WATER LEVELS ON THE GREAT LAKES

BACKGROUND

There is something about the movement of waves against the beach, the sight of a sailboat going past, and the ability to plunge in to the water on a hot summer day that attracts people to shorelines. Because of their popularity, coastal areas tend to become highly developed. Property values near lake shores are high. Lakes, however, can be unpredictable because of water level changes and the impact of those changes on waterfront property. Water levels are also important for maintaining healthy wetlands, fisheries and other ecosystems. For an excellent review of Great Lakes water level science and effects on humans, see ***http://www.great-lakes.net/teach/envt/levels/lev_1.html***.

Most scientists agree that climate change will affect the levels of the Great Lakes, in varying ways depending on a number of factors. While sea level is expected to rise, changes in the Great Lakes region are likely to result in lower water levels, though there will be differences from lake to lake. As the science and climate models progress, there are some baseline conditions of hydrology at work in the Great Lakes Basin. This activity deals with those annual, decadal and longer baselines and introduces scenarios that may result from climate change. An optional Extension activity allows students to identify and model management strategies people are using to adapt to lake level changes.

Teacher Activity: How do the levels of the Great Lakes change?

Objectives: In this activity students analyze, interpret and make inferences from web-based data on Great Lakes water levels.

After completing this investigation, students will be able to:

- Interpret graphic information about water level fluctuations in the Great Lakes.
- Examine the relationship between temperature and precipitation and corresponding changes in lake levels.
- Summarize how changing water levels within the Great Lakes region impact ecosystem health and the people who live there.

Materials, per group:

access to Internet
computer with projector
copy of student activity worksheet (1 per person)
heavy duty, bi-level, paint roller tray (1 per class if used for demonstration or 1 per student group)
water

Time required: 1.5 - 2 class periods, more if doing project-based Extension activity.

ALIGNMENT

National Framework for K-12 Science Education:
SEP 4: Analyzing and interpreting data
CC1: Patterns
ESS2: Earth Systems

Great Lakes Literacy Principles:
#1e, g: The Great Lakes, bodies of fresh water with many features, are connected to each other and the world ocean.
#2c: Natural forces formed the Great Lakes; the lakes continue to shape the features of their watershed.
#3e: The Great Lakes influence local and regional climate and weather.

Climate Literacy Principles:
#5b,c,d: Our understanding of the climate system is improved through observations, theoretical studies and modeling.
#7b: Climate change will have consequences for the Earth system and human lives.

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ENGAGE

Show these two images of the same location in the Lake Erie islands (larger images are attached at the end of this lesson). Brainstorm with the class: What determines how much water we see in the Great Lakes today?

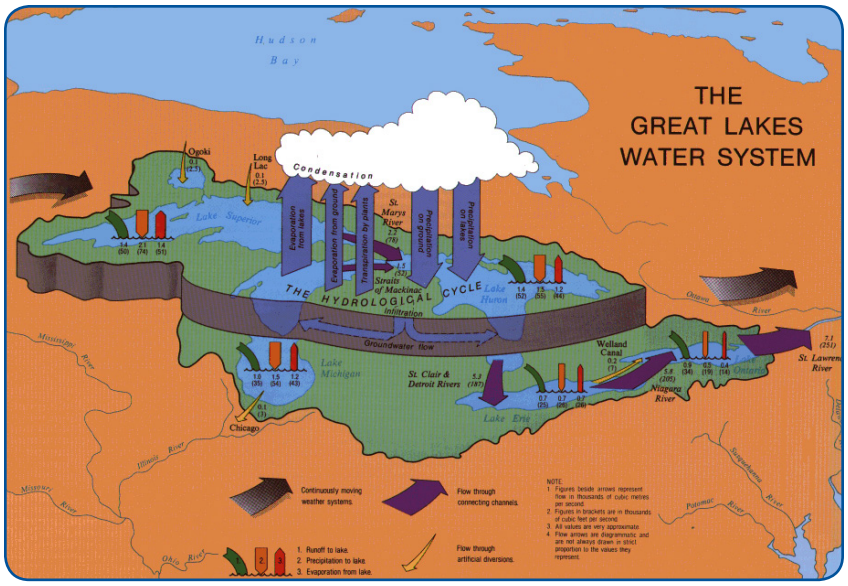




[The complex answer depends on how much rain and snow have fallen, how much evaporation has taken place, the season of the year, how much water is moving to the next lake downstream, and how much water is sinking into the ground. What people see as the observed water level is even influenced by which way the wind is blowing!]

