TEEK and TOM
EXPLORE PLANET EARTH

THE OCEAN-WEATHER-CLIMATE CONNECTION

EDUCATOR'S GUIDE

Acknowledgements

Peg Steffen
STEM Curriculum Developer
Ready, Set, STEM

Bruce Moravchik
Ocean Service Education Coordinator
Teek and Tom Educator's Guide Executive Producer
National Oceanic and Atmospheric Administration,
National Ocean Service

Tom Di Liberto
Climate Scientist and Public Affairs Specialist
Science Advisor, Technical Review, and the "Tom" in *Teek and Tom*
National Oceanic and Atmospheric Administration

Patty Schuster
Graphic Design Guru
Page Designs, Inc.

Gaitlyn Malone
Technical Writer
Integrated Systems Solutions, Inc.
In support of NOAA's
National Ocean Service

Credit: Shutterstock

Welcome to the "Teek and Tom Explore Planet Earth: The Ocean, Climate and Weather Connection!" Educator's Guide

"Teek and Tom Explore Planet Earth: The Ocean, Climate, and Weather Connection!" is the first fully animated series from NOAA to highlight one of the most requested topics from educators — how the ocean and the atmosphere interact and impact our weather and climate.

The lessons in this guide were crafted to supplement the Teek and Tom videos. They allow upper elementary and middle school students to build knowledge of and skills associated with important Earth science concepts. Through the exploration and investigation of NOAA data, visualizations, and content, the lessons support the videos in telling a cohesive story about key Earth systems and how those systems impact each other.

An understanding of how the Earth works as a system and how humans interact with the Earth is important for all our planet's citizens. These lessons are designed to help educators lead their students through a study of the Earth, ocean, and atmosphere connections, so students will become weather- and climate-ready citizens and better stewards of our planet.

User Notes

While developed for students in the upper elementary and middle school grade bands, the lessons include aspects and resources that may be adapted for all grade bands. Each lesson is aligned to the Next Generation Science Standards (NGSS), Common Core Math, English, and Language Arts Standards, and the College, Career, and Civic Life (C3) Framework for Social Studies State (SSS) Standards. These standards have been included in each lesson to reinforce the interdisciplinary nature of ocean, weather, and climate studies, and support the teaching of these topics in all classes. The educator instructions of each lesson highlight the most important NGSS Performance Expectation(s) or Disciplinary Core Idea(s) for the concepts of that lesson along with abbreviated notes from other standards. A comprehensive listing of the standards for all lessons can be found in Appendix A.

Each lesson engages students in content that is locally relevant and includes features to help educators use the video content effectively. Each lesson includes:

- Introduction to the content
- Lesson summary
- Objectives
- Estimated time for the lesson
- Standards addressed
- Materials
- Preparation
- "InvesTeekation" Pathway
- Extensions
- Student record sheets

The "InvesTeekation" Pathway follows the 5E model, which uses five phases to help teachers provide engaging learning experiences for their students: Engage, Explore, Explain, Elaborate, Evaluate. This provides a structure for students to connect science ideas with their experiences and apply their learning to new contexts.

Table of Contents

VIDEO: *"An Ocean of Data From Cool Technology!"*
(https://oceantoday.noaa.gov/teekandtom/episode-4.html)

"They're like eyes in the sky!" Teek and Tom journey through space and kick back at a movie theater to learn all about the cool technologies scientists use to monitor Earth's ocean and atmosphere — from satellites to submarines!

Students learn about the tools used to observe atmospheric conditions, track and predict the impacts of hurricanes, and develop emergency action plans to be implemented before a hurricane makes landfall.

Students investigate tools used to collect data about the ocean floor, water temperature, salinity, ocean currents, and marine creatures. They compare tools' weaknesses and strengths and select tools to investigate a remote part of the ocean.

VIDEO: *"Our Planet Is Changing, and We Can All Help!"*
(https://oceantoday.noaa.gov/teekandtom/episode-5.html)

"Earth is such an amazing place, and it's the only home humans have!" Teek presents the team's final project, with a focus on how Earth's climate is changing, what those changes mean for the health of the planet, and how — by continuing to work together — we can solve big problems!

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

Students demonstrate what they have learned about the connections between the ocean and atmosphere in a presentation to an imaginary Milky Way Galactic Council.

APPENDIX A: National Education Standards

A complete list, description, and links to the Next Generation Science Standards (NGSS), Common Core Math, English, and Language Arts Standards, and the College, Career, and Civic Life (C3) Framework for Social Studies State Standards aligned to each lesson.

APPENDIX B: Washington, D.C. Weather Records from 1873 to 2023

APPENDIX C: NOAA National Weather Service Lightning Safety Brochure

APPENDIX D: NOAA National Weather Service Flood Safety Brochure

Teek and Tom Episode 1

What's the Difference between Weather and Climate?

LESSON 1

What Should I Wear Today?

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.

Introduction

"I'm Teek from planet Queloz (kway-loe-z)…I come in peace...can you help me understand your planet for a school project?" This is the premise for a series of short videos that will help students understand important Earth science concepts.

In the first episode of the video series, NOAA Climatologist Tom Di Liberto teaches his extraterrestrial friend Teek about the difference between weather and climate on Earth. Teek and Tom investigate why it's helpful for earthlings to understand how the ocean influences weather and what the weather might bring days, weeks, or months in advance. They look at climate outlooks and weather trends weeks and months into the future and visit a farm to see how these outlooks can help with decisions on when to plant or harvest.

Over the course of this activity, students will develop their own explanations about the differences between weather and climate. Weather is the current atmospheric conditions, including temperature, rainfall, wind, and humidity. Climate is the usual weather conditions based on 30 years of averaged weather data for a location. Climate is what you expect. Weather is what actually happens.

A short career-focused segment in the video introduces a NOAA National Weather Service (NWS) forecaster who talks about why it's so important for scientists to predict what's to come and for people to be prepared. It's all about being weather-ready and climate-smart.

Lesson Summary

Students will examine the similarities and differences between climate and weather maps, investigate climate characteristics, and develop an explanation of climate and weather to help Teek with their school project. (Teek goes by the pronouns "They/Them/Their" in the videos).

Objectives

- Students will be able to define and contrast weather and climate.
- Students will investigate weather and climate parameters through maps and archived data.
- Students will develop working definitions of weather and climate and communicate their understanding through a visual graphic.

