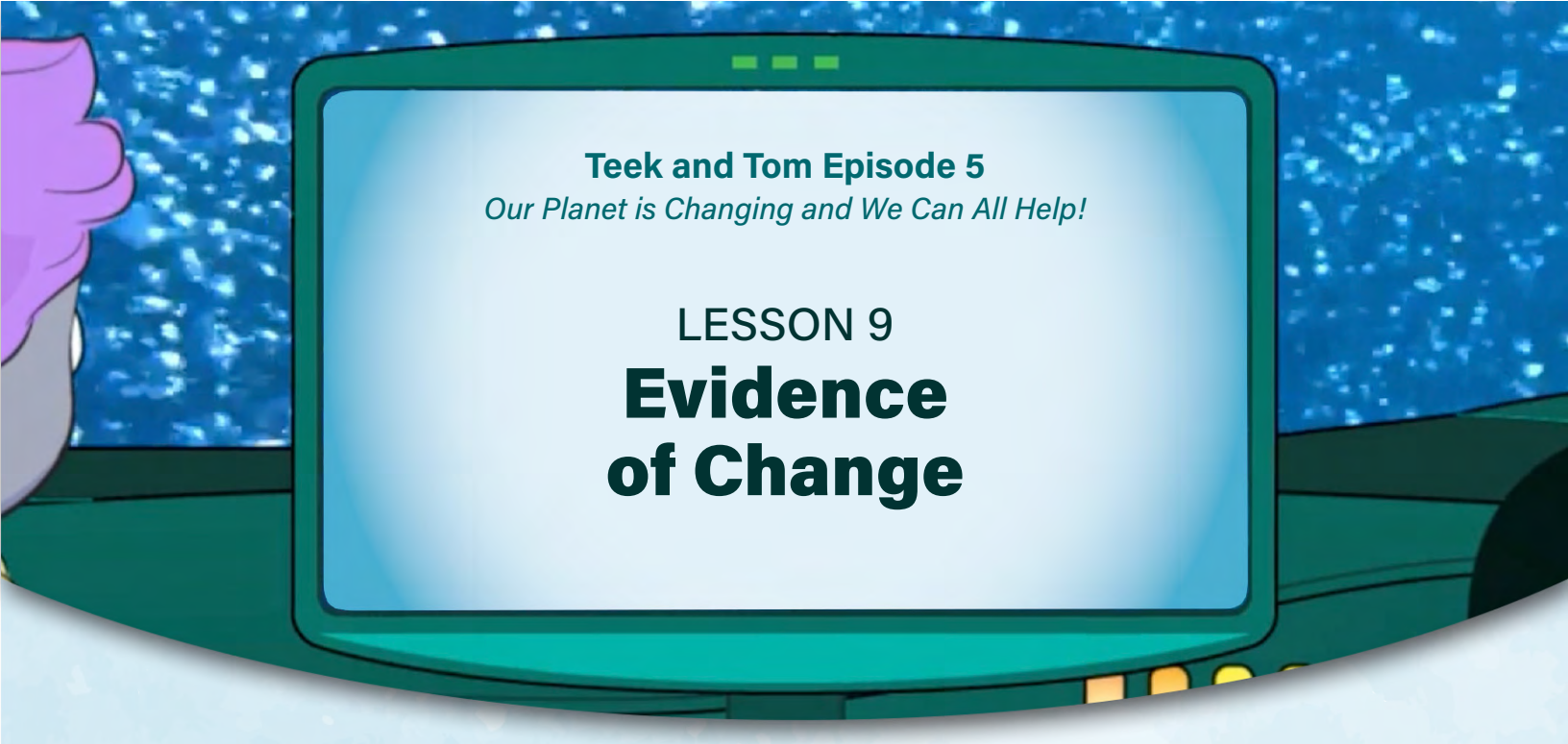


Teek and Tom Episode 5

Our Planet is Changing and We Can All Help!

LESSON 9

Evidence of Change

All URLs were reviewed and accurate at the time of this lesson's publication. If you should come across a non-operational link, contact NOAA Ocean Service Education at oceanserviceseducation@noaa.gov. All images are credited to NOAA unless otherwise noted.

Introduction

Earth gets energy similar to Teek's planet Queloz — from a star. We call ours the sun. Like all stars, our sun generates energy, which is transferred through space to the Earth. Some of this solar energy is absorbed by our planet's surface, heating it; some is absorbed by the atmosphere, heating it; some is reflected back into space; and the rest is radiated back into the atmosphere, heating it as well. The earth-atmosphere energy balance is the balance between incoming energy from the sun and outgoing energy from the Earth.

As the heat energy makes its way through our atmosphere and back out to space, greenhouse gases absorb much of it. Greenhouse gases are more complex than other gas molecules in the atmosphere, with structures that can absorb heat. They radiate the heat back to the Earth's surface, to other greenhouse gas molecules, or out to space. There are different types of greenhouse gases, but the major ones are water vapor, carbon dioxide, methane, and nitrous oxide. These gases act like a blanket over the Earth, maintaining the planet's stable temperature and climate. Without this atmospheric blanket, Earth would be much, much colder and uninhabitable.

The levels of greenhouse gases on Earth have changed naturally over 4 billion years. Then, people started burning ancient dead plants, or fossil fuels, for electricity, heat, transportation, and manufacturing. This released much more greenhouse gases, especially carbon dioxide, into the atmosphere.

The top few meters of the ocean store as much heat as Earth's entire atmosphere, and it is absorbing even more energy as increasing levels of greenhouse gases continue to trap more of our planet's heat. Higher ocean temperatures are causing many problems on our planet, such as sea level rise, large-

scale bleaching of coral reefs, rapid melting of massive glaciers and ice sheets, changes in weather patterns leading to drought and flooding, and increases in specific types of severe weather. There is an extensive list of impacts due to a warming world, but for this activity, we focus on the impacts tied to ocean-weather connections presented in previous activities.

Lesson Summary

Students will investigate data about carbon dioxide in the atmosphere and the resulting warming of the Earth and the ocean. They will construct a "futures wheel" to identify multiple layers of consequences of a warming ocean.

Objectives

- Students will be able to explain the role that the atmosphere plays in regulating heat on Earth.
- Students will be able to use graphs to identify trends in the amount of carbon dioxide in the atmosphere and the corresponding rise in the Earth's temperature.
- Students will be able to identify the impacts of a warming ocean.

Estimated Time

It is estimated that one to two 45-minute class periods are needed for each lesson. This does not include the time required to view Episode 5 of Teek and Tom, *"Our Planet is Changing and We Can All Help!"*, 13:13 minutes (https://oceantoday.noaa.gov/teekandtom/episode-5.html).