EXPLORE

1. Show and discuss the following diagram which summarizes the relative effects of the main factors that affect Great Lakes water supply overall. Review the hydrologic cycle if needed, using the animation at ***http://earthguide.ucsd.edu/earthguide/diagrams/watercycle/***
2. Introduce the idea that water levels vary over time. There are day-to-day, seasonal, and long term cycles. Allow time for students to explore the interactive Great Lakes Water Levels Dashboard at ***http://www.glerl.noaa.gov/data/now/wlevels/dbd/*** before answering questions on their worksheet. If multiple computers are not available for class use, plan to project the web site and allow the class to suggest manipulations of the data. Encourage discussion of trends over short and long periods.



USEPA and Environment Canada, The Great Lakes: An Environmental Atlas and Resource Book. http://www.epa.gov/glnpo/atlas/glat-ch2.html. Accessed May 23, 2012.

Teacher's Note:

The red line on the graph for each lake is the long-term average water level. Blue horizontal lines are annual or monthly averages depending on the number of years you are viewing. The scale at the bottom of the screen can be expanded to show single years in detail or larger numbers of years. Students will need to use this tool to answer questions.

As they examine water levels over time, students should note that drops and increases in levels are fairly consistent across all lakes, though the magnitude of changes may vary. This is an indicator of the importance of water flow from Lake Superior toward the sea, and a documentation of what the Great Lakes are considered a distinct hydrologic system with its own complex interactions of water, land, ice, air and life!

Annual or seasonal variations in water levels are based mainly on changes in precipitation and runoff to the Great Lakes. Generally, the lowest levels occur in winter when much of the precipitation is locked up in ice and snow on land, and dry winter air masses pass over the lakes enhancing evaporation. Levels are highest in summer after the spring thaw when runoff increases.

The irregular long-term cycles correspond to long-term trends in precipitation and temperature. Highest levels occur during periods of abundant precipitation and lower temperatures that decrease evaporation.

EXPLAIN and EVALUATE

After analyzing how water levels change over time and discussing how the hydrologic cycle moves water between the atmosphere, hydrosphere and solid earth, direct the class to look at factors that determine lake level and consider how climate change might affect water level as well.

3. NOAA's National Climatic Data Center, NCDC, keeps records of climate factors over time. Assign groups of 3-4 students to visit ***http://www.ncdc.noaa.gov/temp-and-precip/time-series/index.php*** to see how temperature and precipitation have changed in the states or region affecting the Great Lakes. Groups may be assigned to separate lakes, or to states comprising major parts of the watershed for one lake. For instance, a group might investigate Lake Michigan's watershed region [East North Central] or examine the surrounding states of WI and MI. A map of the US climate regions is at ***http://www.ncdc.noaa.gov/temp-and-precip/us-climate-regions.php***.

4. Groups should compare temperature and precipitation from the NCDC site with water levels from the GLERL Water Level Dashboard and answer questions on their worksheet. They will discover that while water levels in Lakes Michigan-Huron have gone down over recent years, both temperature and precipitation have increased! Discuss whether this means that temperature is the most powerful force in water level determination, or if other factors are at work.

Answers to Student Worksheet

Part A

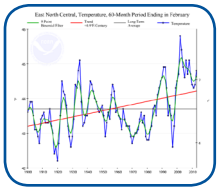
1. Lake Huron and Lake Michigan
2. Lake Erie
3. The Welland Canal contains a series of eight locks built to allow ships to pass around Niagara Falls while travelling between Lake Ontario and Lake Erie.
4. The water levels of the lakes is graphed on the dashboard.
5.

