RESOURCE LIBRARY
LESSON

Shifting Seas

Students make and evaluate predictions related to climate change's effects on the oceans, using evidence from videos, articles, and demonstrations. Next, they examine, analyze, and graph data on ocean acidification, sea surface temperature, and changes in sea level. Finally, students use these data and their visualizations to make evidence-based predictions and examine adaptation technologies. This lesson is part of the *Climate Change Challenge* unit.

GRADES

6 - 8

SUBJECTS

Biology, Ecology, Conservation, Earth Science, Climatology, Oceanography

CONTENTS

5 Activities

In collaboration with

ACTIVITY 1: OCEANIC IMPACTS | 50 MINS

DIRECTIONS

This activity is part of the Climate Change Challenge unit.

Introduce the concept of sea level rise with a video and debrief discussion.

- Distribute the *Ocean Impacts* handout.
- Preview with students the two questions in Part A, Sea Level, before showing the video *Global Climate Change Through the Lens of Changing Glaciers* (6:52).
- After viewing the video, solicit volunteers' responses to the questions on the handout.

- Transition to the next step by asking students:
    - *Why might glaciers be melting in Iceland, where M. Jackson works?* (Glaciers here and elsewhere are melting because Earth's atmosphere is warming.)
    - *Do you know of any other effects that carbon dioxide might be having on Earth's oceans?* (Students may or may not have prior knowledge of sea temperature rise or ocean acidification).

Support students as they read to understand the concept of ocean warming.

- Distribute copies of the article *Ocean Warming Explained* to each student.
- Support students as they read and annotate the article in pairs.
- Ask students to respond to the questions in Part B of the *Ocean Impacts* handout, Sea Temperature, as a Think-Pair-Share.
- Prompt students to reflect on the connections between the impacts in Part A and Part B by asking:
    - *How might sea temperature rise contribute to sea level rise?* (Sea temperature rise causes thermal expansion, in which water takes up more space as it heats.)

Initiate a physical demonstration to inform students' hypotheses about ocean acidification.

- Ask: What *are some sources of carbon dioxide in our atmosphere?* (Students will likely name the burning of fossil fuels.)
- Ask*: What is the gas that you exhale in greater concentrations than you breathe in?* (Carbon dioxide. Note that human breath is not a significant contributor to global warming, but it does have a higher percentage of carbon dioxide than the air we breathe in.)
- Initiate a demonstration consisting of two clear-walled containers with identical amounts of water and a pH indicator (see *Setup* for more information on how to conduct this demonstration).
    - Explain that the color of the water comes from a chemical indicator that will show how acidic or basic the water is.
    - Water itself is roughly neutral. When it becomes more acidic (like lemon juice) or more basic (like bleach), the chemical indicator will change to one color or another. Write

    these color changes in a visible location. (The type of indicator you choose for this demonstration will determine the colors you mention and record here.)
  - Write the pH scale on the board with the colors of the indicator at different pH values noted for students.

- Record the initial color of the water from both containers in the first row ("Prior to breath") of a chart similar to the one in Part C of the *Ocean Impacts* handout.

  - The colors of this initial reading should match, and indicate that the pH is around 7.

- Ask students to make a prediction and record it in Part C of the *Ocean Impacts* handout:

  - *What is your prediction for how the colors will compare after we breathe carbon dioxide into one container?* (Students' predictions may vary, but should include a statement regarding the relative colors of water in the two containers, and a justification based on their understanding of pH levels and how to interpret indicators.)

- Request a volunteer to blow bubbles through a straw (preferably compostable!) into the "breath" container.

  - They may have to blow for a few seconds, but in less than a minute, the color should change. The color should not change in the "no breath" container if it is left undisturbed.

- Chart the final colors in the "After breath" row, and discuss the complete demonstration with the class, asking students to answer the following questions:

  - *How did the color in the "breath" container change as a student blew bubbles into it? Why did this happen?* (The color changed from x to y when the student blew bubbles into it because the pH became more acidic.)
  - *How do you think the oceans are changing as we add more and more carbon dioxide to the air?* (The oceans are getting more acidic.)
  - *Was your expectation about the colors from earlier correct?* (Students' responses will vary, depending on their initial hypotheses.)
  - Have students reflect on their expectations and again note what they learned from this demonstration. Specifically, in response to the: *How did the data prove or disprove your expectation?* prompt in the *Ocean Impacts* handout.

- Look for novel incorporation of information related to ocean acidification under global warming as students revise their understanding.

Support students as they identify causes and consequences of climate change on the oceans.

- As a class, review the three main elements of climate change impacts on the oceans (sea level rise, sea temperature rise, and ocean acidification) and ask students to brainstorm together some possible consequences of these impacts.
- Explain that the video *Climate 101: Oceans* (2:38) will illuminate these three phenomena in detail. Show the video and prompt students to take notes as they watch in Part D, Causes and Consequences, for the *Ocean Impacts* handout.
- Revisit the class *Know and Need to Know* chart, adding any new insights or questions regarding the impacts of climate change on the oceans.

Modification

Step 3: If time and supplies are available, you can conduct the ocean acidification demonstration in this activity as a lab. As a lab, students manipulate the setup and collect data in pairs or small groups, rather than as a class. If supplies for the demonstration are not available, students can still collect data on this phenomenon by watching an online video of *Bromothymol Blue Respiratory Physiology Experiment* (2:52) changing color after exposure to breath.

Tip

Step 3: If you need to introduce the concept of pH to students, this *NOAA resource* has a helpful chart with common examples of materials at different pH values.

Tip

Step 3: Student misconceptions may arise unless it is clear that human breath is not a significant contributor to global warming. However, it does have a higher percentage of carbon dioxide than the air we breathe in. In this demonstration, breathing into the water is simply a proxy for the addition of carbon dioxide to oceans from carbon sources.

