ENVIRONMENTAL PROTECTION AGENCY; LAKE ERIE COMMISSION

PETER ESSICK

A boat pushes its way through a p… …d nearly 2,000 square miles.

United States

0 50 100

Engage

PHOSPHORUS NUMBERS PLUMMET, ALGAE BLOOMS EXPLODE

Before the 1972 passage of the Clean Water Act and a separate phosphorus-reduction agreement

JOURNA

Circle of Blue

TER ESSICK

A b ... are miles.

AGENCY; LAKE ERIE COMMISSION

United States

0 50 100

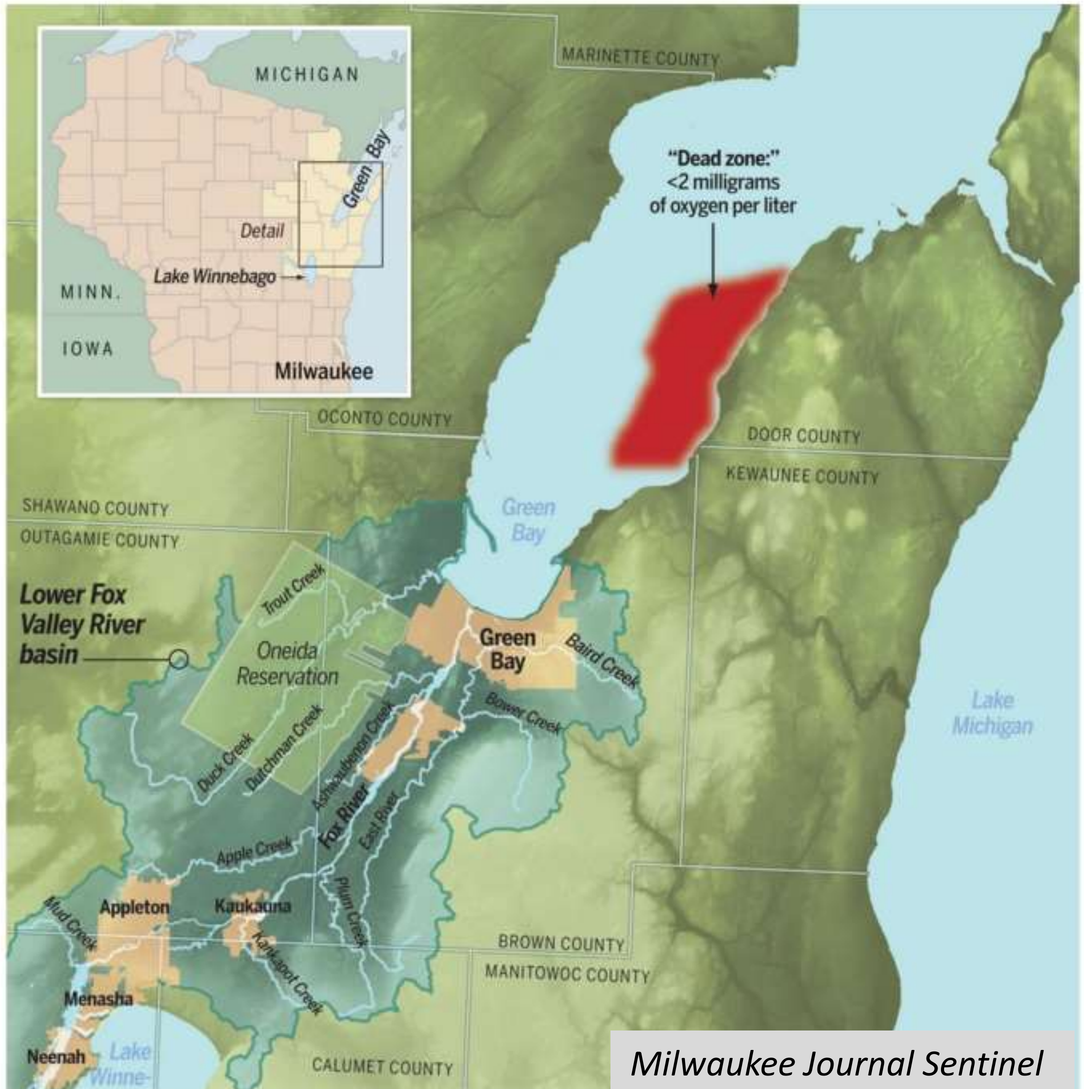
Kilometers

Engage

A DEAD ZONE THRIVES IN GREEN BAY

The phosphorus-driven algae blooms plaguing Green Bay are more than just a nuisance. When that material dies and decays, it burns up massive amounts of oxygen that can lead to "dead zones" – vast areas – so low in oxygen that almost nothing can survive. The problem, driven largely by phosphorus-rich manure seeping into the bay and fueling algae blooms, appears to have gotten worse in recent years.

This dead zone was mapped in 2012. The researchers taking the oxygen recordings did not sample the lower bay at that time, or the near shore areas.



Milwaukee Journal Sentinel

Engage

A DEAD ZONE THRIVES IN GREEN BAY

The phosphorus-driven algae blooms plaguing Green Bay are more than just a nuisance. When that material dies

What’s causing this?

Scientists don’t know but they have guesses (hypotheses)

- Slow progress on nonpoint phosphorus sources (dissolved phosphorus)
- Quagga and zebra mussels eating everything but *Microcystis*
- Stronger thermal stratification as waters get warmer
- Hypoxia releasing phosphorus from sediments

Milwaukee Journal Sentinel

Engage

What's causing this? What can we do?