Estimated Time

It is estimated that one to two 45-minute class periods are needed for this lesson. This does not include the time required to view Episode 1 of Teek and Tom *"What's the Difference between Weather and Climate?"*, 16:45 minutes (https://oceantoday.noaa.gov/teekandtom/episode-1.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-ESS2-1: Earth's Systems.** Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.
- **5-ESS2-1: Earth's Systems.** Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.
- **ESS2.D: Weather and Climate.** Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.

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

- Materials for making a visual representation of weather versus climate. Crayons, markers, or colored pencils, poster board, scissors, and construction paper for individual students or groups of students working together.
- Students will need access to the NOAA NWS website homepage (https://www.weather.gov). Be sure to test the site for access from your school server.
- Students will need printouts of student record sheets, graphs, and/or maps to carry out the activities. Student record sheets are located at the end of this lesson.
- If you would like to provide the maps/graphics on a projection system, students will only need the student record sheets. Depending on the configuration of your classroom, we recommend one set per student or group.
- All maps/graphics 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-1.zip)

Preparation

1. The teacher notes below include information about finding local maps/data.
2. The teacher notes/extensions, etc., below also include ways to explore the topic or activity further.

InvesTeekation Pathway

ENGAGE

Part 1. Engage

1. Ask students how they decided what to wear to school today. Did they look outside? Did they look at the clouds? At a weather report? Did they ask an adult about what the weather would be? Did they make the right decision about what to wear?
2. Ask students to consider what items in their closet might help an alien like Teek understand more about the kinds of weather to expect in your location. Have them compare the contents of their closet to a person in a warmer or colder climate.
3. Ask students to think about the weather where you are. Is today's weather normal or typical? Is it what you'd expect? (That's climate!)
4. In small groups, have the students brainstorm what they know about weather and climate and complete the chart on their student record sheet. Spend a few minutes with class sharing.

Note: Depending on the sophistication of your students, cloud charts may be useful for looking at what is happening in your location. Clouds are a fun way to begin watching the weather. The slide set that accompanies this activity includes a cloud chart, and the Extensions section below provides a link to downloadable versions.

EXPLORE

Part 2. Explore

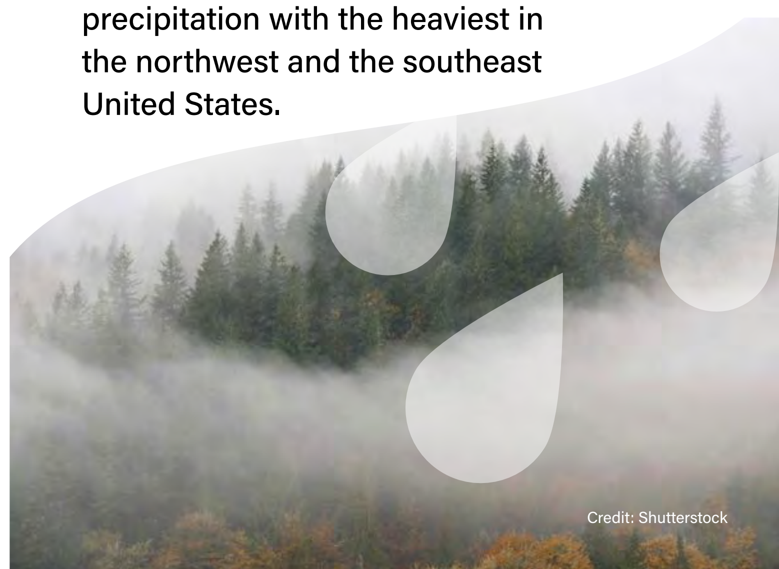
Students will compare images of a weather forecast map and a climate outlook map. They will look for similarities and differences and record their findings on a bubble thinking map. Depending on your class needs, consider projecting both maps simultaneously or providing copies for each group of students. The weather forecast map is a snapshot from a past date. Discuss student observations of the two maps as a class.

Similarities:

- Both show a map of the United States.
- Both maps show state outlines.
- Both maps show precipitation.

Differences:

- Students should notice that the weather forecast map displays one day of time versus 30 years on the climate map.
- The weather map shows much more detail, including high and low pressure, fronts, and expected weather, such as heavy rain, thunderstorms, flash floods, and fire danger.
- The climate map shows average precipitation with the heaviest in the northwest and the southeast United States.



Credit: Shutterstock

Discussion questions

1. Explain the differences that you see between the weather forecast map and the climate outlook map.

   Weather maps are short term and have a lot of detail. Climate outlook maps are specific for one thing like precipitation. They show averages over long periods of time, not specific daily predictions.

2. Ask students to use what they have learned so far to create a one-sentence definition for weather and one for climate. This may be done in pairs or small groups.

   Students may have written something like, "Weather is a short term prediction about weather events, and climate is a longer-term average over many years."

The Extensions section of this lesson, located below, recommends additional resources for this activity.

Part 3. Explain

Students will investigate the parameters of a weather forecast more closely by first finding out what the current weather is in their location. They will need access to the NOAA NWS website (https://www.weather.gov/). Be sure to check that the website is up and working on your students' laptops/Chromebooks. An NOAA NWS glossary with common weather and climate terms is available. Simply search for "NOAA NWS glossary."

Students will compare temperatures from data collected in 2010 and 2020 in Washington, D.C., on Teek's birthday, January 15, 2010.

Discussion questions

1. How did the weather on the two dates compare?

   The high temperatures were similar, but the low temperatures were very different, causing the average to be much higher in 2020.