Education Standards

The lessons that accompany the Teek and Tom series were designed for upper elementary and middle school students. The standards addressed are abbreviated here. A full list of standards is available in Appendix A (https://oceantoday.noaa.gov/teekandtom/educators-guide/appendix-a.pdf).

Next Generation Science Standards

- 3-ESS3-1: Earth and Human Activity. Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard.
- 5-ESS3-1: Earth and Human Activity. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.
- MS-ESS3-2: Earth and Human Activity. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.
- MS-ESS3-5: Earth and Human Activity. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
- ESS3.D: Global Climate Change Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming).

Common Core English and Language Arts: Writing Standards Grades 4-5

Common Core Mathematics: Measurement and Data - Represent and interpret data.

College, Career, and Civic Life (C3) Framework for Social Studies: Geographic Representations

Materials

For a class of 30

- Chart paper (17 by 20 inches or larger). (One sheet per small group of 2-4 students)
- Pencils
- Markers, crayons, or colored pencils
- Students will need printouts of student record sheets to carry out the activities. Student record sheets are located at the end of this lesson. Depending on the configuration of your classroom, we recommend one set per student or group.
- All maps, graphics, and data tables that are presented in the activity are available as a slide set to project or present while teaching these activities. (https://oceantoday.noaa.gov/teekandtom/educators-guide/slide-set-9.zip)

Preparation

No special preparation is needed for this lesson.

Credit: Shutterstock

InvesTeekation Pathway

ENGAGE

Part 1. Engage

Warming sea surface temperatures from climate change are forcing American lobster (*Homarus americanus*) populations to move to higher latitudes, changing fishing communities on the New England coast. While southern New England lobstermen have found increasingly empty traps since the mid-1990s, Maine's lobster fishery has boomed. "It's not that southern New England lobsters are getting up and moving to the south of Maine," explains Jonathan Hare, an oceanographer and director of NOAA's Northeast Fisheries Science Center laboratory in Narragansett, Rhode Island. "Instead, it's that the number of juvenile lobsters that make it to adulthood has dropped in southern New England and risen sharply in the Gulf of Maine."

Discussion questions

1. Compare the two images from 1967 and 2014. What do you notice about where the most lobsters are caught?

   In 1967, most lobsters were caught near Rhode Island, Massachusetts, and New Jersey. In 2014, many more lobsters were caught near Maine.

2. Where do you think the highest number of lobsters will be found in another 50 years?

   If the trend continues, the lobster populations will be higher in Maine and Canada.

3. Is Tom's comment about Canadian lobsters possible?

   Yes, the trend seems to indicate that the lobster population will move into Canadian waters.

EXPLORE

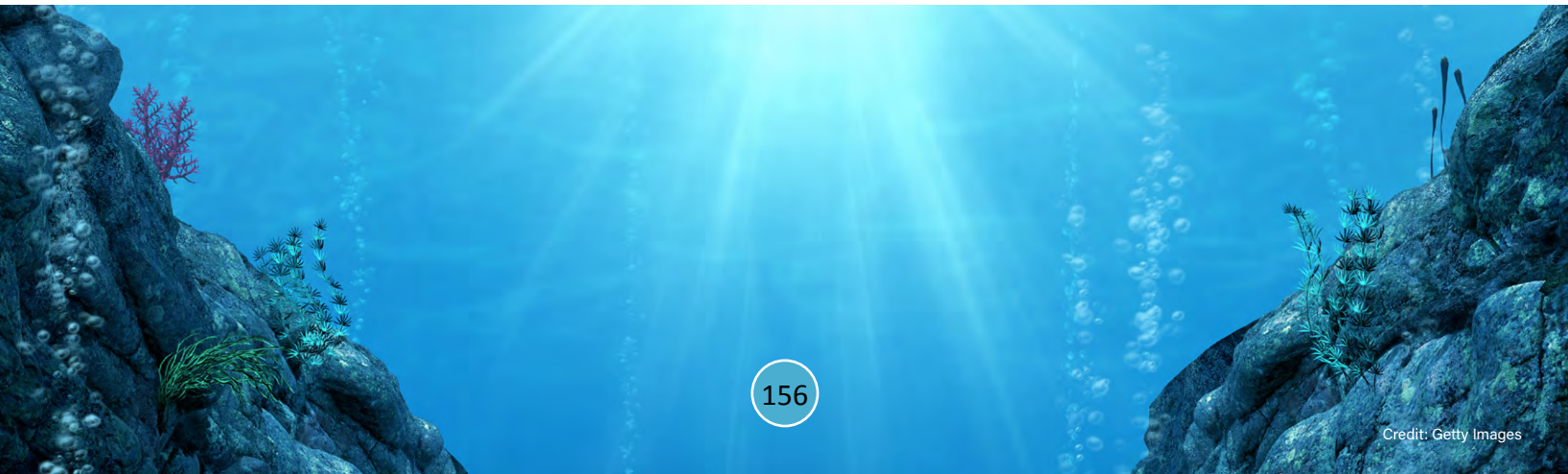
Part 2. Explore

Students will investigate why the ocean is warming. The Earth receives energy from the sun, and some of that heat energy is reflected back into space. Greenhouse gases in the air trap part of the reflected heat energy like a blanket. Students will compare two diagrams showing the natural greenhouse effect and a human-enhanced greenhouse effect, and complete the chart in their record sheets.

Compare	Natural Greenhouse Effect	Human-enhanced Greenhouse Effect
Amount of solar radiation entering the atmosphere from the sun	*Same amount coming from the sun*	*Same amount coming from the sun*
Amount of reradiated heat from the Earth's surface	*Same amount of heat coming from the Earth's surface*	*Same amount of heat coming from the Earth's surface*
Amount of heat that escapes into space	*The same amount of energy Earth receives from the sun is emitted back into space*	*Due to our emissions of greenhouse gases, less heat escapes into space than we receive from the sun. The extra heat energy is why the Earth is warming*
Thickness of greenhouse gas blanket	*Greenhouse gas blanket is thinner*	*Greenhouse gas blanket is thicker*
Amount of heat that bounces off the atmosphere back to Earth (reemitted heat)	*Very little heat is reemitted back to Earth*	*A lot of heat is reemitted back to Earth*

Discussion questions

1. What greenhouse gases are common in the atmosphere? *CO_2 CH_4 and N_2O*
2. From these diagrams, what do you think is the main reason the Earth is getting warmer?
   Human emissions of greenhouse gases are increasing the thickness of the atmospheric "blanket."



Part 3. Explain

The Mauna Loa CO2 dataset represents the longest existing continuous record of CO2 concentration in the atmosphere since modern scientific measurements began in 1958. The data, known as the "Keeling Curve," is central to any discussion of climate change. An increase in greenhouse gases means that we have changed the energy balance of our planet by not letting the heat escape. The result is that global temperatures rose about 1.98 °F (1.1 °C) from 1901 to 2020. And they are still rising!