Informal Assessment

Informally assess students' developing understanding of sea level rise, sea temperature rise, and ocean acidification by examining their *Ocean Impacts* handout.

Extending the Learning

Step 3: If time is available, you may wish to involve students in preparation for the demonstrations of changing ocean conditions.

OBJECTIVES

Subjects & Disciplines

Learning Objectives

Students will:

- Generate and evaluate predictions related to global warming and climate change's impacts on oceans.
- Identify causes and consequences of global warming and climate change on the oceans.

Teaching Approach

- Project-based learning

Teaching Methods

- Demonstrations
- Discussions
- Inquiry

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
  - Information, Media, and Technology Skills

    - Information, Communications, and Technology Literacy
  - Learning and Innovation Skills
    - Critical Thinking and Problem Solving
  - Life and Career Skills
    - Flexibility and Adaptability
- 21st Century Themes
  - Environmental Literacy
  - Global Awareness
- Critical Thinking Skills
  - Analyzing
  - Applying
  - Evaluating
  - Understanding
- Science and Engineering Practices
  - Constructing explanations (for science) and designing solutions (for engineering)
  - Engaging in argument from evidence

National Standards, Principles, and Practices

COMMON CORE STATE STANDARDS FOR ENGLISH LANGUAGE ARTS & LITERACY

• **CCSS.ELA-LITERACY.RST.6-8.7:**
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

NEXT GENERATION SCIENCE STANDARDS

• **Crosscutting Concept 2: Cause and Effect:**
Cause and effect relationships may be used to predict phenomena in natural or designed systems.
• **MS-ESS2-6:**
Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.
• **Science and Engineering Practice 2:**
Developing and using models
• **Science and Engineering Practice 6:**

Constructing explanations and designing solutions

Preparation

BACKGROUND & VOCABULARY

Background Information

Climate change is having a variety of impacts on the world's oceans. Globally, the sea level is rising, the ocean temperature is increasing, and the pH of water is dropping, or becoming more acidic. These effects combined can result in challenges to the Earth's marine ecosystems, as well as danger to humans.

Currents carry the Earth's ocean water around the planet, moving it between the five major basins, the Atlantic, Pacific, Arctic, Indian, and Southern oceans. These currents are driven by factors such as density differences, wind, and gravitational attraction. Ocean currents are also responsible for determining local weather patterns, even over dry land.

Prior Knowledge

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Recommended Prior Activities

- Carbon All Around
- Global Trends
- Heating Up
- Local Emissions
- Meteorological Models
- Now and Then
- Our Greenhouse
- Plot It!
- Weather Interconnections
- Weather, Meet Climate

Vocabulary

Term	Part of Speech	Definition
carbon dioxide	*noun*	greenhouse gas produced by animals during respiration and used by plants during photosynthesis. Carbon dioxide is also the byproduct of burning fossil fuels.
climate change	*noun*	gradual changes in all the interconnected weather elements on our planet.
global warming	*noun*	increase in the average temperature of the Earth's air and oceans.
ocean acidification	*noun*	decrease in the ocean's pH levels, caused primarily by increased carbon dioxide. Ocean acidification threatens corals and shellfish.
pH	*noun*	measure of a substance's acid or basic composition. Distilled water is neutral, a 7 on the pH scale. Acids are below 7, and bases are above.
sea level	*noun*	base level for measuring elevations. Sea level is determined by measurements taken over a 19-year cycle.
temperature	*noun*	degree of hotness or coldness measured by a thermometer with a numerical scale.

ACTIVITY 2: CIRCULATION OF THE SEAS I 50 MINS

DIRECTIONS

This activity is part of the Climate Change Challenge unit.

1. Initiate a physical demonstration to inform students' initial hypotheses about ocean circulation.

- Introduce a simple demonstration consisting of a tank/aquarium full of room temperature water, a capped bottle of cold salty water (labeled with blue food coloring), and a capped bottle of hot freshwater (labeled with red food coloring).
    - See the *Setup* section for more information on how to conduct this demonstration.
- Explain to students the contents of the two bottles, distribute the *Circulation of the Seas* handout, and ask students to record their predictions for this demonstration in Part A:

- *What is your prediction for where the cold, salty blue water will flow when I uncap it sideways within the tank?*
- *What is your prediction for where the hot, fresh red water will flow when I uncap it sideways within the tank?* (Students' expectations may vary but should include a statement regarding the flow of this water, and a justification using prior knowledge.)

- Uncap the bottles gently and prompt students to record their observations in the chart from Part B of the *Circulation of the Seas* handout.
- Solicit volunteers' responses.
- Ask students:

  - *How might the phenomena you are observing here in this tank be relevant to the oceans?* (Students' responses will vary, but listen for any connections between water flow in this demonstration and the flow of water from place to place within ocean basins.)

2. Use a video and article to introduce the relationship between water temperature, salinity, and ocean currents.

- Prompt students to begin Part C of the *Circulation of the Seas* handout as they watch the *Ocean Currents and Climate* video (2:33).
- After watching the video, have students share their responses to check for initial understanding. Emphasize that the video only addresses one factor (temperature) that drives ocean circulation.
- Then assign students to work in pairs to read and annotate the *Ocean Currents and Climate* article. Prompt students to identify additional factors influencing the density of water and record the information in Part C of the *Circulation of the Seas* handout.
- Solicit volunteers' responses to ensure that students have a comprehensive list of characteristics that:

  - Make water more dense/sink (low temperature and high salt content).
  - Make water less dense/rise (high temperature and low salt content).