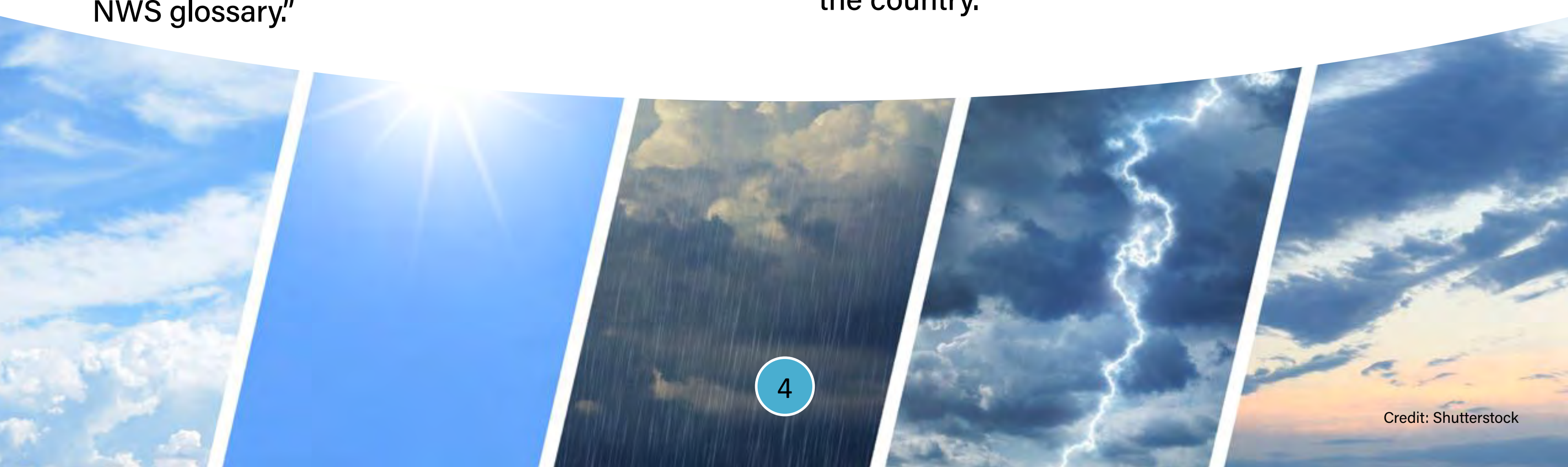
2. Let's see how the temperatures on those dates compare to monthly temperature averages. Look at the table below and record the average January temperature in Washington, D.C., for 2010 and 2020.

Monthly Average Temperature Jan 2010°F	Monthly Average Temperature Jan 2020°F
35.3°F	*42.4°F*

3. Now, compare the average temperature in January 2010 with the average January temperature in 2020.

   The average temperature in January 2010 was 35.3°F , and in 2020 it was 42.5°F . January 2020 is over seven degrees warmer than January 2010.

Appendix B (https://oceantoday.noaa.gov/teekandtom/educators-guide/appendix-b.pdf) contains data for Washington, D.C., for each month and year from 1871 through 2023. Students might appreciate the large amount of data saved from every weather station around the country.



Credit: Shutterstock

ELABORATE

Part 4. Elaborate

Students will look at color-coded maps of average temperatures from the past. Point out that the data can be displayed in many ways and that these maps use the same data they were just analyzing. Temperatures are displayed using colors, with each color representing a 10-degree range.

Discussion questions

1. What was the average maximum temperature range where you live in January 2010?

   Answers will vary from 90 to less than 10°F, depending on where the student lives.

2. What was the average maximum temperature range where you live in January 2020?

   Answers will vary from 90 to less than 10°F, depending on where the student lives.

3. Find your state on the map and the temperature range that is shown. Compare the January maximum temperatures from 2010 on Map 3 that you identified earlier with the climate map that shows 30 years of data (Map 5). What is the difference in temperature between the two maps? What evidence do you have to support your answer?

   The climate map used here represents average values from 1991 to 2020. Having many years of data allows for better predictions in the future. Students should compare the 2010 January maximum identified earlier with the climate map. In general, temperatures are trending higher. Students should provide observational evidence from the maps to support their statements.

4. Let's look at data from over 70 years ago. Compare the January maximum temperatures from 1950 on Map 6 with the climate map that shows 30 years of data (Map 5). What is the difference in the temperature between the two maps for locations in your state? What evidence do you have to support your answer?

   Students should compare the 1950 January maximum with the climate map (Map 5). Students should provide observational evidence from the maps to support their statements.

Credit: Shutterstock

EVALUATE

Part 5. Evaluate

Ask students to create a visual, art piece, or graphic that Teek can use to help their classmates understand the difference between weather and climate. This can be done individually, in pairs, or in small groups. Depending on the materials you have on hand, allow students to use art options to express their understanding. Providing different outlets for expressing ideas may be especially important to ESL or students who struggle with writing. They should be able to explain how their art or visual demonstrates the difference between weather and climate. Post in your room as reminders about what they have learned.

Be sure to save the students' work. They will need to use it in the second lesson!

Credit: Thinkstock Photos

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.

Extensions

Simple Cloud Chart (https://www.ncei.noaa.gov/sites/default/files/sky-watcher-cloud-chart-noaa-nasa-english-version.pdf)

Advanced Cloud Chart (https://www.noaa.gov/clouds/noaawise)

You can access the forecast section of Weather.gov using the menu header at the top of the website (https://www.weather.gov/forecastmaps).

If you would like to use additional maps to the ones provided, go to the NOAA National Centers for Environmental Information U.S. Climate Atlas webpage (https://www.ncei.noaa.gov/access/climateatlas/). Choose min temp or max temp, the year, and the month. Turn "Compare" on to add another set of variables to compare with the first data. Choose the same min temp or max temp, month, and year. You can choose to see the graphics in several different ways. Maps are available for a particular month and year from 1895 to the present.

Your students can also find out what the weather was in the city where they were born on their birthday.

1. Have them choose the correct forecast office in their birth state by clicking on the region of the state where they were born on the NOAA NWS Climate webpage (https://www.weather.gov/wrh/climate).
2. Choose the appropriate weather station, which is identified by city in a pull-down menu.
3. Click the "Daily Data for a Month" button, then select the birth date.
4. Hit "Go," and the weather parameters for that month will pop up.