Scientists don't know but they have guesses (hypotheses)

- Slow progress on <u>nonpoint phosphorus sources</u> (dissolved phosphorus)
- <u>Quagga and zebra mussels</u> eating everything but *Microcystis*
- Stronger <u>thermal stratification</u> as waters get warmer
- Hypoxia releasing <u>phosphorus from sediments</u>

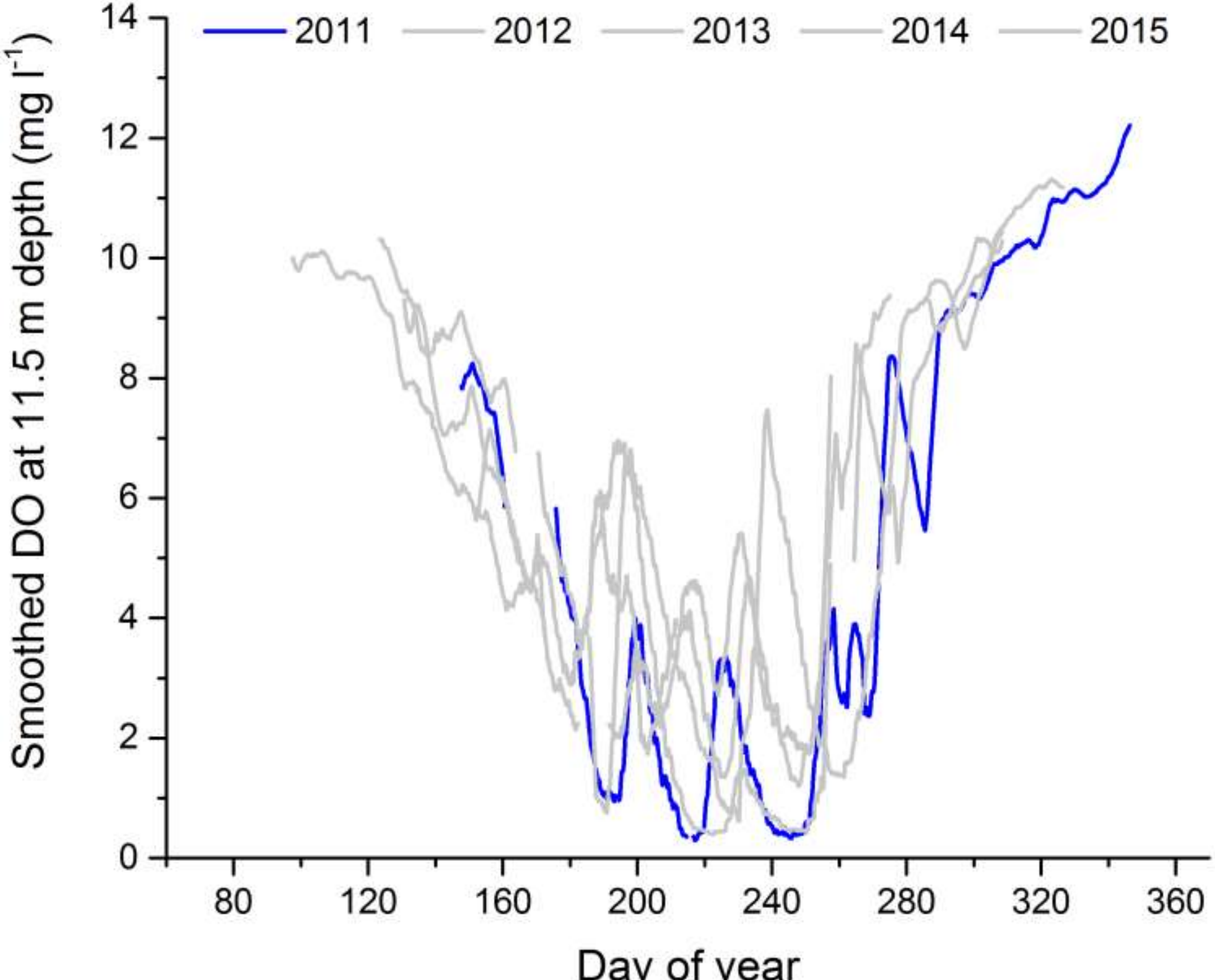
Milwaukee Journal Sentinel

Explore

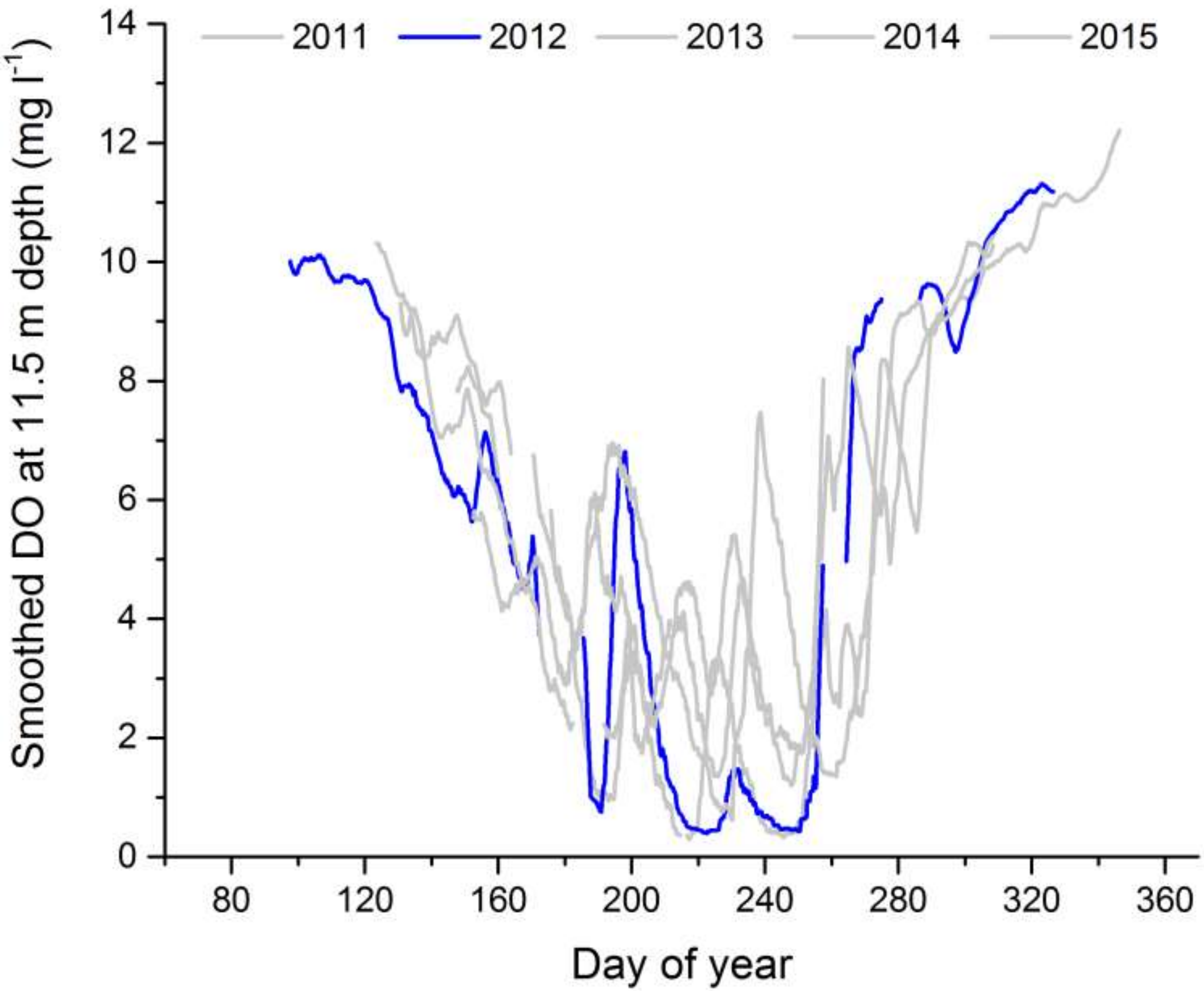
