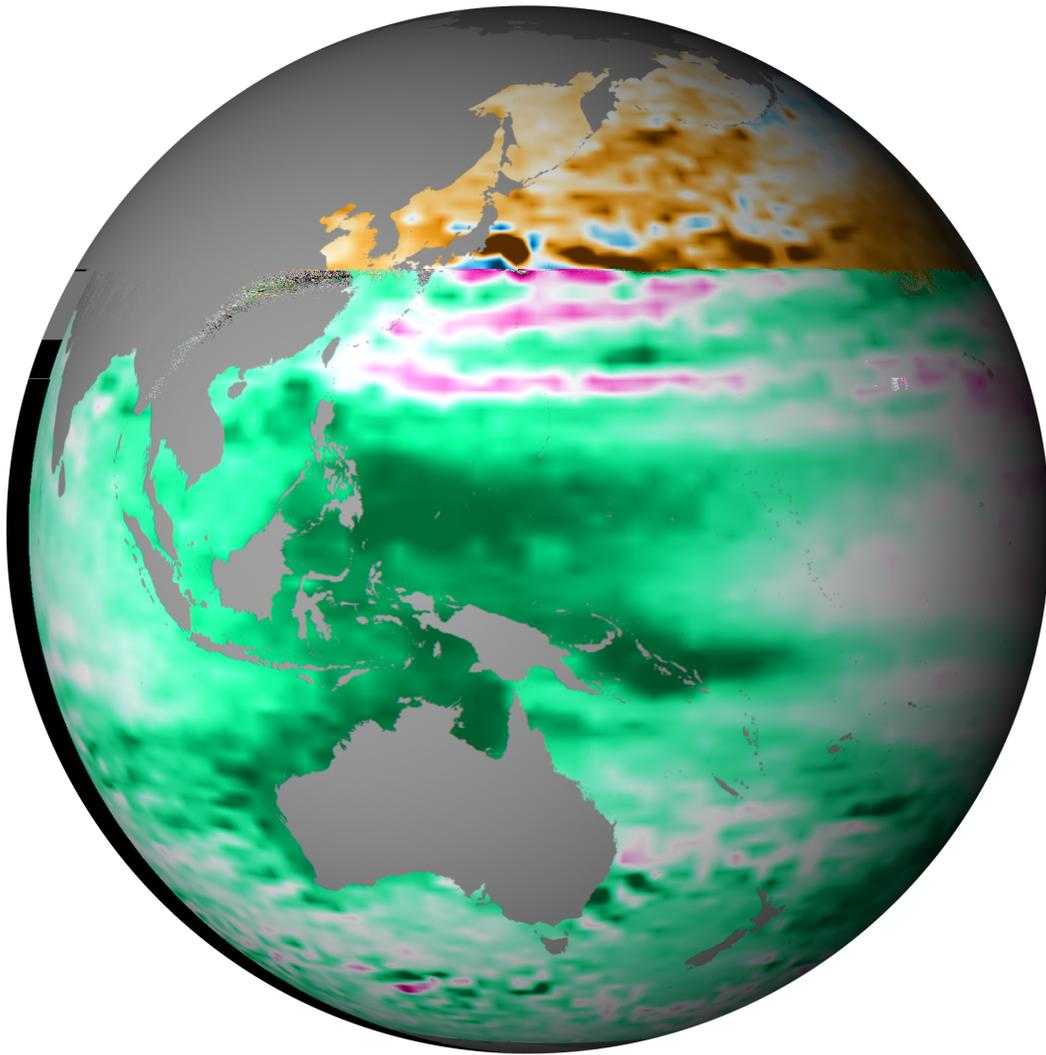


DATA IN THE CLASSROOM

INVESTIGATING SEA LEVEL USING REAL DATA



3rd Edition (2022)

This curriculum module was originally developed for the NOAA Ocean Data Education (NODE) Project by Caroline Joyce and Todd Viola under a contract with the National Marine Sanctuary Foundation. The 3rd edition (2022) was completed under contract by Amy Dean. Data in the Classroom is a collaboration of many NOAA programs and offices including: National Environmental Satellite, Data, and Information Service (NESDIS), National Estuarine Research Reserve System, National Oceanographic Data Center and the Office of National Marine Sanctuaries.

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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.