Discussion questions

1. What do you notice about the amount of atmospheric carbon dioxide at Mauna Loa since 1958?

   It has been rising at a steady rate.

2. What do you predict will happen in the next 10 years?

   If the trend continues, it will go higher.

3. As we burn fossil fuels like coal, oil, and natural gas and cut down trees, we add carbon dioxide to the atmosphere. Suggest one way to limit the amount of carbon dioxide that goes into the atmosphere.

   Students may suggest such things as driving less, using mass transportation, planting trees, or using solar and wind power.

4. Look at the two images showing the long-term trend of Earth temperatures. The top image is from 1901-2023. How many years does this represent?

   123 years

5. The lower image is from 1994-2023. How many years does this represent?

   30 years

6. Which image shows a higher warming trend **per year**? What evidence supports your idea?

   The map from 1994-2023 shows a higher warming trend. This means that more warming occurred during the 30 years from 1994-2023 than over the 123 years from 1901-2023. We can see this as a lot more areas are red, showing more than a 1-degree increase over 30 years, especially in northern areas, compared to the map from 1901-2023.

7. What parts of the world seem to be heating up the fastest? *The Arctic, the northern and eastern United States, and Europe.* Do you live in one of those places? *Answers will vary, but students who live in the eastern United States should notice an increasing temperature trend.*

8. What differences do you observe in the temperature anomalies (differences from the average) in 1960 and 2020 compared to the 1971-2000 average ocean surface temperature?

   The temperature anomaly in 2020 was a positive 1 degree compared to 1960, which is minus 0.25 degrees.

9. Based on the changes you see from 1880-2020, what temperature trend do you predict the graph will show in 2030?

   Based on the upward trend, a temperature anomaly of positive 1.5 is possible by 2030.

ELABORATE

Part 4. Elaborate

Impacts of a Warming World

1. Review key points in previous lessons related to weather and climate change with students. Ask students to summarize what they have learned about the ocean's impact on weather and severe events, including what they know about the impact of a warming ocean. This topic was introduced in part five of lesson six.

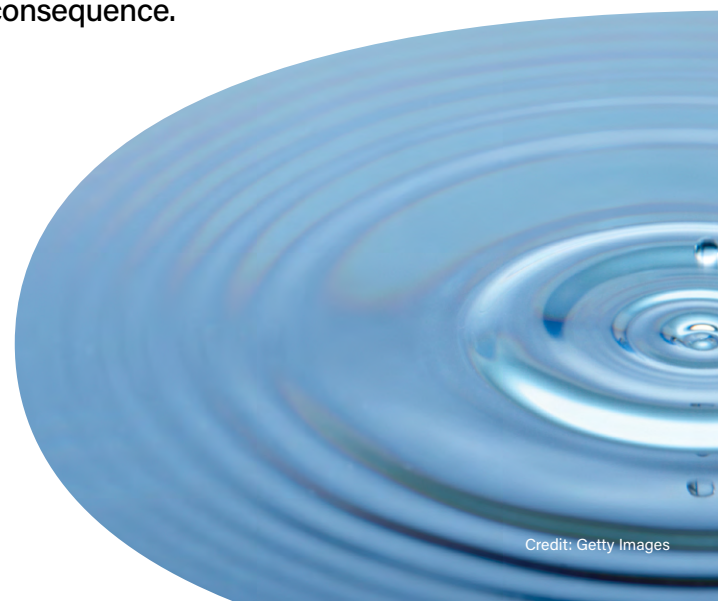
   The main points include:

   - Prevailing winds move air masses and moisture from the ocean or Great Lakes. The warmer the water, the more moisture is in the air, which could mean wetter and stronger hurricanes and rainstorms. Hurricanes are expected to cause more intense rainfall, coastal floods, and higher storm surge caused by rising seas.
   - Climate change will likely increase atmospheric river intensity, causing more extreme events. A warming ocean leads to more moisture for the powerful storms they bring, causing heavy precipitation for the coasts and for storms inland.
   - Ocean and atmospheric conditions that "feed" hurricanes and other severe weather may become warmer and wetter. Heat energy is the fuel for storms.

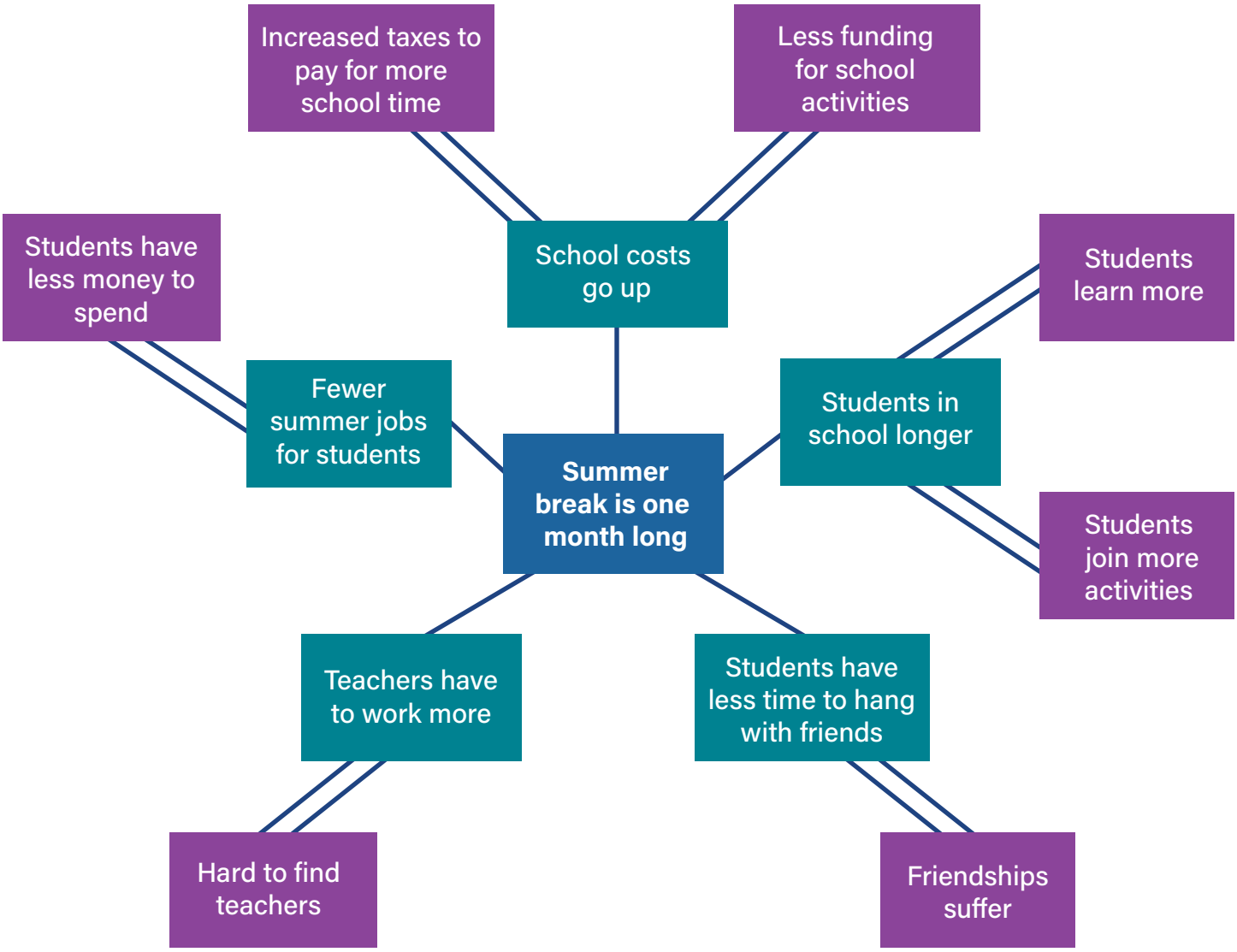
2. A futures wheel is designed to examine the consequences of a future event. Some have referred to this strategy as structured brainstorming. It is a good introduction to futuristic thinking, as students must project possibilities into the future. Students are frequently made aware of alternatives and choices but seldom are required to think about the consequences of those choices. For example, if a student chooses to purchase an item like a phone, they may not think long term about the costs and consequences of owning this technology. Completing a full futures wheel in class is best done the first time with the instructor and then later in small groups or individually. Consider doing one as a class using a trend that students can easily relate to, such as "summer break is one month long" or "school is only done remotely."

