# Understanding Sea Level Using Real Data

## 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 National Standards in Mathematics, Science, and Geography. See page 8.**

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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National Marine Sanctuaries

National Estuarine Research Reserve System

IOOS Integrated Ocean Observing System

# Introduction

Sea level is an interesting topic, which is particularly relevant in the context of climate change and the prospect for long-term sea level rise. Data from the last hundred years already show a trend of rising sea level around the world.

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 at different scales. 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. Many of these different observation systems from satellites and ground stations are part of the U.S. Ocean and Coastal Observing System.

Studying sea surface height also provides good linkages with middle school mathematics curricula and standards. Charts of sea surface height data are excellent examples of the use of mathematical mean or average. Through these activities, students will learn how to interpret real data that is measured relative to an historical mean.

# Sea Level Basics

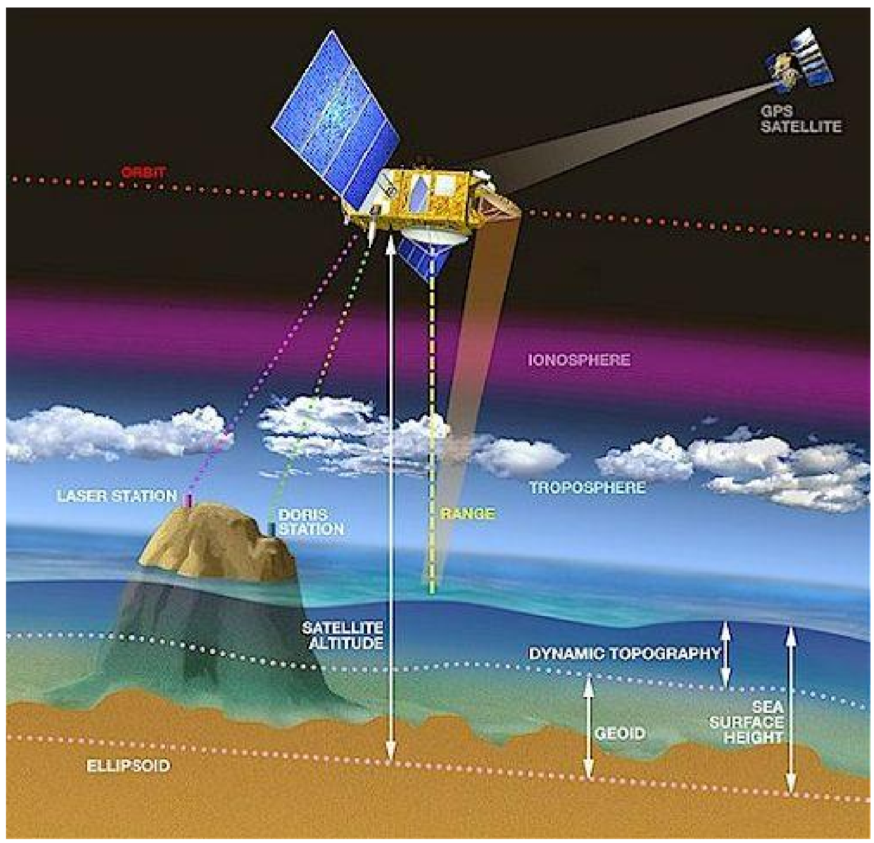
**Web Links**

**For links to helpful Web sites about Sea Level, visit www.dataintheclassroom.org.**

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.

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 250 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

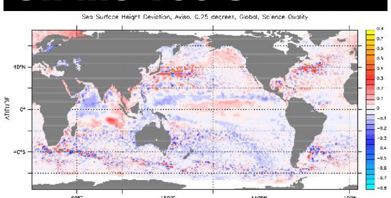
1 Entry

# 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.

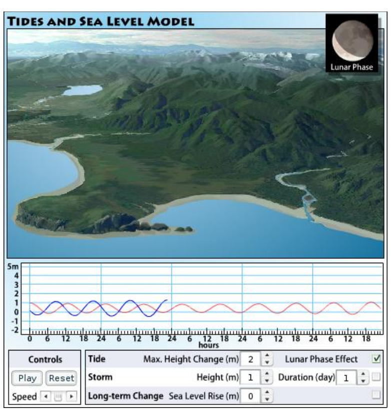
The levels serve a dual purpose. They are designed to engage students in increasingly sophisticated modes of understanding and manipulation of data. They are also intended to help you, as a teacher, familiarize yourself with online tools for accessing data and to provide you with models for integrating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

## Online Tools



**Satellite altimetry data is available at www.dataintheclassroom.org.**

These activities utilize technology in several ways. First, the dataintheclassroom.org Web site 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.org, students can use a simple, user-friendly interface to access data in a way that directly supports these activities.




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

In addition to accessing data, the Web site includes an interactive tide model to help students picture the effects of rising and falling water levels. More information on the use of this model is found in activities at Levels 2, 3, and 4.

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

Dwyer, D. C., Rwgstaff, C., & Shanholtz, 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 investigate and measure what happens to water height during a storm event.

3 **Adaptation: Reading Tide Data:** Students will apply their skill calculating the mean to real tide data in order to characterize the typical tide behavior at a selected location.

2 **Adoption: Finding the Mean:** Students will generate some sample data using a simple model of the ocean. Using these data, they will compute values for mean and deviation in order to understand how real data is reported.

1 **Entry: Reading Sea Surface Height Data:** Students will learn how to read maps of global sea surface height deviation (SSHD) based on satellite altimetry and relate what they see to simple hands-on demonstrations of forces that influence sea surface height. Teacher-led discussion and activity.

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 dataintheclassroom.org Web site 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 in a library or computer center outside of class.