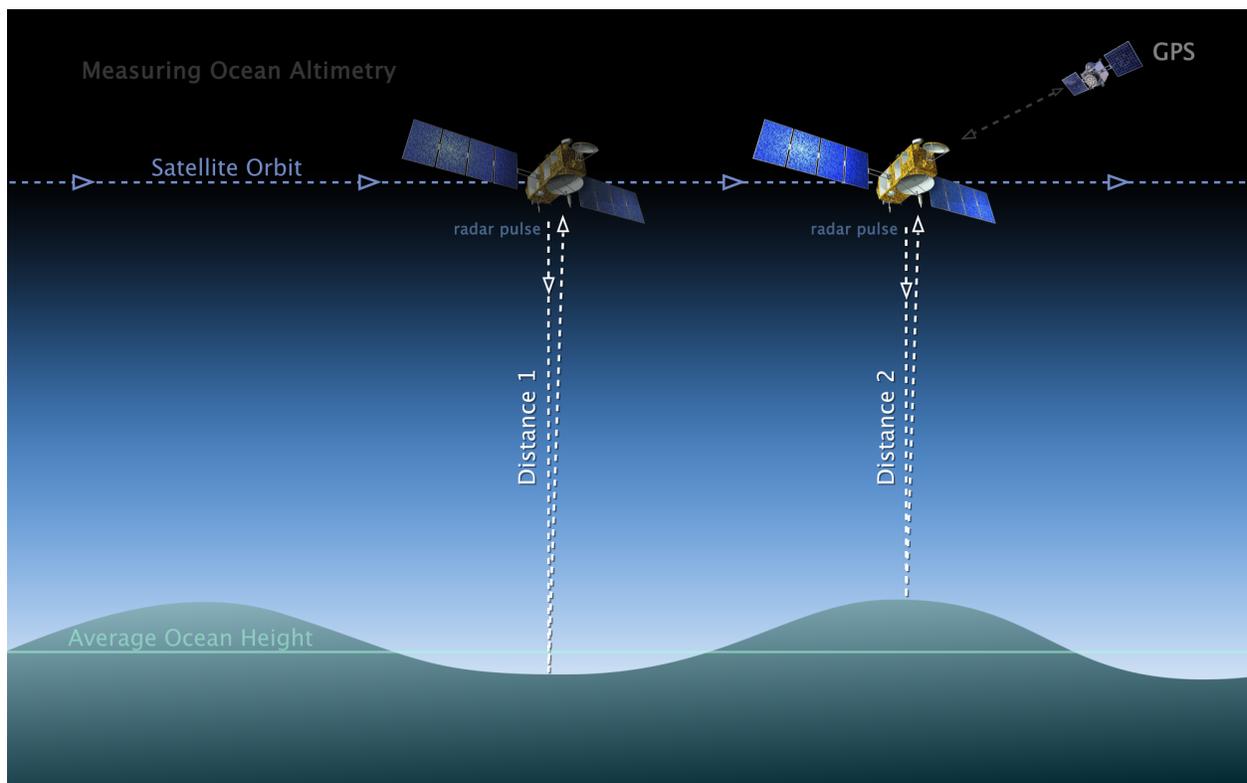
Studying sea level also provides good linkages with middle school mathematics and science standards. Charts of sea surface height data are excellent examples of the use of mathematical mean or average. Additionally, sea level data activities can support classroom lessons on ocean density, circulation,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

Sea Level Basics

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. Laser instruments onboard orbiting satellites bounce light waves off the ocean surface. The satellite instruments record the time it takes for the signal 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.



Measuring Sea Surface Height Using Satellite Altimetry: Satellites use lasers to bounce a signal off the surface of the ocean and back into space. The higher the ocean surface (e.g., a wave or increase in sea level), the faster the signal will be returned to the satellite.

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.

CURRICULUM OVERVIEW

This activity is part of a 5-lesson module that offers activities at five different levels of student interaction, sometimes referred to as Entry, Adoption, Adaptation, Interactivity and Invention. Levels 1 and 2 are very directed and teacher driven. Levels 3-5 of Adaptation through Invention are more student directed and open up opportunities to design lessons featuring student inquiry. This chart illustrates the five levels of this module, Investigating 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: Measuring Sea Level From Space: 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: Calculating the Mean Sea Level – Students will learn how to calculate a mean from a series of measurements related to sea level, and the deviation from the mean.

Next Generation Science Standards (NGSS)

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 Standards¹ (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. You can learn more about how this module relates to specific NGSS components by visiting the [Data in the Classroom website](#).

Ocean Literacy Principles

This curriculum module also supports the following Essential Principles of Ocean Sciences.²