Lake	Variation in water level (m)	Rank (greatest variation 1, to least variation 4)
Superior	0.91 m	4
Michigan/Huron	1.51 m	1
Erie	1.23 m	2
Ontario	1.13 m	3

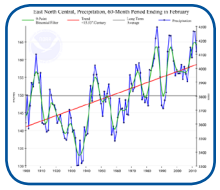
6. Highest water levels in the upper lakes occur in late summer.
   Highest water levels in the lower lakes occur in early summer.
7. Lowest water levels in the upper lakes occur in late winter.
   Lowest water levels in the lower lakes occur in late fall and early winter.
8. Answers will vary but should include factors such as seasonal fluctuations of temperature and precipitation, latitude differences, amount of snow and ice, outflow of water from one lake to another
9. The upper lakes exhibit below average water levels. The lower lakes exhibit average water levels.
10. a. F b. T c . T
11. Water levels in Lake Ontario seem less variable and are closer to the expected average than the other lakes.
12. Lake levels seem to be decreasing.
13. The lake levels are predicted to continue dropping.
14. a. Superior has been regulated since 1921 in order to vary the amount of water allocated to hydropower production while at the same time regulating the outflow from Lake Superior to Lakes Michigan/Huron
    b. Ontario has been regulated since 1958 in order to provide of deep-draft navigation through the St. Lawrence, Lake Ontario system; provide hydroelectric power generation; protect shoreline property owners; and improve Montreal Harbor levels.
15. Lake Superior has less seasonal variability; overall lake levels still lower than average
    Lake Ontario has less seasonal variability; overall lake levels near average

Part B

16. a. the temperature trend shows an increase;
    b. the observed individual temperatures fluctuate above and below the trend line

16. 

17. a. precipitation trend also indicates an increase;
    b. the observed precipitation levels fluctuate above and below the trend line

17. 

18. As precipitation and temperatures increase over Lake Michigan, lake levels continue to decrease. This may indicate that increasing temperatures have a greater impact on overall lake levels than precipitation does, most likely by the mechanism of evaporation and the long term impact of such dryness in the watershed.

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EXTEND

Option 1

Climate change is expected to impact the Great Lakes through warmer temperatures year-round, and increased storm activity, sometimes with increased precipitation. The additional heat from both the land and water could result in more evaporation than precipitation. The corresponding drop in water levels may be as much as one meter in the worst case scenarios, but some lakes may even experience a small rise in lake level [Lofgren, et al, 2011]. Regardless of the amount of lake level change, people in the region likely will notice differences in water levels over time.

Use clips of the webinar presented by Dr. Drew Gronewold about why it is important to understand fluctuating lake levels, specifically those of the Great Lakes. See the resources section.

Do the activity "Which Great Lakes factors will increase and which will decrease as a result of climate change?" using a central concept of LAKE LEVEL DROPS ONE METER. Have students think about what will happen to shorelines, shipping, wetlands, swimming beaches, marinas, docks, fish spawning, and other factors that are related to water levels. They may wish to collect photographs or make drawings of the changes they anticipate. Teachers may choose to supplement this activity with *Impacts on Water: Our Region's Vital Resource*, a fact sheet depicting the cascading effects of climate change on water resources in the Great Lakes region (see the resources section).

Option 2

Day-to-day changes are caused by winds that push water onto or away from shore. This is called 'wind set-up' or "surge" and is usually associated with a major lake storm, which may last for hours or days. When wind subsides, water that has been pushed in this way will oscillate back and forth until it reaches equilibrium, in a process known as a 'seiche.' This is often likened to waves in a bathtub. See the Lake Levels webinar (slides 40 and 41) in the resources section for graphic representation of this phenomenon.