Theory: stratification drives hypoxia

Does hypoxia get worse as the summer goes on?

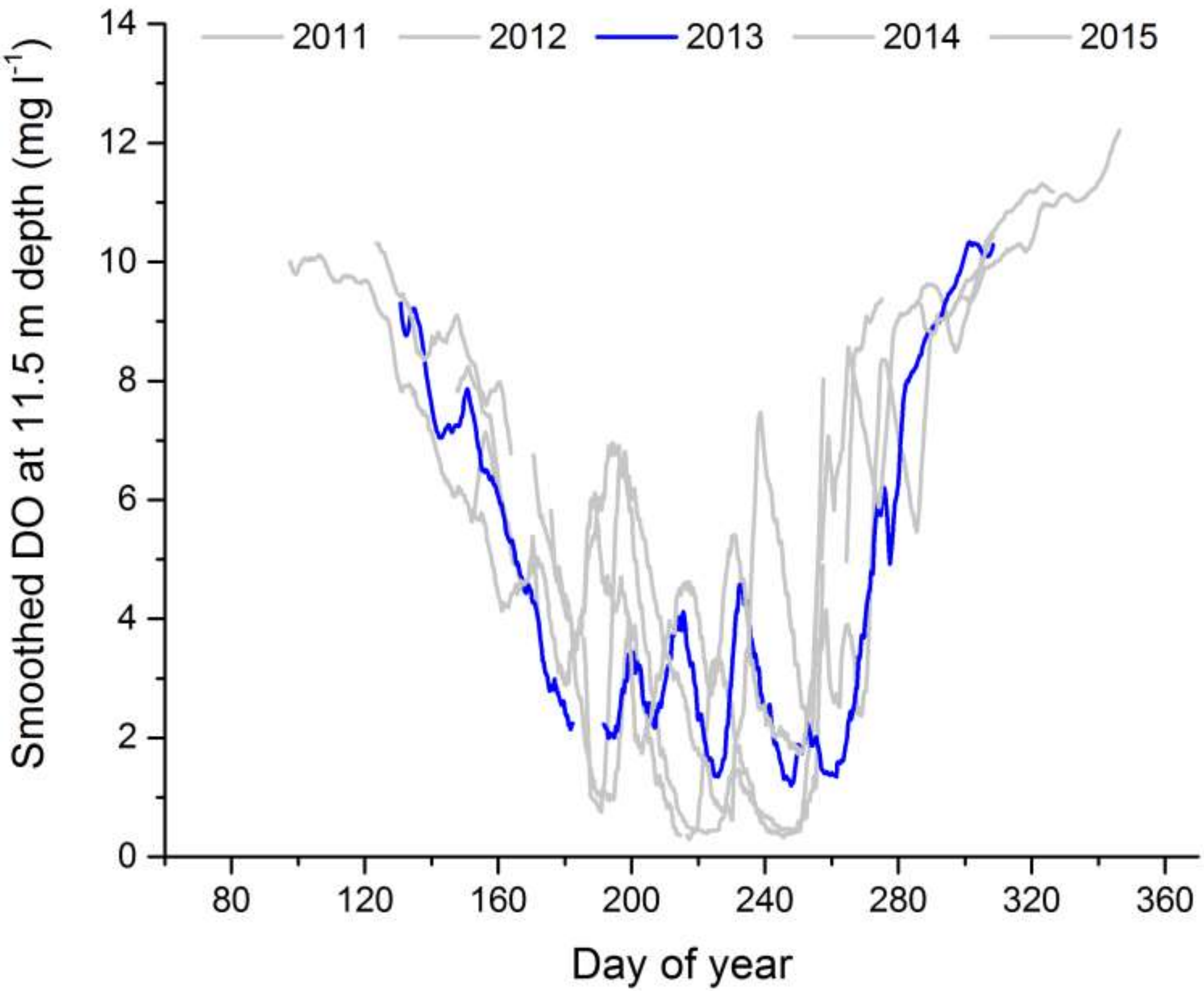
www.gvsu.edu/buoy



2011
2012
2013
2014
2015
Smoothed DO at 11.5 m depth (mg l-1)
0
2
4
6
8
10
12
14
80
120
160
200
240
280
320
360
Day of year



2011
2012
2013
2014
2015
Smoothed DO at 11.5 m depth (mg l⁻¹)
0
2
4
6
8
10
12
14
80
120
160
200
240
280
320
360
Day of year