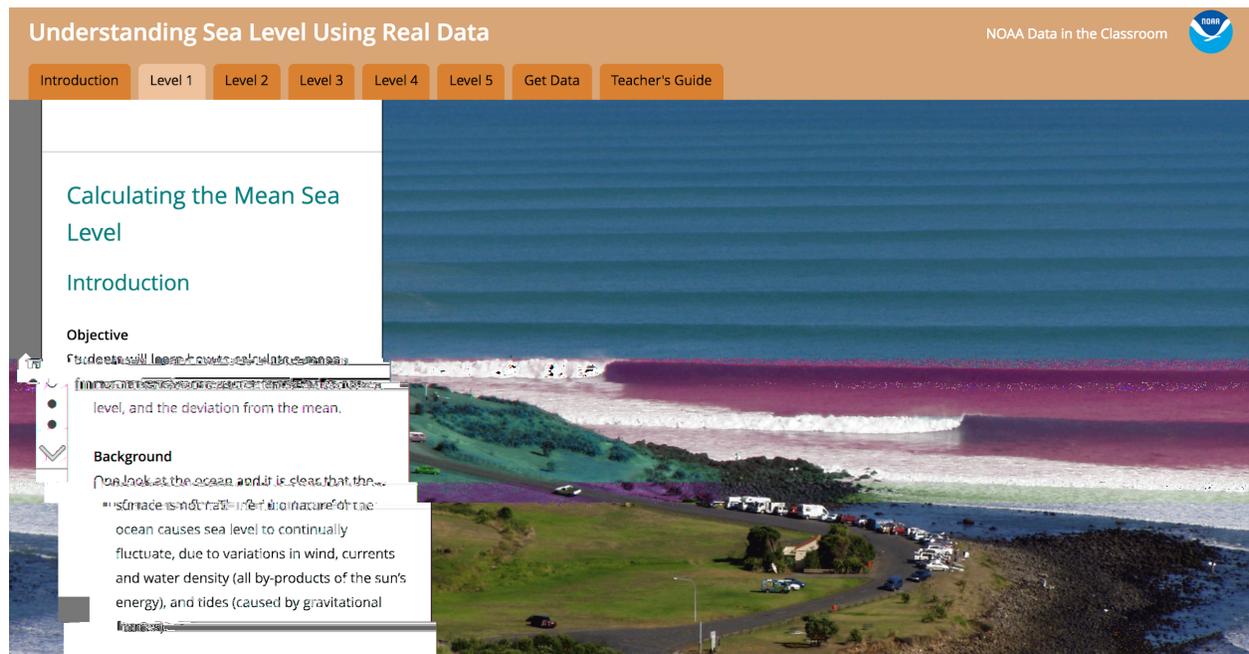
1. The Earth has one big ocean with many features.
 - a. Sea level is the average height of the ocean relative to the land, taking into account the differences caused by tides. Sea level changes as plate tectonics cause the volume of the ocean basins and the height of the land to change. It changes as 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.

¹ NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington D.C.: 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.

² Ocean Literacy Network (2005). Ocean Literacy - The Essential Principles of Ocean Sciences K-12. Washington, D.C.

LEVEL 1: ENTRY

CALCULATING THE MEAN SEA LEVEL



The screenshot shows a web interface for a lesson titled "Calculating the Mean Sea Level". At the top, there is a navigation bar with tabs for "Introduction", "Level 1", "Level 2", "Level 3", "Level 4", "Level 5", "Get Data", and "Teacher's Guide". The "Level 1" tab is selected. Below the navigation bar, there is a large image of a coastal scene with waves breaking on a beach. Overlaid on the left side of the image is a white box containing the lesson's objective and background information. The objective states: "Students will learn how to calculate mean sea level, and the deviation from the mean." The background section explains that the ocean causes sea level to continually fluctuate due to variations in wind, currents, and water density (all by-products of the sun's energy), and tides (caused by gravitational forces).

SUMMARY

- Grade Level: 6-8
- Teaching time: 45 minutes
- Activities: a) Participate in introductory sea level demonstrations and discussions, b) analyze sea height measurements, c) calculate means and deviations and d) use a balloon model to generate sea level data (optional).
- Vocabulary:
 - *Deviation*: the difference between one data value in a set and the mean value for that set.
 - *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.

LESSON PLAN – LEVEL 1

Objectives

Students will understand the primary causes of global sea level change. Students will learn how to calculate a mean from a series of measurements related to sea level, and the deviation from the mean.

Background

One look at the ocean and it is clear that the surface is not flat. The fluid nature of the ocean causes sea level to continually fluctuate, due to variations in wind, currents and water density (all by-products of the sun's energy), and tides (caused by gravitational forces).

Understanding the concept of a mean, or average, is important to interpreting sea level data at any scale. Throughout the activities in this module, students will explore two types of sea level data: global sea surface height data (derived from satellites) and local tide data. Both data are reported as deviations from an expected or mean height.

For this reason, the activities in this level give students the opportunity to practice calculating means and deviations. This is a skill that is used continuously throughout the activities in this module in order to interpret sea level data.

Materials

- Computer, projector and access to the internet
- One round balloon and one long balloon
- Clear glass baking dish
- Blue food coloring
- Straws
- Water

Teacher Prep

There are a variety of ways to implement this activity. Decide which works best for your classroom, and prepare as appropriate.

- Go to the [Data in the Classroom website](#) and familiarize yourself with the Level 1 activities.
- Student worksheets are available via the website to use in conjunction with the activities.

Procedure

Introduction to Global Sea Level

1. Fill a round balloon with water and hold it up as a simple model of earth. Remind students that the ocean covers more than 70 percent of the surface of our planet.
2. Explain that global sea level is defined as the height of the ocean's surface (relative to the center of the earth). 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 a balloon?*
 - *Do you think the height of the ocean's surface is the same all over the planet?*
 - *Can water in the ocean change its shape?*
3. Navigate to [Level 1](#) of the online activities. Using a projector, display the image.
 - This image shows that the surface of the ocean is not flat. It has hills and valleys, much like the hills and valleys on land. In this photo, the hills and valleys are caused by waves. Ocean surface topography can also be caused by tides, currents and the loading of atmospheric pressure.
 - Because of the fluid nature of the ocean, the hills and valleys of the ocean's surface are constantly moving and changing. As a result, 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).

