Understanding Sea Level Using Real Data

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Summary

Five lessons at increasing levels of sophistication incorporate real data from NOAA to help students understand how sea level is measured and monitored.

Grade Level: 6 - 8

Aligned to Next Generation Science Standards.

This curriculum module was developed for the NOAA Ocean Data Education (NODE) Project by Caroline Joyce and Todd Viola under a contract with the National Marine Sanctuary Foundation and in collaboration with these offices of the National Oceanic and Atmospheric Administration: National Marine Sanctuary Program, National Estuarine Research Reserve System and National Oceanographic Data Center.

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2nd edition (2016): completed by Amy Dean.

National Marine Sanctuaries

National Estuarine Research Reserve System

Integrated Ocean Observing System

Introduction

Sea level and *sea level rise* are important topics that impact everyone, particularly the 160 million+ people that live along our nation's coasts. Investigations of sea level can help your students better understand Earth's natural cycles while investigations of sea level rise can help your students understand how humans are affecting our planet.

Sea level, or sea surface height, is also a good topic to study using real data because of the interesting data sets that are available both globally and locally. Satellite data gives a global view, while a network of monitoring stations and buoys provide long-term data at specific locations around the United States.

Studying sea level also provides good linkages with middle school mathematics and science standards. Charts of sea surface height data are excellent examples of the use of mathematical mean or average. Additionally, sea level data activities can support classroom lessons on ocean density, circulation, tides and global climate change.

Sea Level Basics

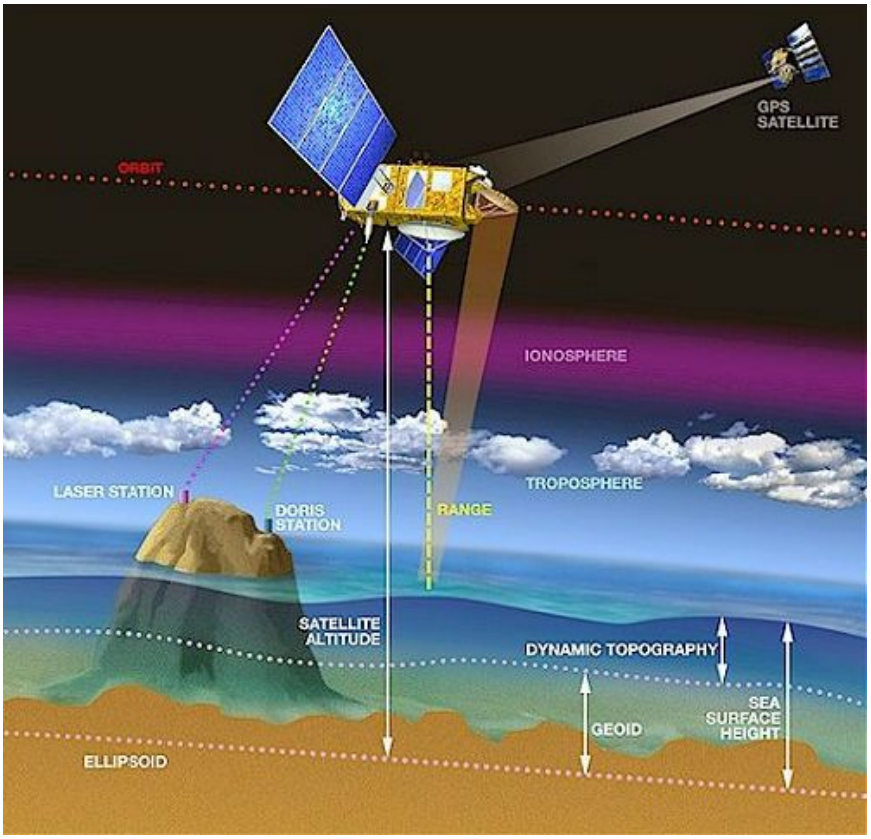
Web Links

For links to helpful websites about sea level, visit datainthe classroom.noaa.gov.

The ocean is not flat. Water, as a fluid, is influenced by many forces that determine its shape, and thus the height of the sea around the globe. These forces include winds, tides, glacier melt, density, and gravity, the effects of which compound to determine water height around the globe at any point in time. In mathematical terms, scientists studying sea level must isolate and measure the effects of these different forces, and then add them together.

One tool scientists use to measure sea level is satellite altimetry. Radar instruments onboard orbiting satellites bounce radar waves off the ocean surface. The satellite instruments record the time it takes for the radar wave to bounce back to the satellite. This measurement enables scientists to calculate the distance from the satellite to the surface very accurately (to about 2 cm or 1 in.).

In order for satellite altimetry to work, scientists must know precisely where the satellite is traveling in its orbit. Earth-based stations help monitor the satellite's path for this purpose. Also, the Earth's ocean is not shaped like a perfect sphere of water. The shape of the Earth's crust causes natural variations in the height of the ocean's surface around the globe. Scientists must have very good measurements and models of these variations, so they can account for them when interpreting the satellite data. Only by subtracting the known variations in the ocean's height can scientists measure changes in height caused by other factors they are interested in studying, such as tides, winds, and currents.



The sea-surface height is the difference between the satellite's altitude relative to the reference ellipsoid and the altimeter range.
Image copyright CNES (http://www.cnes.fr/). Used with permission.

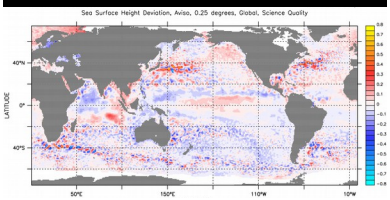
Satellites are not the only tools for measuring water levels. The National Oceanic and Atmospheric Administration (NOAA) has developed long-term data sets of local tide measurements from an array of permanent monitoring stations around the United States. Over the years, the technology for recording tides has changed from early mechanical recorders to modern acoustic and electronic devices. Today, this network of monitoring stations records tide measurements electronically every six minutes at over 3000+ stations around the country. The data is transmitted to NOAA headquarters via satellite, where it is processed, archived, and made available online.

In the case of both satellite altimetry and NOAA tide monitoring stations, water level data is frequently reported relative to an average or "expected" height based on historical data. For this reason, understanding the concept of a mean, or average, is important to interpreting water level data at any scale. Understanding and calculating a mean is a skill that is developed and carried through the activities in this module.

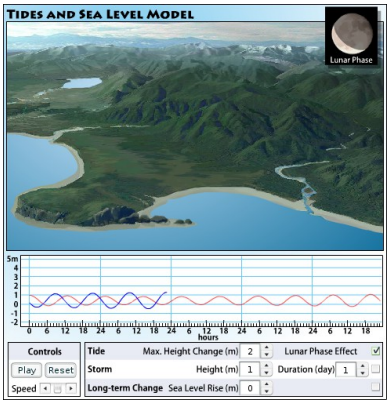
Scaled Levels

5 Invention
4 Interactivity
3 Adaptation
2 Adoption
1 Entry

Online Tools



Satellite altimetry data are available at dataintheclassroom.noaa.gov.



A simple, interactive model to help visualize rising and falling water along a coastline.

Lesson Overview

This curriculum incorporates a scaled approach to learning. Each module offers activities at five different levels of student interaction, sometimes referred to as Entry, Adoption, Adaptation, Interactivity, and Invention. The early levels are very directed and teacher driven. They are important first steps, however, when learning something new. The levels of Adaptation through Invention are more student directed and open up opportunities to design lessons featuring student inquiry.

The levels serve a dual purpose. They are designed to engage students in increasingly sophisticated modes of understanding and manipulation of data. They are also intended to help you, as a teacher, familiarize yourself with online tools for accessing data and to provide you with models for integrating the use of real data into your classroom practice.[1]

These activities utilize technology in several ways. First, the website offers a simple gateway to access real data on water levels. Two data sources are used: satellite altimetry and local tide data. These data are available in other places on the internet, but through dataintheclassroom.noaa.gov, students can use a simple, user-friendly interface to access data in a way that directly supports these activities.

In addition to accessing data, the website includes an interactive tide model to help students picture the effects of changing sea levels and the potential impacts of rising sea level on coastal communities.

1 For more information about the research behind this approach, consult these papers:

Dwyer, D. C., Ringstaff, C., & Sandholtz, J. H. (1990). Teacher beliefs and practices, Part I: Pattern of change. ACOT Report # 8. Cupertino, CA:Apple Classroom of Tomorrow Advanced Technology Group, Apple Computer, Inc.

Bransford, J.D., Goin, L., Hasselbring, T.S., Kinzer, C.K., Sherwood, R.D., & Williams, S.M. (1999). Learning with technology: Theoretical and empirical perspectives. *Peabody Journal of Education*. 5-26.

The chart below illustrates the five levels of this module, Understanding Sea Level Using Real Data.

5 **Invention: Designing Your Own Investigation:** Students will design their own plan to answer a research question. They will describe how they will use data and consider the limitations of the data.

4 **Interactivity: Measuring Storm Effects:** Using what they learned about typical tide measurements at a location, students will use NOAA tide data to analyze the effect of storms on coastal sea level.

3 **Adaptation: Tides and Local Sea Level:** Students analyze local tide data and apply their skills of calculating a mean to describe the cyclical patterns of tides.

2 **Adoption: Analyzing Global Sea Level Data:** Students will analyze real data from satellite altimetry maps to provide evidence for global variations in sea level. Students will construct an explanation for sea level variations across the equatorial Pacific Ocean.

1 **Entry: Sea Level From A Global Perspective:** Through teacher-led demonstrations and discussion, students will learn that natural variations in global sea level are propelled by sunlight and gravity and that, over the past century, sea levels are rising due to global climate change. Students will learn to calculate means and deviations, a skill that will be used to interpret sea level data throughout this module.