3. Start with a statement in the center of a piece of chart paper. Ask students to consider what consequences might occur (good or bad) if the event were to occur. Write each of these effects around the central issue. The initial reactions are called first-order consequences. They are indicated by single lines connecting to the center occurrence.

4. Tell students they will consider the possible effects of each first-order consequence. These become second-order consequences and are connected to the first-order consequence by two lines. The process continues for third- and fourth-order consequences depending on how extensive you want to make the exercise. Notice that there can be two or more second-order consequences for each first-order consequence.



Credit: Getty Images



5. Students will focus on the consequences of ocean temperatures going up. Discuss with them how negative and positive consequences flow from first- to second-order consequences and then to third- and fourth-order consequences. Examples of first- and second-order consequences have been provided in the table on the Student Record Sheet. Students should work in small teams to complete the rest of the table by adding third- and fourth-order consequences before they draw the futures wheel. Possible answers are provided in the table below. Depending on your students' skill or the time you have, consider providing the entire table below and ask them to add fifth- and sixth-order consequences on their wheel after the first-order through fourth-order consequences have been drawn.

Ocean water is getting warmer

First-order Consequences	Second-order Consequence	Third-order Consequences	Fourth-order Consequences
Sea surface temperature rises	**Higher temperatures for coral reef ecosystems**	*More coral reef bleaching events that may kill the corals*	*Fish that live in and around coral reefs migrate or die off*
		Coral reef animal and plant species decrease	*Negative effect on fishing and tourism*
	Ocean temperatures rise in colder coastal water	*Plant and animal ecosystems change*	*Some native species populations go down due to increase in invasive species*
		Animals like lobsters migrate	*People who catch lobsters for a living lose their jobs*
More water vapor in the air	**Stronger and wetter hurricanes**	*More flooding in coastal areas*	*Coastal communities are damaged or destroyed*
		More damage from hurricane winds	*People and animals may be killed or have to move to other areas*
	More intense rainfall on the coasts and inland	*More flash flooding of cities*	*Roads, houses, and businesses are flooded*
		Rivers and streams overflow	*Croplands are flooded*
More water vapor in atmospheric rivers	**Atmospheric rivers become wider and longer**	*A broader area receives heavy precipitation at the same time*	*Transportation, schools, and commerce are affected over a larger region*
		More water in areas that may need it	*Dams and reservoirs get filled quicker*
	Heavier rainfall during rain events	*Flash floods cause landslides*	*Roads and houses are washed out*
		More water in areas that may need it	*Cities and agriculture get needed water*
Changes in weather patterns	**Ecosystems and agriculture are affected**	*Some areas get drier*	*Farmers may have to change the crops they grow*
		Some areas get wetter	*New marshes or lakes may form*
	Droughts get more frequent, intense, and longer lasting.	*More heat waves*	*People and animals suffer from the heat*
		Crops die from heat and no rain	*Farmers go out of business*
Glaciers and ice sheets melt faster	**Sea level rises in coastal areas**	*Coastal cities have more frequent flooding*	*Homes and businesses need to move inland*
		Coastal ecosystems are flooded	*Animals have to move to higher ground*
	Melting glaciers expose land, reflecting less solar radiation	*More heat is absorbed from darker land*	*Additional heat fuels weather and climate extremes*
		Faster heating of the atmosphere	*Ocean temperatures rise faster*

EVALUATE

Part 5. Evaluate

Ask students which consequences they relate to in their daily life. Have them color those consequences so they are easy to identify.