Introduction continued - Sea Level Demonstrations

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

4. Demo #1: The watery hills and valleys across the earth's ocean
 - 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. 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.
 - Ask the students if any water was lost or if it took a new shape.
Answer: It took a new shape.
 - 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).
 - 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.

-
- 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.

- Ask students to now consider sea level change over a longer time period, over 10, 20 or 50 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. You will learn more about sea level rise in Level 2.

5. Demo #2: The effect of wind on global sea level

- 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.

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

- 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.

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

Part 1: Calculating the Mean

Before students can start using data to understand sea level, they need to learn how sea level is measured and reported using means and deviations. This is a great opportunity for students to apply their math skills in a real world context, interpreting sea level data.

1. Working at a computer, ask students to navigate to [Level 1](#) of the module. Scroll down to the section titled 'Calculating the Mean.'
2. The student worksheet can be used with the online activities.
3. Ask: 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.

4. Review how to calculate a mean.
 $Mean = (\text{Sum of all measurements}) / (\# \text{ of measurements})$
5. Explain to the students that they will use the sample sea level data in the graphic on the right of their screen in order to calculate the mean.

-
5. Give students time to calculate, optionally using the student worksheet at the end of this lesson.

Answer: 483

Part 2: Calculating the Deviation From the Mean

Sea level is frequently reported as a deviation from a mean height. For example, a sea level measurement taken from an orbiting satellite may be reported this way:

sea surface height deviation = 0.92 m

Restated, this simply means that the height of the sea's surface at that location is 0.92 meters above the ocean's mean height.

1. Scroll down to the next section titled 'Calculating the Deviation From the Mean.' Here, you'll find the same graphic on the right as in the previous activity, except each measurement is instead reported as the deviation from the mean.
2. Use the graphic to discuss deviations. Review how to calculate a deviation.
Deviation = observed - mean
3. Point out that positive deviations are sea level measurements that are above the mean and negative deviations are below the mean.
4. If using the student worksheets, find the text at the end of this section that says, "Click here to display the original image." Click on it. Give students time to calculate the deviations, using the table on their worksheets. Review their answers.
5. Give students time to answer the 'Check Your Understanding' questions at the end of this section.

Answer: +92, -133, +167, -23, -103

Answers - Question 1: 0.2; **Question 2:** 0; **Question 3:** -0.1

Supplemental Student Activity

As an alternative to the online activities in Parts 1 & 2, you may conduct the following activity and use the student worksheets at the end of this section.

Materials

- One long balloon
- Paper and marker
- Plastic tub or basin
- Ruler
- Copies of Student Worksheets

Procedure

1. Ask: 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 balloon from the previous demonstrations 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 Worksheet: 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 worksheet.
4. Have all students perform step 6 on the worksheet. 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 worksheet: 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.

7. 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.

8. Finally students should graph their results, following the instructions on the Student Worksheet: Graph Your Results.

9. 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.

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.



Instructions:

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 in the table below.

- 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 in the table.
- 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.

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

- 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.

$$\text{deviation} = \text{height measurement} - \text{mean height}$$

Measurement	Height	(- Mean)	Deviation
1			
2			
3			
4			
5			
6			
TOTAL			
MEAN			

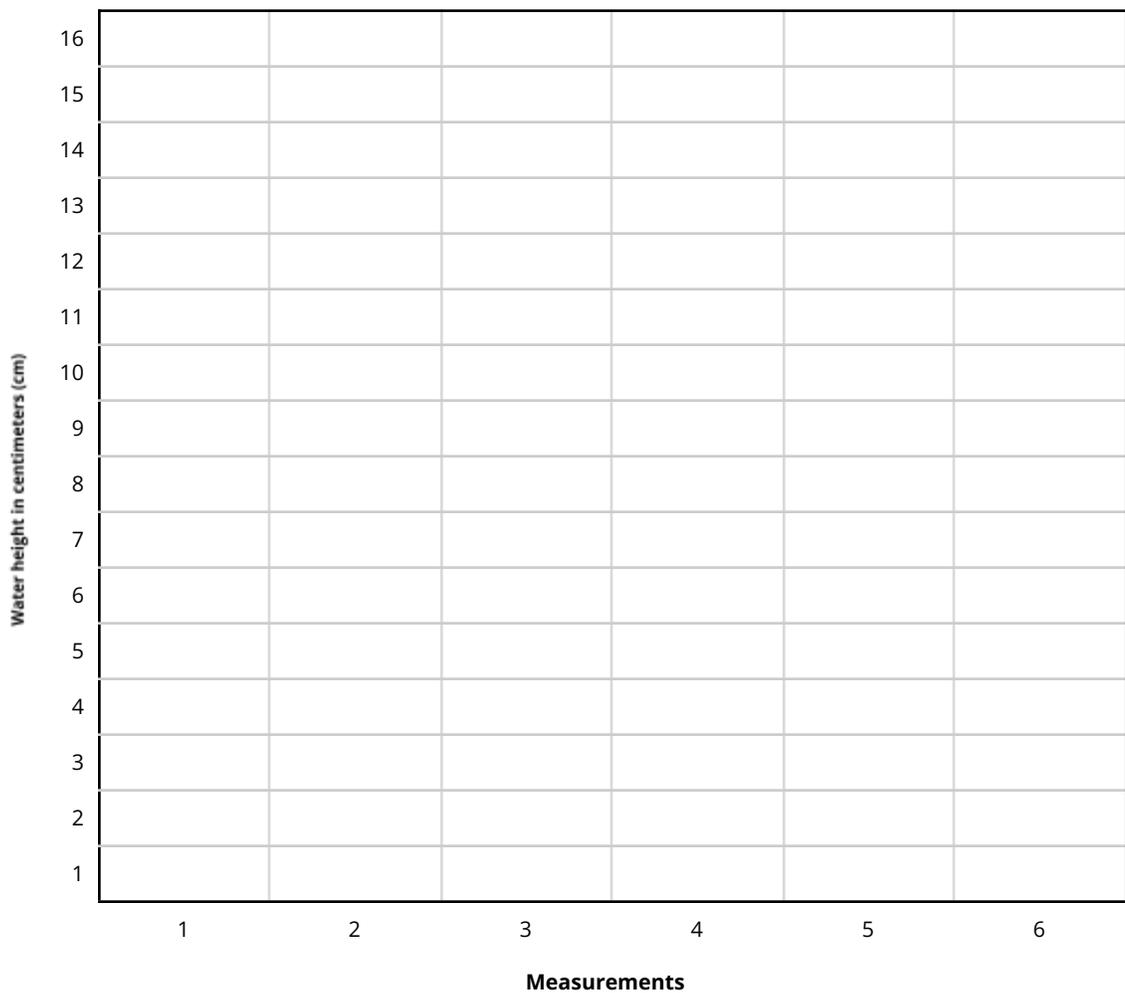
Answer the following questions:

- Why are some deviation values greater than zero and some less than zero?
- What does it mean when a deviation value is negative?

Graph Your Results

Instructions:

- Make a bar graph of the height data gathered from the balloon model. Using the grid below, 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.



Answer the following question:

3. How are the height deviations you calculated represented on your bar graph?

LEVEL 2: ADOPTION

MEASURING SEA LEVEL FROM SPACE

Understanding Sea Level Using Real Data

NOAA Data in the Classroom

Introduction Level 1 Level 2 Level 3 Level 4 Level 5 Get Data Teacher's Guide

Measuring Sea Level From Space

Height Deviation

NOAA and its partners have been working together to maintain a series of satellite altimeters that measure sea surface height from space. The satellites use radar altimeters to measure the distance from the satellite to the ocean and back into space. The higher the ocean surface (e.g., a wave or increase in sea level), the faster the radar signal will be returned to the satellite.

Since the speed of sound is constant, the distance from the satellite to the ocean will take longer to return back to the satellite.

Ocean Height

Average

After many years of measurements, a historical average (or mean) sea level is calculated for every centimeter of the

SUMMARY

- Grade Level: 6-8
- Teaching time: 45 minutes
- Activities: a) Analyze satellite maps of global sea surface height, and b) construct explanation for sea level variations.
- Vocabulary:
 - *Altimeters*: laser instruments used to measure sea surface height from satellites.
 - *Sea surface height deviation (SSH)*: the height of the sea surface above or below some reference point, usually the historical average height.

LESSON PLAN – LEVEL 2

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

Why do scientists measure the height of the sea surface around the world? 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. Mean global sea level has risen approximately 8 inches (20 cm) since the beginning of the 20th Century. Many locations have seen over 12 inches (30 cm) rise in just the last 20 years. While that may not seem like much, it is enough to completely submerge islands and drastically change low-lying coastal communities.

This change in sea level is a direct result of climate change. 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.

Materials

- Projector
- Computers and internet access
- Photocopies of student worksheet (optional)

Teacher Prep

There are a variety of ways to implement this activity. Decide which works best for your classroom, and prepare as appropriate.

- Go to the [Data in the Classroom website](#) and familiarize yourself with the Level 2 activities.
- Student worksheets are available via the website to use in conjunction with the activities.

Procedure

Part 1 - Background: How and Why Is Sea Level Measured?

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 1).
2. Navigate to Level 2 of the online activities. Scroll down to the section titled 'Background.' Using a projector, play the video. Students should understand that satellites (like Jason-3) are used to monitor global sea level.

Part 2 - Calculating Sea Surface Height Deviation

1. Scroll down to the next section. Explain that, in order to measure sea level, satellites are equipped with laser instruments called altimeters. Use the diagram and associated text to describe how altimeters work. Students should understand that sea level data from satellites are reported as deviations from a mean height.

-
2. Students should be able to explain the term *Sea Surface Height Deviation (SSHD)*.