The levels provide a natural opportunity for you to adapt and customize the curriculum module as needed. For example, if students already have experience with the topic, you may find that you can skip the entry level activities.

Using the Technology

Using technology in conjunction with classroom lessons presents some challenges. Because this curriculum demonstrates strategies for using real scientific data available on the internet, it assumes that you and your students will have access to the internet at some point during the investigation. However, because the level and availability of internet access varies widely from setting to setting, you may need to adapt the activities to suit your particular situation. To help you, the activities are designed with flexibility in mind.

For example:

- When access to real data is needed, the Preparation section describes steps that can be performed outside of class. Data and results can be saved for use in class.

- Data can be accessed through the website using special forms that have been designed for this project. While it is recommended that you familiarize yourself with how to access data using these tools, the early lessons also contain blackline masters of important maps, graphs and other data products, which can be used in settings where live internet access is not available.

- An important outcome of these activities, especially at the higher levels, is for students to learn how to access and manipulate data themselves. In the ideal case, students will access the internet individually or in groups in order to generate maps and graphs using real data. In settings where this is not possible, the curriculum provides student masters, which can be reproduced and used in class. To fully explore the questions posed in the highest level activities, however, students in these settings will need to access the internet.

Next Generation Science Standards

This module was developed to build data literacy, engaging students in increasingly sophisticated modes of understanding and manipulation of data. It was completed prior to the release of the Next Generation Science Standards[2] (NGSS) and, in 2016, was adapted to incorporate the innovations described in the NGSS where possible. An alignment document has been developed to help teachers and educators understand how the activities in this module align with the new standards. This document is available on the website.

Ocean Literacy Essential Principles

This curriculum module also supports the following Essential Principles of Ocean Sciences.[3]

1. The Earth has one big ocean with many features.

    a. Sea level is the average height of the ocean relative to the land, taking into account the differences caused by tides. Sea level changes as plate tectonics cause the volume of the ocean basins and the height of the land to change. It changes as the ice caps on land melt or grow. It also changes as sea water expands and contracts when ocean water warms and cools.

2. The ocean and life in the ocean shape the features of the Earth.

    b. Sea level changes over time have expanded and contracted continental shelves, created and destroyed inland seas, and shaped the land surface.

2 NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press. Next Generation Science Standards is a registered trademark of Achieve. Neither Achieve nor the lead states and partners that developed the Next Generation Science Standards was involved in the production of, and does not endorse, this product.

3 Ocean Literacy Network (2005). *Ocean Literacy - The Essential Principles of Ocean Sciences K-12.* Washington, D.C.

Sea Level From a Global Perspective

Summary

Grade Level: 6-8

Teaching Time: 45 minutes

Activities:

- **Participate in introductory sea level demonstrations and discussions.**
- **Use a balloon model to generate sea level data.**
- **Compute a mean value from sample data.**

Vocabulary

Mean –the arithmetic average of a set of numbers. It is found by adding all the values in the set and dividing the sum by the total number of values.

Deviation – the difference between one data value in a set and the mean value for that set.

Objectives

Students will understand that natural variations in global sea level are propelled by sunlight and gravity and that, over the past century, sea levels are rising due to global climate change. Students will be able to calculate means and deviations, a skill that will be used to interpret sea level data throughout this module. This is a teacher-led discussion and activity.

Background

Sea level and sea level rise are important topics that impact everyone, particularly the 160 million+ people that live along our nation's coasts. Investigations of sea level can help scientists understand Earth's natural cycles and how humans are affecting our planet.

By studying the height of the sea's surface across the world's ocean, scientists know that the surface of the ocean is not flat. It has hills and valleys, much like the hills and valleys on land. Because of the fluid nature of the ocean, sea level continually fluctuates due to variations in wind, currents and water density (all by-products of the sun's energy) and tides (caused by gravitational forces).

Why study the height of the sea's surface? One important reason is to monitor how much heat is stored in the ocean. As water in the ocean heats up, it expands, and as it cools, it contracts. Therefore the height of the sea surface often corresponds to the amount of heat stored in the upper layers of the ocean. Among other things, this information is used to predict the severity of storms, such as hurricanes.

Another reason sea surface height is monitored is to track the speed and directions of ocean currents. Ocean currents are streams of water flowing

through the ocean, driven by wind or by the mixing of waters of differing densities. Because currents are moving bodies of water, they result in changes in the ocean surface, altering the height of the sea surface by a few tens of centimeters to more than a meter. Although this seems like a small amount, these changes are important. Ocean currents transport heat (from the sun), redistributing it around the globe as it is eventually released back into the atmosphere as water vapor (part of the hydrologic cycle). These currents regulate our global climate.

Finally, a critically important reason to study sea surface height is to increase our understanding of global sea level rise. Currently, long-term studies of sea surface height have revealed that *mean* sea level has risen approximately 8 inches (20 cm) since the beginning of the 20th Century[3]. This is a direct result of climate change. As the temperature of the earth's atmosphere increases, ocean temperatures also increase and sea levels rise. What causes the rise in sea level? Warmer air melts glaciers and ice sheets on land, while rising ocean temperatures cause water to expand and take up more space. While some of the lessons in this module focus on natural changes in sea level due to tides and storms, students can conduct their own investigations of global sea level rise in Level 5.

Due to the fact that the ocean is always in motion, it is difficult to report measurements of sea surface height in absolute terms. Instead, scientists measure the difference between the ocean's height and the expected or average height (based on historical data) at any given location. Student will need to understand the concept of a *mean*, or average, before they can interpret sea level data at any scale. Understanding and calculating means and *deviations* are skills that are developed in Level One and carried throughout the activities in this module.

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3 IPCC, 2014: *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. In IPCC AR5 Synthesis Report website.

Materials

- **Computer, projector and access to the internet**
- **One round balloon and one long balloon**
- **Ruler**
- **Plastic tub or basin**
- **Clear glass baking dish**
- **Blue food coloring**
- **Straws**
- **Water**
- **Paper and marker**
- **Copies of Student Masters**

Preparation

Assemble materials needed for the lesson (see column at left).

Prepare for two short demonstrations. If you do not have a waterproof lab surface to work on, you should prepare and store these materials in a large, plastic tub to catch spills.

- Water Balloon demo: Fill one round and one long balloon with water from a tap. Do not fill it too full. The long balloon must be allowed to stretch and change shape when handled, without breaking.

- Trade winds demo: Fill a clear-glass baking dish with water until the water is about 1 cm (½ in.) deep. Add a few drops of blue food coloring and stir to mix the color.

Procedure

Part 1: Sea Level Demonstrations

1. Hold up the round water balloon as a simple model of Earth. Remind students that the ocean covers more than 70 percent of the surface of our planet. Engage students in a discussion about sea level. Accept any answer to the questions below:

    - Do you think the surface of the ocean is flat, like the surface of the balloon?

    - Do you think height of the sea surface is the same all over the planet?

    - Can water in the ocean change its shape?

2. Next, explain that you will do two demonstrations to show how natural forces can cause changes in sea level.

3. For the first demonstration, show the students a long balloon filled with water. Tell students that the balloon containing the water is a simple model of the ocean. Lay the balloon on a flat surface and explain that the upper surface of the balloon represents the ocean surface.

4. Next, push down gently on the middle of the balloon with your hand. The water height should rise on the ends and decrease in the middle.

5. Ask the students if any water was lost or if it took a new shape.

   Answer: It took a new shape.

6. Explain that the model demonstrates how the ocean surface can have hills and valleys much like the hills and valleys on land. Since water is fluid and always in motion, these watery hills and valleys are constantly moving and taking new shapes. Next, push down on one side of the balloon to cause the water to rise on the opposite end. Ask students what type of natural forces can make the water in the ocean rise or fall.

   Possible answers: wind, currents and water density (all by-products of the sun's energy) and tides (caused by gravitational forces).

7. Explain that changes in ocean temperature can also impact sea level. Ask students if they can explain why.

   Answer: When water temperature increases, the density decreases. This results in an increase in the volume of the water.

8. Ask students to predict whether sea level might change along the East Coast or the Gulf Coast during the warm summer months.

   Answer: Yes, the ocean water warms in the summer and sea level rises.

9. Ask students to now consider sea level change over a longer time period, over 10, 20 or even 100 years. Can students predict how global sea level might be changing in response to the warming of the planet.

   Answer: As the temperature of the earth's atmosphere rises (due to climate change), so does sea level. This extra heat not only melts glaciers and ice sheets on land, it also causes ocean water to expand and take up more space. This raises the elevation of the sea surface and causes flooding in low lying coastal areas. Satellite data, together with data from local tide gauges, have revealed that sea level has risen 8 inches (20 cm) since the beginning of the 20th Century. Two short video demonstrations that help students understand the causes of sea level rise can be found within a 20-minute educational video on sea level rise, created by NOAA and NASA. Start the video at minute 12:15.

Video

Access the 'Sea Level Video' via a link on the Data in the Classroom website. Start video at minute 12:15 to view the sea level rise demos.

10. The second demonstration uses a straw to imitate the effect of wind blowing across the surface of the ocean. If students are familiar with trade winds, you can model the effect of trade winds blowing across the equatorial Pacific Ocean.

11. Place the glass baking dish with colored water in an area where students can easily view the demonstration.

12. Next, take a straw and gently blow across the surface of the water. Ask students what they see.

    Answer: Darker colored bands or waves moving across the dish.

13. Blow harder through the straw. The side of the dish farthest away from where you blew from the straw should be darker blue. Ask students if they can explain what they observe.

    Answer: More water has piled up on the far side of the dish.