3. Prompt students to predict the movement of water in ocean currents using a model of thermohaline circulation.

- Introduce the concept of *thermohaline circulation* by first breaking down the origin of the term. Thermo refers to heat, and haline, to saltiness.
- In a Think-Pair-Share, ask students to complete Part D of their handout using their knowledge of how water behaves depending on temperature and salt content.
- Review students' responses by projecting the *Ocean Conveyor Belt* diagram, also shown on students' handouts, and asking volunteers to choose the correct labels from each pair.
- Students' labeled diagrams should indicate that:
    - Near the poles, the temperature is cold. As ice forms, it forces out the salt crystals, so the water below the ice gets saltier, causing it to sink.
    - Near the equator, the temperature is warmer. Compared to the poles, the water is less salty and rises.
- Next, project *The Global Conveyor Belt* infographic showing a more detailed depiction of the process. Draw students' attention to:
    - The cold, salty, deep current near the South Pole.
    - The warm, less salty, shallow current near the equator.
    - The direction of flow, indicated by the Ocean Water Flow inset graphic.
    - The locations where changes in the temperature and salt content of the water cause it to sink or rise, driving the currents around the globe (where the currents make sharp bends in the North Atlantic, Indian, and North Pacific oceans).

4. Lead a class discussion on the interactions of thermohaline circulation with effects of global warming and climate change.

- Prompt students to revisit the causes of three main impacts on the world's oceans in the *Oceanic Impacts* handout from the *Oceanic Impacts* activity:
- Warming oceans
- Rising sea levels
- Ocean acidification
- In a Think-Pair-Share format, ask students how thermohaline circulation might contribute to or interact with each of these processes.
- (Listen for students' responses that incorporate the movement of water around the globe distributing the effects of global warming or climate change, for example by moving water warmed at the equator to the poles, where it might melt additional sea ice and raise sea levels).

- Revisit the class *Know and Need to Know* chart to incorporate new insights regarding how thermohaline circulation drives ocean currents, and how these currents can interact with global warming and climate change impacts on the oceans.

Modification

Step 2: If it is not possible to conduct the thermohaline circulation demonstration, there are videos with similar demonstrations online. However, these demonstrations may not align precisely with the lesson instructions (for example, water colors may differ).

Tip

Step 2: The demonstration in this activity requires preparation; please check the *Setup* instructions a few days before conducting the activity to ensure that you have the necessary supplies. To view a video of a similar demonstration, please visit *Surfing Scientist live experiment: Thermohaline circulation* (1:45).

Informal Assessment

Informally assess students' understanding of thermohaline circulation and its role in ocean currents by examining their responses to the video, demonstration, and discussion in their *Circulation of the Seas* handout.

Extending the Learning

Step 3: For a more detailed dive into how ocean currents move water and objects around the world, students may complete the activity *Mapping Ocean Currents*.

OBJECTIVES

Subjects & Disciplines

Earth Science

- Climatology
- Oceanography

Learning Objectives

Students will:

- Identify the variables that drive thermohaline circulation.
- Generate and evaluate predictions related to thermohaline circulation.
- Predict movement of water in ocean currents using their understanding of thermohaline circulation.
- Relate what they learn about thermohaline circulation to ocean temperature rises and acidification.

Teaching Approach

Teaching Methods

- Demonstrations
- Discussions
- Lab procedures

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
  - Learning and Innovation Skills
    - Communication and Collaboration
    - Critical Thinking and Problem Solving
  - Life and Career Skills
    - Initiative and Self-Direction
    - Social and Cross-Cultural Skills
- 21st Century Themes
  - Environmental Literacy
  - Global Awareness
- Critical Thinking Skills
  - Applying
  - Evaluating
  - Understanding

- Geographic Skills
  - Acquiring Geographic Information
  - Answering Geographic Questions
- Science and Engineering Practices
  - Constructing explanations (for science) and designing solutions (for engineering)
  - Developing and using models

National Standards, Principles, and Practices

COMMON CORE STATE STANDARDS FOR ENGLISH LANGUAGE ARTS & LITERACY

• **CCSS.ELA-LITERACY.SL.7.1:**
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on Grade 7 topics, texts, and issues, building on others' ideas and expressing their own clearly.

NEXT GENERATION SCIENCE STANDARDS

• **Crosscutting Concept 2: Cause and Effect:**
Cause and effect relationships may be used to predict phenomena in natural or designed systems.
• **MS-ESS2-6:**
Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.
• **Science and Engineering Practice 2:**
Developing and using models
• **Science and Engineering Practice 6:**
Constructing explanations and designing solutions

Preparation

BACKGROUND & VOCABULARY

Background Information

Currents carry the Earth's ocean water around the planet, moving it between the five major basins—the Atlantic, Pacific, Arctic, Indian, and Southern oceans. These currents are driven by factors such as density differences, wind, and gravitational attraction. Ocean currents are also responsible for determining local weather patterns, even over dry land.

Thermohaline circulation is also called the ocean conveyor belt. It is a particular type of current driven by differences in temperature and salinity within ocean waters. Cold, saltier water is denser and, therefore, sinks. Warm, less salty water is less dense and, therefore, floats. At a few positions in the north and south called deep water formations, water cools, becomes saltier, and sinks, pushing water around the globe and making a full circuit about once every thousand years. If these deepwater formation sites become less cold and salty due to global warming, thermohaline circulation could be disturbed, with major consequences for climate around the world.

Prior Knowledge

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Recommended Prior Activities

- Carbon All Around
- Global Trends
- Heating Up
- Local Emissions
- Meteorological Models
- Now and Then
- Oceanic Impacts
- Our Greenhouse
- Plot It!
- Weather Interconnections
- Weather, Meet Climate

Vocabulary

Term	Part of Speech	Definition

Term	Part of Speech	Definition
climate change	*noun*	gradual changes in all the interconnected weather elements on our planet.
density	*noun*	number of things of one kind in a given area.
global warming	*noun*	increase in the average temperature of the Earth's air and oceans.
ocean conveyor belt	*noun*	system in which water moves between the cold depths and warm surface in oceans throughout the world. Also called thermohaline circulation.
salinity	*noun*	saltiness.
temperature	*noun*	degree of hotness or coldness measured by a thermometer with a numerical scale.
thermohaline circulation	*noun*	ocean conveyor belt system in which water moves between the cold depths and warm surface in oceans throughout the world.