Part 3 - Mapping Sea Surface Height Deviation

1. Scroll down to the next section. Here, you'll find a map of sea surface height deviation (the hills and valleys) across the ocean from January 2016. Discuss the key features of the map.
 - The ocean is colored in various shades of red and blue. The colors represent sea surface height deviation (SSHD).
 - Locate the color legend on the map, and click the information icon to display. This legend indicates the SSHD in meters.
 - Ask: What color indicates the ocean's hills? (red) And the valleys? (blue)
 - Ask: How high are the highest 'hills' on the map? How deep are the valleys?
Answer: approximately 0.3 m (30 cm) above or below the mean sea surface height.
2. Give students time to answer the questions at the end of this section.
Answer - Question 1: the sea surface height is higher than the historical mean height
Answer - Question 2: 0.1 meters

Part 4 - Analyzing SSHD maps

Now that students can read a sea surface height deviation (SSHD) map, challenge them to interpret a map from April 2013 on their own.

1. Give students time to answer the questions at the end of this section.
Answer - Question 3: Higher

Part 5 - Comparing Change Over Time

Once students are comfortable reading SSHD maps, they can explore changes in sea surface height over time. *Note: additional information about sea level rise can be found in the online Teacher Guide page of the online activity.*

-
1. Scroll down to the next section. Here, you'll find an interactive SSHD map. Click and slide the vertical bar left and right to view and compare the data. The left hand map is from 1993 when satellite measurements of SSHD first began. The right map is from 2016.
 2. Give students time to answer the questions at the end of this section.
Answer - Question 4: Areas of higher than normal mean sea surface height are more common in 2016.
 3. Ask: Are these maps clear evidence that global sea levels are rising?
Answer: Though these maps indicate that sea levels are different between 1993 and 2016, two years of data (from 1993 and 2016) are not enough to draw conclusions. You would need to evaluate continuous data over long periods of time to better understand trends in sea level.
 4. Ask: Can students predict *WHY* 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.

Part 6 - Global Sea Level Trends

1. Scroll down to the last section in Level 2. Locate and click the text that says "global rise in sea level." This graph shows the global change in sea level since 1993 as observed by satellites.
2. Ask: Is this graph clear evidence that sea levels are rising?
Answer: Yes, this graph shows that sea levels have been continuously rising over a period of 24 years.
3. Click the text that says 'Back' above the graph. A SSHD map will appear in the window. The map shows two things: a) how much, in total, sea levels have risen over the past 20 years and b) world population density.

-
4. Give students time to analyze the map and answer the questions at the end of this section.

Answer - Question 5: Western Pacific

Answer - Question 6: Asia

5. With continued warming, sea levels will likely rise for many centuries at rates higher than that of the current century. Discuss how global sea level rise may impact populated areas around the world both now and in the future.

LEVEL 3: ADAPTATION

TIDES AND LOCAL SEA LEVEL

Understanding Sea Level Using Real Data NOAA Data in the Classroom 

Introduction **Level 1** Level 2 **Level 3** Level 4 Level 5 Get Data Teacher's Guide

Tides and Local Sea Level

Introduction

Objective
Students use real data to describe the cyclical patterns of tides, as well as the relationship between lunar cycles and tides. Students will apply their skill calculating the mean to real tide data in order to characterize typical tide behavior at a selected location.

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



SUMMARY

- Grade Level: 6-8
- Teaching time: Two 45-minute periods
- Activities: a) Generate and interpret charts of real tide data, and b) 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 period*: elapsed time between successive high waters and low waters.
 - *Tidal range*: difference in height 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.

LESSON PLAN – LEVEL 3

Objectives

Students use real data to describe the cyclical patterns of tides, as well as the relationship between lunar cycles and tides. Students will apply their skill calculating the mean to real tide data in order to characterize typical tide behavior at a selected location.

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.

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.