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

- Happening Now: State of the Climate in 2013 (https://oceantoday.noaa.gov/stateoftheclimate/)
- Old Weather (https://oceantoday.noaa.gov/oldweather/)

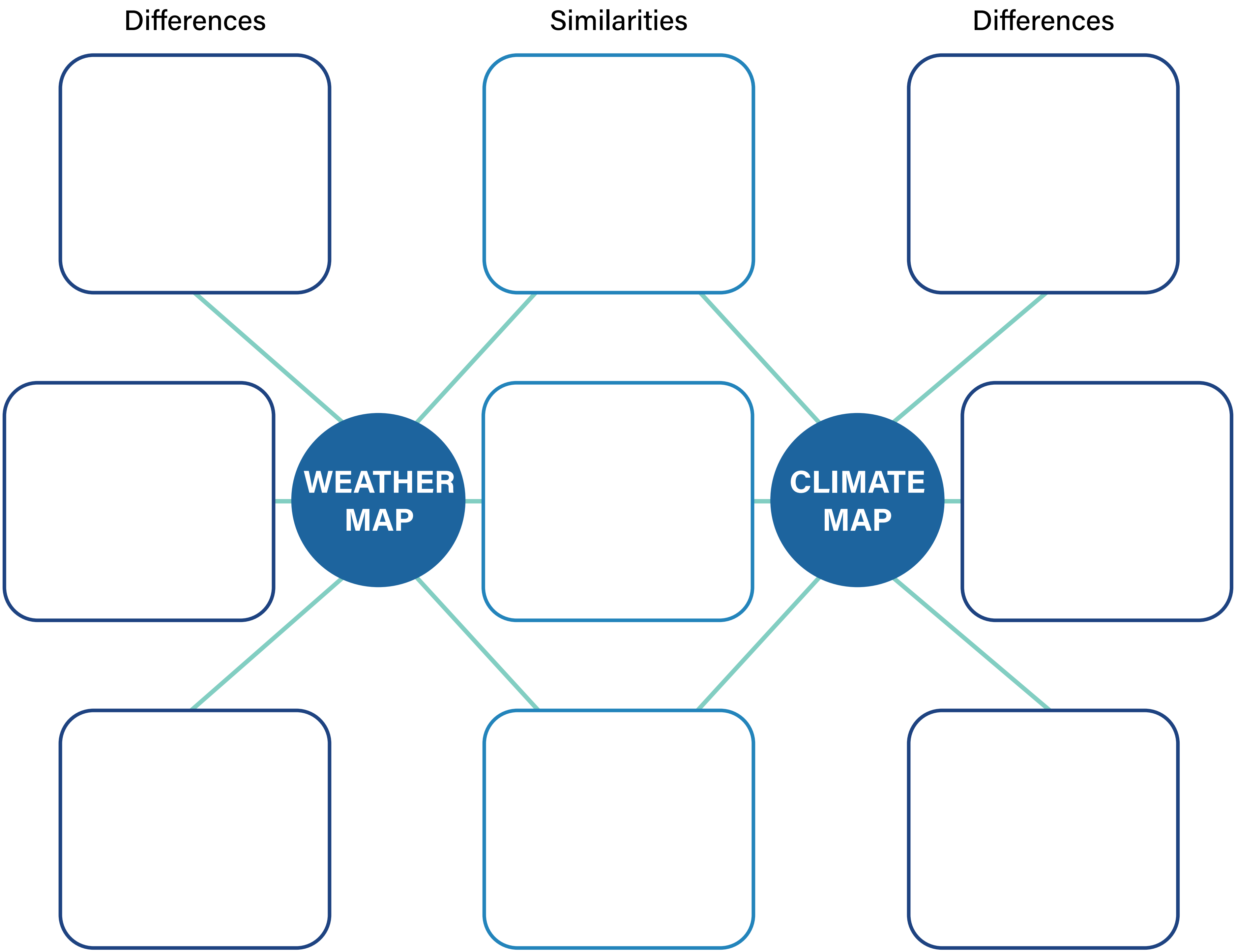
Student Record Sheets

PART 1. Our extraterrestrial friend, Teek, has asked for help with their class project about the Earth. What do you know about weather and climate? Work in a small group to complete the brainstorm chart below. Share your ideas with the class.

WEATHER	CLIMATE

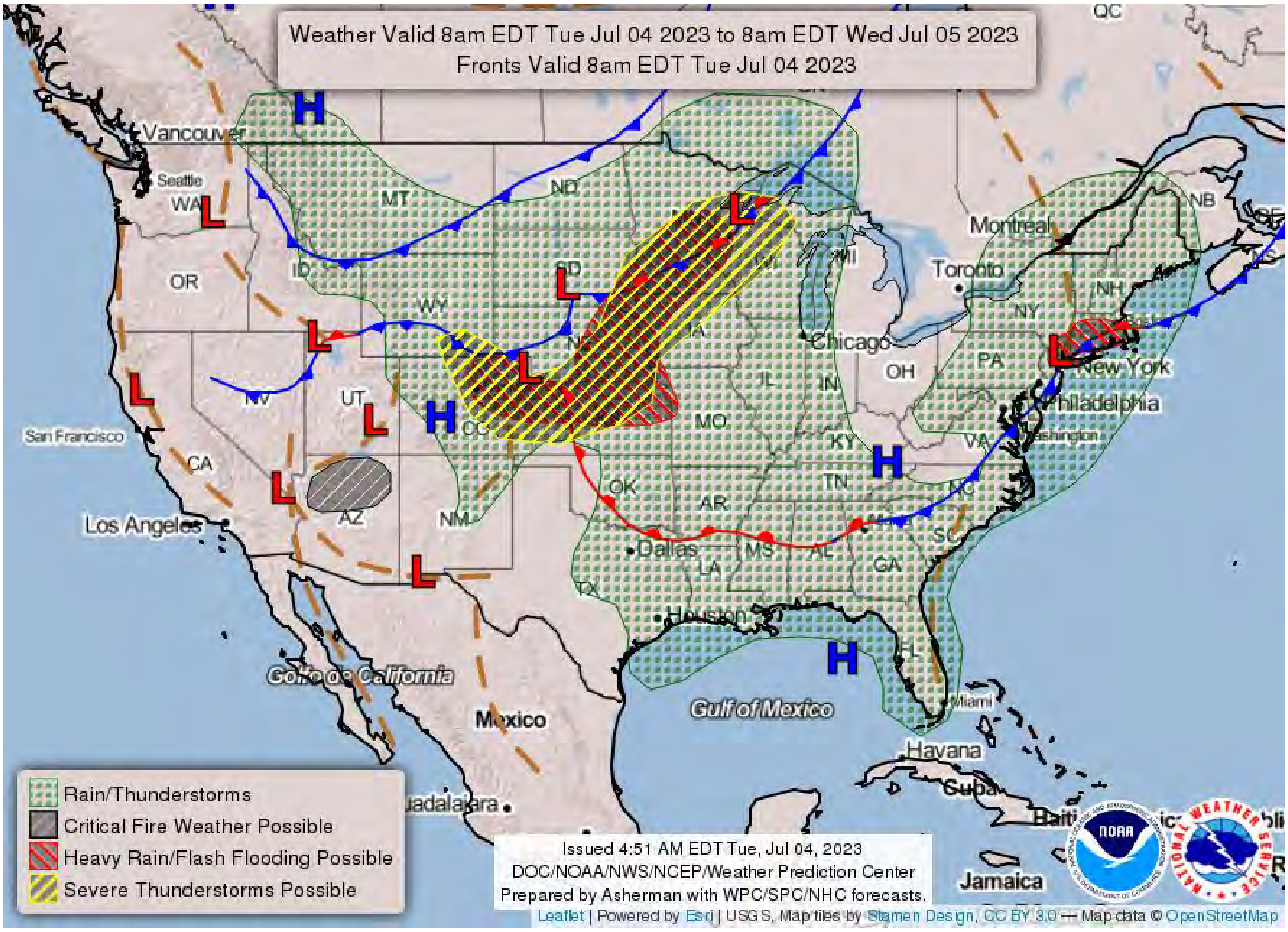
PART 2. You will be shown two maps. One is a weather forecast map, and the other is a climate map. Look carefully at the information on each map. Describe what you see in the table below. Then, list some similarities and differences between the two maps in the bubble chart.