Explain that the wind can push water around in the ocean, causing water to pile up on top of resting water. This results in greater sea surface height in some locations.

14. If students have prior knowledge of trade winds, ask them to make predictions about how the trade winds might affect sea level in the tropical Pacific Ocean.

    Answer: Accept any answer.

15. Summarize key points learned from the demonstrations:

    - The surface of the ocean is not flat. It has hills and valleys that cause variations in sea level across the global ocean.
    - Short-term, natural variations in sea level occur due a variety of factors, including tides, wind, and seasonal changes in temperature.
    - The long-term rise in mean global temperature has caused global sea level to rise over the past century.

Part 2: Student Activity – Finding the Mean

1. If the ocean is constantly moving and the sea level changing, how do scientists get a general measurement for the water level at a certain location? How can you tell if a change in the water level is large or small?

   Answer: You compute an average or mean to describe the height. Then you can compare your measurements to the mean.

2. Explain to the students that they will generate some sample water level data using a balloon as a simple model of the ocean in order to calculate the mean. You can use the long water ballon from the previous demo for this activity. Select two students to gather data to be used by the class.

3. Have the two students perform steps 1 through 5 on the *Student Master: Finding the Mean*, while the class follows along. One student can apply pressure to the balloon, while the other measures height data. Ask all of the students in the class to record this collected data on their own copies of the Master.

4. Have all students perform step 6 on the Master. They can compute the mean of the water height data by following the instructions.

5. Have all students complete step 7 to calculate how much each data point deviates from the mean.

6. Ask students to complete the questions on the Master:

   Why are some deviation values greater than zero and some less than zero?

   Answer: Some height measurements are higher than average and some are lower than average.

   What does it mean when a deviation value is negative?

   Answer: It means the height measured at that point is lower than average, or less than the mean height at that point.

7. Finally students should graph their results, following the instructions on the *Student Master: Graph Your Results.*

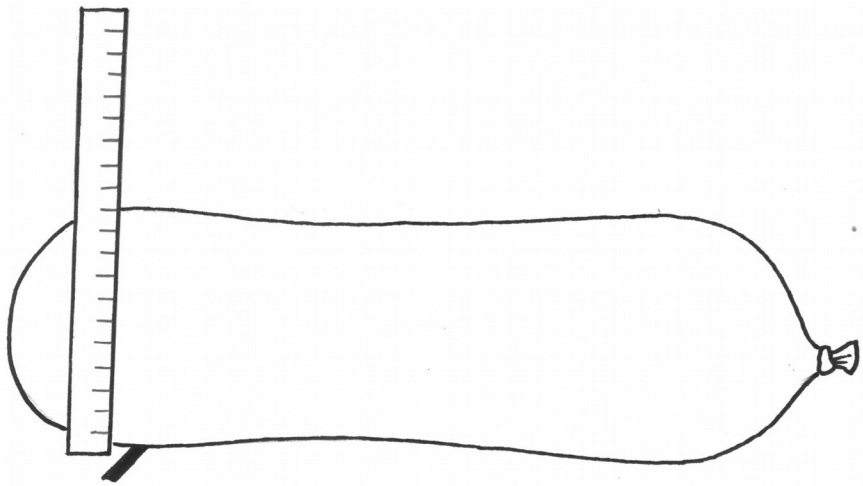
8. Explain to students that understanding the concept of a mean, or average, is important to interpreting water level data at any scale. Scientists report sea level data as deviations from an expected or mean height.

Part 3: Check for understanding – After completing Level 1, you may optionally use the Level 1 quiz on the website as an assessment tool.

Student Master

Finding the Mean

Sea surface height is the height of the ocean's surface. It is sometimes reported as the height difference relative to an expected or average height at any given location. In this activity, you will use a balloon as a simple model of the ocean in order to collect some data.



1. Place a sheet of paper across the bottom of a waterproof plastic tub or basin. Lay a balloon filled with water across the paper.

2. Sea surface height data is reported as the height difference relative to an expected or average height at any given location. Choose a location along the length of the balloon. Use a marker to mark that location next to the balloon on the paper at the bottom of the basin.

3. With the balloon sitting undisturbed, stand the ruler at the mark you made on the paper. Measure the height of the balloon at the mark in centimeters and record the height on the data sheet.

4. Now apply pressure somewhere on the balloon so that its shape changes. While pressing on the balloon, measure the height at the mark on the paper and record the height on the data sheet.

5. Repeat step 4 at least three times. Each time, vary the pressure put on the balloon. You can put pressure on a different spot or vary the amount of pressure you apply. Each time, record the height on the data sheet.

6. Next, compute the mean for the data collected. The mean is equal to the sum of all the measurements, divided by the number of measurements recorded.

   $$\text{mean height} = \frac{\text{sum of height measurements}}{\text{number of measurements}}$$

7. Once you have the mean, calculate how much each data point deviates from that mean. To do this, subtract the mean from each height measurement recorded. Write the results in the column marked Deviation.

   deviation = height measurement − mean height

Measure-ment	Height	(- Mean)	Deviation
1			
2			
3			
4			
5			
6			
Total			
Mean			

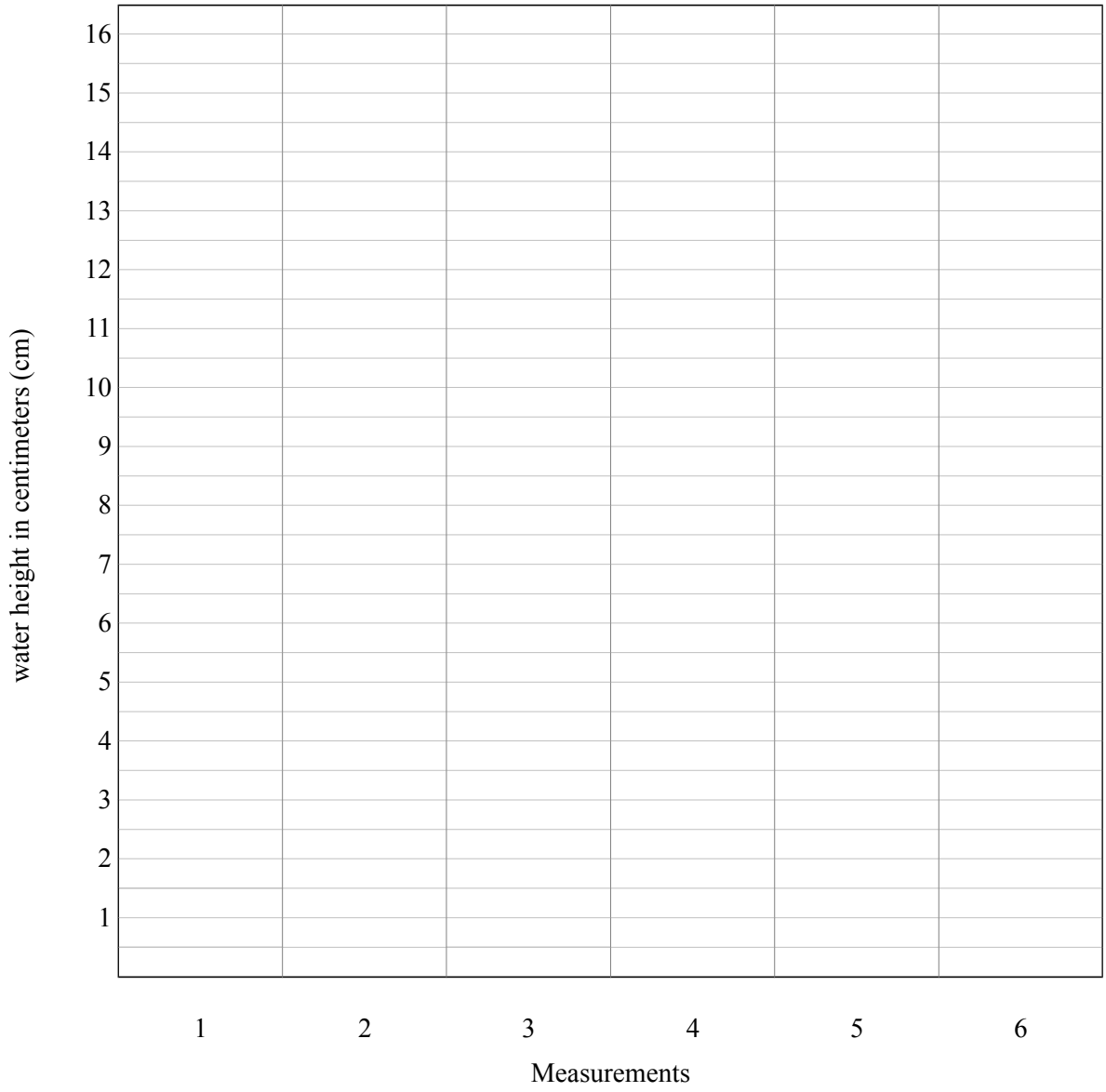
Answer the following questions:

1. Why are some deviation values greater than zero and some less than zero?

2. What does it mean when a deviation value is negative?

Student Master

Graph Your Results



Make a bar graph of the height data gathered from the balloon model. Using the grid above, draw a bar to represent each height measurement you recorded.

Next, draw a horizontal line on the grid to represent the mean height you calculated.

How are the height deviations you calculated represented on your bar chart?

Analyzing Global Sea Level Data

Summary

Grade Level: 6 - 8

Teaching Time: 45 minutes

Activities:

- **Analyze satellite maps of global sea surface height**
- **Construct explanations for sea level variations.**

Vocabulary

Altimeters – radar instruments used to measure sea surface height from orbiting satellites.