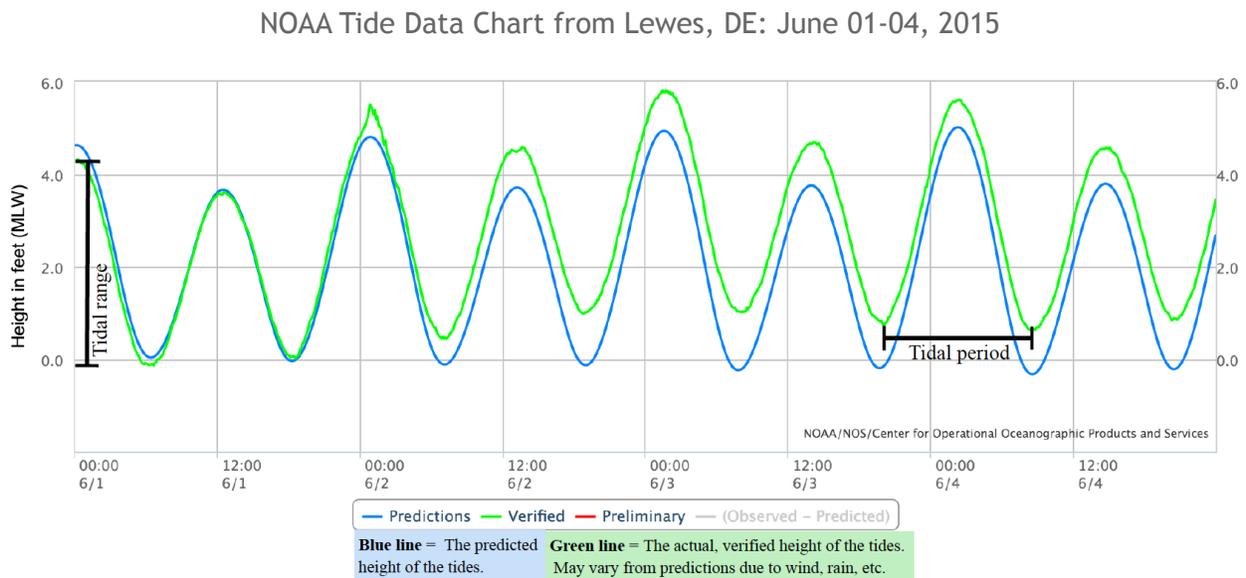


Figure 1: Observed and predicted tide data from a monitoring station near Lewes, DE. This tide chart can be generated by using the online data tools associated with this lesson.

Materials

- Projector
- Computers and internet access
- Photocopies of student worksheet (optional)

Teacher Prep

- Go to the [Data in the Classroom website](#) and familiarize yourself with the Level 3 activities.
- Student worksheets are available via the website to use in conjunction with the activities.
- Familiarize yourself with the data tool in this level. Practice creating a tide chart. Be prepared to demonstrate the data tool for students.

Procedure

Part 1 - Moon Phase and Tides

1. Navigate to Level 3 of the online activities. Scroll down to the section titled, 'Moon Phase and Tides' and project the animated image.
2. Engage students in a discussion about tides, asking "what are tides" and "what causes tides." Explain spring and neap tidal patterns.
3. Give students time to answer the question at the end of this section.
Answer: Higher than normal.

Part 2 - Visualizing Moon Phase and Tidal Cycle

1. Scroll down to the section titled 'Visualizing Moon Phase and Tidal Cycle.' Click on each moon phase and view the associated tide animation. Students should pay close attention to variations in tide height (along the y-axis) with each moon phase.
2. Ask students: How does the height of the high tide and low tide differ with each moon phase?
Answer: During new and full moons, the high tides are higher and the low tides are lower (spring tides). During quarter moons, tides are less extreme (neap tides).
3. Give students time to answer Question 2 at the end of this section.
Answer: As the moon approaches its quarter phase, tides become less extreme.

Part 3 - Preparing to Use Tide Data

1. Scroll down to the next section. Here, students will learn how to read and generate a tide chart. First, students will learn to read a NOAA tide graph from Monterey, CA.
 - To calculate the tidal range (using the example chart), students should measure the difference in height between a high tide (4.25 ft) and the succeeding low tide (0 ft). In this case, the tidal range equals 4.25 feet.
 - To calculate the tidal period, students should measure the length of time between the two consecutive low tides shown on the chart. In this case, the low tide on September 2nd was approximately midnight (00:00) and the following low tide was at 12:30 PM. Tidal period equals 12.5 hrs.
2. At the end of this section, students will learn how to create their own tide chart. Click on the *Tides Get Data* tool. Individually or together as a class, use the tool to create a tide chart at any location on the map.
 - To use the tool, simply click on any marker on the map. Inside the small pop-up window, click 'More info' and today's tide chart will be generated.
 - Note, you can simplify the graph and make the blue 'tide prediction' data disappear from view by clicking on 'predictions' inside of the chart legend.
 - Ask students to find today's date and time along the x-axis.
 - Ask students how many high and low tides occur daily at this location?
 - Ask: What is the tide doing right now (increasing or decreasing)? What is the tide height in feet (use the y-axis)? What is the tidal range at this location (height of high tide minus the height of the next low tide)?

Part 4 - Answering a Question with Tide Data

1. Pair up students into teams. They should use the Level 3 worksheet or a notebook to record their claim, evidence and reasoning.

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2. Ask: Can you think of any reason why it might be important for everyday people to understand tides? Possible answers might include: safety on a beach, fishing, surfing, boating, tide pooling, clam digging, wildlife viewing, etc.
 3. Demonstrate for students how to use the tide tool.
 4. After accessing and reviewing their data, students should answer the interpretation questions and complete the conclusion statement at the end of the worksheet.
 5. Discuss student answers to “What are likely the BEST dates to see horseshoe crab spawning in May 2016?”
Answer: Approximately from May 5-11, 2016
 6. Share conclusions. Successful conclusions may include the following:
 - a. The most extreme, spring tides occur during either new and full moons and therefore are likely the best days to see horseshoe crabs spawning.
 - b. Because the highest numbers of crabs are often seen during night time highs, it is likely that the best time to see horseshoe crab spawning in May 2016 is sometime around Sunday, May 9th during the nighttime high tide at 21:36 (9:36 PM).

