

Name: _____

Date: _____

Student Activity 1

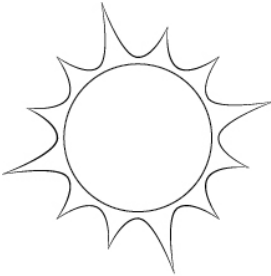
Carbon Dioxide

Part 1: Carbon Dioxide in the Atmosphere

How does carbon dioxide in the atmosphere affect climate? To investigate, analyze the Keeling Curve Graphs, created from data collected from the Mauna Loa Observatory in Hawaii.

1. What effects do you think carbon dioxide has on Earth's atmosphere? How do we experience these effects?

2. Watch the short video clip, and indicate where thermal energy (heat) is being absorbed, reflected, or radiated. Label these energy flows as visible light, infrared light, or both.



3. What effect does carbon dioxide have on the energy being transferred from the Sun to Earth?
What about the energy being radiated from Earth to space?

4. What will happen to the amount of energy radiated from the Sun to Earth if the amount of carbon dioxide in the atmosphere continues to increase? What about from Earth to space?

Name: _____

Date: _____

5. The total amount of carbon on Earth today is the same as when Earth was formed 4.5 billion years ago. It has not increased over time. So, why is carbon such a problem now? (**Hint:** Recall the carbon cycle.)

6. What is driving the overall trend for the concentration of carbon dioxide for the last 10 000 years of Earth's history? What is driving the trend for the concentration of carbon dioxide for the last 100 years of Earth's history?

Part 2: Carbon Dioxide in the Ocean

While the concentration of carbon dioxide in the atmosphere has increased dramatically in the recent past, the spike is not as sharp as it should be. The ocean actually absorbs and stores a substantial amount of the carbon dioxide produced each year. What is the effect of the ocean storing carbon dioxide?

1. Collect two beakers of seawater solution. Place 5 or 6 drops of bromothymol blue in each solution. Stir using a glass rod to evenly dilute the indicator. Based on the colour of the solution, estimate the pH using an indicator scale.
The pH of seawater is _____.
2. Predict what will happen if you continuously blow into one of these solutions. What changes will take place, if any?

3. Take a straw and softly blow into the second solution continuously for 30–60 s. Record your observations. Discuss them with your group.

4. Using prior knowledge and what you know about your breath, explain why these changes have occurred.

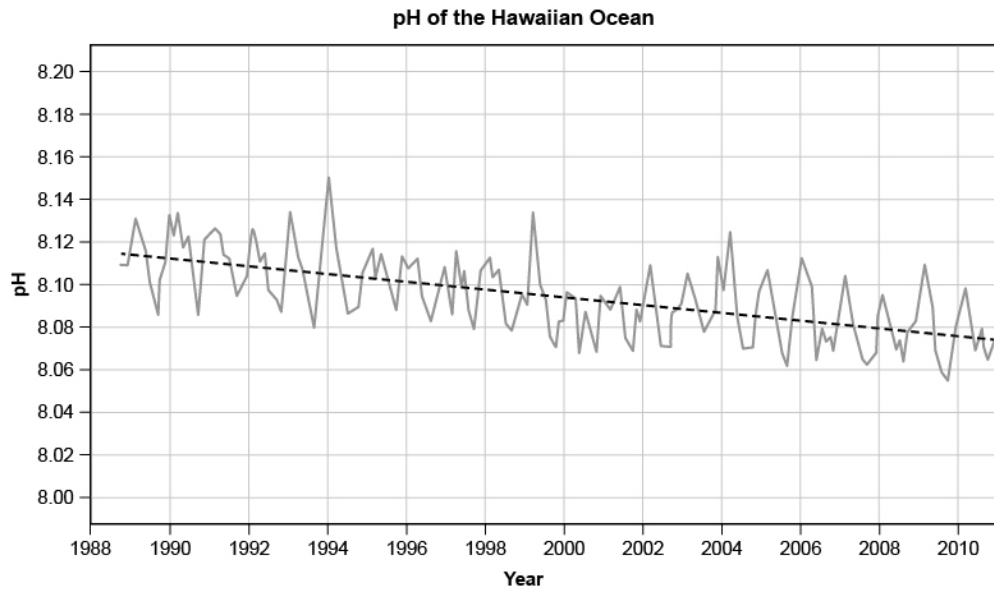
5. Using the indicator scale, estimate the pH of the seawater you blew into. The pH of the seawater you blew into is _____. Compare this to the pH of the seawater you did not blow into.

6. Using your knowledge about the increasing carbon dioxide concentration from Part 1 of this activity, predict how the pH of seawater has been changing in recent history.

Name: _____

Date: _____

7. Compare and contrast your prediction to the following graph of seawater pH in the Hawaiian Ocean:



Source: Hawaii Ocean Time-series (HOT) Station Aloha, Hawaii, North Pacific

8. What do you think the consequences of the changing pH of seawater are? Compare your answers with those of a partner and be prepared to share your ideas.