Sea surface height deviation (SSHD) – the height of the sea surface above or below some reference point.

Objectives

Students will analyze real data maps from satellites to provide evidence for global variations in sea surface height. Students will construct an explanation for sea surface height variations across the equatorial Pacific Ocean.

Background

Since the 1990's, global sea level, or sea surface height, has been monitored using satellites. These satellites are equipped with radar instruments called *altimeters*. The altimeters bounce radar waves off the ocean surface and record the time it takes to return to the satellite. This measurement enables scientists to calculate the distance from the satellite to the surface very precisely (to about 2 cm or 1 in.). For more information about satellite altimetry, see the module introduction (pages 2-4).

NASA and other partners, including NOAA, have been working together to maintain a series of satellite missions aimed at continually monitoring sea surface height from space. The satellite altimetry data currently available on the Data in the Classroom website allow users to access data from various satellite missions. The AVISO tool on the website displays data from the earliest satellite missions (1992-2006) while the NOAA/PMEL tool displays satellite altimetry data from the Jason-2 satellite (2008-current). The newest satellite, Jason-3, was recently launched into space in early 2016 from Vandenberg Air Force Base, California. Jason-3 currently monitors 95% of the Earth's ice-free oceans every 10 days. Data from this satellite will be available to the public in the future.

In this activity, students will learn to read and interpret maps of satellite

altimetry data. Satellite-derived sea surface height data are reported as deviations from a measured historical mean. *Sea surface height deviation* (SSHD) is the difference between the height of the sea surface and the expected average height, based on historical data. The scale for SSHD data is measured in meters above and below the average (or mean) value for a given location.

Using the online AVISO tool, students will access and analyze real sea surface height data focusing on the equatorial Pacific Ocean. Students should have a basic understanding of the trade winds prior to completing the activity. Students will discover, from assessing the data, that the sea level in the western Pacific is higher than sea level in the eastern Pacific. These deviations from mean sea surface height occur because the easterly trade winds drag the surface waters in the eastern Pacific away from the coast of the Americas. As a result, warm surface water builds up in the western Pacific, around Indonesia, raising the sea level approximately half a meter.

Materials

- **Computer or overhead projector**
- **Student Masters – copies for class**
- **Teacher Master – or map images saved to your computer.**

Preparation

Familiarize yourself with the AVISO data tool on the website. Make color copies of the data map needed for the activity, if your students cannot print color maps in class.

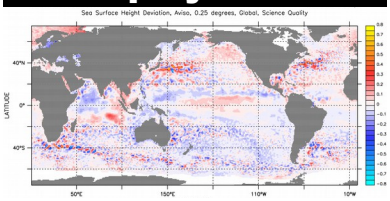
1. Visit dataintheclassroom.noaa.gov, and find the Sea Level module.

2. Follow the link to 'Satellite Data.' You will be using the AVISO tool, the first of the two data tools on this webpage.

3. Select the date 16-Dec-1993. Click 'Get Data.'

4. Repeat steps above to retrieve data from 16-Dec-2005. This is the map needed for the student activity. Print color copies, if necessary.

To Display



Generate this satellite image by using the Data in the Classroom website.

Procedure

1. Before students begin, they should understand that means and deviations are used by scientists to report measured increases or decreases in sea level (from the activity in Level One).

2. Explain how and why satellites measure sea surface height. Optionally, you can show students a short video such as Jason-3: Continuing Decades of Ocean Surface Measurement.

3. Display the *Teacher Master: Monthly Average Sea Surface Height Deviation map for December 1993* or access the same data map using the AVISO satellite data tool on the website. Explain the key features of the map.

   - The map shows a global view of sea surface height deviation (SSHD). The color scale indicates the difference in meters above or below the average height for a given location.
   - x axis = longitude, degrees east and west.
   - y axis = latitude, degrees north and south of the Equator.

9. Ask students to relate what they just learned about means and deviations to explain the color scale on the satellite data map.

   Answer: The warm (reds and yellows) colors represent areas where the water level is higher than average. White or pale areas represent areas where the water level is roughly the same as the average. Cool colors (blues and purples) represent areas where the water level is lower than average.

10. Tell students that they will be accessing real data using the Data in the Classroom website. Their job will be to use the AVISO satellite data tool to create a global map of sea surface height from December 2005. If conducting this activity in class, you may want to keep the *Teacher Master: Monthly Average Sea*

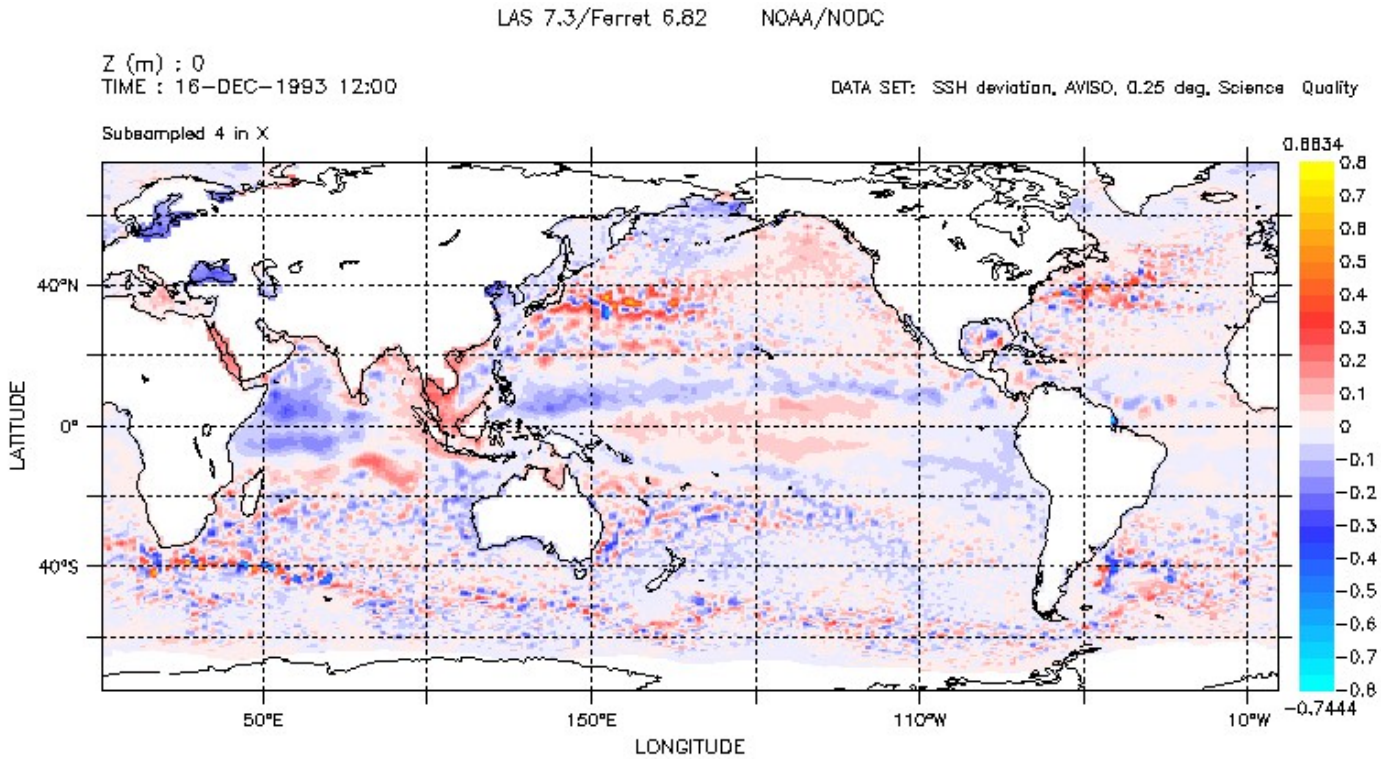
Surface Height Deviation map for December 1993 on display so that students can answer question 6 on the student worksheet.

11. Students should use a computer (or a projected image of the December 2005 data map) to complete the questions on the worksheet, *Student Master – Interpreting Global Sea Level Data.* An answer key can be found on page 25.

12. Check for Understanding: After completing Level 2, you may optionally use the Level 2 quiz on the website as an assessment tool.

13. Optionally, students can explore more recent data from the Jason-2 satellite using the NOAA/PMEL tool. For additional opportunities to explore data using the satellite tools on the Data in the Classroom website, see the online list of sample research questions at Level 5 – Design Your Own Investigation.

Monthly Average Sea Surface Height Deviation, December 1993



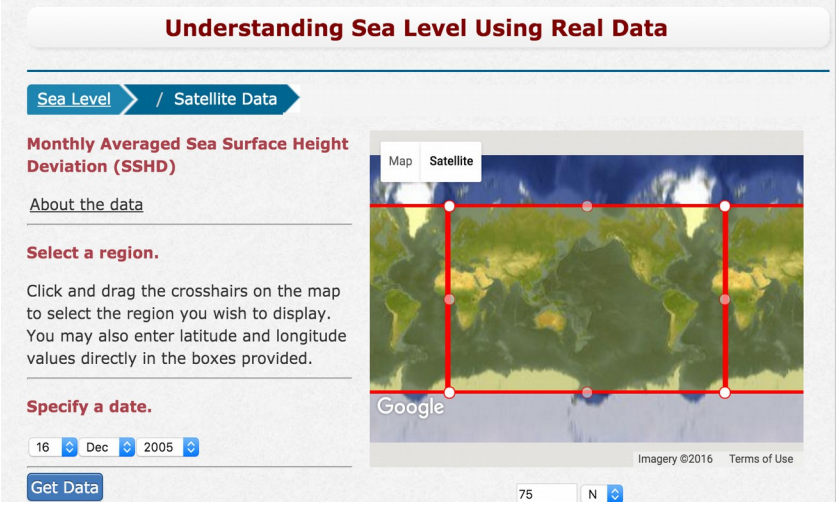
Sea Surface Height Deviation: monthly (m)

Student Master

Interpreting Global Sea Level Data from December 2005

Instructions –

- Visit dataintheclassroom.noaa.gov. Click on 'Sea Level.'
  Next, click on 'Satellite Data' located on the left side of the page.
- Locate the AVISO tool and the heading 'Specify a date.' Use the dropdown menu to select December 16, 2005.
- Click the "Get Data" button.