LEVEL 4: INTERACTIVITY

MEASURING STORM EFFECTS

Understanding Sea Level Using Real Data

NOAA Data in the Classroom

Introduction Level 1 Level 2 Level 3 Level 4 Level 5 Get Data Teacher's Guide

Sea Level - Level 4

Introduction

Using what they learned about typical tide 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

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

NOAA tide data to analyze the effect of

storm surge on sea level

NOAA

SUMMARY

- Grade Level: 6-8
- Teaching time: Two 45-minute periods
- Activities: a) Get water height data for storm events, and b) create a research plan using real data.
- 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.

LESSON PLAN – LEVEL 4

Objectives

Using what they learned about typical tide measurements at a location, students will use NOAA tide data to analyze the influence of tides on flooding caused by a storm.

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, causing 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. During this lesson, students are asked to answer a research question using tide data.

Materials

- Projector
- Computers and internet access
- Photocopies of student worksheets

Teacher Prep

- Go to the [Data in the Classroom website](#) and familiarize yourself with the Level 4 activities.
- Student worksheets are available via the website to use in conjunction with the activities.

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- Practice using the tides 'Get Data' tool used in the online activity. Be prepared to demonstrate the data tool for students.
 - Research a few recent storms in a coastal area of interest. These can be used to help students identify a storm to investigate, if needed.

Procedure

Connecting Storm Surge and Tides

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* or Hurricane *Dorian* as possible examples.
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 determine the extent to which tides influence the severity of flooding during a storm or hurricane.
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 worksheet: 'Research Project: Determining Storm Surge Height,' and record their data and calculations on the table provided.
4. The worksheet can be used to guide the students through this task.
5. After students complete their research, provide time for them to present their findings to the class.

LEVEL 5: INVENTION

DESIGNING YOUR OWN INVESTIGATION

The screenshot shows a lesson page with a navigation bar at the top containing 'Introduction', 'Level 1', 'Level 2', 'Level 3', 'Level 4', 'Level 5', 'Get Data', and 'Teacher's Guide'. The NOAA logo and 'NOAA Data in the Classroom' text are in the top right. The main content area is titled 'Designing Your Own Investigation' and includes a 'Objectives' section with text about applying learning to sea level data, a 'Background' section about local data, and a 'Summary' section about examining data at different scales. A satellite map of a coastal city is overlaid with various colored overlays (pink, green, blue) representing different data layers. A green arrow icon is visible at the bottom left of the content area.

SUMMARY

- Grade Level: 6-8
- Teaching time: Two 45-minute periods
- Activities: Design an investigation using real data to examine a hypothesis.

LESSON PLAN – LEVEL 5

Objectives

Students will apply what they have learned to consider sea level data on a larger scale. To do this, students will ask questions, collect and analyze data and construct an argument that shows how data supports their conclusions.

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.

Sample research questions with links to data tools are available in the online Level 5 activity. Students can be challenged to apply what they have learned about reading and understanding data to interpret a variety of data products.

Materials

- Projector
- Computers and internet access
- Photocopies of student worksheets

Teacher Prep

- Go to the Data in the Classroom website and familiarize yourself with the Level 5 activities. Familiarize yourself with the sample questions and data tools.

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- Student worksheets are available via the website to use in conjunction with the activities.
 - Practice generating graphs using the data tools in Level 5. Be prepared to demonstrate the tools for students.

Procedure

This activity challenges students to think like scientists by designing a scientific investigation in which data collection and analyses are important parts of the process. Students are challenged to engage in a number of scientific practices, including asking questions, analyzing data and constructing explanations using data.

1. Assign students to work in teams of two and give each team a copy of the student worksheet, *Design Your Own Investigation*.
2. Project Level 5 onto a screen and scroll down to the section titled 'Plan Your Investigation.' Locate the list of data tools.
3. Prior to developing a question, students will need to understand what types of data are available to them. The data tools and visualizations that are available in Level 5 are described below. Instructions to use the tools can be found by clicking the 'Get Data' tab in the upper navigation bar. With students, discuss these data and demonstrate how to use the data tools, if needed.
 - a. Sea Surface Height - Map Viewer (1992 - 2016): This data visualization can be used to identify long-term changes in global sea surface height over time.
 - b. Sea Surface Height Data Tool (1993 - present): This data tool will enable students to download global *Sea Surface Height Deviation* (SSH_D) maps. Students may also make their own graphs using the data tool and a spreadsheet program such as Microsoft Excel.
 - c. Tide Data Tool: This tool allows students to search and access tide data for 236 locations around the United States, territories in the Pacific, and Bermuda.

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4. 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 Sea Level Rise Viewer, 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.
 5. Guide student selection of a research question (or have them make up their own) that is appropriate to their academic experience. Sample questions are highlighted in the online Level 5 activities.
 6. Next, in their small groups, students should determine what data are needed to answer their question, making a list on their worksheet.
 7. Using the data tools on the website, students can then access, save and/or print the graphical displays of data. If necessary, help students determine if they have enough data to answer their question and identify areas where they may need to seek out additional sources of information.
 8. After accessing and reviewing their data, students should work together to write a detailed interpretation of what their data shows and complete the conclusion section at the end of the worksheet.
 9. After students complete their research, provide time for them to present their findings to the class.
 10. Use student presentations as an opportunity to relate their investigations to the current news and debate about sea level rise and global climate change.