9. How is this effect changing over time, and why?

Name: _____

Date: _____

Consolidate Your Learning

Answer the following questions to check your understanding of concepts relating to carbon dioxide emissions in the atmosphere and in the ocean.

1. Looking at recent trends of atmospheric temperature and ocean pH, do you think these trends will continue indefinitely? Why or why not?

2. If the industrial revolution had not occurred, what would you expect the carbon dioxide levels to be like? What would the relative effects on the atmosphere and the ocean be? Justify your answers.

3. How is the increasing concentration of carbon dioxide affecting Earth's ecosystems? Support your answer using observational evidence.

4. Governments can help reduce carbon dioxide emissions by imposing a carbon tax. A carbon tax attaches a cost to polluting. What are some pros and cons for this approach? What other ideas might work?

Pros	Cons

Student Activity 2

Climate Modelling

Science Background

How do forcing factors such as ozone depletion or volcanic eruptions change Earth's average temperature? In this activity, you will explore how a climate model can be used to answer this question. A climate model is a computer program that allows scientists to isolate variables called forcing factors to determine the impact of each variable on the global temperature anomaly. The global temperature anomaly describes the change in average temperature relative to a baseline period. Normally, the energy flowing into our planet would be equal to the energy flowing out, and the temperature anomaly would fluctuate around zero. Your group will examine the data generated by the NASA Goddard Institute for Space Studies (GISS) climate model.

Part 1: Analyzing Individual Forcing Factors

1. As a group, choose one of the graphs you've been given. Examine it, read the information on the back, and answer the questions below. Graph _____
 - (a) Look at the scale and units for the vertical axis. How much has the temperature changed over the time shown? Does this seem significant to you?

- (b) Look for patterns in the data. Are there cycles? Are there trends? Are there exceptions? Briefly describe three patterns that you notice.

- (c) What questions do you have about the data?

Part 2: Comparing Forcing Factors

1. Examine all of the graphs together.
 - (a) Put the factors in order from largest to smallest contributor. (**Hint:** The vertical scales are not the same for all graphs.)

- (b) Group the factors by their effects: Do they increase temperature, decrease temperature, or have a negligible effect on temperature?

Effect of Forcing Factors on Temperature

Increase Temperature	Decrease Temperature	Negligible Effect

- (c) Which factors are anthropogenic (made by humans)?

- (d) Are you surprised by any of the graphs? Discuss.

2. The Temperature Change Due to All Forcings Combined graph shows the average temperature anomaly generated by the model when all forcing factors are included. Examine it closely, and compare it to your prediction and the individual graphs to answer the following questions.

- (a) What is the overall trend when all the forcing factors are combined?

- (b) There are several noticeable dips in the graph. What do you think caused these changes?

3. The Observed Global Temperature Anomaly graph combines data collected by thousands of weather stations around the world since 1900. Examine it closely and discuss the following with your group:

- (a) What is the overall trend? Does it match up with the trend predicted by the models?

- (b) The Paris Accord set a target of keeping the anomaly below 2°C above pre-industrial levels. Use the data to estimate when we will reach that level if we don't change anything.

Consolidate Your Learning

Answer the following questions to check your understanding of climate modelling, forcing factors, and climate change data.

1. What are the two most significant forcing factors? How are they similar? How are they different?

2. Some climate change deniers say that the current trend in temperature is due to natural events. Is this statement supported by data? Give examples.

5. What personal actions are you willing to take to reduce your impact on the climate? List at least two, and explain how these actions will help.

Student Activity 3

A Warming World

Part 1: Where will the heat go?

Humans are emitting greenhouse gases into the atmosphere, causing more and more heat to be trapped. But what effect will this have? There are three videos that demonstrate a set of simplified models of Earth's climate, which you will use to explore the answer to this question.

1. **Predict and explain** what you think will happen in column 2 of **Table 1**. Obtain a stamp.
2. **Observe and explain** the demonstration videos at tinyurl.com/b6u2heatdemos_MHS and record these in column 3. Use the space in column 4 to make a sketch to support your explanation. You may need to replay the demonstrations a couple of times.
3. These models allow us to make inferences about our changing climate. Using your observations, answer the questions in column 5.

(prediction stamp here)

Part 2: Data from the Sea

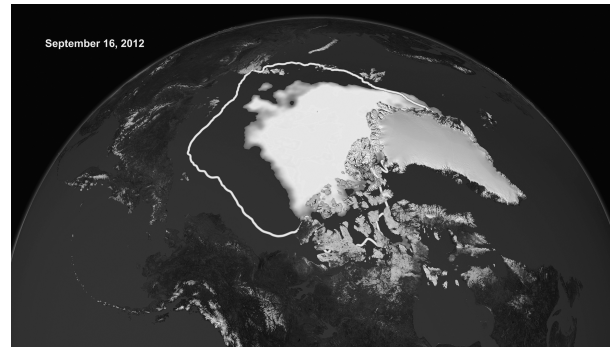
Our oceans have absorbed 90% of the excess heat trapped by increasing amounts of greenhouse gases. Measurements of the oceans suggest they are undergoing significant changes.