2011
2012
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2015
Smoothed DO at 11.5 m depth (mg l^{-1})
Day of year
0
2
4
6
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12
14
80
120
160
200
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280
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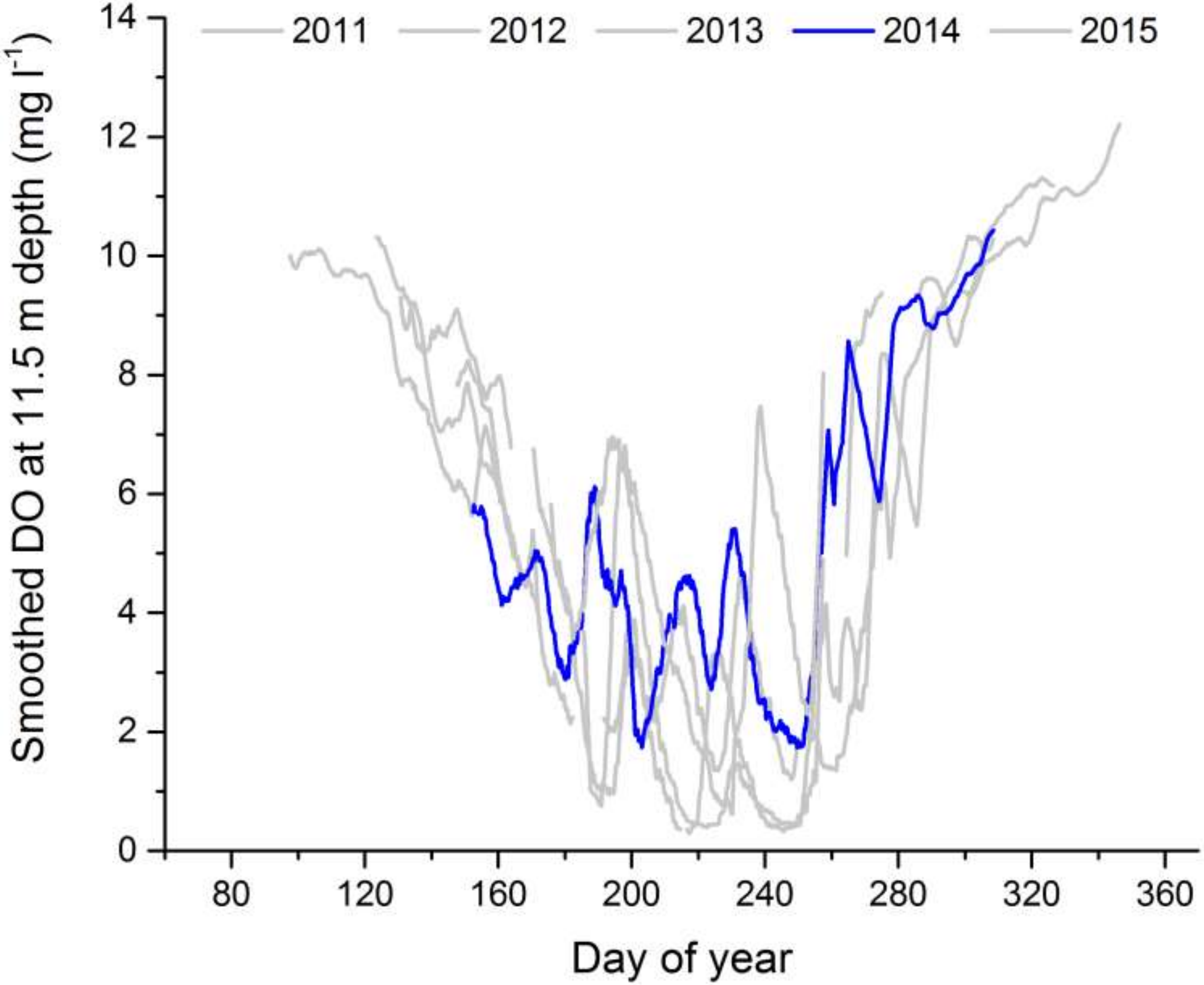