WEATHER FORECAST MAP	CLIMATE MAP



Differences
Similarities
Differences
WEATHER MAP
CLIMATE MAP

Map 1. Weather Forecast Map for July 4-5, 2023

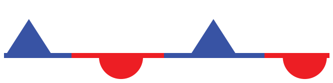


H This symbol represents an area of high air pressure. High air pressure generally brings light winds and clear skies.

L This symbol represents an area of low air pressure. Low pressure generally brings clouds and precipitation.

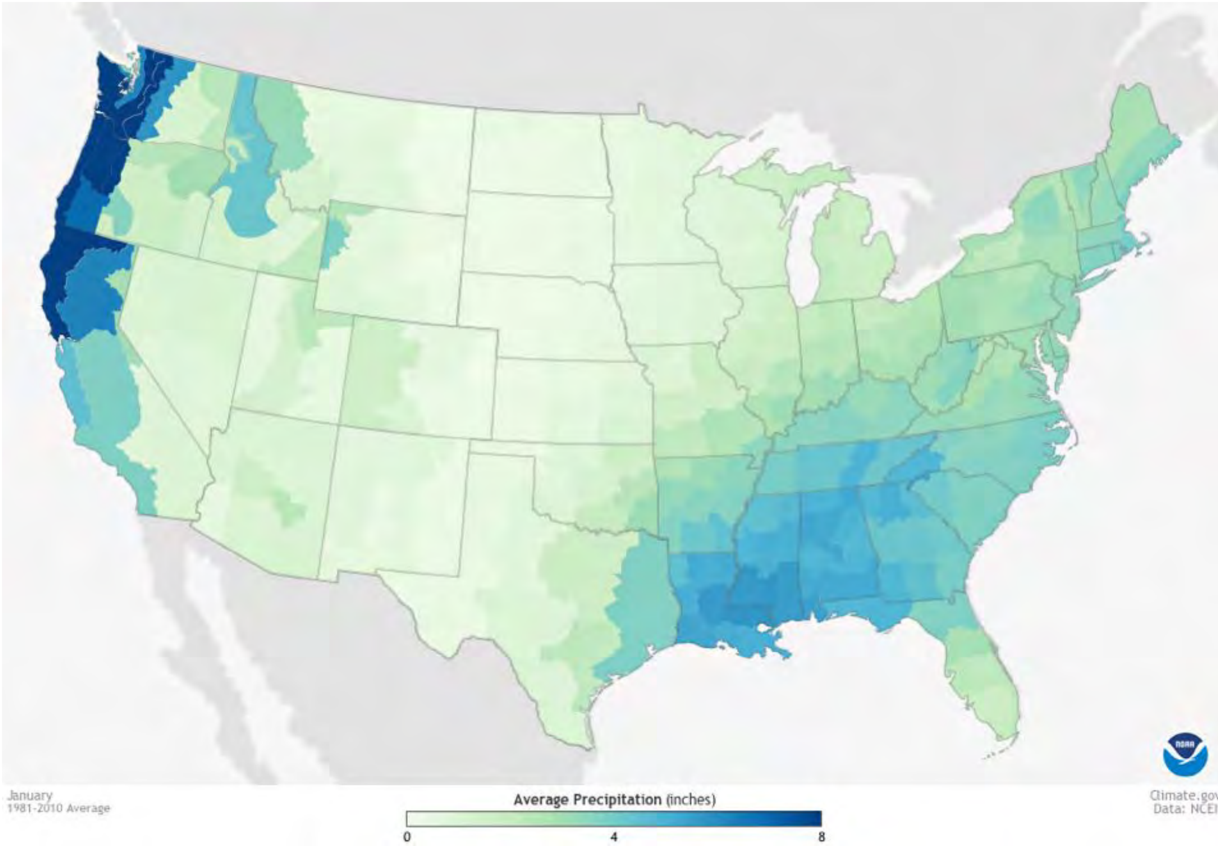
This symbol represents a cold front. An advancing cold front can bring sudden and intense storms.

This symbol represents a warm front. An advancing warm front can bring slow steady rain.



This symbol represents a stationary front. A stationary front can result in several days of cloudy skies.