Discussion questions

1. Which consequences might affect your area of the country the most?

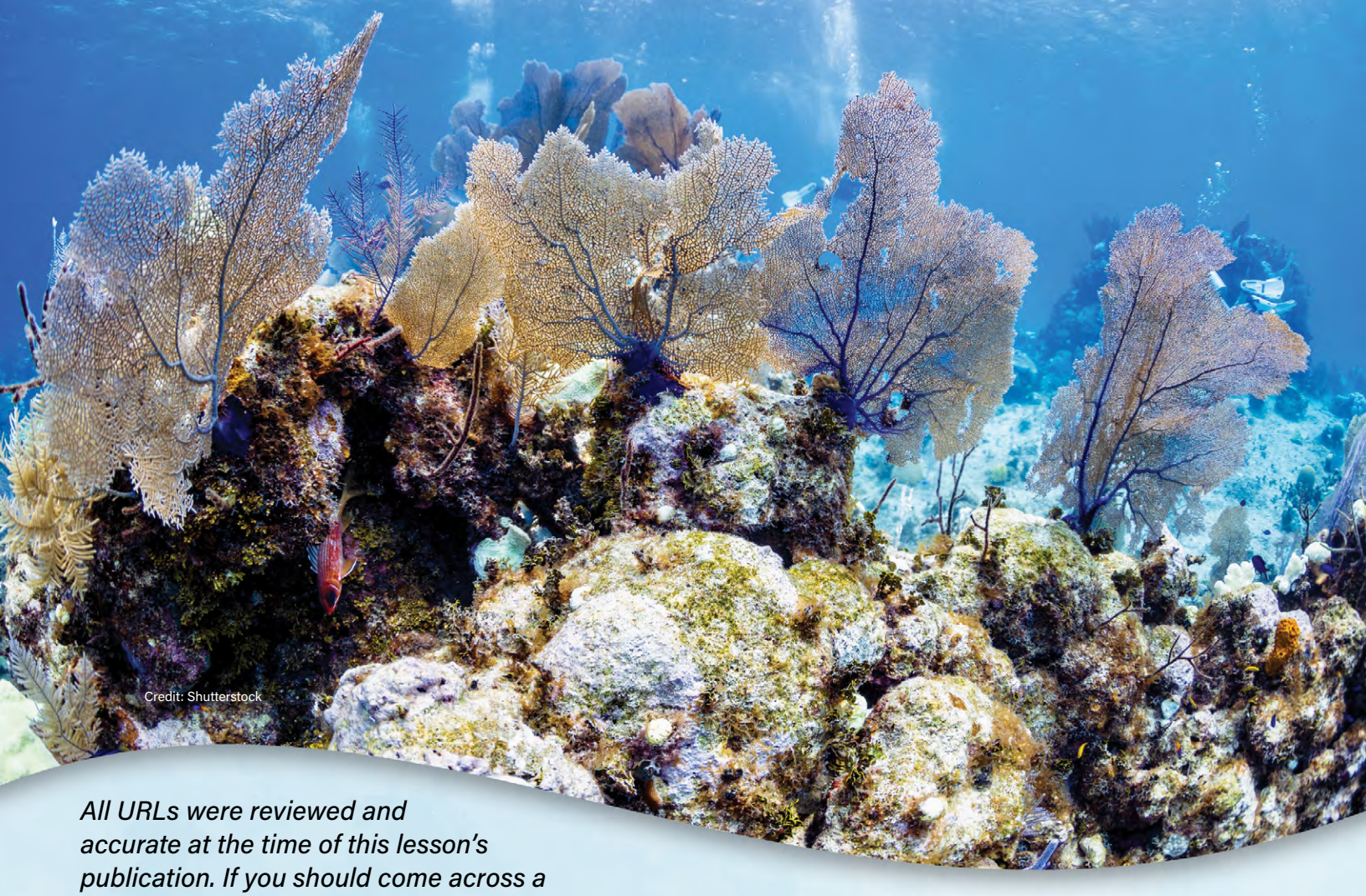
   Answers will vary, but students should be able to identify that they might be affected by more severe storms, heat waves, coastal flooding, or drought.

2. What preparations are needed for the weather events that may affect your area of the country?

   Depending on the weather events selected, students may identify better warning systems, coastal preparation, and better construction in the event of hurricanes.

3. Compare wheels from different groups. What two new ideas did you see on other wheels?

   Students should be able to identify additional consequences from the class. Consider having two groups compare, then open the discussion to the whole class to identify some unique consequences.


Credit: Shutterstock

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Extensions

This simulation about the Greenhouse Effect (https://phet.colorado.edu/en/simulations/greenhouse-effect/about) allows students to change parameters to see what happens in different scenarios.

The carbon journey game allows students to follow the journey of carbon as it moves around the spheres of the Earth. The Incredible Carbon Journey (https://oceanservice.noaa.gov/education/discoverclimate/noaa_activity10_the_incredible_carbon_journey_111213.pdf).

Climate change impacts corals and coral reef ecosystems through bleaching and ocean acidification (https://oceanservice.noaa.gov/education/tutorial_corals/coral08_climatechange.html).

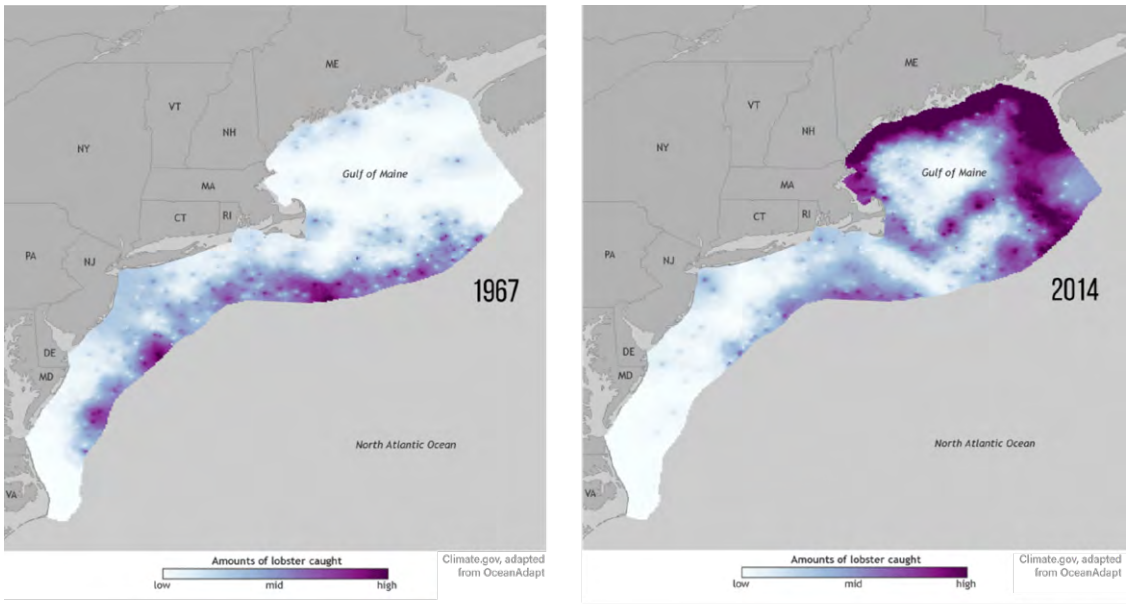
These Ocean Today Videos will be helpful for student understanding during discussions about their ideas.

- Taking the Ocean's Temperature (https://oceantoday.noaa.gov/takingtheoceanstemp/)
- Happening Now: Arctic Sea Ice Sets Record Low (https://oceantoday.noaa.gov/happennowarcticseaice/welcome.html)
- Global Impacts of Sea Level Rise (https://oceantoday.noaa.gov/roleofice_pt3/)

Student Record Sheets

PART 1.

In episode 5, Tom joked to Teek that Maine lobsters might become Canadian lobsters. Data is collected each year on the number and location of lobsters caught along the east coast of the United States. Let's look at where lobsters have been caught over the past 47 years in the northeast United States. The dark purple locations have the highest number of lobsters caught.



Change in lobster catch distribution from 1967 to 2014. The dark purple locations represent the highest number of lobsters caught. Credit: NOAA Climate.gov via data from Rutgers University OceanAdapt.