Questions –

1. Locate and label: a) the equator, b) the Pacific Ocean, c) the EASTERN tropical Pacific Ocean and d) the WESTERN tropical Pacific.
   Question: Is the sea level in the WESTERN Pacific higher or lower than mean sea level? _____
2. What is the highest measured sea surface height deviation (above zero) in the WESTERN Pacific? _____
3. What is the lowest measured sea surface height deviation (below zero) in the EASTERN Pacific? _____
4. What is the approximate difference in sea surface height between the eastern and western Pacific? _____
   Hint: to find the answer, subtract '*your answer for question 2*' from '*your answer for question 3.*'
5. Propose an explanation for these differences in sea surface height.

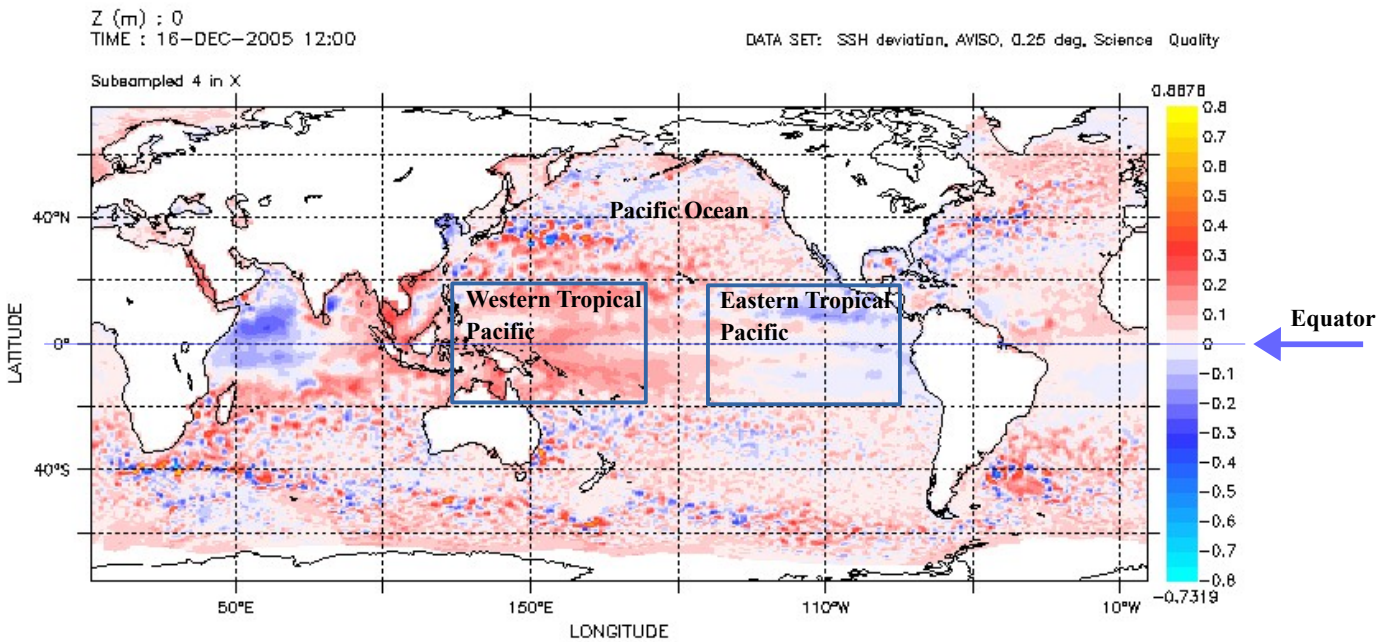
   _____

6. Compare data maps from December 1993 and December 2005. What is a major difference between the two maps? Propose an explanation.

   _____

Answer Key

Interpreting Global Sea Level Data from December 2005



Questions –

1. Is the sea level in the WESTERN Pacific <u>higher</u> or <u>lower</u> than mean sea level? Mostly higher
2. What is the highest measured sea surface height deviation (above zero) in the WESTERN Pacific? Approximately 0.3 m
3. What is the lowest measured sea surface height deviation (below zero) in the EASTERN Pacific? Approximately -0.1 m
4. What is the approximate difference in sea surface height between the eastern and western Pacific? Approximately 0.4 m (15 inches)
5. Propose an explanation for these differences in sea surface height. In your explanation, refer to the demonstrations you saw in class.
   As the trade winds blow across the Pacific from east to the west, water moves and builds up in the western Pacific.
6. Compare data maps from December 1993 and December 2005. There is a change in color scale (to mostly red). This might suggest a potential increase in global sea surface height over time. More data and in-depth analyses would be needed to validate this proposed explanation.

Tides and Local Sea Level

Summary

Grade Level: 6-8

Teaching Time:

Two 45 minute periods

Activities:

- **Generate charts of real tide data.**
- **Calculate means**

Vocabulary

Gravity – the force of attraction that causes objects on Earth to fall to the center of the Earth.

Tide – periodic rising and falling of the sea surface that results from gravitational attraction of the Moon and the Sun acting on the rotating Earth.

Tidal range – difference in height between successive high waters and low waters.

Tidal period – elapsed time between successive high waters and low waters.

Mean low water (MLW) – a reference point for measuring tide heights based on historical data. MLW is the average water height observed at low tide during a 19-year period.

Objectives

Students use real data to describe the cyclical patterns of tides and how tides contribute to changes in sea level. Students use data to construct a diagram describing the approximate orientation of the moon relative to the earth during a given time period.

Background

In Levels 1 and 2, students learned about global sea level, how it is measured and why it is important to study. In this level, students investigate sea level changes at a local scale. Students will focus on the regular, daily changes in sea level due to *tides*.

Day-to-day and month-to-month, tides are generally the largest source of regular fluctuations in sea level. Tides are generated by the gravitational attraction of the Moon and Sun on the ocean's waters. Because the Moon is much closer to the Earth than is the Sun, its impact on ocean tides is larger despite the Sun's greater mass. The gravitational pull of the Moon causes water to bulge away from the Earth at the point closest to the Moon. At the same time, centrifugal force causes a similar bulge on the opposite side of the Earth. As the Earth spins on its axis, different parts of Earth's surface move through these tidal bulges, resulting in a cycle of high and low tides around the globe.

The Sun also plays a role in producing tides. As the Moon orbits the Earth, its position relative to the Earth and Sun changes. Sometimes the Moon and Sun are lined up with the Earth, and the resulting gravitational pull of both bodies causes higher tides. These are called spring tides, and they occur during full and new Moon phases. During quarter Moon phases, when the Moon and Sun are not in line with the Earth, lower neap tides are produced.

Curriculum Link

You can use this activity to supplement other material in your middle school physical science curriculum, particularly material dealing with tides and the gravitational pull of the Moon.

Tidal high and lows are not the same everywhere and local variations can depend on different factors including the shape of the coastline and the depth of the ocean basin. Generally, along most coastlines including the U.S Atlantic and Pacific, there are two high tides and two low tides each day. In contrast, along the Gulf Coast, there is one high tide and one low tide each day. In addition to tidal frequency, the magnitude of the tide can also vary from place to place. The difference in height between a high tide and a succeeding low tide is called the *tidal range*. The highest tides in the United States can be found near Anchorage, Alaska, with tidal ranges up to 12.2 meters (40 feet).

NOAA measures and monitors local changes in sea level by using an array of permanent monitoring stations around the United States. Over the years, the technology for recording tides has changed from early mechanical recorders to modern acoustic and electronic devices. Today, this network of monitoring stations records tide measurements electronically every six minutes at 3000+ stations around the country. The data is transmitted to NOAA headquarters via satellite where it is processed, archived, and made available online.

Materials

- **Computer or overhead projector and access to the internet**
- **Student Masters – copies for class**
- **Teacher Master – or map images saved to your computer.**

Preparation

1. Prepare materials needed for this activity (see column at left).

    a) Preview the *Sea Level Rise* video available on the Sea Level section of the Data in the Classroom website. The first 3:45 minutes of the video focuses on changes in sea level associated with tides.