## National Education Standards

This curriculum module is aligned with the national education standards in science, math, and geography for grades 5-8. The table below presents a list of core standards covered at the different activity levels. These standards-based activities are designed to be easily integrated into pre-existing school science and math curricula, not as "add ons" but as ways to enhance existing standards-driven curricula by using real-time data. The standards that support this curriculum facilitate learning by having students practice using real-time data within the context of a variety of standards- and inquiry-based activities.

| | **Mathematics**[2] | **Geography**[3] | **Science**[4] |
|---|---|---|---|
| **Level 1** | ■ Use tables, maps, and graphs to describe situations. | ■ Use the characteristics, functions, and applications of satellite-produced images and models. | ■ Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to such factors as distance and location.<br>■ Physical Standard Content Standard B Interactions of Energy and Matter: Waves on water have energy and can transfer energy when they interact with matter. |
| **Level 2** | ■ Use observations about the differences between two different characteristics on the bases of maps, histograms, box plots, and scatter plots.<br>■ Select and use appropriate statistical methods to analyze data by finding, using, and interpreting measures of center and spread, including the mean.<br>■ Use visualization, spatial reasoning, and modeling to solve problems. | ■ Use mental models to identify the locations of certain physical features on maps to mark major ocean currents, wind patterns, sea level deviations, and climate regions on a map. | ■ Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to such factors as distance and location. |

2 National Council of Teachers of Mathematics. (2001). *Principles and Standards for School Mathematics*. Washington, D.C.
3 Geography Education Standards Project. (1994). *Geography for Life: The National Geography Standards*. Washington, D.C.: National Geographic Society Committee on Research and Exploration.
4 National Academy of Sciences. (1996). *National Science Education Standards*. Washington, D.C.: National Academy Press.

| | Mathematics | Geography | Science |
|---|---|---|---|
| **Level 3** | ■ Develop and use tables, graphs, and rules to describe a situation.<br>■ Apply techniques, tools, and/or formulas to determine measurements to use as common benchmarks from which to select appropriate methods for estimating measurements. | ■ Use mental models to identify locations of certain physical features on maps or plots to mark major ocean currents, tides, and landforms. | ■ Earth-Space Science: All students should develop an understanding of the Earth and Solar System.<br>■ Physical Standard Content Standard B: Motion and Forces: Gravitation is a universal force that each mass exerts on any other mass. The strength of the gravitational attractive force between two masses is proportional to the masses and inversely proportional to the square of the distance between them. |
| **Level 4** | ■ Solve problems that arise in mathematics and other contexts. Create and use representations to organize, record, and communicate mathematical ideas. | ■ Explain how physical processes help to shape features and patterns on the Earth's surface, as exemplified by being able to compare and interpret maps and charts to explain how physical processes affect features of the Earth's surface. | ■ Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to such factors as distance and location. |
| **Level 5** | ■ Apply and adapt a variety of appropriate strategies to solve problems. | ■ Identify the conditions that cause changes in climate and the consequent effects on ocean levels. | ■ Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as distance, size and location. |

## Ocean Literacy Essential Principles

This curriculum module also supports the following Essential Principles of Ocean Sciences.[5]

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

    d. 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.

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

## Summary

**Grade Level: 6-8**

**Teaching Time: 45 minutes**

**Activities:**

- **Read satellite maps of sea surface height deviation.**
- **Relate map readings to demonstrations of different forces that influence sea level deviation**

## Vocabulary

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

**Pascal's Principle –** a principle that states that pressure applied to an enclosed liquid at rest is transmitted undiminished to every portion of the liquid and to the walls of the closed container.

**Satellite altimetry –** a technique for measuring sea surface height using radar instruments traveling on orbiting satellites.

# Objective

Students will learn how to read maps of global sea surface height deviation (SSHD) based on satellite altimetry, and relate what they see to simple hands-on demonstrations of different forces that influence sea surface height. This is a teacher-led discussion and activity.

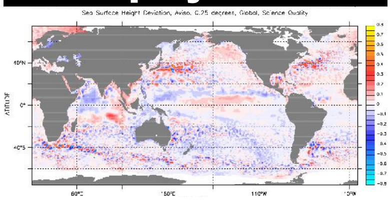
# Background

Researchers believe that sea level worldwide is presently rising. Over the last 100 years, global sea level has risen about 15 cm (6 in.) and recently the rate of rise has increased.[6] To study this phenomenon, scientists need to make good measurements of the sea surface height around the world. One tool they use is satellite altimetry, which allows them to look at a snapshot of SSHD around the world. 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.

Looking at an SSHD map, one sees immediately that sea level is not the same everywhere. Sea surface continually fluctuates due to natural forces, such as the trade winds, tides, waves, glacier melts, density, and gravity.

6 Bindoff, N.L., J. Willebrand, V. Artale, A, Cazenave, J. Gregory, S. Gulev, K. Hanawa, C. Le Quéré, S. Levitus, Y. Nojiri, C.K. Shum, L.D. Talley and A. Unnikrishnan, (2007). *Observations: Oceanic Climate Change and Sea Level. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge, United Kingdom, and New York, NY, USA: Cambridge University Press. pp. 409-410.

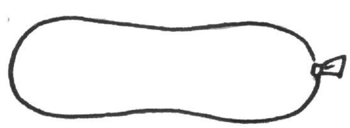
## To Display



**Generate this image at www.dataintheclassroom.org.**

## Tip

**For best results use elongated balloons, but not the professional twist balloons used for making animal sculptures.**



# Preparation

If you have access to a computer and projector, you can display a color version of Monthly Average Sea Surface Height Deviation for November 1993 (shown at left). Use the following steps:

1. Visit www.dataintheclassroom.org, and find the Sea Level module.

2. Follow the link to "Satellite Data."

3. Using the form, select the date 16-Nov-1993.

4. Click the "Get Data" button.

5. Save the map image to your local computer. On a PC, right-click with the mouse and select "Save as...." On a Mac, hold down the Ctrl key and click with the mouse.

Alternatively, you can make a transparency of this map for display using an overhead projector. Copy the Teacher Master on page 16.

Prepare the materials you will need for the 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.

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

- 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.

## Materials

- Computer or overhead projector
- Map image saved to your computer or transparency of Teacher Master
- Long balloon
- Ruler
- Clear-glass baking dish
- Straws
- Water
- Blue food coloring
- Copies of Student Master

# Procedure

1. Display the Monthly Average Sea Surface Height Deviation map for November 1993 on an overhead or computer screen. 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.

2. Ask the students the following series of questions.

   a) Do you think the ocean is flat?

   Accept any answer.

   b) Do you think sea surface height is the same all over the planet?

   Accept any answer. Students may refer to color key to explain differences in height.

   c) Can water change its shape? Give examples.

   Accept any answer. For example, students may observe that water changes shape in different containers.

3. Next, explain that you will do two demonstrations to show how water is a fluid with certain characteristics. The first demonstration uses a water balloon.

4. 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. Take a ruler and

measure the height of the balloon three inches from each end of the balloon and in the middle. The heights should be roughly equal. Explain that the water in the balloon is at rest.

5. Next, push down gently on the middle of the balloon with your hand and then measure the height of the balloon 5 cm (2 in.) from each end of the balloon and in the middle. The water height should rise on the ends and decrease in the middle.

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

   Answer: It took a new shape.

7. Explain that the model demonstrates how water can rise or fall in the ocean as well as in a balloon. When sea level falls in one location, it rises in another. 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, weight of a glacier, gravity, tides, or atmospheric pressure systems (such as a low or high pressure system).