2011
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200
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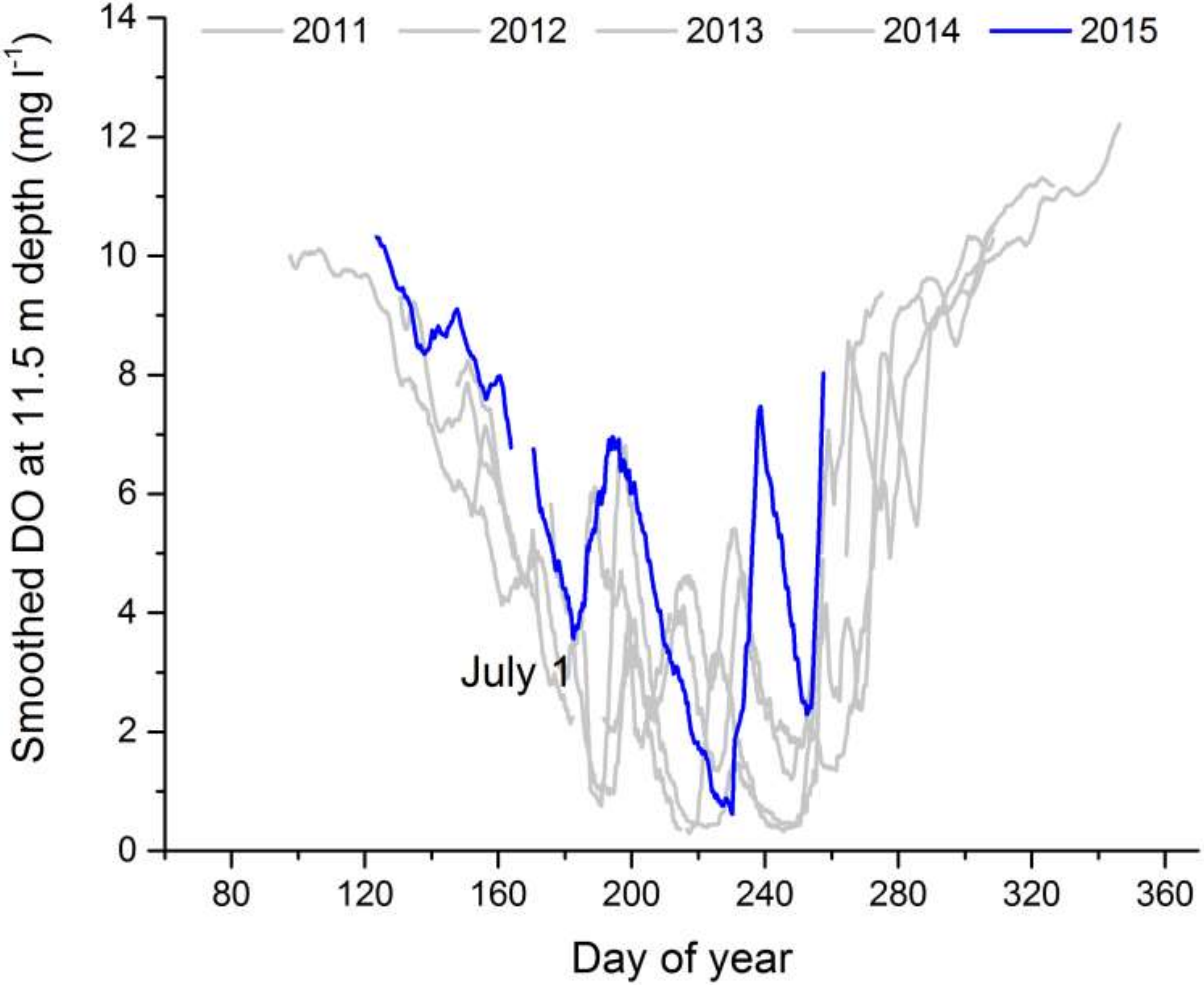
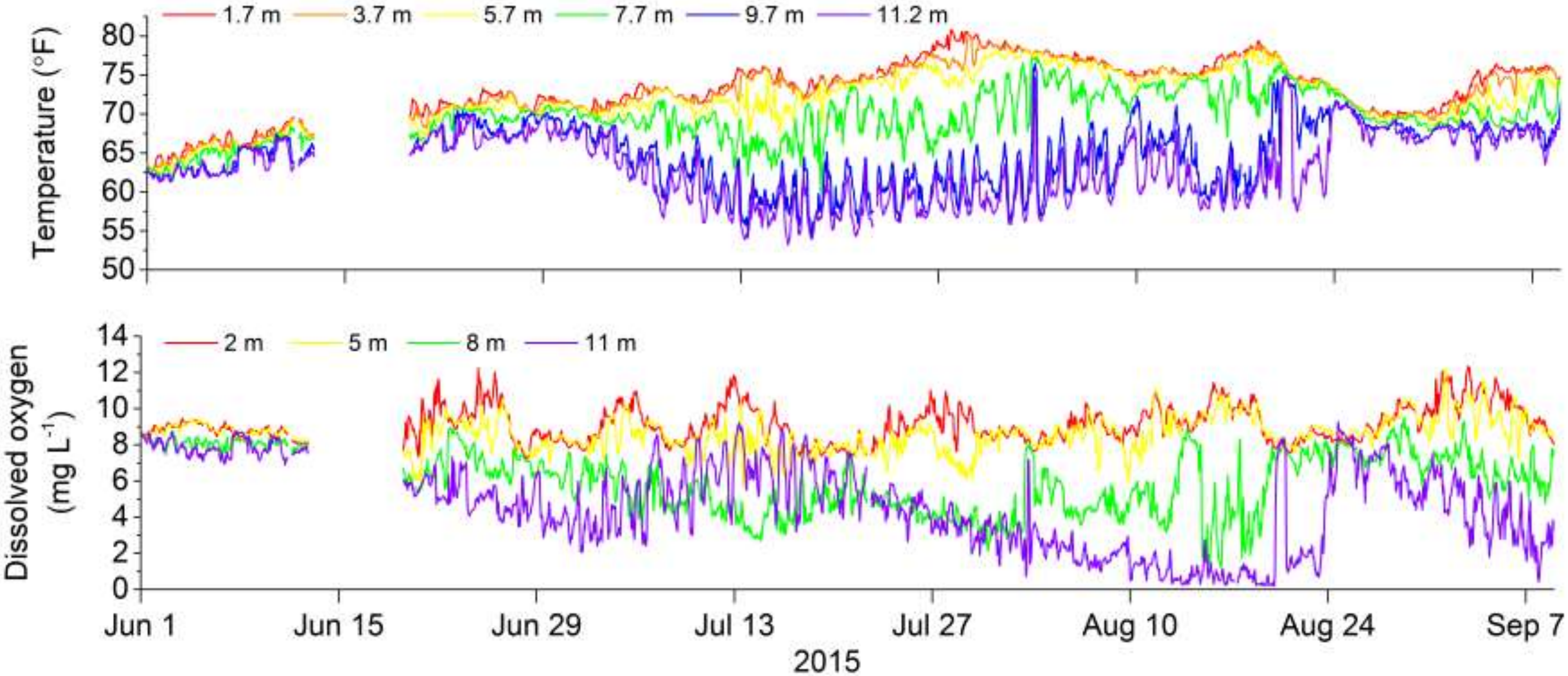
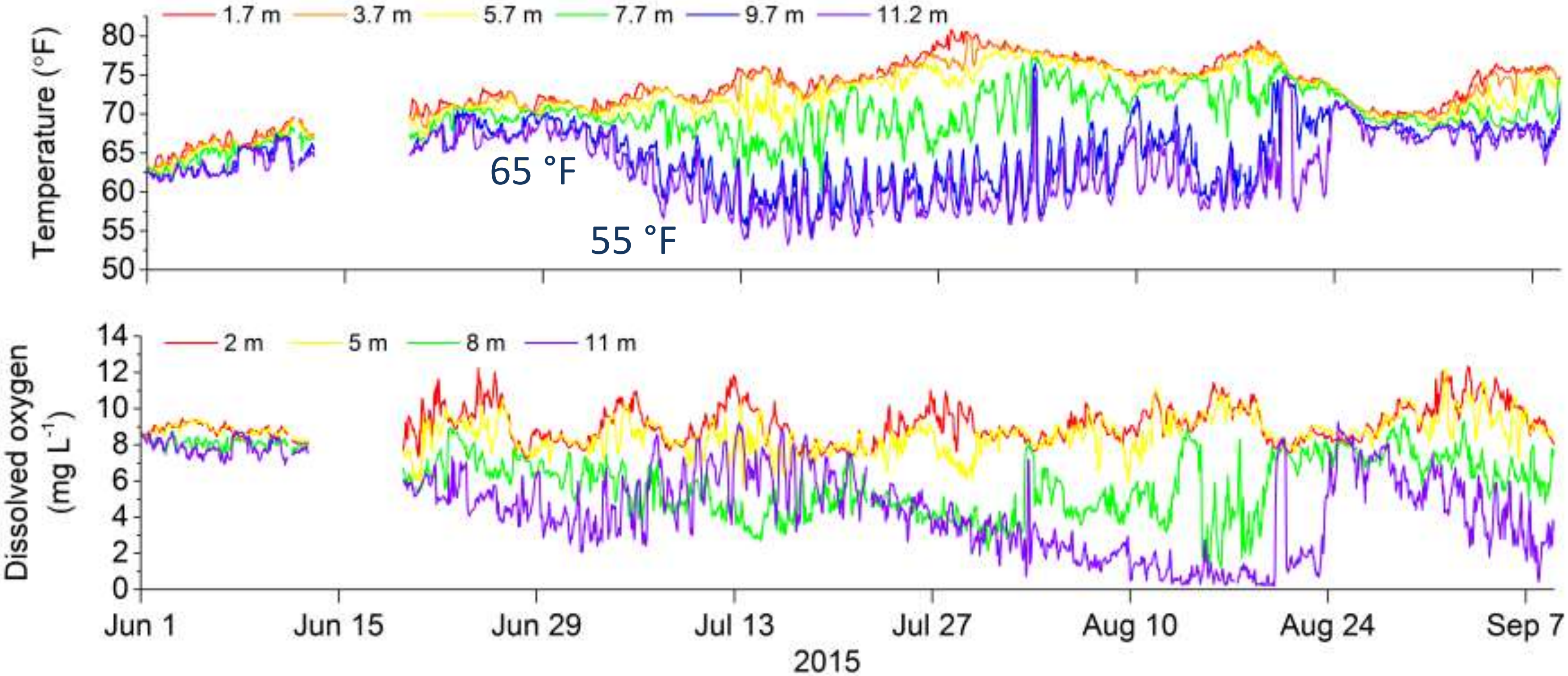
360
Day of year