ACTIVITY 3: OCEAN ACIDIFICATION: THE EVIDENCE | 50 MINS

DIRECTIONS

This activity is part of the Climate Change Challenge unit.

1. Show a video and prompt students to identify and describe in detail the effects of ocean acidification.

- Ask students to revisit their *Ocean Impacts* handout from the *Oceanic Impacts* activity. Solicit volunteers to name the three important impacts of climate change on the world's oceans:
    - Warmer oceans
    - Rising sea levels
    - Ocean acidification
- Focusing on ocean acidification, prompt students to brainstorm as a class all of the marine organisms that they think might be affected by these impacts.
- Project a video about the impact of ocean acidification on wildlife and ask volunteers to compare and contrast what they learned with the class brainstorm.

- Assign students to add any new information on the causes and consequences of ocean acidification to Part 1: Causes and Part 2: Consequences of the *Ocean Impacts*handout.

2. Model and support students as they read and summarize linear trends using a graphical representation.

- Project the *NOAA Hawaii Carbon Dioxide Time-Series* graph onto a writable surface (whiteboard or chart paper) and distribute copies to students, prompting them to identify the aspect of this data representation that they have seen before.
- The Keeling Curve analyzed during Lesson 1: *Carbon Concerns* appears in red on this chart.
- Distribute the *Ocean Acidification Trends* handout.
- Using an I Do, We Do, You Do format, support students as they complete Part A of the handout:
    - Draw a trend line on the graph that passes through the data for the red line: Atmospheric Carbon Dioxide. (This is the Keeling Curve, with which students are already familiar.)
    - Complete the first row of this chart for the red line, "thinking out loud" as students observe your choices. Note that the trend summary can be created formulaically, using the information in the y-axis, Trend direction, and y-axis columns:
        - Variable & Identifier: red line = Atmospheric CO_2
        - Y-axis (units): CO_2 (ppm)
        - Trend Direction (increase/decrease): *Increase*
        - X-axis (units): *Time (years)*
        - Trend Summary: *Carbon dioxide concentration has been increasing in the years since 1958.*
    - Then use volunteers' contributions to complete the second row of this chart for the green line: Seawater pCO_2. This line represents a measure of the amount of carbon dioxide in ocean water.
    - Finally, assign students in pairs to complete the final row of the chart for the blue line: Seawater pH.
- In a Think-Pair-Share, prompt students to compare the three trends that they have examined, asking:
    - *Do all three trends occur in the same direction?*
    - *Which trend seems the strongest, and how do you know?*

- *How can we use math to determine which trend is strongest?*
- Students' answers to these questions will help you gauge their prior knowledge of trends and slope, in preparation for the next step

3. Direct students to assess current rates of change in ocean acidification by analyzing current trends.

- Use an I Do, We Do, You Do format to find the slope (m) of each line in the *NOAA Hawaii Carbon Dioxide Time-Series* graph, using Part B of the *Ocean Acidification Trends* handout (see *Tip*) to track your calculations.
- Direct students to compare the values of m (which will differ slightly depending on which points were chosen) with the three lines on the chart, asking:

  - *What is the difference between a positive and a negative slope?* (A positive slope shows an increasing trend over time; a negative slope shows a decreasing trend over time.)
  - *What is the difference between a small value for slope and a large value?* (The larger the slope, the steeper the line.)
  - *Which of these variables is changing most quickly over time?* (Whichever variable has the steepest slope is changing the most quickly, regardless of whether the slope is positive or negative. This is likely the Keeling Curve (red line) in students' calculations; the amount of carbon dioxide in the atmosphere typically changes faster than the other variables that it affects.)
  - *How do these findings connect back to ocean acidification?* (This data tells us that the ocean is indeed getting more acidic (pH is dropping) as carbon dioxide concentrations are rising.)

- Revisit the class *Know and Need to Know* chart, recording any new nuances in students' understanding of the impacts of ocean acidification.

Tip

Step 3: There are multiple ways to calculate slope; students may be familiar with particular methods. If it is necessary to walk students through this calculation, you can do so as follows:

- Choose an early point (Point 1) and later point (Point 2) at either end of the trend line and record their approximate x and y coordinates in the chart.

- Calculate the trend "rise" by subtracting the y-value of Point 1 from the y-value of Point 2 (y2-y1). Calculate the trend "run" by subtracting the x-value of Point 1 from the x-value of Point 2 (x2-x1). These calculations should be done by hand in this activity; in future activities within the lesson, students may move to digital calculation.
- Calculate the slope of the line by dividing the rise by the run (m).
- See below for examples of each of these observations and calculations:
  - **Variable & Identifier:** red line = Atmospheric CO_2
  - **Point 1:** (x1, y1): *(1958, 320)*
  - **Point 2:** (x2, y2): *(2018, 410)*
  - **Rise:** y2-y1: *410-320 =* ***90 ppm***
  - **Run:** x2-x1: *2018-1958 =* ***60 years***
  - **m slope rise/run:** *90/60 =* ***1.5 ppm/year***

Informal Assessment

Informally assess students' understanding of ocean acidification from the details they add to their *Ocean Impacts* handout after watching the video. Assess their ability to summarize linear trends verbally and calculate slope with the *Ocean Acidification Trends* handout.