8. Explain that water is a fluid, and that a physicist named Pascal stated the following important principle: Pressure applied to an enclosed liquid [balloon or the ocean] at rest is transmitted to every portion of the liquid and to the walls of a closed container.

9. Set up the next demonstration, which uses a straw to imitate the effect of wind blowing across the surface of the ocean. Place the glass baking dish with colored water on the overhead projector.

10. 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.

11. Next, blow harder through the straw and ask students what they observe. The side of the dish farthest away from where you blew from the straw should be a darker blue. Ask students why they think this is so.

    Answer: There may be more water piled up on the opposite side of the dish.

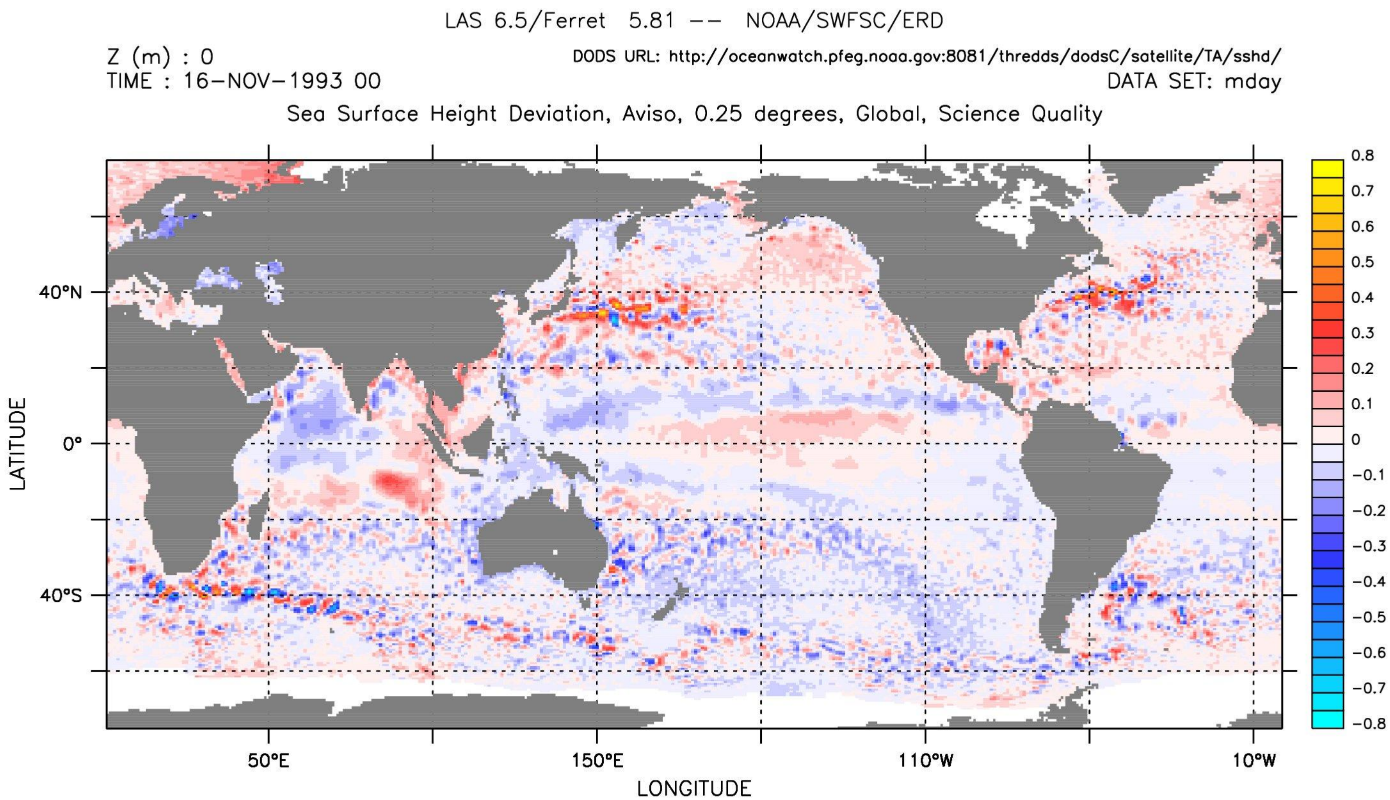
    Explain that the wind can push water around in the ocean, causing water to pile up on top of resting water. This results in greater sea surface height in some locations.

12. Assign students to examine the Monthly Average Sea Surface Height Deviation map for November 1995 and answer the questions on the sheet.

    Answers: Student answers will vary according to locations chosen. Students should be able to explain SSHD by describing the possible effects of wind, glacier height, gravity, tides, or atmospheric pressure systems.