2011
2012
2013
2014
2015
Smoothed DO at 11.5 m depth (mg l-1)
July 1
Day of year
0
2
4
6
8
10
12
14
80
120
160
200
240
280
320
360



1.7 m
3.7 m
5.7 m
7.7 m
9.7 m
11.2 m
Temperature (°F)
80
75
70
65
60
55
50
2 m
5 m
8 m
11 m
Dissolved oxygen (mg L-1)
14
12
10
8
6
4
2
0
Jun 1
Jun 15
Jun 29
Jul 13
Jul 27
Aug 10
Aug 24
Sep 7
2015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Jun 29
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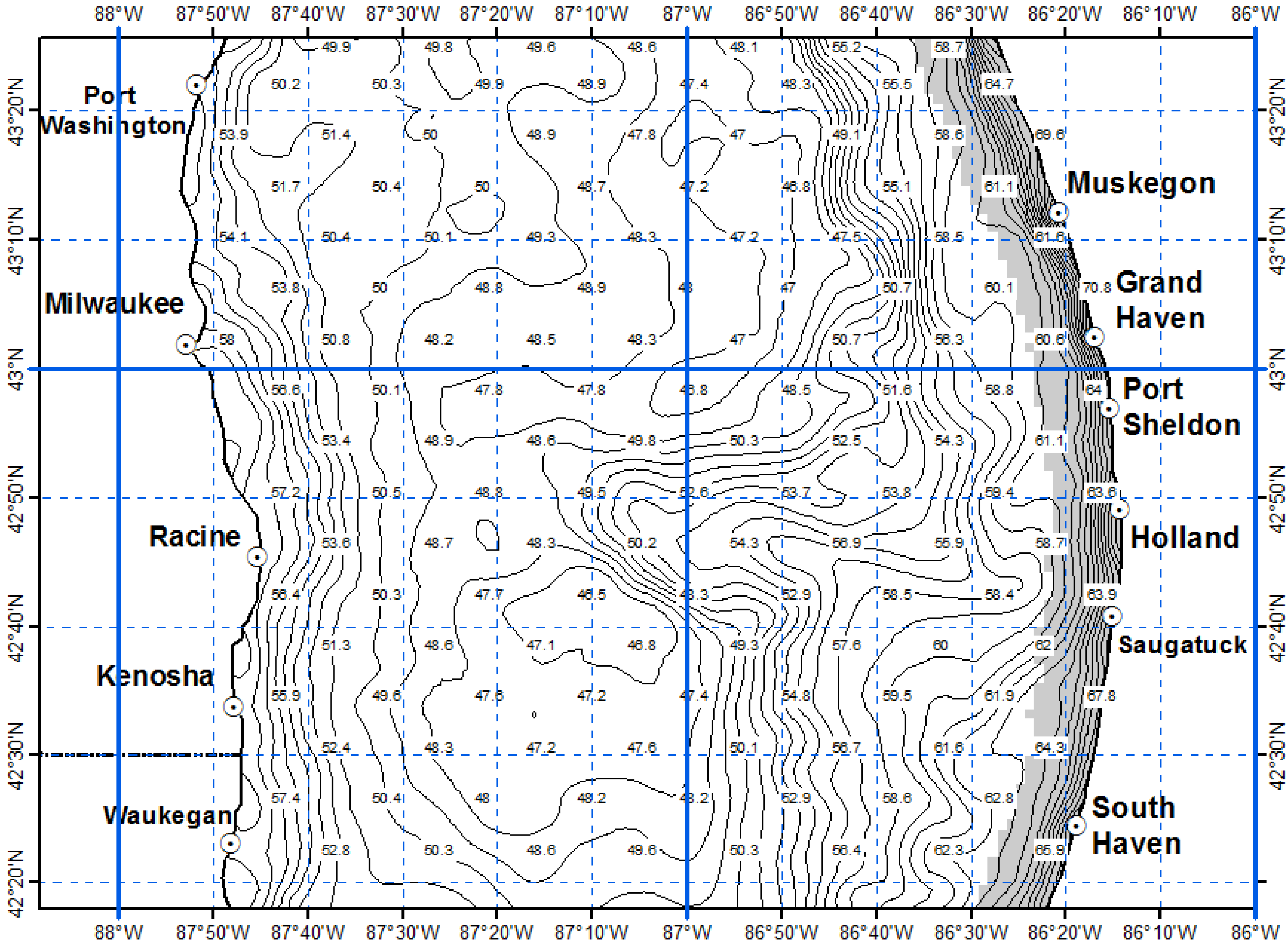
Aug 24
Sep 7
2015