Map 2. Climate Map – Average Monthly Precipitation for 1981-2010



Earth Curiosities

Temperature Extremes

Mesquite Flat Sand Dunes, Death Valley National Park. (USGS)

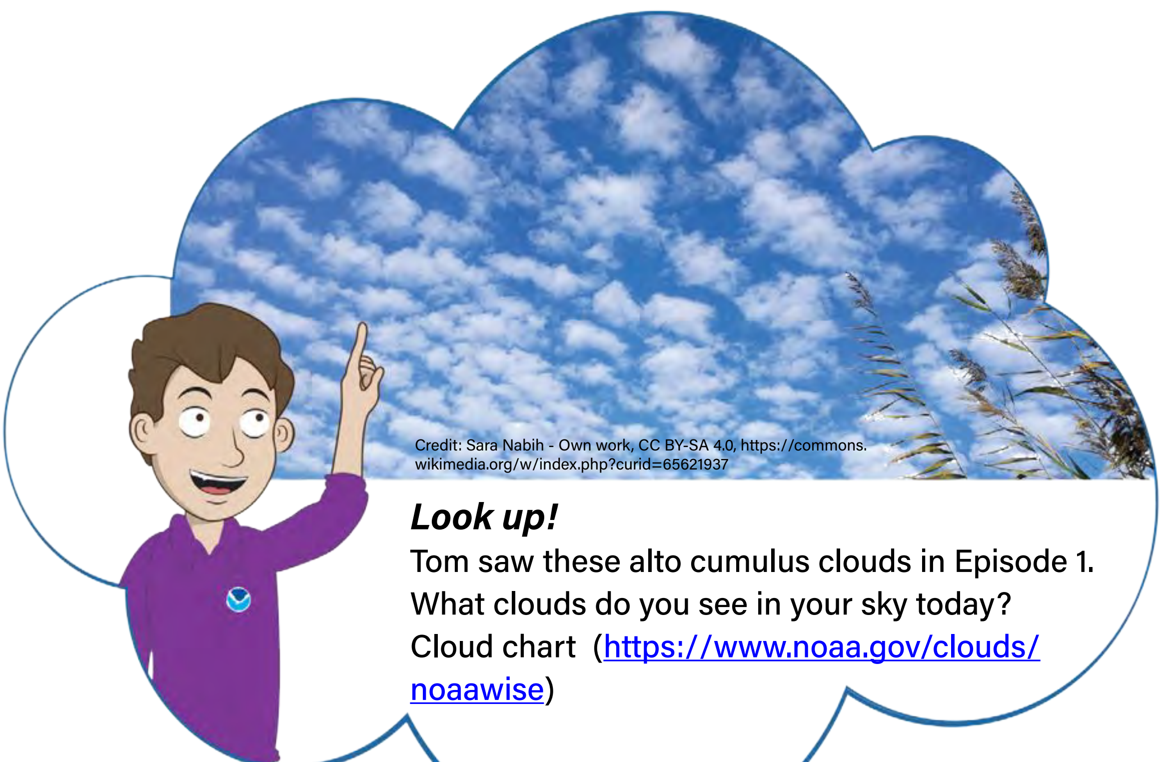
It's hot! Death Valley is famous for being one of the hottest and driest places in North America. In fact, Death Valley holds the record for the world's highest surface air temperature ever recorded: 134 °F observed at Greenland Ranch on July 10, 1913.

The East Antarctic Plateau is a windswept, desolate expanse the size of Australia. (Ted Scambos, NSIDC)

It's cold! The coldest place in the world is a high ridge in Antarctica, where temperatures can dip below minus 133.6 °F.

1. Explain the differences that you see between the weather forecast map and the climate outlook map.

2. Use what you have learned so far to create a one-sentence definition for weather and a one-sentence definition for climate.



Credit: Sara Nabih - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=65621937

Look up!

Tom saw these alto cumulus clouds in Episode 1. What clouds do you see in your sky today? Cloud chart (https://www.noaa.gov/clouds/noaawise)

PART 3. What is the expected weather today? Go to the NOAA NWS website (https://www.weather.gov/) and click on the part of the state where you live now. You should see a graphic with town names. Click on the town closest to you. Record today's weather information below.

Expected High Temperature	Expected Low Temperature	Current Wind Speed	Humidity	Visibility

Let's find out about some weather readings from the past. Teek was born on January 15, 2010, on the planet Queloz. Let's find out what the weather was like 10 years later on Earth in Washington, D.C., where Tom Di Liberto lives.

	January 15, 2010°F	January 15, 2020°F
Maximum Temperature	57	58
Minimum Temperature	24	40
Average Temperature	40.5	49
Precipitation	0	0
Snowfall	0	0

1. How did the weather on the two dates compare?

2. Let's see how the temperatures on those dates compare to monthly temperature averages. Look at the table and record the average January temperature in Washington, D.C., for 2010 and 2020.

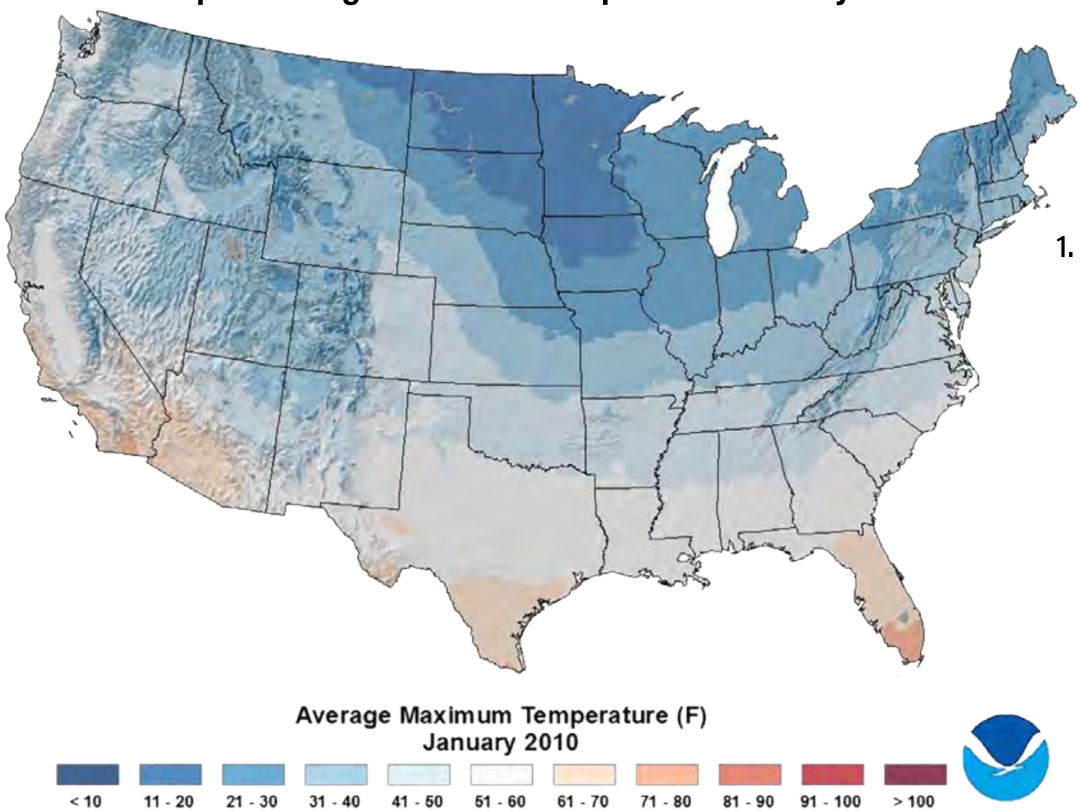
Monthly Average Temperature Jan 2010°F	Monthly Average Temperature Jan 2020°F