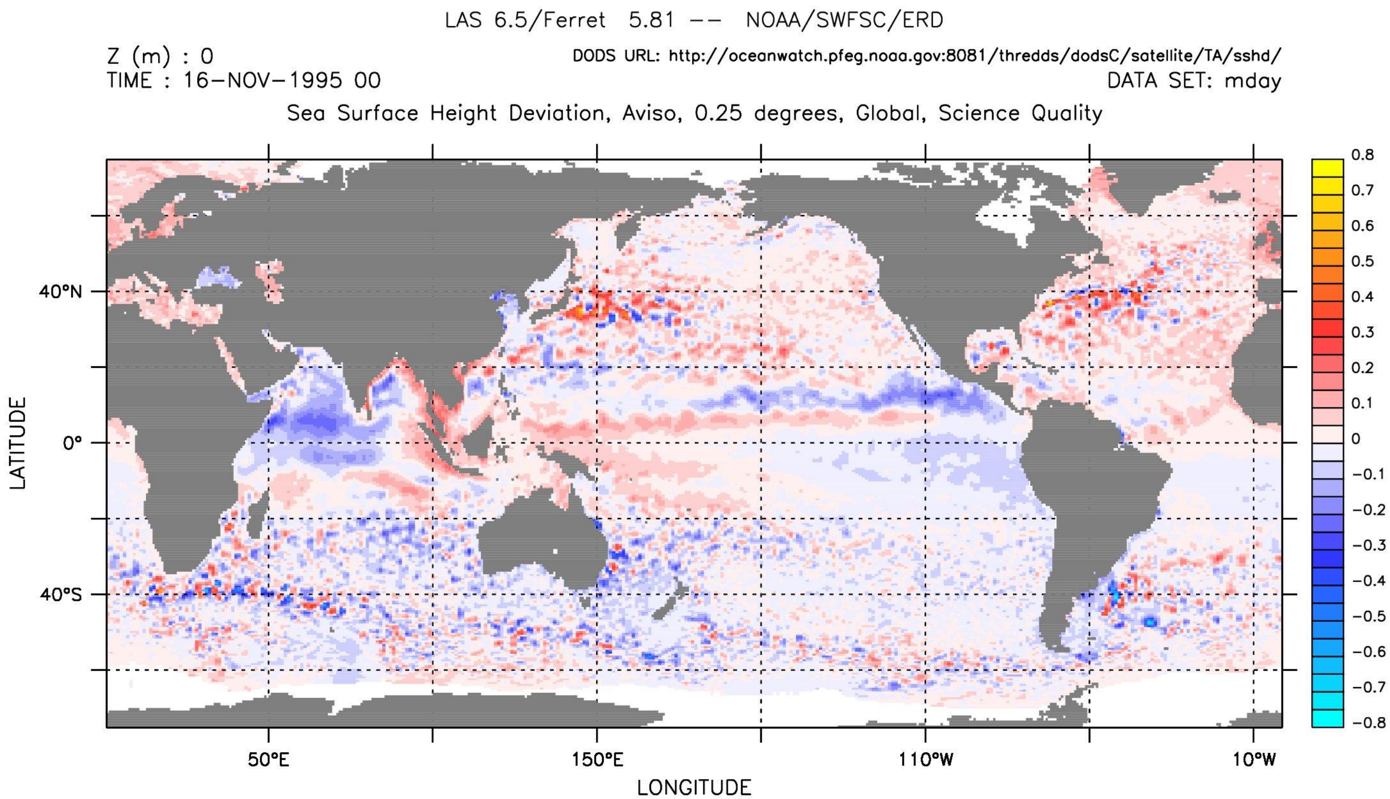
**Teacher Master**

# Monthly Average Sea Surface Height Deviation, November 1993




Sea Surface Height Deviation: monthly (m)

# Monthly Average Sea Surface Height Deviation, November 1995




Sea Surface Height Deviation: monthly (m)

**Questions**

1. Circle three places on the map where the measured sea surface height deviation is more than 0.2 meters above or below average.
2. Record the approximate latitude and longitude of each location you chose.
3. Using the color key, record the sea surface height deviation at each location you chose.
4. Explain what might be happening at one of your locations. In your explanation, refer to the balloon and wind demonstrations you saw in class.

# Finding the Mean

## Summary

**Grade Level: 6 - 8**

**Teaching Time: 45 minutes**

**Activities:**

- **Use a balloon model to generate water level data.**
- **Compute a mean value from the data.**
- **Use an online tide model to illustrate changing water level along a coastline.**

## Vocabulary

**Data –**any information obtained by observing and/or measuring.

**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 generate some water level data, using a balloon as a simple model. Students will calculate the mean and make a chart of their data. By understanding how to report data in terms of deviations from the mean, students will be prepared to interpret real sea level data from different sources.

## Background

The Earth's oceans are not shaped like a perfect sphere of water. Factors such as the shape of the Earth's crust, variations in the planet's gravitational field, winds, and currents cause natural variations in the height of the ocean's surface around the globe. Because of these natural variations, and the fact that the oceans themselves are always in motion, it is difficult to give measurements of sea surface height in absolute terms. Instead, scientists measure the difference between the ocean's height and the expected or average height at any given location.

Understanding the concept of a mean, or average, is important to interpreting water level data at any scale. Satellite-derived sea surface height data and local tide gauge data are both reported as deviations from an expected or mean height.

## Preparation

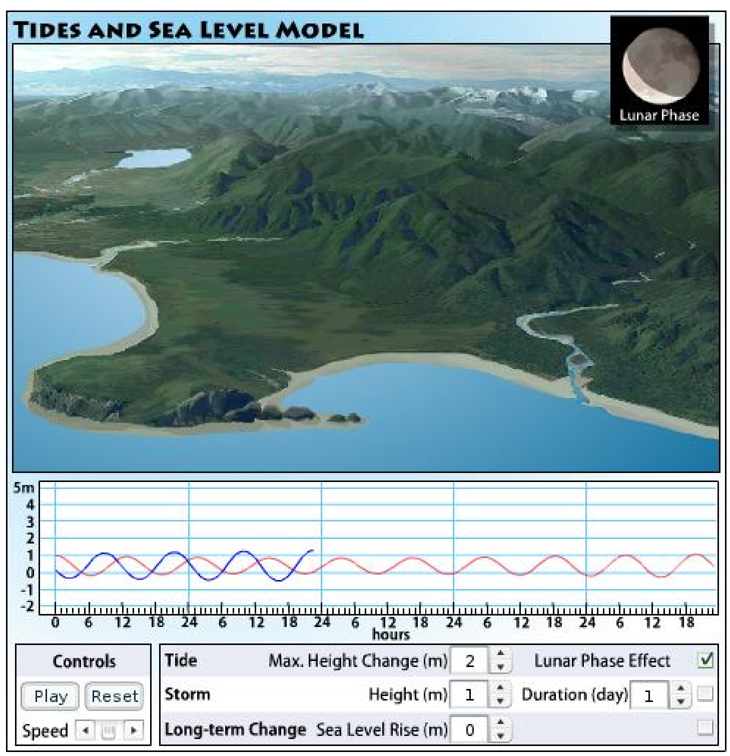
Familiarize yourself with the online tide model, so that you can demonstrate it to the class. The purpose of the interactive tide model is to help students see the effects of typical changes in water level. It is a simple model, but it can be programmed with values students derive from real data in order 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 coastline.

1. Visit www.dataintheclassroom.org, and find the Sea Level module.

2. Follow the link to "Tide Model."

3. In this activity, you will be using 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.



4. Enter 1.2 meters in the box labeled Max. Height Change.

5. 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.

   You can pause the model and enter different numbers to change the water level behavior.

Prepare the other materials you will need. 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.

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

**See an Example**

**A sample spreadsheet showing a graph of water height data is available at www.dataintheclassroom.org.**

In this activity, students will be asked to create data tables and simple graphs using water height data they find on the Internet. If you prefer, students may also use spreadsheet software such as Microsoft Excel to help them with these tasks. This is optional, however.

## Materials

- Computer or overhead projector
- Long balloon
- Water
- Plastic tub or basin
- Ruler
- Paper and marker
- Copies of Student Master: Finding the Mean
- Copies of Student Master: Graph Your Results

# Procedure

1. Display the online tide model on your computer or projector. Program the model with a tidal change of 1.2 meters as described in the Preparation section on page 20.