2. Familiarize yourself with the 'Tide Data' tool and features on the website by following the steps outlined below:

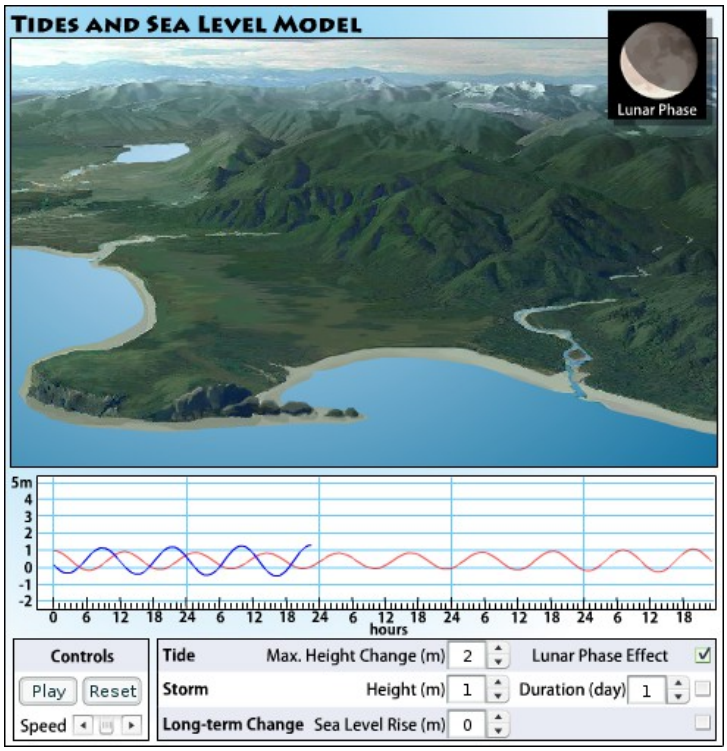
    a) Visit dataintheclassroom.noaa.gov and find the Sea Level module. Next, follow the link to 'Tide Data' located in the

left-hand navigation bar.

b) Select a location from the dropdown list of recording stations. Select a start and end date, for example 05/01/2016 – 05/05/2016. Click 'Get Data.'

c) Use *Teacher Master – Interpreting Tide Data* (page 34) to familiarize yourself with the various features of the online tide chart. Note that the predicted and actual tide data appear as you move your cursor over the tide chart. Click inside of the legend (below the chart) to hide the blue tide predictions, if desired. Scroll down to the features below the chart to adjust options and replot the chart. Practice saving the chart to your computer.

3. Familiarize yourself with the online 'Tide Model' tool on the website so that you can demonstrate it to the class. The purpose of the interactive tide model is to help students see the effects of



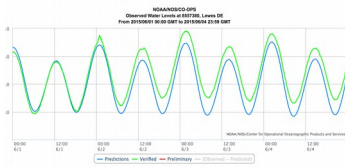
typical changes in water level. It is a simple model, but it can be programmed with values students derive from real data in order to help them visualize how different factors influence water level.

Use of the tide model is optional in this activity, but if you have a computer and projector, the applet is a helpful tool for illustrating and discussing changing water level along a coast.

a) Visit dataintheclassroom.noaa.gov, and find the Sea Level module. Next, follow the link to 'Tide Model' located in the left-hand navigation bar. Watch the video tutorial. You can optionally use the model to help illustrate how water levels constantly change. To program the model to show a typical tidal change, look for the line of controls labeled 'Tide.'

b) Enter 1.2 meters in the box labeled Max. Height Change. Click the Play button to start the model. The model will illustrate the changing water level height in two ways: first, as an animation of water rising and falling along the image of the coastline; and, second, as an animated graph showing the change in water level over time. The image and graph are synchronized. Pause the model and enter different numbers to change the water level behavior.

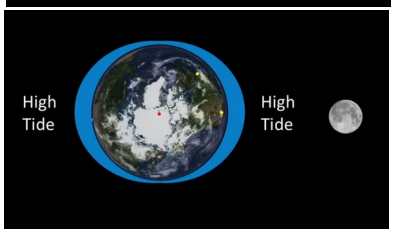
To Display



Generate this image at

dataintheclassroom.noaa.gov.

Video



View this video at

dataintheclassroom.noaa.gov

Procedure

1. Engage students in a discussion about tides, asking "what are tides" and "what causes tides." Use the *Teacher Master – What Causes Tides?* (page 33) and/or view the first two minutes of the video 'Sea Level Rise' found via a link on the Data in the Classroom website. Explain spring and neap tidal patterns.

2. You may choose to use the 'Tide Model' tool on the website to help students visualize how tides affect coastal areas.

3. Next, use a computer and projector to demonstrate how to use the website to generate graphs of tide data. Refer to the Preparation steps described on page 27. Show students how to explore the many tides stations where data is monitored using the Google map interface.

4. Use the *Teacher Master – Interpreting Tide Data* (page 34) to help students learn to read a tide chart. Introduce axes, definitions and chart features below.

   - The y-axis on the chart shows the height of the water relative to the mean low water (MLW). Mean low water is a reference point used by scientists for measuring tide heights based on historical data. MLW is the average water height observed at low tide during a 19-year period.
   - The x-axis shows the date and time of the water level observations. Look carefully at the time scale. In the example shown on the Master, the x-axis is labeled every 12 hours. 00:00 indicates midnight.
   - Along the y-axis, the measured difference in height between a high tide and a succeeding low tide is the **tidal range**.
   - Along the x-axis, the measured length of time between consecutive low tides or consecutive high tides is the **tidal period**.

- The green and blue lines indicate the predicted vs actual measurements of the tide. When using the website, students can simplify the graph and make the blue 'tide prediction' data disappear from view by clicking on 'predictions' inside of the chart legend.

5. Explain the student activity described in the Student Master (pages 35-37). Demonstrate for the students how to use the tide tool on the website and how to complete the table (page 37).

6. Students will need access to the internet to conduct this activity. Depending on the setting, this can be done in class (individually or in groups) or assigned as homework. You may ask your students to print or save their tide charts and turn them in with the completed activity.

7. Students may present their findings to the class, comparing observations of tidal patterns at their chosen vacation spots.

   - Answers: Question 2C (length of tidal period) should be similar across nearly all locations, approximately 12.5 hours, with the exception of some locations including the Gulf Coast. Answer to question 2D is 'tidal period.' Question 3, regarding tidal range, will vary. It is important to note that the mean that students calculate is ONLY a mean across a period of two or three days and cannot be used to compare tidal ranges, generally, from one location to another.

   - For more information about tides and why they vary in range and frequency, visit NOAA's Tides and Water Levels Education and Tides and Currents Education web pages.

8. Check for Understanding: After completing Level 3, you may optionally use the Level 3 quiz on the website as an assessment tool.

Assessment Rubric

In assessing student performance, consider how students approached analyzing their tide data and creating a model to describe the approximate orientation of the moon relative to the earth.

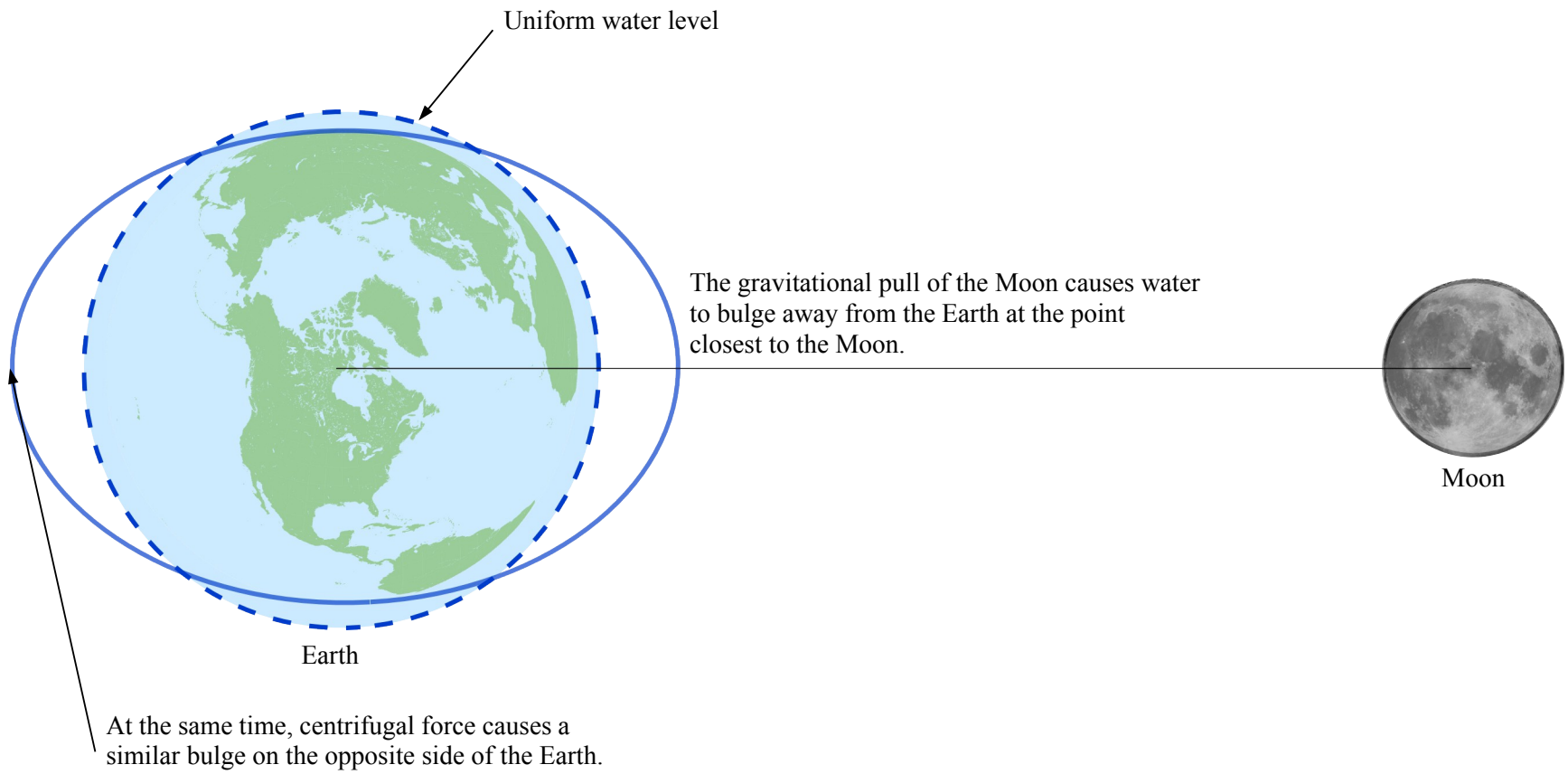
Successful student work may include:

- Correct use of the tide chart to measure tidal range and period.
- Calculation of mean tidal range.
- A working definition of a mean or average.
- Correct use of tide chart to identify monthly spring and neap tidal patterns.
- Ability to develop an accurate diagram describing the orientation of the moon relative to the earth using data from the tide charts.