Extending the Learning

Collaboration with students' math educators may help support and extend their learning as you work with linear trends and their equations in this lesson.

OBJECTIVES

Subjects & Disciplines

Biology
- Ecology

Earth Science
- Climatology
- Oceanography

Learning Objectives

Students will:

- Describe the effects of ocean acidification in detail.
- Verbally summarize linear trends associated with ocean acidification.
- Calculate slope using graphical representations of ocean acidification.

Teaching Approach

- Project-based learning

Teaching Methods

- Lab procedures
- Modeling
- Multimedia instruction

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
  - Information, Media, and Technology Skills
    - Information Literacy
  - Life and Career Skills
    - Flexibility and Adaptability
- 21st Century Themes
  - Environmental Literacy
  - Global Awareness
- Critical Thinking Skills
  - Analyzing
  - Applying
  - Remembering
  - Understanding
- Science and Engineering Practices
  - Analyzing and interpreting data
  - Using mathematics and computational thinking

National Standards, Principles, and Practices

COMMON CORE STATE STANDARDS FOR ENGLISH LANGUAGE ARTS & LITERACY

• **CCSS.ELA-LITERACY.RST.6-8.7:**
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

NEXT GENERATION SCIENCE STANDARDS

• **Crosscutting Concept 2: Cause and Effect:**
Cause and effect relationships may be used to predict phenomena in natural or designed systems.
• **Crosscutting Concept 4:**
Systems and system models
• **Crosscutting Concept 7:**
Stability and change
• **MS-ESS3-2:**
Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.
• **Science and Engineering Practice 4:**
Analyzing and interpreting data
• **Science and Engineering Practice 5:**
Using mathematics and computational thinking

Preparation

BACKGROUND & VOCABULARY

Background Information

Ocean acidification occurs when carbon dioxide in Earth's atmosphere becomes dissolved within the sea, combining with water to form carbonic acid. This change in pH will likely cause problems for some marine organisms with shells and skeletons: the changed conditions make creating and maintaining these structures more challenging. When organisms low on the food chain struggle to stay healthy because of ocean acidification, it affects all of the organisms higher up who rely on them for food, including humans!

Graphical representations help to communicate the messages of data in visual form. Different types of graphical representations, such as bar and line graphs, are suited for use with different types of data. Labels help an audience to interpret graphs. Typically, a graph should have a title, and each axis (x and y) should have a brief text description of the variable being measured.

Prior Knowledge

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Recommended Prior Activities

- Carbon All Around
- Circulation of the Seas
- Global Trends
- Heating Up
- Local Emissions
- Meteorological Models
- Now and Then
- Oceanic Impacts
- Our Greenhouse
- Plot It!
- Weather Interconnections
- Weather, Meet Climate

Vocabulary

Term	Part of Speech	Definition
carbon dioxide	*noun*	greenhouse gas produced by animals during respiration and used by plants during photosynthesis. Carbon dioxide is also the byproduct of burning fossil fuels.

Term	Part of Speech	Definition
climate change	*noun*	gradual changes in all the interconnected weather elements on our planet.
global warming	*noun*	increase in the average temperature of the Earth's air and oceans.
Keeling curve	*adjective*	graph illustrating the amount of carbon dioxide (CO_2) in Earth's atmosphere as measured at the Mauna Loa Observatory in Hawaii.
ocean acidification	*noun*	decrease in the ocean's pH levels, caused primarily by increased carbon dioxide. Ocean acidification threatens corals and shellfish.
pH	*noun*	measure of a substance's acid or basic composition. Distilled water is neutral, a 7 on the pH scale. Acids are below 7, and bases are above.
slope	*noun*	slant, either upward or downward, from a straight or flat path.

ACTIVITY 4: SEA TEMPERATURE: THE EVIDENCE | 50 MINS

DIRECTIONS

This activity is part of the Climate Change Challenge unit.

1. Show a video and prompt students to identify and describe in detail the effects of rising ocean temperatures.

- Prompt students to revisit their *Ocean Impacts* handout from the *Oceanic Impacts* activity to review the three main effects of climate change on the oceans: ocean acidification (covered in the *Ocean Acidification: The Evidence* activity), sea temperature rise (the subject of this activity), and sea level rise.
- In a Think-Pair-Share, ask students to consider whether they think the marine organisms affected by ocean acidification are likely to be the same or different from those affected by rising ocean temperatures.
- Explain to students that the *Rising Ocean Temperatures are "Cooking" Coral Reefs* video (2:52) will give greater detail on this impact. Assign students to add any new information on the causes and consequences of sea temperature rise to Part 1: Causes and Part 2: Consequences of the *Ocean Impacts* handout as they watch.
- Project the video and then solicit volunteers' responses.

2. Model and support students as they summarize linear trends in sea surface temperature using a digital data set.

- Ask students to predict how they think the rate of change in sea surface temperature will compare to the rate of change in dissolved carbon dioxide or pH, based on the *Ocean Acidification: The Evidence* activity.
- Project the *EPA Climate Change Indicators: Sea Surface Temperature* graph, and distribute a copy to each student.
- In a Think-Pair-Share, ask students to respond to the following questions:

  - *How would you describe the data trend on this graph?* (Sea surface temperature has been increasing since about 1910.)
  - *Is the slope (m) of this trend positive or negative?* (The slope of this trend is positive because the line shows an increase in sea surface temperature, overall.)
  - *What do you think the term* anomaly *means in the graph's y-axis?* (This term describes not the temperature itself, but how far above or below the temperature falls compared to the 1971-2000 average; see *Tip*.)
  - It may help students to reach this conclusion if you draw their attention to the 1971-2000 average, depicted as a horizontal dashed line on the chart.