Central Southern Lake Michigan Surface Temperature

Image Date: 6/23/2015 **Image Time: 10:59 (EDT)**

Michigan State University Remote Sensing & GIS Research and Outreach Services



Probably Cloudy Cloudy

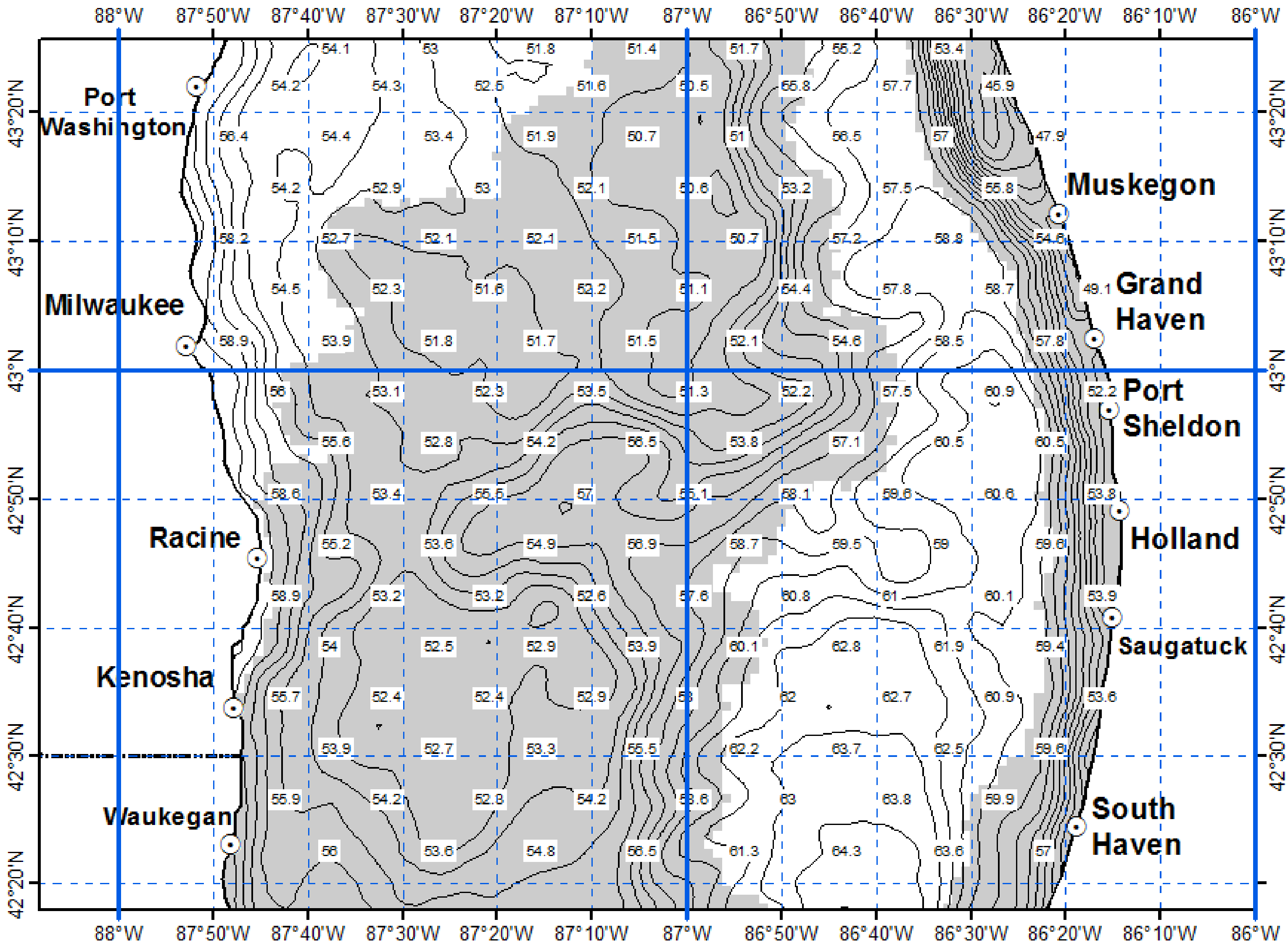
Each contour line represents one degree (F) change in temperature.

NOT TO BE USED FOR NAVIGATIONAL PURPOSES
Questions? See www.coastwatch.msu.edu/help.html
AVHRR Imagery Provided by NOAA/GLERL CoastWatch Program
PUBLIC DATA NOT FOR SALE