1. Compare the two images from 1967 and 2014. What do you notice about where the most lobsters are caught?

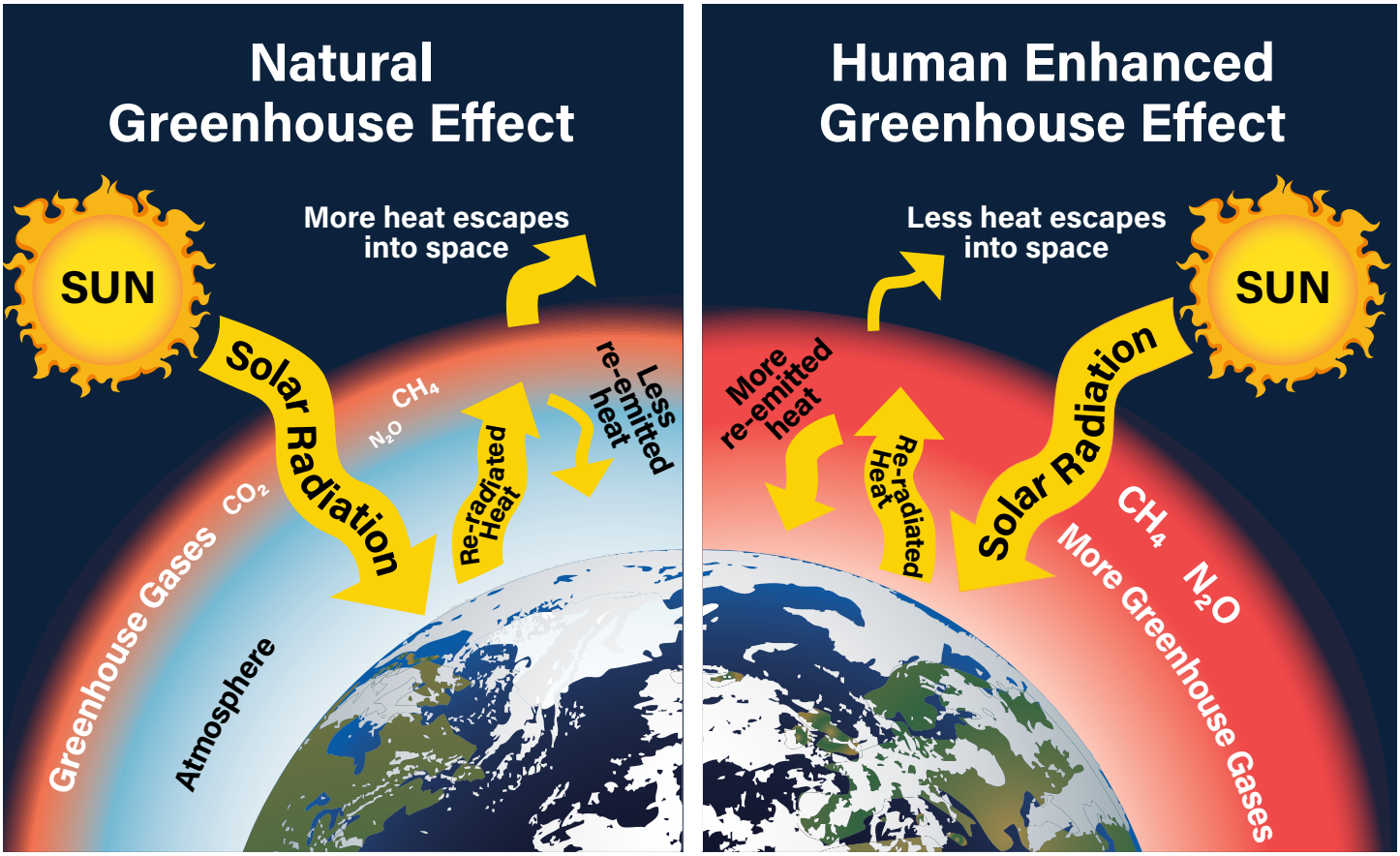
2. Where do you think the highest number of lobsters will be found in another 50 years?

3. Is Tom's comment about Canadian lobsters possible?

PART 2.

Lobster populations do not do as well in warm water, and population change is one example of how animals respond to a changing climate. Let's investigate why the ocean is warming. The Earth receives energy from the sun. When the sun's heat enters Earth's atmosphere, some reflects back into space. Gases in the atmosphere, called greenhouse gases, are mixed throughout the air and trap part of the heat like a blanket. These gases have naturally kept our planet just toasty enough for life to survive. Without them, the Earth would be freezing cold.

Compare the following features of the two images.



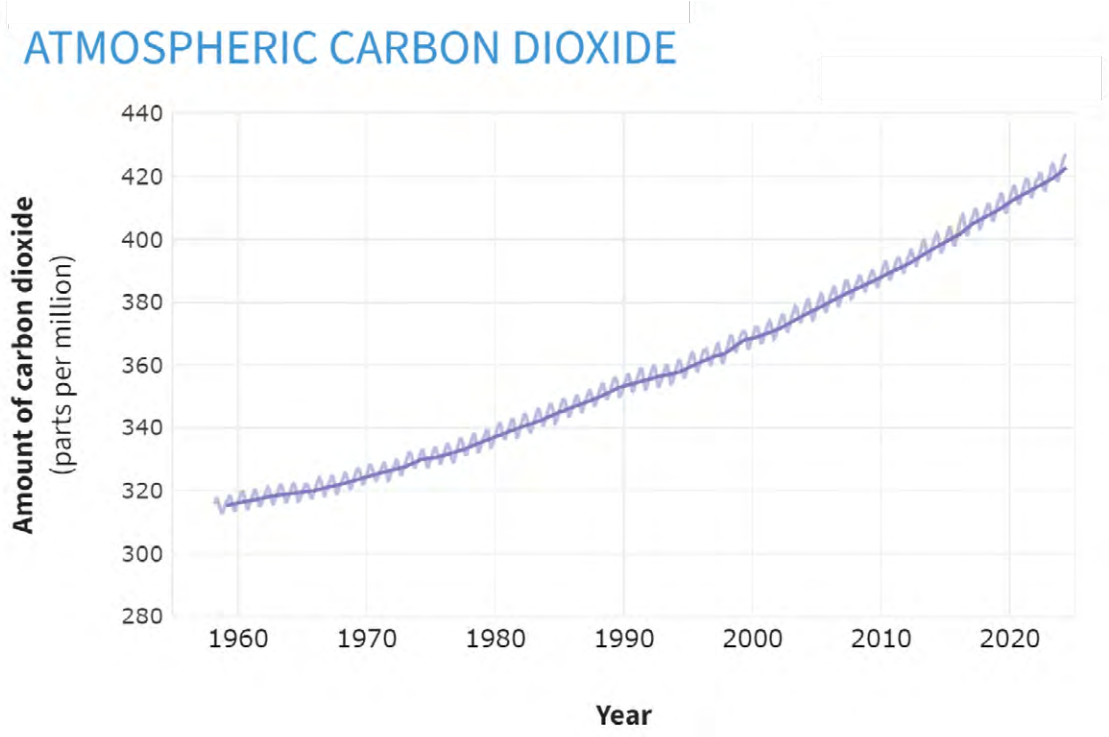
Compare	Natural Greenhouse Effect	Human-enhanced Greenhouse Effect
Amount of solar radiation entering the atmosphere from the sun		
Amount of reradiated heat from the Earth's surface		
Amount of heat that escapes into space		
Thickness of the greenhouse gas blanket		
Amount of heat that bounces off the atmosphere back to Earth (reemitted heat)		