- Click on the spreadsheet link below the graph to project the sea surface temperature data set, prompting students to focus on the Year and Annual Anomaly columns only.
- Distribute the *Sea Temperature Trends* handout to students. Using an I Do, We Do, You Do format, support students as they calculate slope digitally or by hand during three decades in this dataset (1880-1889, 1940-1959, and 2000-2009), as the class did in the *Ocean Acidification: The Evidence* activity. Prompt students to record their calculations in Part A of the handout.

  - Note that students are now using data directly, rather than interpreting from a graph (as in the *Ocean Acidification: The Evidence* activity). So, calculations from all students and the teacher should match in this activity. For example:

    - Decade: 1880-1889
    - Point 1 = (x1, y1): (1880,-.470)
    - Point 2 = (x2, y2): (1889,-.472)
    - Rise = y2-y1: .002 degrees
    - Run = x2-x1: 9 years
    - m = rise/run: .002/9 = 0.00022 degrees/year

3. Model and support students as they use the slope to predict future sea surface temperature from a digital data set.

- Ask students:
  - *How might the slope of a trend help us to predict the future?*
- Using an I Do, We Do, You Do format, support students as they calculate a prediction of the change in sea surface temperature. Use the same three decades of data from the previous step and prompt students to record their calculations in Part B of the *Sea Temperature Trends* handout.
  - For the first row, 1880-1889, rewrite the slope (m), calculated in Part A of the handout.
  - To predict the change in sea surface temperature over the next 100 years based on the decade of data between 1880 and 1889, multiply the slope (m) by 100.
    - Decade: 1880-1889
    - Slope = m: 0.00022 degrees/yr
    - Sea temperature change in 100 years = 100(m): 0.02 degrees/century
  - Calculate the prediction for the period from 1940-1949 alongside students.
  - Direct students to perform the calculations independently for the period from 2000-2009.
- Project the *EPA Climate Change Indicators: Sea Surface Temperature* graph again and ask students to Think-Pair-Share in response to the following questions:
  - *Which decade of data predicts the greatest temperature change in the next 100 years?* (The decade 1940–1949 predicts the greatest temperature change because this was a decade of particularly rapid change (see *Tip*).)
  - *Why do the three decades of data predict different temperature changes for the next 100 years?* (The prediction for each decade depends on the slope. If the temperature happened to increase or decrease during this decade, it would predict a temperature change that matches this local trend within the overall global trend of increase. This is why these are predictions: they are not certain but are educated guesses based on the data.)
  - *Which decade of data do you think makes the most accurate prediction of temperature change over the next 100 years?* (2000–2009 makes the most accurate

prediction, because it contains the most recent data, and because this decade matches those that came before and after it well (the trend in this decade is similar to the overall trend).)

- Revisit the class *Know and Need to Know* chart, incorporating students' evolving understanding of sea temperature rise’s rate and impacts.

Tip

Step 2: Temperature anomalies can be a challenging concept for students to understand. It may help to explain that anomalies let us see small changes up or down from the normal state. This is particularly important in cases like ocean temperature change, where a small change can have a big impact.

Modification

Step 3: If students are already familiar with the linear equation y = mx + b and how to calculate its elements, all the information necessary to predict the sea surface temperature for a particular year is available in this data set. Predictions for the year 2100 may be substituted for the more general predictions of temperature change over 100 years made during this step.

Tip

Step 3: Students may notice that sea surface temperature dropped during the 1940s, according to this data set. Scientists attribute this drop to volcanic eruptions and industry at that time, emitting certain chemicals into the atmosphere that actually scatter or absorb the sun’s energy. When the levels of these chemicals began to fall, the increased greenhouse effect again caused sea surface temperatures to rise.

Informal Assessment

Informally assess students’ understanding of sea temperature rise from the details they add to their *Ocean Impacts* handout after watching the video. Assess their ability to calculate slope and future values of sea temperature using a linear equation with the *Sea Temperature Trends* handout.

Extending the Learning

Collaboration with students' math educators may help to support and extend their learning as you work with linear trends and their equations in this lesson.

OBJECTIVES

Subjects & Disciplines

- Conservation

  Earth Science
  - Climatology
  - Oceanography

Learning Objectives

Students will:

- Describe the effects of sea temperature rise in detail.
- Calculate slope with digital sea temperature data and use it to predict future changes in sea temperature.

Teaching Approach

- Project-based learning

Teaching Methods

- Lab procedures
- Modeling
- Multimedia instruction

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes

- Information, Media, and Technology Skills
    - Information Literacy
- Life and Career Skills
    - Flexibility and Adaptability
- 21st Century Themes
  - Environmental Literacy
  - Global Awareness
- Critical Thinking Skills
  - Analyzing
  - Applying
  - Remembering
  - Understanding
- Science and Engineering Practices
  - Analyzing and interpreting data
  - Using mathematics and computational thinking

National Standards, Principles, and Practices

COMMON CORE STATE STANDARDS FOR ENGLISH LANGUAGE ARTS & LITERACY

• **CCSS.ELA-LITERACY.RST.6-8.7:**
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

NEXT GENERATION SCIENCE STANDARDS

• **Crosscutting Concept 2: Cause and Effect:**
Cause and effect relationships may be used to predict phenomena in natural or designed systems.
• **MS-ESS3-2:**
Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.
• **Science and Engineering Practice 4:**
Analyzing and interpreting data
• **Science and Engineering Practice 5:**
Using mathematics and computational thinking

Preparation

BACKGROUND & VOCABULARY

Background Information

Prior Knowledge

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Recommended Prior Activities

- Carbon All Around
- Circulation of the Seas
- Global Trends
- Heating Up
- Local Emissions
- Meteorological Models
- Now and Then
- Ocean Acidification: The Evidence
- Oceanic Impacts
- Our Greenhouse
- Plot It!
- Weather Interconnections
- Weather, Meet Climate

Vocabulary

Term	Part of Speech	Definition
carbon dioxide	*noun*	greenhouse gas produced by animals during respiration and used by plants during photosynthesis. Carbon dioxide is also the byproduct of burning fossil fuels.
climate change	*noun*	gradual changes in all the interconnected weather elements on our planet.
global warming	*noun*	increase in the average temperature of the Earth's air and oceans.