2. Ask students about the rising or falling water level. If it is always moving, how do you get a general measurement for the water level at a 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.

3. 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. Select two students to gather data to be used by the class.

4. 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.

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

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

7. 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.

   Relate what you just learned to the color scale on the satellite SSHD map.

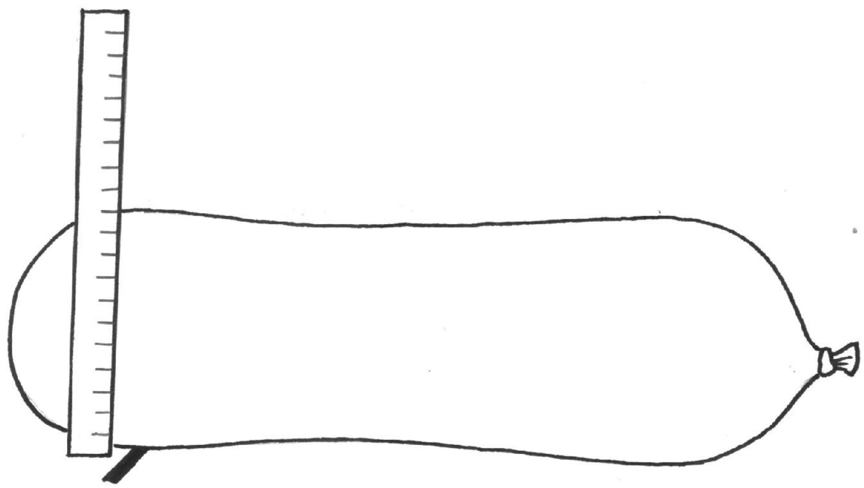
   Answer: The warm (reds and yellows) colors represent areas where the water level is higher than average. White or pale areas represent areas where the water level is roughly the same as the average. Cool colors (blues and purples) represent areas where the water level is lower than average.

8. Finally students should graph their results, following the instructions on the Student Master: Graph Your Results. If they are using spreadsheet software, students may need guidance on setting up their spreadsheet and graphs.

**Student Master**

# Finding the Mean

Sea surface height 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.

   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

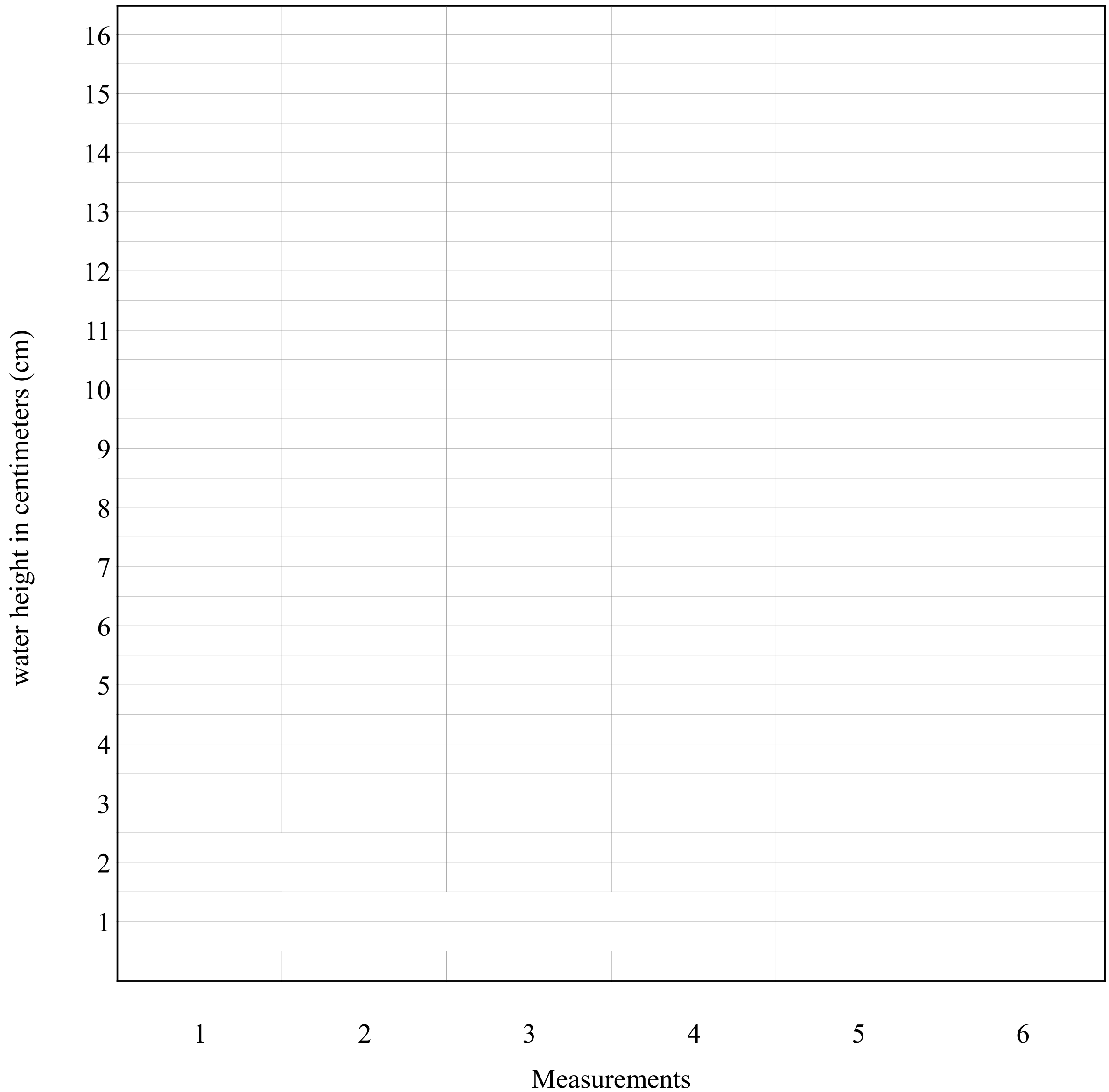
| Measure-ment | Height | (- Mean) | Deviation |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| Total | | | |
| Mean | | | |

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?
3. Relate what you just learned to the color scale on the satellite SSHD map.

**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?

# Reading Tide Data

## Summary

**Grade Level: 6-8**

**Teaching Time:**

**Two 45 minute periods**

**Activities:**

- **Generate charts of real tide data.**
- **Use tide model to help visualize tide effects.**

## 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 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.

## Objective

Students will go online to generate charts of real tide data. Students will apply their skill calculating the mean to real tide data in order to characterize typical tide behavior at a selected location.

## Background

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.[7]

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.