1. Examine the images below, showing the retreat of a glacier and the decline of sea ice in the Canadian Arctic. Brainstorm possible consequences of these changes for humans and animals.



Credit: NASA Earth Observatory

Like the vast majority of glaciers, the Gangotri Glacier in the Himalayas has shown a consistent retreat.



Credit: NASA/Goddard Space Flight Center Scientific Visualization Studio

The sea ice in the Canadian Arctic in 2012 has declined significantly compared with 30 years ago (yellow line).

Name: _____

Date: _____

2. Over 40% of the world's population lives within 100 km of a coast. Scientists project that sea levels will rise by 0.50–1.65 m by the year 2100. Examine the flood risk map suggested by your teacher. Brainstorm consequences of sea level rise on populations and infrastructure.

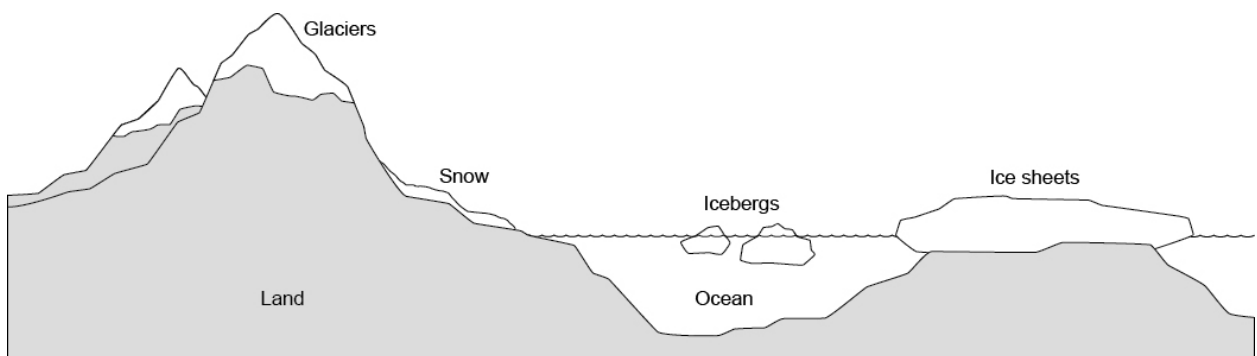
3. Your friends in Kansas tell you they aren't worried about sea level rise since they don't live near an ocean. In what ways might populations living far from a coast be affected?

Consolidate Your Learning

Answer the following questions to check your understanding of concepts relating to the effects of climate change.

1. Some friends are discussing an article stating that the global average temperature has increased by less than a degree since 1880. They wonder whether the climate is really changing. How might you respond?

2. Examine this sketch of different types of ice. Circle the types that will contribute to sea level rise. Explain your answer in the space below.



Name: _____

Date: _____

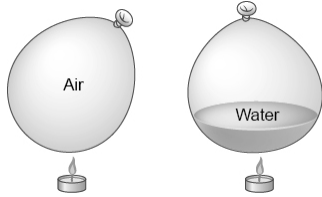
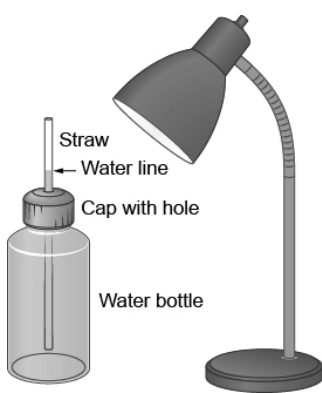
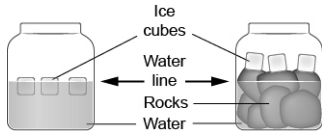
3. How might sea level change affect you and your community? Specifically consider the financial costs to individuals. What could your community do to lessen the effects?

4. How might decreasing sea ice and rising sea levels affect Inuit communities in the far North?

Name: _____

Date: _____

Table 1

1. Demonstration	2. Predict and Explain	3. Observe and Explain	4. Sketch a Model	5. Infer
<p>Balloon with air and balloon with water</p> 	<p><i>Which balloon will pop first when held over a flame? Why?</i></p>	<p><i>Observations:</i></p> <p><i>Explanation:</i></p>		<p><i>As the planet continues to warm, where will most of the additional heat be stored? In the atmosphere or in the ocean?</i></p>
<p>Water bottle with heat source</p> 	<p><i>What will happen to the water level in the straw as the water absorbs heat? Why?</i></p>	<p><i>Observations:</i></p> <p><i>Explanation:</i></p>		<p><i>How will the volume of the ocean change if it absorbs heat?</i></p>
<p>Container with water and ice and container with water, rocks, and ice</p> 	<p><i>What will happen to the water level in each container over time? Why?</i></p>	<p><i>Observations:</i></p> <p><i>Explanation:</i></p>		<p><i>How will melting land ice and sea ice affect sea levels?</i></p>