Depending on the monitoring station and time period selected, the tide data chart may look different than the example charts provided in these pages. Students may encounter multiple small highs and lows that they may find difficult to interpret. NOAA's Tides and Water Levels Education and Tides and Currents Education web pages may aid in the interpretation of tide charts, if needed.

Teacher Master

What Causes Tides?

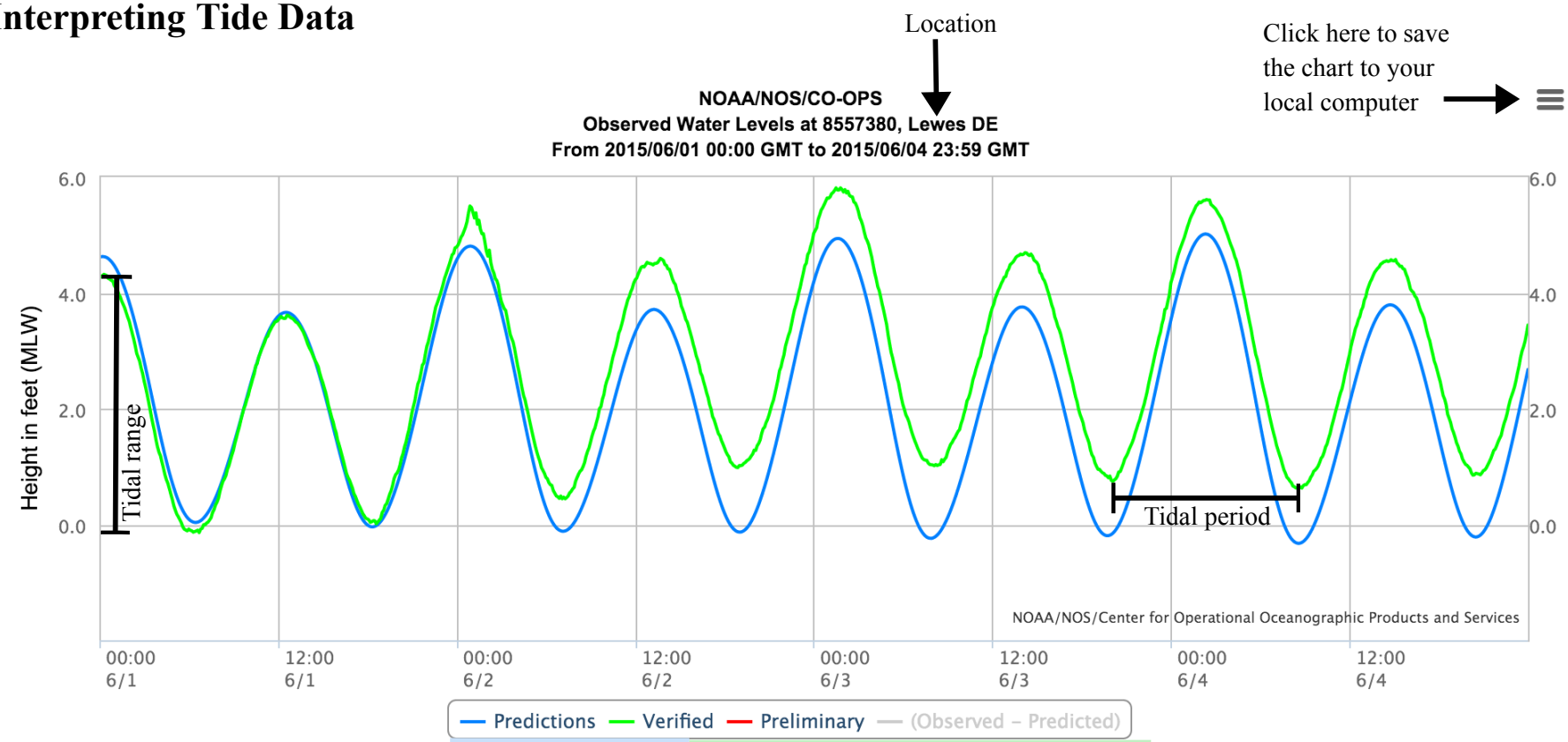


Adapted from Sverdrup, K. & Armbrust, E. V. (2008). *An Introduction to the World's Oceans*, 9th ed. McGraw-Hill. Figure 11.5, p. 284.

Moon image: NASA

Teacher Master

Interpreting Tide Data



Blue line = The predicted height of the tides.

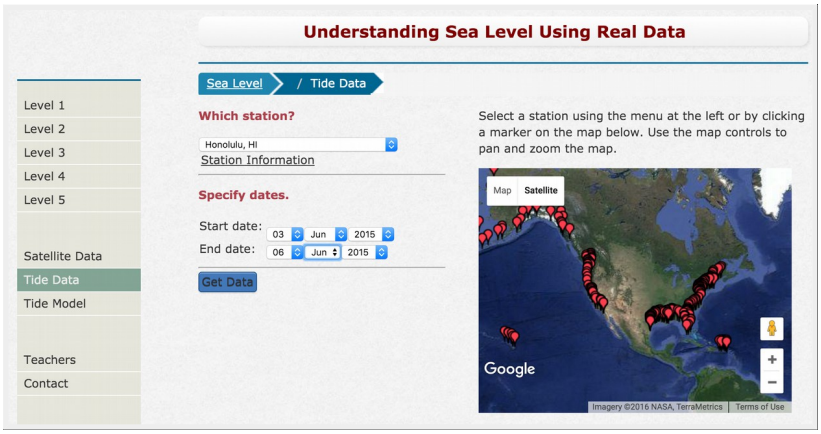
Green line = The actual, verified height of the tides. May vary from predictions due to wind, rain, etc.

Along the y-axis, the measured difference in height between a high tide (4.3 ft) and a succeeding low tide (-0.1 ft) is the **tidal range**. In the case above, the tidal range equals 4.4 feet.

Along the x-axis, the measured length of time between consecutive low tides or consecutive high tides is the **tidal period**. In this case, the low tide on the evening of June 3rd was at 8:00 PM (20:00) and the following low tide was at 8:30 AM. Tidal period equals 12.5 hrs.

Student Master

Accessing Online Tide Data



Every day, the regular rise and fall of the tides contribute to changes in sea level. If you live by the coast, or take a trip to the shore, the tides can influence your daily activities. Using tide charts can help you determine the best times to go fishing, tide pooling or surfing. Tide charts can also help you decide the best times to see wildlife like resting harbor seals or mating horseshoe crabs. In this activity, you will learn to access and interpret tide data from a real (or imaginary) trip that you took to the shore last summer.

To get started, follow the instructions below.

- Visit [dataintheclassroom.noaa.gov.](dataintheclassroom.noaa.gov) Click on 'Sea Level.' Next, click on 'Tide Data' located in the navigation menu on the left side of the page. You should see a page that looks similar to the image above.

- Choose a real or imaginary vacation spot by zooming into a place of interest on the Google map (e.g. Hawaii) and click on a nearby red marker (e.g. Honolulu). The red markers indicate places where tide data is available.

- When did you go on your vacation? Specify any start and end date over a period of 3 days (e.g. June 1, 2016 – June 3, 2016).

- Click the 'Get Data' button. A tide chart should appear.

- Find the legend located directly beneath the chart. Inside the legend, click 'Predictions.' The blue line should disappear, leaving only the 'verified' tide data visible on the chart. Save or print the chart, if possible.

- Use the online tide chart to answer the questions on the following pages.

Student Master

Your Tidal Excursion

Vacation location (station name): _____ Start Date:_____ End Date:_____

1. How many high tides and low tides were there on your first day of vacation? _____

2. On your second day of vacation, you explored the shoreline at low tide in search of your favorite sea creature, _____.

   a) What time was the low tide? _____

   b) You had so much fun exploring that you went out to the shore again on the very *next* low tide. What time was this low tide? _____

   c) How much time passed between these two consecutive low tides? _____ hours

   d) The measured length of time between these two low tides is called the _____

3. What was the approximate mean tidal range during your vacation? *To answer the question, follow the instructions below and complete the table on the next page. An example table is below.*

   - Record the height of the first high tide and the first low tide in your table (see example below).
   - Calculate the tidal range, or the change in sea level, between the first high and low tide.
   - Record the height of the next consecutive high and low tides, completing the table. Calculate the mean tidal range.

Table: Example

Date	Low tide or high tide	Tide height (ft)	Tidal range (high tide height – low tide height)
06/01/2016	High	4.3 ft	
06/01/2016	Low	-0.1 ft	4.3 - (-0.1) = 4.4 ft
06/01/2016	High	3.6 ft	3.6 - (-0.1) = 3.7 ft

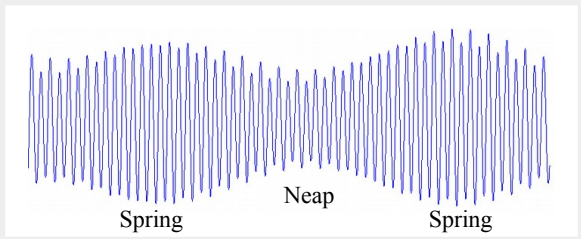
Table: Mean Tidal Range

Date	Low tide or high tide	Tide height (ft)	Tidal range (high tide height – low tide height)
	High		
	Low		
	High		
	Low		
	High		
	Low		
	High		
	Low		
		TOTAL	
		MEAN TIDAL RANGE	

4. Next, find the gray box located below your online tide chart with the heading 'Options for.' Adjust the 'to' and 'from' dates so that they encompass a full month around which you took your vacation (e.g. June 1, 2016 – June 30, 2016). Click the blue 'Plot' button on the bottom right of the page to update your tide chart. Look for evidence of spring and neap patterns. Use the graphic (at right) to help you.