1. What greenhouse gases are common in the atmosphere?

2. From these diagrams, what do you think is the main reason the Earth is getting warmer?

PART 3.

Human activities are increasing the amount of greenhouse gases in our atmosphere. Some greenhouse gases can stay in the atmosphere for hundreds to thousands of years. One type of greenhouse gas, carbon dioxide, has reached a level in our atmosphere that the Earth hasn't seen for more than 2 million years. Researchers have kept track of the carbon dioxide data at the Mauna Loa Observatory in Hawaii since 1958.



1. What do you notice about the amount of atmospheric carbon dioxide at Mauna Loa since 1958?

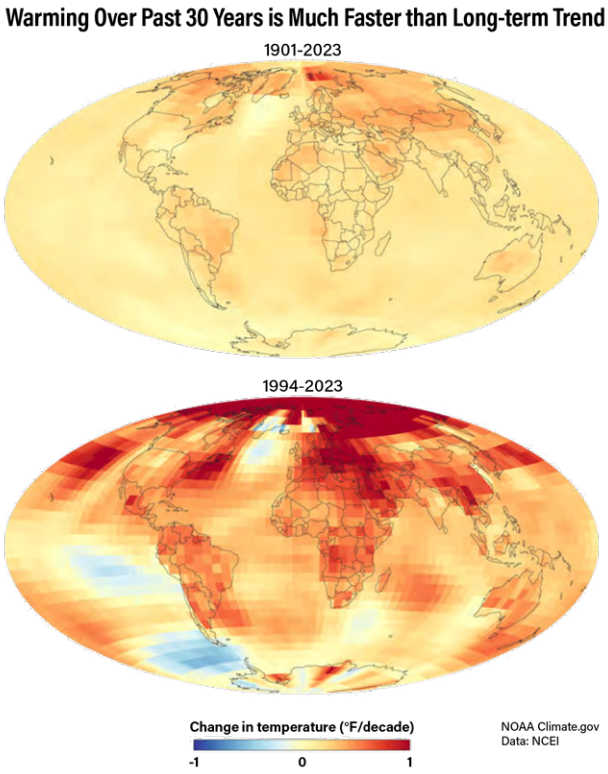
2. What do you predict will happen in the next 10 years?

3. As we burn fossil fuels like coal, oil, and natural gas and cut down trees, we add carbon dioxide to the atmosphere. Suggest one way to limit the amount of carbon dioxide that goes into the atmosphere.

4. Look at the two images showing the long-term trend of Earth temperatures. The top image is from 1901-2023. How many years does this represent?

5. The lower image is from 1994-2023. How many years does this represent?

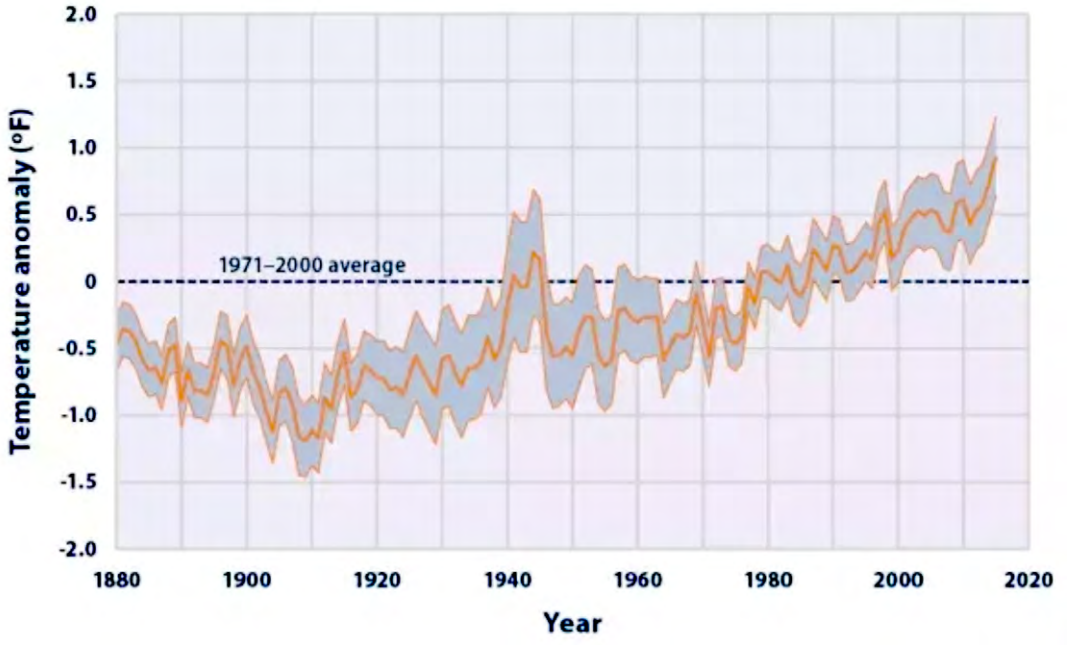
6. Which image shows a higher warming trend **per year**? What evidence supports your idea?



7. What parts of the world seem to be heating up the fastest? Do you live in one of those places?

Credit: BigStockphoto

Our global ocean serves as the largest solar energy collector on Earth. It stores and releases heat over long periods of time, giving the ocean a big role in Earth's climate system. This graph shows how the average surface temperature of the world's oceans has changed since 1880. The dotted line is the average surface temperature from 1971 to 2000 and serves as a baseline for showing change.



8. What differences do you observe between the temperature anomalies in (differences from the average) in 1960 and 2020 compared to the 1971-2000 average ocean surface temperature?