Tides do not occur with the same frequency and magnitude everywhere. Tides influence the rise and fall of water both in the open ocean and along the coasts, although that rise and fall can be much more pronounced near land, which can have an amplifying effect.

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

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 250 stations around the country. The data is transmitted to NOAA headquarters via satellite where it is processed, archived, and made available online.

## Preparation

Familiarize yourself with using the dataintheclassroom.org Web site to generate charts from tide data.

1. Visit www.dataintheclassroom.org, and find the Sea Level module.

2. Follow the link to "Tide Data."

3. Using the form, select "Cape May, NJ" from the list of recording stations.

4. Select a start date for the data you want to retrieve, for example: 08/01/2007.

5. Select an end date, for example: 08/05/2007.

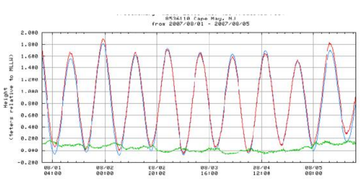
6. Click the "Get Data" button.

7. Save the map image to your local computer. On a PC, right-click with the mouse and select "Save as...." On a Mac, hold down the Ctrl key and click with the mouse.

### 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.**

### To Display



**Generate this image at www.dataintheclassroom.org.**

## Materials

- Computer or overhead projector
- Transparency of Teacher Master: What Causes Tides?
- Tide chart saved to your computer or transparency of the Teacher Master: Looking at Tide Data
- Copies of Student Master: Practice Reading Tide Data
- Rulers

# Procedure

1. On an overhead projector, display the Teacher Master: What Causes Tides? Point out that tides are caused by the pull of gravity between the Moon, Sun, and Earth. Ask students to indicate where the water has a bulge.

   Answer: The water bulges in alignment with the pull of the Moon's gravity.

   Explain that because the Earth and Moon are relatively close to one another in space, the force of gravity between them is strong. The gravitational pull of the Moon causes water to bulge away from the Earth as it tries to move toward the Moon. This effect moves around the globe, as the Earth and the Moon move relative to each other.

2. Display the tide chart from Cape May, NJ (either from the file saved on your computer or using a transparency of the Teacher Master: Looking at Tide Data). Describe features of the chart.

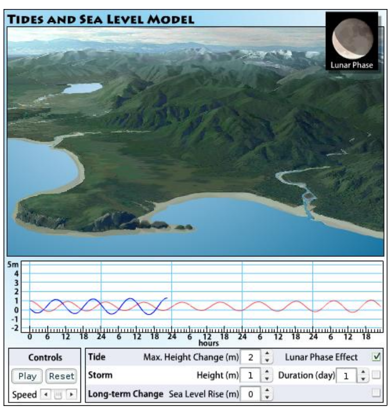
   - The y-axis on the chart shows the height of the water relative to the mean low water (MLW). Mean low water is a reference point used by scientists for measuring tide heights based on historical data. MLW is the average water height observed at low tide during a 19-year period.
   - The x-axis shows 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 20 hours.
   - Along the y-axis, the measurement from the lowest point to the highest point in each tide cycle is the change in water level due to the tide.
   - Along the x-axis, the measurement between consecutive low tides or consecutive high tides is the period of the tidal cycle.

3. Explain that students will go online to generate tide charts for themselves using real data. Their task is to measure the tide height change and period from data collected at a monitoring a station.

4. If you have not done so in earlier activities, use a computer and projector to demonstrate how to use the dataintheclassroom.org Web site to generate graphs of tide data. Refer to the Preparation steps described on page 27.

5. Students will need to access the Internet to generate and save data maps and graphs. Depending on the setting, this can be done in a computer lab or assigned as homework, assuming students have access to the Internet at a library or computer center. Students should follow the instructions on the Student Master and record their data and calculations on the table provided.

**Online Tool**




**Use the tide model to visualize students' data. Visit www.dataintheclassroom.org**

6. When students have finished gathering data and making calculations, conclude the activity with a demonstration to help students visualize their data. Follow the procedure on page 19 to display the online tide model.

   Ask for a volunteer to enter his or her data into the model. Look for the line of controls labeled Tide. Enter the averages he or she calculated from the box on the data sheet 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.

   You can stop the model and enter different numbers to change the behavior.

## Assessment Rubric

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

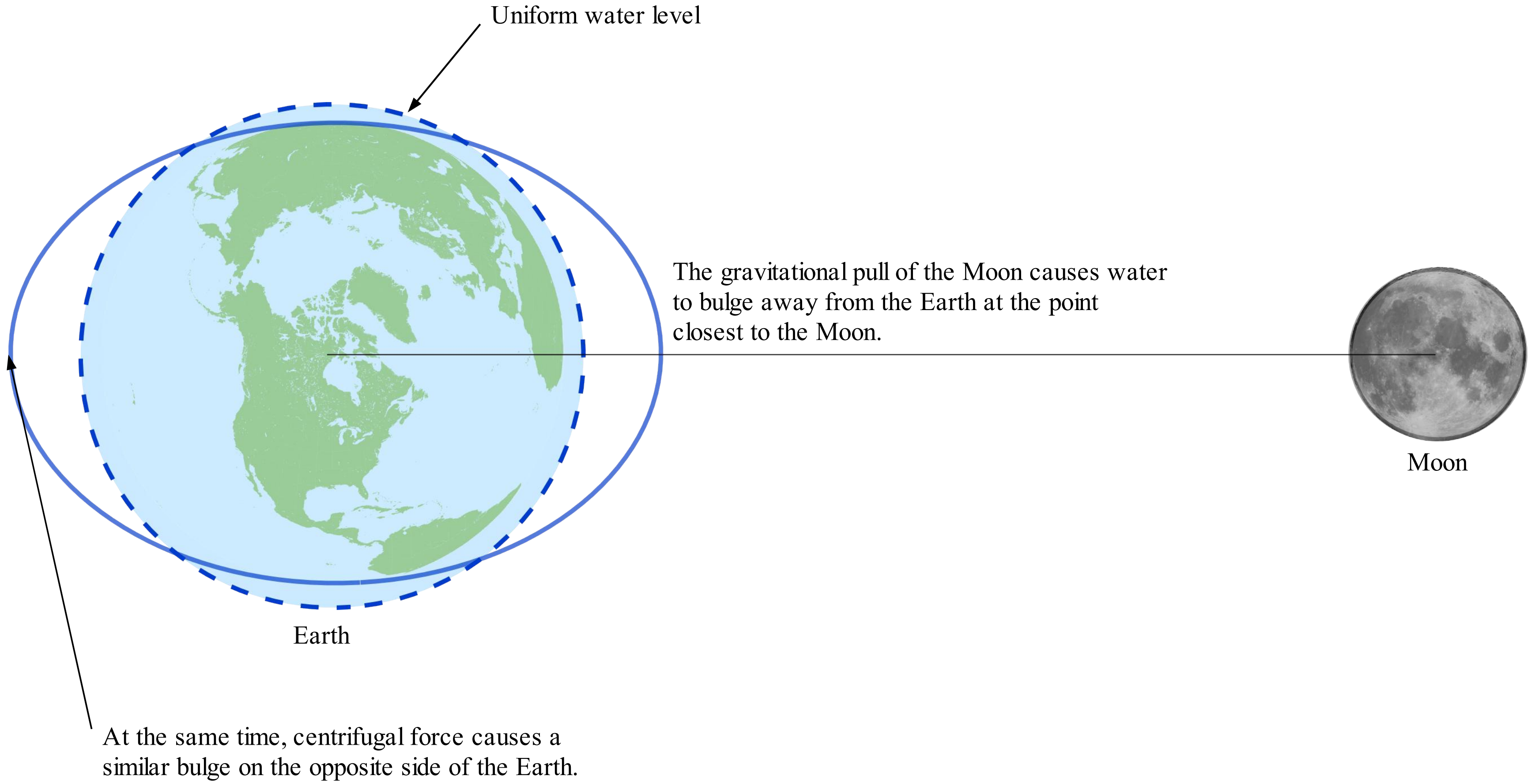
Successful student work may include:

- Correct use of the y-axis to measure height changes and the x-axis to measure time intervals.
- A selection of data from a selected station during several different periods of time.
- Calculation of the average low tide height, high tide height, and height change using data from different time periods.
- A working definition of a mean or average.
- A working definition of relative height change or deviation.

Depending on the measuring 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. Be prepared to guide students through the process of making their measurements on more complicated tide charts.

**Teacher Master**

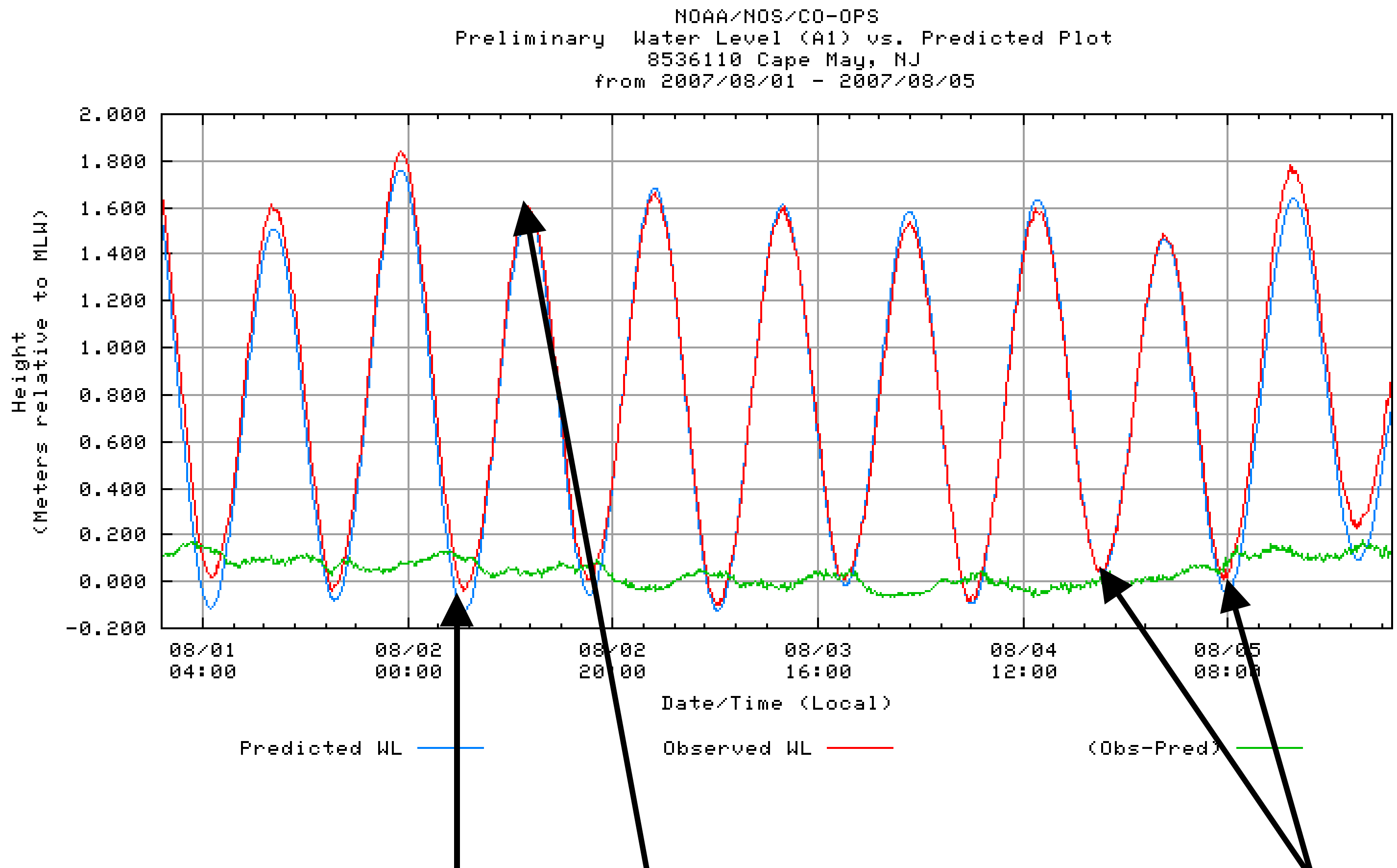
# What Causes Tides?