3. Now, compare the average temperature in January 2010 with the average January temperature in 2020.

YEAR	JAN
2010	35.3
2011	33.7
2012	40.8
2013	40.3
2014	32.3
2015	35.6
2016	34.9
2017	42.1
2018	35.7
2019	37.2
2020	42.4
NORM	37.5

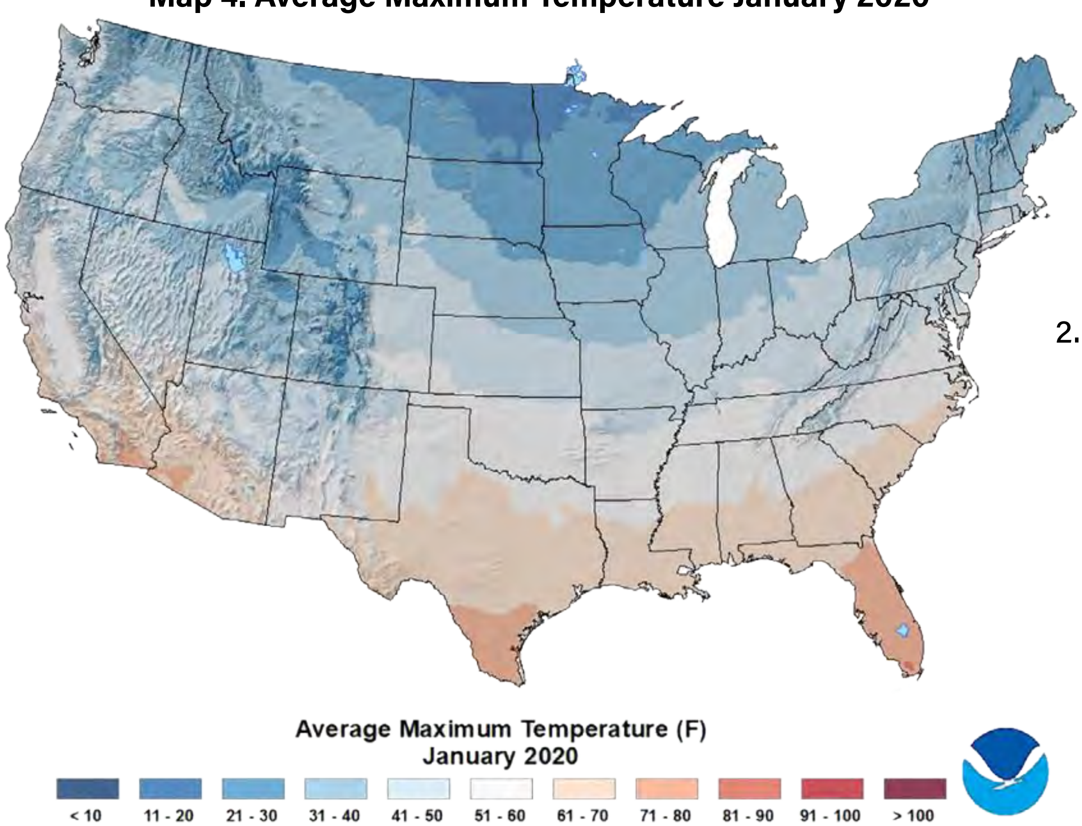
PART 4. Let's take a look at some graphic temperature averages from the past. Temperatures are displayed using colors, with each color representing a 10-degree range. Look at the temperatures in the part of the state where you live.

Map 3. Average Maximum Temperature January 2010



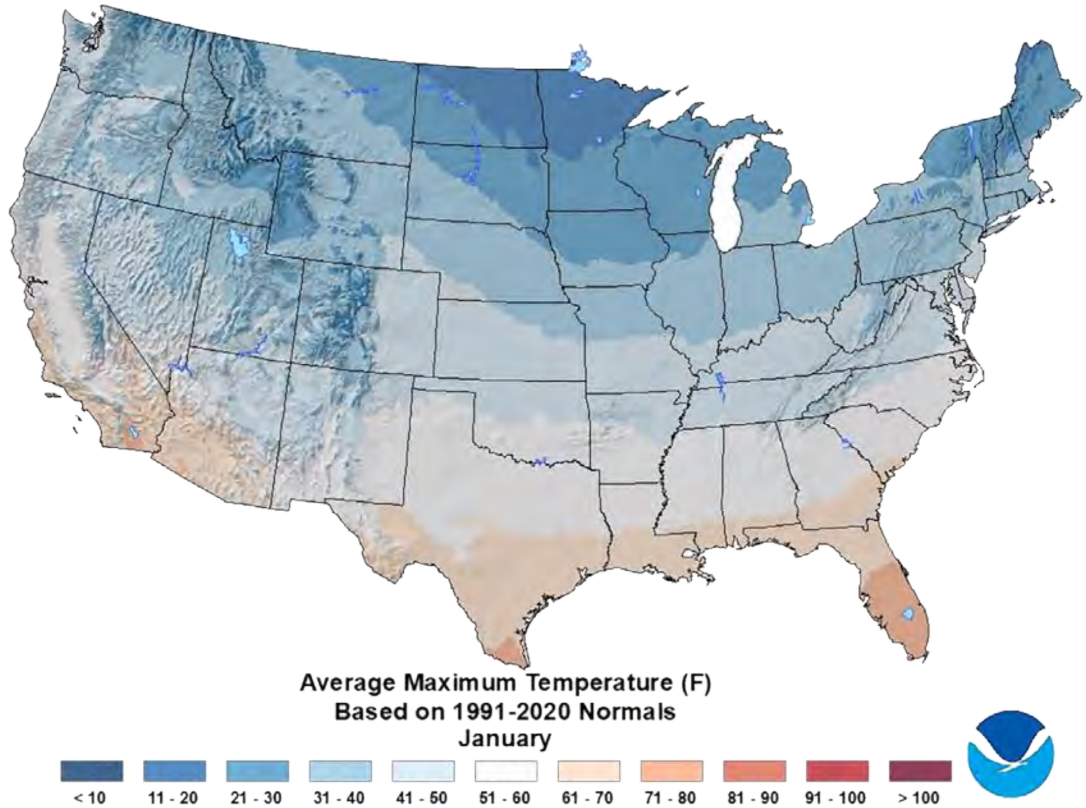
1. What was the average maximum temperature range where you live in January 2010?