9. Based on the changes you see from 1880-2020, what temperature trend do you predict the graph will show in 2030?

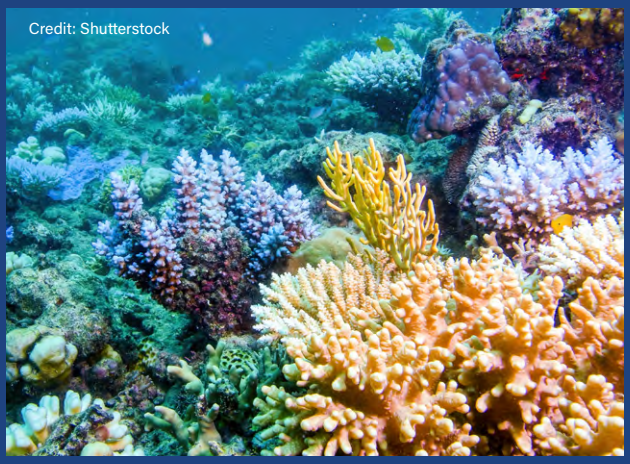
Credit: iStockphoto

Earth Curiosities

The Only Living Thing on Earth Visible from Space

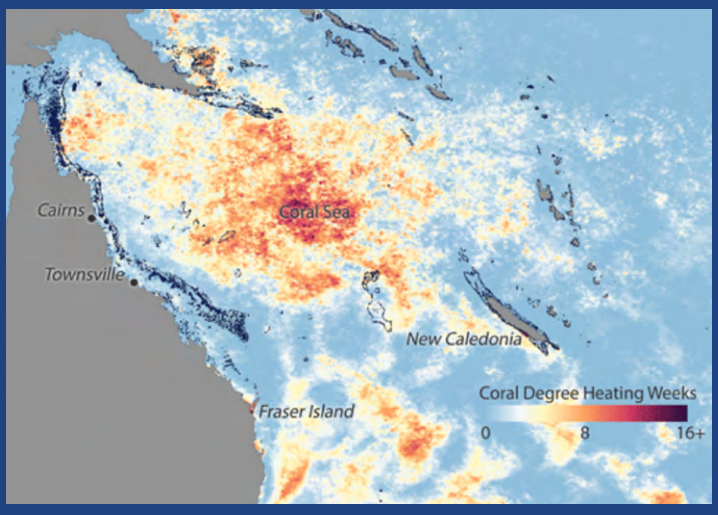
The Great Barrier Reef is the world's largest coral reef. It extends for over 2,300 kilometers (1429 miles) along the northeastern coast of Australia. The reef is home to over 9,000 known species and is one of the richest and most complex natural ecosystems on the planet. A warming ocean due to climate change is the biggest threat to the future of coral reefs around the world. When corals suffer heat stress, they expel the microscopic algae that live inside their tissues, revealing their white skeletons. Bleached corals are not dead but are at very high risk of starvation and disease.

Climate change is also increasing the frequency and intensity of severe weather events. Coastal water regions like the Great Barrier Reef are exposed to damaging cyclones, storms, and heat waves.



Credit: Shutterstock

Credit: Shutterstock



The image shows the extent of the Great Barrier Reef along the coast of Australia and the warm ocean water in shades of orange and red.

Thermal stress around the Great Barrier reef from January March 2017. NOAA Climate.gov image by Dan Pisut, based on NOAA Coral Reef Watch maps.

PART 4.

1. Summarize what you have learned from previous lessons about the ocean's impact on weather and severe events. Also include what you know about the impact of a warming ocean on hurricanes, rainstorms, heat waves, and other inland storms.

2. With a small team, you will build a futures wheel about the impacts of a warming ocean on weather and climate. A futures wheel is a visual diagram of the positive and negative consequences of an occurrence. In this case, we will start with the issue of **"Ocean water is getting warmer."** Ocean temperatures worldwide are rising. This has led to more atmospheric water vapor over the oceans, which feed systems that produce severe weather.

3. You have been provided with some information in the table below. The first column shows the effects of a warmer ocean, called first-order consequences. Samples of second-order consequences are in the second column of the table below. These are positive and negative events that may happen as a result of the first-order consequence. Complete the table with the effects of third-order consequences, and then add fourth-order consequences.

Credit: Getty Images

Ocean water is getting warmer

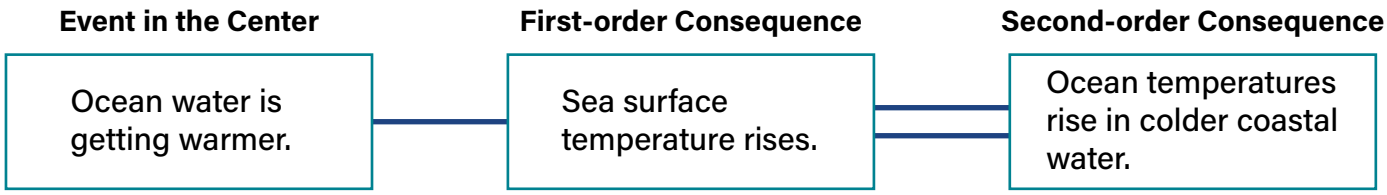
First-order Consequences	Second-order Consequence	Third-order Consequences	Fourth-order Consequences
Sea surface temperature rises	Higher temperatures for coral reef ecosystems		
	Ocean temperatures rise in colder coastal water		
More water vapor in the air	Stronger and wetter hurricanes		
	More intense rainfall on the coasts and inland		

First-order Consequences	Second-order Consequence	Third-order Consequences	Fourth-order Consequences
More water vapor in atmospheric rivers	Atmospheric rivers become wider and longer		
	Heavier rainfall during rain events		
Changes in weather patterns	Ecosystems and agriculture are affected		
	Droughts get more frequent, intense, and longer lasting.		

First-order Consequences	Second-order Consequence	Third-order Consequences	Fourth-order Consequences
Glaciers and ice sheets melt faster	Sea level rises in coastal areas		
	Melting glaciers expose land, reflecting less solar radiation		

4. Once your table is complete, print this statement in the center of a large piece of paper, **"Ocean water is getting warmer."** Draw a box around it. Add boxes around the central box for the first-order consequences and add each item from the table. Add a line between the central box and each first-order consequence.

5. Next, add the second-order consequences to the coordinating first-order consequence, drawing a box around each. Connect the secondary boxes to the first with two lines between them. Look at the sample below.



6. Continue this process of adding levels of consequences using three lines for third-order consequences and four lines for the fourth-order consequences. When you are finished, your diagram will have the event in the center and the consequences radiating out like the spokes of a wheel.

PART 5.

On your futures wheel, think about each of the consequences that you created. Which ones might have an impact on you? Using colored pencils or crayons, color the consequences that might impact you.

1. Which consequences might affect your area of the country the most?

2. What preparations are needed for the weather events that may affect your area of the country?

3. Compare wheels from different groups. What two new ideas did you see on other wheels?

Credit: Shutterstock