Central Southern Lake Michigan Surface Temperature

Image Date: 7/2/2015 **Image Time: 7:00 (EDT)**

Michigan State University Remote Sensing & GIS Research and Outreach Services



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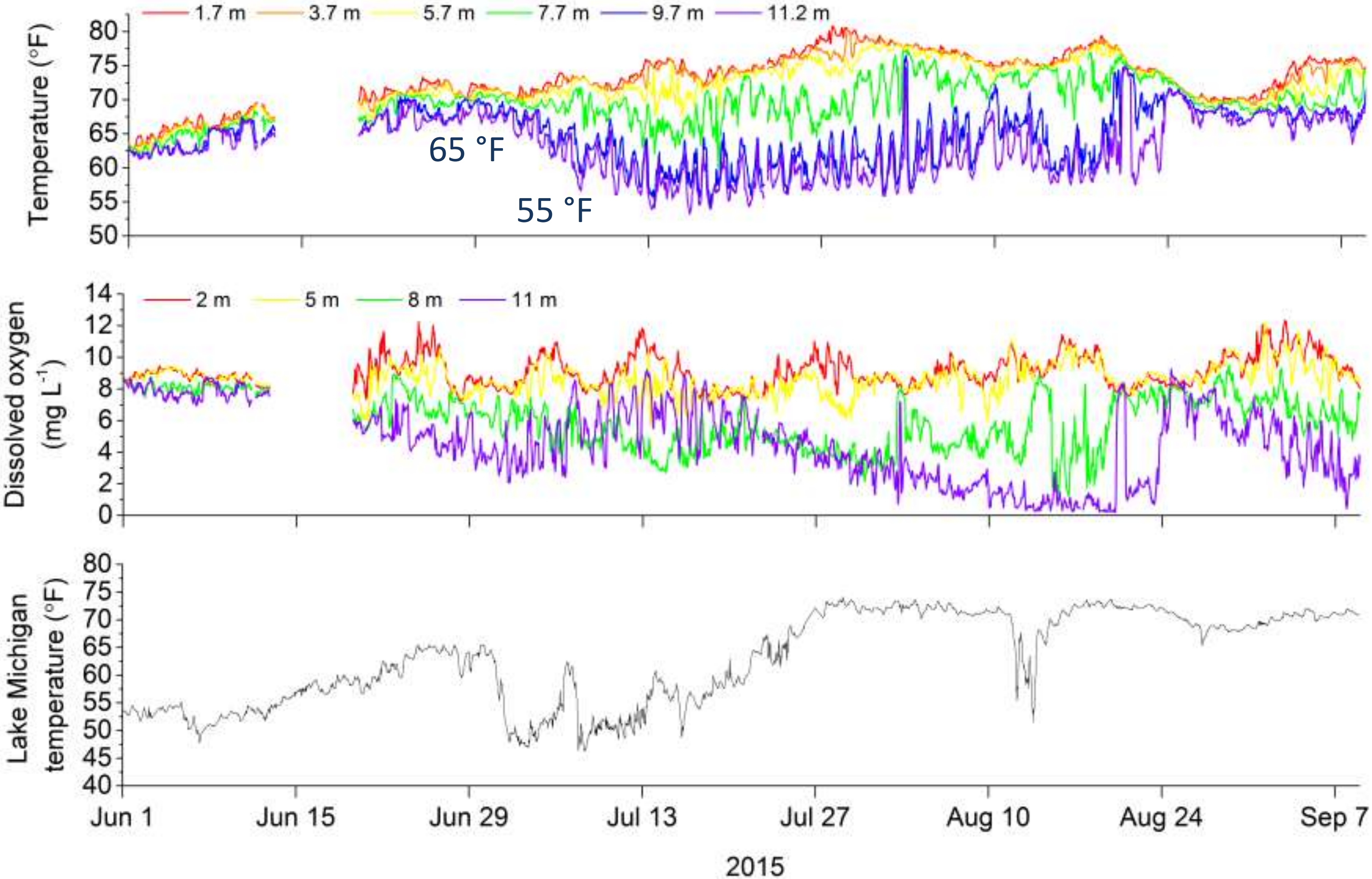

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11.2 m
Temperature (°F)
80
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65 °F
55 °F
2 m
5 m
8 m
11 m
Dissolved oxygen (mg L⁻¹)
14
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Lake Michigan temperature (°F)
80
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Jun 1
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Aug 10
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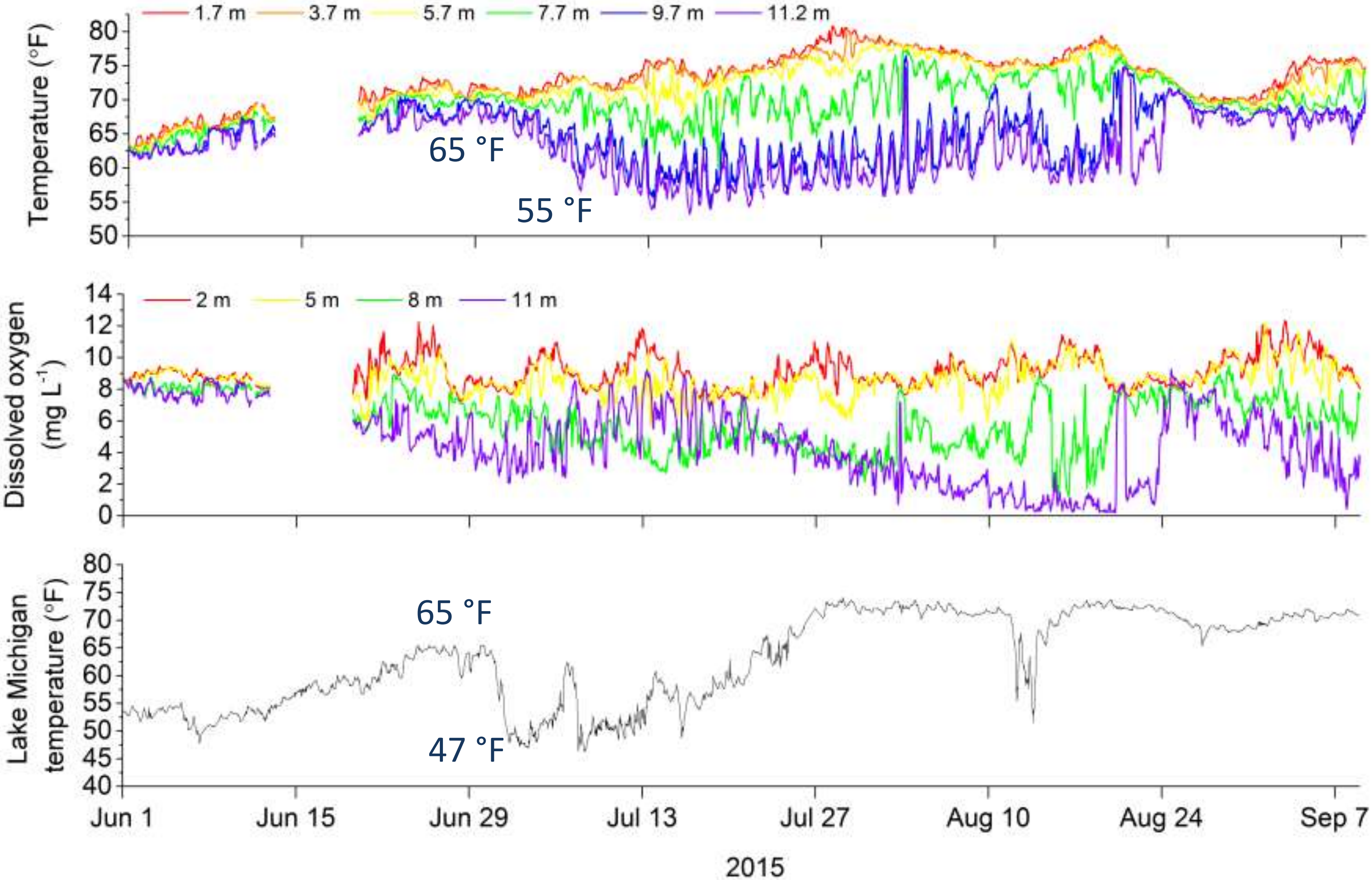
Sep 7
2015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65 °F
47 °F
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2015