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

# Looking at Tide Data



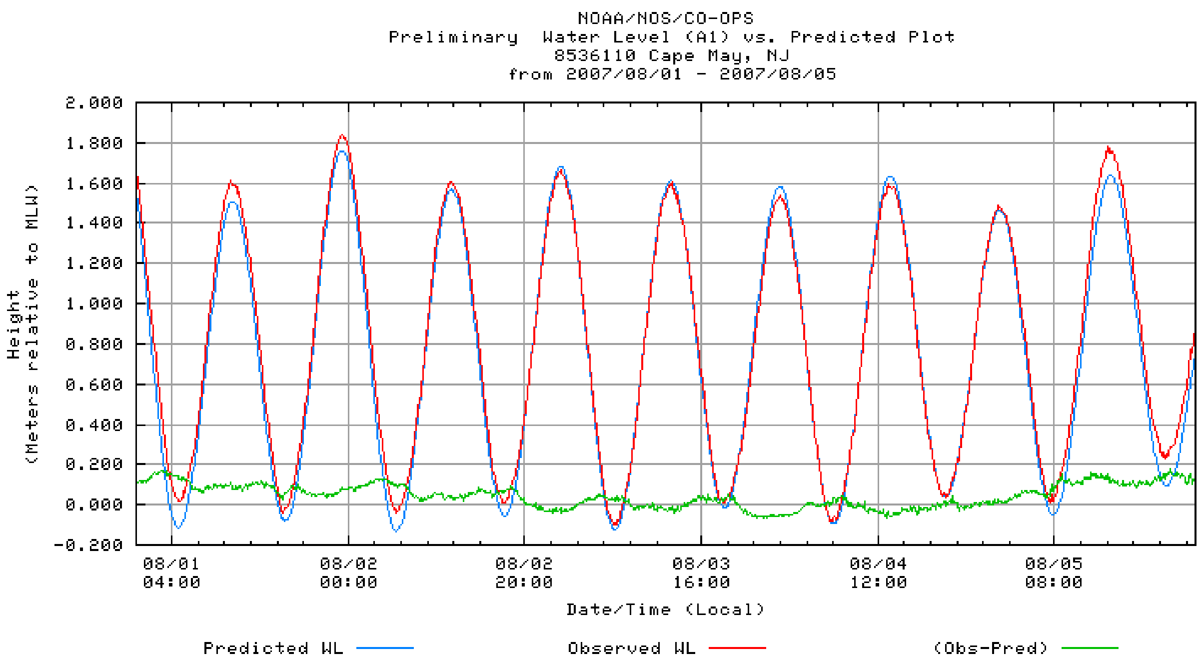

Along the y-axis, the measurement from the <u>lowest point</u> to the <u>highest point</u> in each cycle is the tidal change in water level.

Along the x-axis, the measurement between <u>consecutive low tides</u> or <u>consecutive high tides</u> is the time period of the tidal cycle.

**Student Master**

# Practice Reading Tide Data

Water level around the globe is always changing as a result of many factors. One of those factors is the effect of tides caused by the gravitational attraction of the Moon. In this activity, you will use charts of real tide data, like the one shown below, to research tides in a specific location. Your goal is to describe the typical height change and period of the tidal change.




1. Visit www.dataintheclassroom.org, and find the Sea Level module.

2. Follow the link to "Tide Data."

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

4. Select a start and end date for the data you wish to retrieve. Be sure to retrieve data over a period of at least several days, so that you can see a number of tide cycles.

5. Click the "Get Data" button.

6. If you have access to a printer, print a copy of the tide data chart. Otherwise, save a copy to your computer so that you can refer to it later. On a PC, right-click with the mouse and select "Save as...." On a Mac, hold down the Ctrl key and click with the mouse.

7. Look at the chart and see if you can identify a pattern of low and high tides. Choose a point on the chart that represents a low tide. Use the scale on the y-axis to determine the relative height of the water at that point. Record the approximate time and the relative water height on your data sheet.

8. Now find the point that represents the next high tide, and record the relative height of the water then.

9. Calculate the difference between the water height at high and low tides. This is the height change. Record this change on your data sheet.

10. Next choose two points on the chart that represent consecutive low or consecutive high tides. Use the time scale on the x-axis to determine the time period of the tide cycle. Record the period on your data sheet.

Do you think the measurements you just made provide a good description of the tides at this location?

**Hint:** Make measurements using data from the same location at other times to see if the tides are different. Once you have made several measurements, can you make calculations to find the average height change and period from the data you collected?

## Data Sheet

Station Name:

| Date | Time (Approx) | Low Tide Height | High Tide Height | Tide Height Change | Tide Cycle Period |
|---|---|---|---|---|---|
| 08/02/2007 | 20:00 | 0 m | 1.75 m | 1.75 m | 12 hrs |
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# 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 investigate and measure what happens to water height during a storm event.

## Background

Storms 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.[8]

During this lesson, students are asked to answer a research question: How do storm events impact water levels at a coastal location? To accomplish this task, students must take the calculations they made in the last activity and use them as a baseline to evaluate the tide heights observed during a storm.

8 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.

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 a computer lab or assigned as homework, assuming students have access to the Internet at a library or computer center. 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 with a demonstration to help students visualize their data. Follow the procedure on page 19 to display 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 and duration he or she calculated in the boxes from the Data Log Sheet labeled Max. Height Change.

   Click the Play button to start the model. You can stop the model and enter different numbers to change the behavior.

## 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 and the x-axis to measure time intervals.
- 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 maximum high tide and the average high tide they found in the last activity.
- A working definition of a mean or average.
- A working definition of relative height change or deviation.

**Student Master**

# 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 www.dataintheclassroom.org, and find the Sea Level module.

   b) Follow the link to "Tide Data."

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

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

e) Using the form on the Web site, select start and end dates around the time of the storm event you found.

f) Click the "Get Data" button.

g) If you have access to a printer, print a copy of the tide data chart. Otherwise, save a copy to your computer so that you can refer to it later. On a PC, right-click with the mouse and select "Save as...." On a Mac, hold down the Ctrl key and click with the mouse.

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.**

a) What were the highest and lowest tides recorded during the storm event?

b) How did the tides during the storm compare with the average high and low tides you calculated for this station previously?

c) Calculate the different between the highest tide measured during the storm and the average high tide for the area.

d) Can you use the data to determine how long the storm impacted the area?

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:

| Date | Time (Approx) | Low Tide Height | High Tide Height | Tide Height Change | Tide Cycle Period |
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# 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 water level on a larger scale will provide a good starting point. Here are some examples of questions:

Research questions:

- Do changes in water level have the same impact everywhere on Earth?
- How is sea surface height changing over time?

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, links to long-term trend analyses are available, and students can be challenged to apply what they have learned about reading and understanding data to interpret these long-term data products.

## Web Links

**For links to long-term sea level trend data, visit www.dataintheclassroom.org.**

## 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. 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 www.dataintheclassroom.org 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 and debate about global climate change. Ask: *From your own experience looking at real data, how do these data relate to the question of global climate change?*

**Student Master**

# Research Project: Designing Your Own Investigation

<u>**Planning your project:**</u>

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 www.dataintheclassroom.org, 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 looked at. Consider whether each new piece of data helps support or disprove your hypothesis.

| | Data set | Region / Station | Dates | Notes |
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