   Did you take your vacation during a spring or neap tidal cycle (or sometime in between)?

   _____



5. On a separate sheet of paper, make a diagram of the approximate orientation of the moon relative to the earth and sun during your 3-day vacation. Color a blue tidal bulge around the earth, indicating an approximate spring tide or neap tide. Label your diagram.

Measuring Storm Effects

Summary

Grade Level: 6-8

Teaching Time:

Two 45 minute periods

Activities:

- **Get water height data for storm events.**
- **Create a research plan using real data.**
- **Use interactive tide model to visualize storm effects.**

Vocabulary

Storm tide – a storm surge event that takes place along the coast, which produces exceptionally high water. A storm tide is generated by storm, wind stress, and low atmospheric pressure. Storm surges are made even higher when associated with high tide and shallow depths.

Objective

Using what they learned about typical tide measurements at a location, students will use NOAA tide data to analyze the effect of storms on coastal sea level.

Background

While tides typically cause the greatest fluctuations in sea level over relatively short time scales, storms caused by wind and barometric pressure changes can have a big impact on local water levels in coastal areas. A storm surge happens when water is pushed toward the shore by high powered winds from a storm such as a hurricane. The storm interacts with the normal tide to create a storm tide that can increase the normal water height by 4 to 5 meters (15 feet) or more. These events can cause extreme flooding in coastal areas. Most coastlines in the United States are only 3 meters (10 feet) or less above mean sea level, which means that storms can be very dangerous for people who live near the coast.[4]

During this lesson, students are asked to answer a research question: How do storm events impact water levels at a coastal location?

4 Ross, A. R.(1995). Introduction to Oceanography. New York: Harper Collins. p. 230.

Materials

- **Computer or overhead projector**
- **Copies of Student Master: Research Project: Determining Storm Surge Height**
- **Copies of Student Master: Data Log Sheet**
- **Rulers**

Procedure

1. On an overhead projector, display a news report from a recent storm. Explain that water level is affected by lots of different factors, not just tides, and that these factors actually compound or add together. If you live along the East Coast, you could use winter storm *Jonas* as an example. *Jonas* hit the coast of the mid-Atlantic in January 2016.

2. Explain that students will continue the investigation of water level from the last activity. This time, they will go online to look at data related to storms. Their task is to make a research plan using real data to describe the effects of storms on coastal water levels. Their goal is to determine the additional effect a storm can have on water height.

3. Students will need to access the internet to generate and save data maps and graphs. Depending on the setting, this can be done in class or assigned as homework. Students should follow the instructions on the *Student Master: Research Project: Determining Storm Surge Height*, and record their data and calculations on the table provided.

4. When students have finished gathering data and making calculations, conclude the activity by simulating a storm using the online 'Tide Model.'

   Ask for a volunteer to enter his or her data into the model. Look for the line of controls labeled 'Storm.' The student should enter the storm surge height (in meters) and duration he or she calculated from question 5 (page 42). When you are ready, click the checkbox to activate the storm.

Assessment Rubric

In assessing student performance, consider how students approached collecting their tide data, and what calculations they made based on the data.

Successful student work may include:

- Correct use of the y-axis to measure height changes.
- A selection of data from a selected station during several different periods of time. In particular, students should attempt to determine how long the storm impacted the area – from when the storm effect was first seen to when it went away.
- Determine the maximum high tide recorded during the storm.
- Calculation of the difference between the verified high tide and the predicted high tide during the storm event.

Research Project: Determining Storm Surge Height

You are joining a team of scientists who are studying the effects of storms along the U.S. coast. Your task is to pick a storm event for a coastal location and design a research plan to help you gather data about the water height before, during, and after the storm. You already know something about the typical or average water height in the area due to tides. Your goal now is to determine the additional effect a storm can have on water height. Once your plan is accepted, you are to carry out your data collection, analyze it, and report your findings to the team.

Planning your project:

1. **Form a hypothesis before designing your investigation.**

   Research question: How do storm events impact water levels at my coastal location?

   Hypothesis: Storms produce a surge, which raises water levels above what would normally occur during a typical tide cycle.

2. **Design a plan to test your hypothesis and answer your research question.**

   What do you need?

   a) More information: Do you need more information about specific storm events and their effects?

   b) Specific data: When you go online to collect data, what dates will you look at, and what charts will you generate?

3. **Go online and get data.**

   a) Visit dataintheclassroom.noaa.gov and find the Sea Level module. Next, follow the link to 'Tide Data' located on the left side of the page.

   b) Choose a location you wish to study, and write the name on your data sheet. Using the form on the website, select the location from the list of recording stations.

   c) Search internet news and weather sources for information about storms that impacted the area near your location. Identify a storm event to investigate and take note of the date of the storm.

d) Using the form on the website, select start and end dates around the time of the storm event you found.

e) Click the 'Get Data' button.

f) If you have access to a printer, print a copy of the tide chart. Otherwise, save a copy to your computer so that you can refer to it later.

4. Complete the Data Log Sheet. Record data for each high tide on your chart.

5. Analyze the data.

a) What was the height of the highest storm tide?

b) At the time of the highest storm tide, how much did the sea level rise above the predicted (or expected) sea level?

c) How long did the storm last at the location you selected? Use the data on your tide chart to answer the question.

6. Draw conclusions.

Write down what you learned from your investigation. Use your data to help you decide if your hypothesis was supported.

Student Master

Data Log Sheet

Station Name:

Storm name and/or description:

Hypothesis:

Date	Time of High Tide	Predicted Tide Height (ft)	Verified Tide Height (ft)	Storm surge (difference between the verified and predicted tide height)

Designing Your Own Investigation

Summary

Grade Level: 6-8

Teaching Time:

Two 45 minute periods

Activity:

- **Design an investigation using real data to examine a hypothesis.**

Objective

Students will apply what they have learned to consider sea level data on a larger scale. To do this, students will design their own plan to answer a research question using real data.

Background

Students have used real data to begin to understand changes in water levels. Most of the work has been an examination of how sea level changes on a relatively small scale – at a single location or station and over a very short period of time. Now, it is time for students to examine sea level on a larger scale by developing their own investigation using real data.

Students should be encouraged to develop their own research questions and hypotheses for this activity. In general, questions that lead them to considering changes in sea level on a larger scale will provide a good starting point.

Students choosing to look at changes in sea level over time will naturally consider the prospect of long-term sea level rise due to climate change. It may not be easy for students to detect and interpret long-term trends using the kinds of data tools and analysis available to them. However, sample research questions with links to additional data and resources are available on 'Level 5' of the Sea Level section of the website. Students can be challenged to apply what they have learned about reading and understanding data to interpret a variety of data products.

Materials

- **Copies of Student Master: Research Project: Designing Your Own Investigation**
- **Copies of Student Master: Data Log Sheet**
- **Student access to computers with Internet connections**

Procedure

1. Distribute the *Student Master: Research Project: Designing Your Own Investigation* and *Student Master: Data Log Sheet.*

2. Guide student selection of a research question (or allow students to make up their own) that is appropriate to their academic experience. The website provides a list of sample research questions on Level 5 of the Sea Level section. Review student hypotheses to make sure they are appropriate and that students will be able to support or disprove them using the kinds of data they will have available.

3. Have students design a research project to answer the question.

4. Check each research project plan before students begin, to see if it is in keeping with the question and the resources available.

5. Assign students to use the tools at dataintheclassroom.noaa.gov to access the data they need.

6. When students complete their research, provide time for them to present their findings.

7. Use the student presentations as an opportunity to relate this investigation to the current news about global climate change.

8. Optional extension: If your students' data investigations are focused on sea level rise, they may naturally be interested in learning how sea level rise will impact their community or favorite place along the coast. What roads, homes, beaches or parks are at risk of flooding? Students can use the interactive map, NOAA Digital Coast, to visualize the potential impacts of rising sea levels. By moving the slider bar at the upper left of the page, they can increase sea levels up to 6 ft.

Student Master

Research Project: Designing Your Own Investigation

Planning your project:

1. **Develop a research question. Then form a hypothesis to investigate.**
   Be sure to review your hypothesis with your teacher before you begin.

   Research question:
   Hypothesis:

2. **Design a plan to test your hypothesis and answer the research question.**

   What do you need?

   a) More information:

   b) Specific data:

3. **Go online and get data.**

   a) Visit dataintheclassroom.noaa.gov, and find the Sea Level module.

   b) Follow the link to 'Satellite Data' or 'Tide Data.'

   c) Using the form, select the data and parameters you wish to look at.

   d) Click the "Get Data" button.

4. **Use the Data Log Sheet to keep a record of the data you select, so you can refer to it later.**

5. **Analyze the data.**

6. **Draw conclusions.**

   Write down what you learned from your investigation. Use your data to help you decide whether your hypothesis is supported. If your hypothesis is not supported, think about other data you might need to collect.

Student Master

Data Log Sheet

As you use the online data access form to select data about sea level, keep a record of the parameters you select on this data log sheet. Your data log will help you remember and keep track of the data you have explored. Consider whether each new piece of data helps support or disprove your hypothesis.

	Data set	Region / Station	Dates	Notes