Teachers can demonstrate a seiche by using a sturdy, bi-level paint roller tray partially filled with water. Use a small fan to simulate wind moving across a lake during a storm. Try starting from the deep end, then move to the shallow, etc. Discuss any observations as a class. Ask students if a seiche demonstrates a phenomenon of climate or weather? [A seiche is classified as a weather event because of its short-term occurrence.]

REFERENCE

Lofgren, B. M., T.S. Hunter, & J. Wilbarger, 2011. Effects of using air temperature as a proxy for potential evapotranspiration in climate change scenarios of Great Lakes basin hydrology. *Journal of Great Lakes Research* 37: 744–752.

RESOURCES

Background for Great Lakes water levels and their human effects: ***http://www.great-lakes.net/teach/envt/levels/lev_1.html***

Regulation of Great Lakes Water Levels: ***http://www.in.gov/dnr/water/3660.htm***

NOAA's National Climatic Data Center, NCDC, keeps records of climate factors over time:
http://www.ncdc.noaa.gov/temp-and-precip/time-series/index.php

Webinar "*Lake Levels*" by Dr. Drew Gronewold contains GLERL images of lake level changes: see slides 9-13, 19, 74,
http://changingclimate.osu.edu/webinars/archives/2011-05-10/

Extension lesson: Which Great Lakes factors will increase and which will decrease as a result of climate change?
http://changingclimate.osu.edu/assets/docs/2012edu_CurriculaVisualizingV6-Final.pdf

Union of Concerned Scientists' *Impacts on Water: Our Region's Vital Resource* fact sheet:
http://www.ucsusa.org/greatlakes/pdf/glwaterresources.pdf

Information about ships, shipping, and passage through the different levels of the Great Lakes:
http://www.great-lakes.net/teach/business/ship/ship_5.html

Michigan Sea Grant's *Preparing for Variable Lake Levels Fact* Sheet
http://www.miseagrant.umich.edu/downloads/climate/11-700-Preparing-for-Variable-Lake-Levels.pdf

Additional Great Lakes Climate Change lessons are available from Ohio Sea Grant.
Please call 614.292.8949 for more information.

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Student Activity: How do the levels of the Great Lakes change?

OBJECTIVE

When you finish this lesson you should be able to interpret graphs of how and when water levels change in the Great Lakes, and describe how temperature and precipitation are related to lake level.

Part A: How do the levels of the Great Lakes change?

Just as sea level is expected to rise, most scientists agree that climate change will affect water levels in the Great Lakes. Changes in the region are likely to result in lower water levels, though there will be differences from lake to lake. This lesson is about how lake levels already change through the years and decades.

To begin, here is a profile of the Great Lakes showing how far above sea level they are.

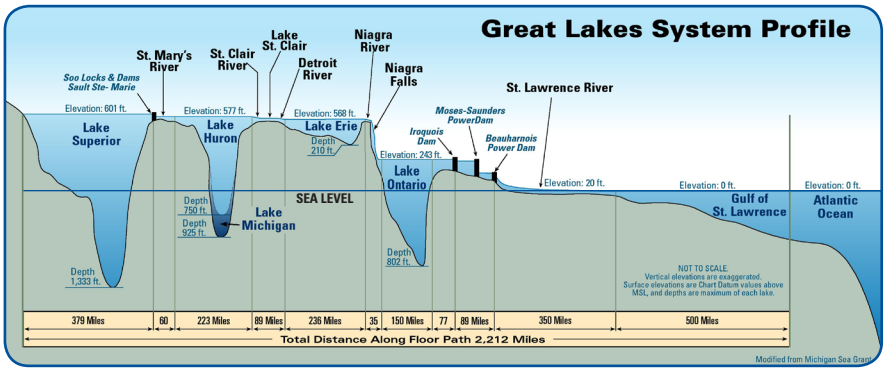


Figure 1. Ohio Department of Natural Resource

1. Based on this diagram, which two lakes are at the same elevation above sea level?

2. Which is the only Great Lake whose floor does not reach sea level? _____

3. The Welland Canal looks like stairs in this diagram! Describe what it really is, with information from ***http://www.great-lakes.net/teach/business/ship/ship_5.html***.