Term	Part of Speech	Definition
slope	*noun*	slant, either upward or downward, from a straight or flat path.
temperature	*noun*	degree of hotness or coldness measured by a thermometer with a numerical scale.

ACTIVITY 5: SEA LEVEL: THE EVIDENCE I 1 HR 15 MINS

DIRECTIONS

This activity is part of the Climate Change Challenge unit.

1. Show a video and prompt students to identify and describe in detail the effects of sea level rise.

- Ask students to recall information related to sea level rise, and brainstorm possible effects of this change:
  - *Why is sea level rising in some places around the world?*
  - *In coastal cities or towns, how might the waterfront be affected if the sea level rose two feet?*
  - *How might businesses and homes be affected?* (If your state is inland, it may help to pose this question in terms of rising water levels for a local body of water, then ask students to extrapolate for the ocean.)
- Prompt students to revisit their *Ocean Impacts* handout from the *Oceanic Impacts* activity, identifying the three main effects of climate change on the oceans: ocean acidification, sea temperature rise (covered in *Ocean Acidification: The Evidence* and *Sea Temperature: The Evidence* respectively) and sea level rise (the subject of this activity).
- Explain to students that the *Sea Level Rise and Coastal Cities* video (3:16) will give greater detail on this impact. Assign students to add any new information on the causes and consequences of ocean acidification to Part 1: Causes and Part 2: Consequences of the *Ocean Impacts* handout as they watch.
- Project the video and then solicit volunteers' responses.
- In a Think-Pair-Share, ask students:

- *Do you think sea level rise in Miami is predicted to be high or low compared to other coastal cities in the United States? Why?*

2. Prompt students to summarize linear trends in sea level using a digital data set.

- Distribute the *Sea Level Rise Trends* handout to students. Project the *NOAA Sea Level Trends from U.S. Stations* map. Start by examining the key below the map, which clarifies the meaning of the arrows for each major coastal city. Ask students the following questions, writing volunteers' answers in a visible location:
  - *What does a red up arrow mean in terms of predicted sea level rise?* (A red up arrow means the water is predicted to rise more than 9mm/year or 3 feet/century.)
  - *What does a green up arrow mean?* (A green up arrow means that the water is predicted to rise from just over 0 to 3 mm/year or 0 to 1 feet/century.)
  - *What does a down arrow mean?* (A down arrow means the sea is predicted actually to fall relative to the coastal land in this area. This is true for many cities in the far north, where melting glaciers actually allow the land to move up as their weight decreases. See *Tip* for more information.)

- Zoom in on Miami, the city featured in the video from Step 1. Click on the green arrow to review the precise sea level trend for this city: 2.39mm/year in the period from 1931–1981.
  - Point out to students that this is a measure of slope. For this reason, students do not need to calculate slope, as they did in the previous two activities. Prompt them to simply enter this value in the first row of the chart in Part A of their *Sea Level Rise Trends* handout.

- As students observe, remind students how to calculate the predicted sea level rise in 100 years from this value, by multiplying the slope (2.39 mm/yr) by 100 years, if current rates remain unchanged.
  - City: Miami
  - Slope = m: *2.39 mm/yr*
  - Sea level change in 100 years = 100 (m): 239 mm

- Visualize this by marking, with tape on the wall, the height of water in Miami 100 years from now.

- In pairs, have students look up an additional city to determine its recent sea level rise trend. Calculate the predicted sea level rise in 100 years, if current trends continue, with their partner.
    - Encourage pairs to choose different cities from one another so a wide variety of sea level rise trends are represented.
- Direct pairs of students to add to the visualization of sea level rise by marking their cities' predicted changes on the classroom wall with tape.
- End by supporting students as they reflect on these trends, asking:
    - *Which cities have the highest predicted sea level rise?* (Any cities with orange or red arrows from the original map will have high predicted sea level rise compared to those with green arrows).
- *How does Miami, which we know from the video will struggle with sea level rise, compare to the other cities represented here?* (Miami has a low predicted sea level rise relative to many other U.S. cities.)

3. Model and support students as they graph linear trends in sea level and predict future sea level changes.

- In an I Do, We Do, You Do format, beginning with Miami on the *NOAA Sea Level Trends from U.S. Stations* map, demonstrate and walk students through reading sea level data, creating a scatterplot, and adding a linear trendline (see *Tip*).
- When students have finished creating a scatterplot for one of the cities of their choice (initiating their portfolio product for this lesson), assign them to write an evidence-based statement regarding sea level trends in this city. First, students should draft it using Part B of the *Sea Level Trends* handout. Then add it immediately below their digital graph of sea level rise to help non-scientists interpret the information.
    - For example, an evidence-based statement for Miami would be: *Sea level is increasing in Miami, at a rate of 2.39 mm/year. In 100 years, the ocean there will rise 239 mm.*

4. Direct students to examine strategies for adapting to the effects of sea level rise.

- Ask students: *What actions do you think humans can take to adapt to sea level rise?*

- In pairs, assign students to read and annotate one of two articles about adaptation in response to sea level rise:
    - *Sea level rise, explained*
    - *As the climate crisis worsens, cities turn to parks*
- When students have finished reading, assign pairs to create a list in Part C of their *Sea Level Trends* handout. Have students include all the strategies they discovered in the two articles involving the use of technology, specifically, to fight the effects of sea level rise. Emphasize that technology can be as simple as a park and as complicated as an underground structure to hold floodwaters.
- Prompt pairs to choose at least three of these technologies the articles describe as effective and that they think will be particularly helpful to the city they focused on in the previous step. Direct students to record them below their evidence-based prediction and graph in their portfolio product.
- Distribute the *Changing Seas Rubric* to pairs and assign them to self-assess their portfolio product (graph, evidence-based prediction, and adaptation technologies) using this tool.
- Allow students time to incorporate their findings from the rubric and ensure that each student saves a digital copy of their product, for assessment and for incorporation into their final project portfolio.
- Revisit the class *Know and Need to Know* chart to incorporate any new knowledge of sea level rise or its consequences.

Modification

Step 2: If students are already familiar with the linear equation y = mx + b and how to calculate its elements, all the information necessary to predict the sea level change for a particular year is available in this dataset. Predictions for the year 2100 may be substituted for the more general predictions of sea level change over 100 years made during this step.

Tip

Step 2: It may be challenging for students to understand why sea level is dropping, relative to the local landmasses, in the far northern United States. Although this is due to a variety of forces, one important driver involves melting glacial ice removing mass from on top of the land, allowing it to rise. An *image* of this process may help students to grasp its function.

Modification

Step 3: If time is short, students may simply save the NOAA graph of their city's data and use this rather than creating a digital graph of their own in the portfolio product. The critical aspect of this work is students' ability to interpret and explain the trends they see!

Tip

Step 3: To model the creation of a scatterplot with linear trend line from sea level data, complete the following steps:

- For a given city, click on the *Linear Trend* link under *Choose Plot* to view the data associated with this sea level trend. Then, click the *Export to CSV* button and open the data in a spreadsheet program.
- Examine the data labels, noting that the first column contains the year, the second column contains the month, and the third column (Monthly_MSL) is the mean surface level for that month.
- Generate a simple scatterplot for the data (year and Monthly_MSL columns only) and add a linear trend line. Show the equation for this trend line on the chart. Note that the slope for this trend line should match the slope reported for each city (for example, 2.39 mm/year for Miami), but the units for the data are in meters, rather than millimeters.
- Add x- and y-axis labels, as well as a title to the chart.

Rubric

Formally assess students' ability to graph linear trends from large datasets, to interpret trends in the data, and to explain adaptation technologies using the *Changing Seas Rubric*, to meet PE *MS-ESS3-2*: Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

Extending the Learning

Collaboration with students' math educators may help to support and extend their learning as you work with linear trends and their equations in this lesson.

OBJECTIVES

Subjects & Disciplines

Earth Science

- Climatology
- Oceanography

Learning Objectives

Students will:

- Describe the effects of sea level rise in detail.
- Use the slope of sea level trends to make an evidence-based statement predicting future sea level change.
- Identify technologies used to adapt to sea level rise.

Teaching Approach

- Project-based learning

Teaching Methods

- Lab procedures
- Modeling
- Multimedia instruction

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
  - Information, Media, and Technology Skills
    - Information Literacy
  - Life and Career Skills
    - Flexibility and Adaptability
- 21st Century Themes

    - Environmental Literacy
    - Global Awareness
- Critical Thinking Skills
    - Analyzing
    - Applying
    - Remembering
    - Understanding
- Science and Engineering Practices
    - Analyzing and interpreting data
    - Using mathematics and computational thinking

National Standards, Principles, and Practices

COMMON CORE STATE STANDARDS FOR ENGLISH LANGUAGE ARTS & LITERACY

• **CCSS.ELA-LITERACY.W.7.1:**
Write arguments to support claims with clear reasons and relevant evidence.

NEXT GENERATION SCIENCE STANDARDS

• **Crosscutting Concept 2: Cause and Effect:**
Cause and effect relationships may be used to predict phenomena in natural or designed systems.
• **Crosscutting Concept 4:**
Systems and system models
• **MS-ESS3-2:**
Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.
• **Science and Engineering Practice 4:**
Analyzing and interpreting data
• **Science and Engineering Practice 5:**
Using mathematics and computational thinking

Preparation

BACKGROUND & VOCABULARY

Background Information

Sea level rise occurs in response to global warming for two main reasons. First, heat causes the water already within oceans to expand. Second, when glaciers and other ice melts, the resulting water joins the world's oceans. Global sea level has risen already, and the rate of rise is increasing as well. However, different locations will experience different degrees of local sea level rise. In addition to causing persistent flooding in coastal areas, sea level rise can also cause greater storm surges, which can be damaging and even deadly.

Graphical representations help communicate the messages of data in visual form. Different types of graphical representations, such as bar and line graphs, are suited for use with different types of data. Labels help an audience interpret graphs. Typically, a graph should have a title, and each axis (x and y) should have a brief text description of the variable being measured.

Prior Knowledge

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Recommended Prior Activities

- Carbon All Around
- Circulation of the Seas
- Global Trends
- Heating Up
- Local Emissions
- Meteorological Models
- Now and Then
- Ocean Acidification: The Evidence
- Oceanic Impacts
- Our Greenhouse
- Plot It!
- Sea Temperature: The Evidence
- Weather Interconnections
- Weather, Meet Climate

Vocabulary

Term	Part of Speech	Definition
carbon dioxide	*noun*	greenhouse gas produced by animals during respiration and used by plants during photosynthesis. Carbon dioxide is also the byproduct of burning fossil fuels.
climate change	*noun*	gradual changes in all the interconnected weather elements on our planet.
global warming	*noun*	increase in the average temperature of the Earth's air and oceans.
sea level rise	*noun*	increase in the average reach of the ocean. The current sea level rise is 1.8 millimeters (.07 inch) per year.
slope	*noun*	slant, either upward or downward, from a straight or flat path.