Use the Great Lakes Water Levels Dashboard ***http://www.glerl.noaa.gov/data/now/wlevels/dbd/*** to answer the following questions.

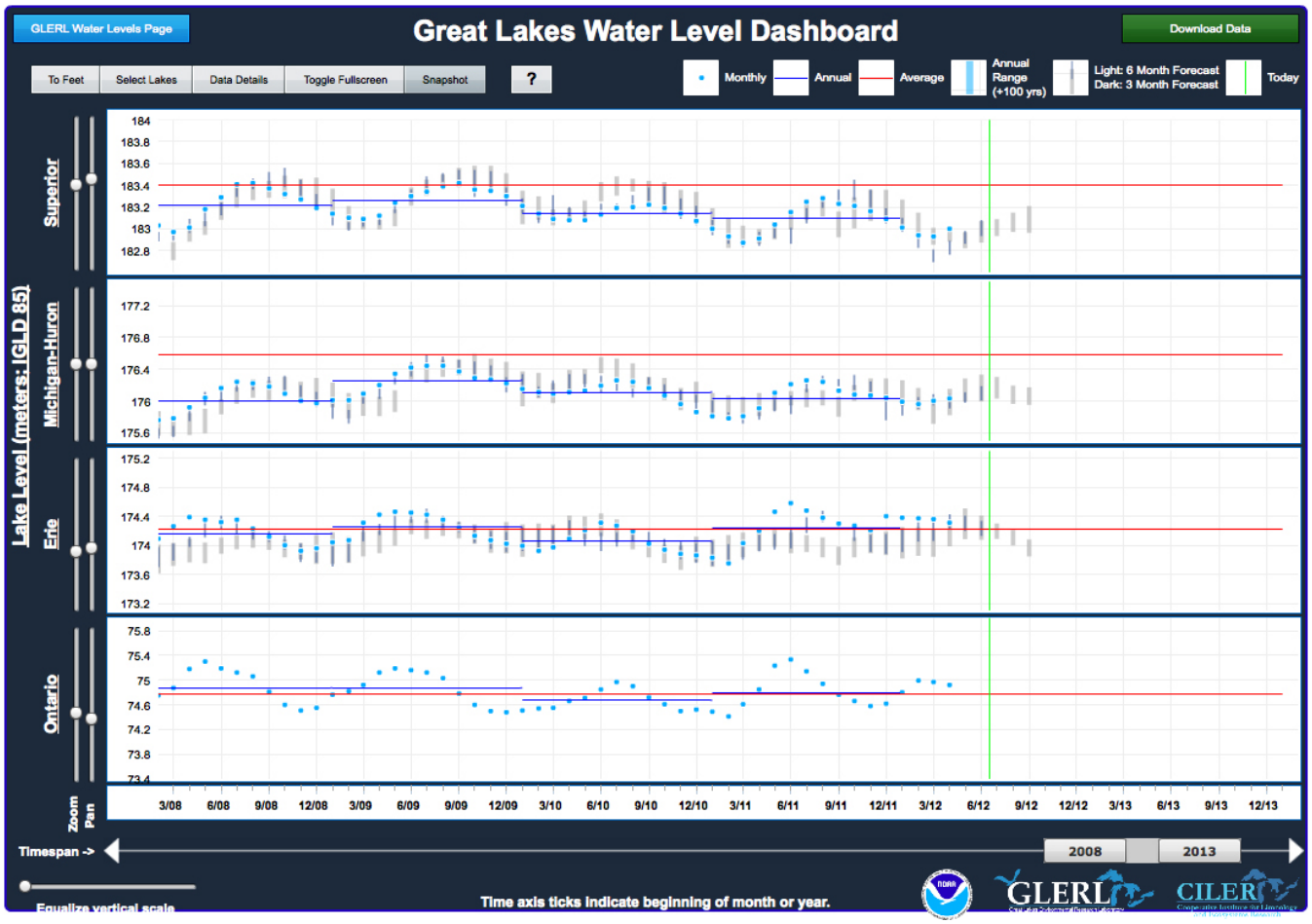
4. What characteristic of the lakes is graphed on the Dashboard?

5. With all the lake graphs in view, determine each lake's variations in water level [from highest to lowest numbers of meters] from 1997 to 2012. Record your data in the table.

Lake	Variation in water level (m)	Rank (greatest variation 1, to least variation 4)
Superior		
Michigan/Huron		
Erie		
Ontario		

Use the sliding scale at the bottom of the Dashboard to focus in on just a few years, so you can see Month/Year on the X-axis. The record for 2008-2012 will look like Figure 2.

Figure 2. Monthly lake level data for the Great Lakes



6. a. During what season of the year did the HIGHEST water level occur in the "Upper Lakes," [Lakes Superior and Michigan/Huron]?

b. What season had the highest water in Lakes Erie and Ontario [the "Lower Lakes," geographically]?

7. a. During what season did the LOWEST water level occur in the Upper Lakes?

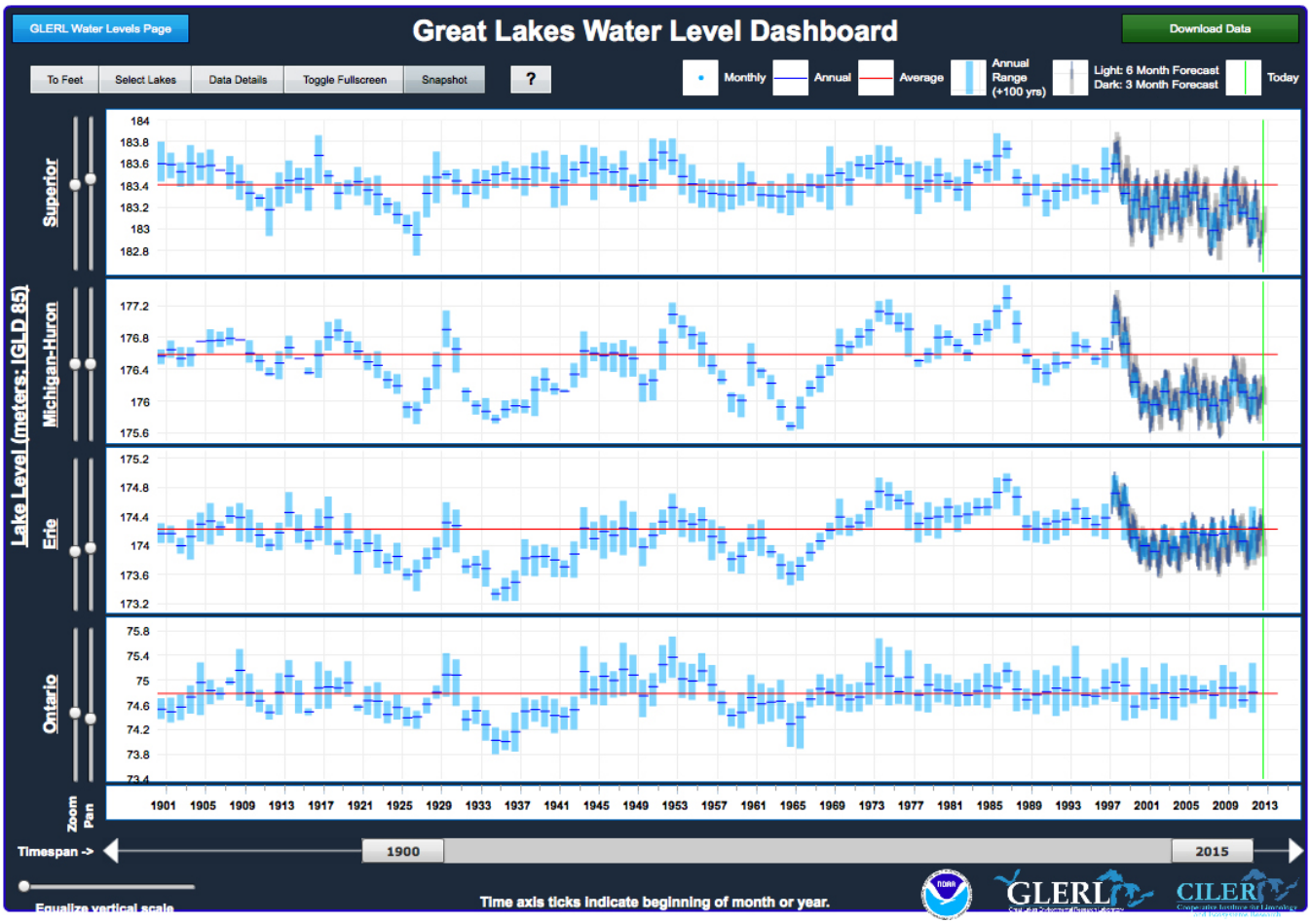
b. What season had the lowest water in the Lower Lakes?

8. What could cause these seasonal differences in water level among the lakes?

9. The red line is the long-term average water level for each lake. Judging from the short period of data in Figure 2, is water level above, below, or about average for the lakes shown?

Now look at a longer period of time using the sliding scale at the bottom of the Dashboard.

Figure 3. Great Lakes water levels since 1900



10. The annual pattern of high and low water you identified above disappears when you look at this scale of data. Practice interpreting data. Put a checkmark next to the statements that are accurate interpretations of the data in Figure 3.
    a. _____ Water levels were below average in Lake Superior in the 1930s.
    b. _____ Water levels were typically above average in all five lakes in the late 1940s and early 1950s.
    c. _____ Lake Superior differed from the other lakes in the 1930s. Its water level were typically above average while the other lakes experienced lower than average water levels.

11. Now examine the Lake Ontario graph. How do water level changes compare with those of the other lakes?

12. Many climate records [for heat, drought, floods, etc.] have been set in the last two decades. Look at the lake level data since 1990. What seems to be the pattern of lake level during the period since 1990?

13. How do the projected lake levels for the next few years compare with the observed pattern of this century?

14. Read about regulation of Lake Ontario and Lake Superior at ***http://www.in.gov/dnr/water/3660.htm***.

    How long have these lakes been regulated: Superior since _____ and Ontario since _____.

    Why are the lake levels regulated?

    Superior:

    Ontario:

15. Mark Figure 3 for the dates of regulation on their respective lakes. How do lake levels vary since regulation began?

    Superior:

    Ontario:

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Part B: How do temperature and precipitation relate to water levels?

Use ***http://www.ncdc.noaa.gov/temp-and-precip/time-series/index.php*** to investigate what is happening, or has happened, with two of the factors that influence lake water levels.

16. Use the web choices to plot the temperature for Lake Michigan over the last 60 months, ending with the most recent month.
    This means you will select from the pull-down menus as follows:
    Parameter: Temperature
    Month: February [accept the month on the web page]
    Year: 2013 [accept the year on the web page]
    Filter: 60-month average
    State/Region: East North Central
    Click on PLOT

    a. What is the general trend of the observed temperature over this period?

    b. How does the observed temperature differ from the long-term average for the period?

17. Now change the Parameter to Precipitation and click on PLOT.
    a. What is the general trend of the observed precipitation over this period?

    b. How does the observed precipitation differ from the long-term average for the period?

18. Compare the changes in temperature and precipitation that you have plotted with the change in water level in Lake Michigan over the last century. Which, if either, parameter seems to be related to the water levels you discovered in questions from Part A #13-14? How might you explain this?

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