Map 4. Average Maximum Temperature January 2020



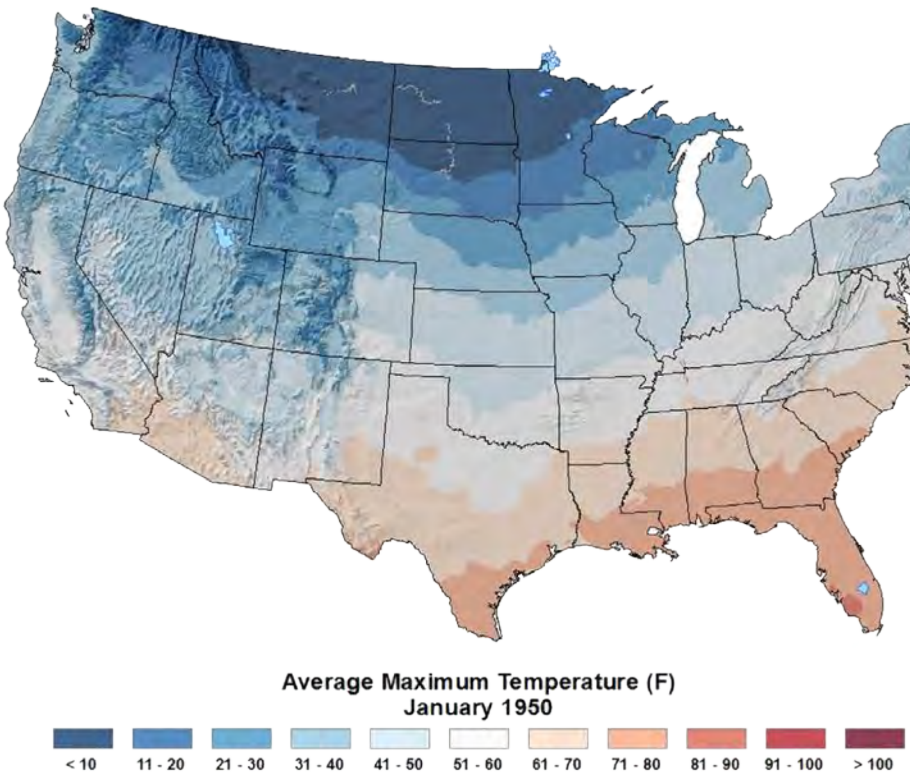
2. What was the average maximum temperature range where you live in January 2020?

Map 5. The climate map below is a record of the average maximum temperature. It is based on **30** years of data from 1991-2020. The map presents data from thousands of U.S. weather stations located across the 50 states and territories. Having many years of data allows for better predictions in the future.



3. Find your state on the map and the temperature range that is shown. Compare the January average maximum temperatures from 2010 on Map 3 that you identified earlier with the climate map that shows 30 years of data (Map 5). What is the difference in the temperature between the two maps? What evidence do you have to support your answer?

Map 6. Average Maximum Temperature January 1950



4. Let's look at data from over 70 years ago. Compare the January average maximum temperatures from 1950 on Map 6 with the climate map that shows 30 years of data (Map 5). What is the difference in the temperature between the two maps for locations in your state? What evidence do you have to support your answer?

PART 5. Use what you have learned and materials in your classroom to design and create an art piece, a visual, or a graphic that Teek can use to help their classmates understand the difference between weather and climate. These will be posted around the room.

Teek and Tom Episode 1

What's the Difference between Weather and Climate?

LESSON 2

It's All about the Weather... and the Climate

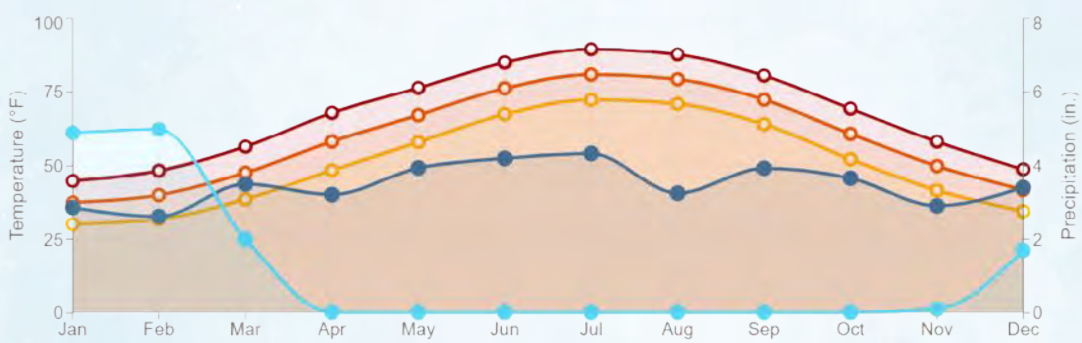
All URLs were reviewed and accurate at the time of this lesson's publication. If you should come across a non-operational link, contact NOAA Ocean Service Education at oceanserviceseducation@noaa.gov. All images are credited to NOAA unless otherwise noted.

Introduction

Weather stations across the United States have provided observations over many decades. The weather measurements collected over the most recent 30 years are averaged to produce "climate normals." Climate normal data can be put into simple graphs of temperature and precipitation to show a location's climate. These are updated every ten years. Weather and climate use measurements of temperature, precipitation, humidity, wind speed, and direction. Weather forecasts use short-term data, while climate predictions use averages of 30 years of data.

The climate normal graph below shows 30 years of averaged data. The average monthly precipitation (rain) at Ronald Reagan Washington National Airport (AP) in Virginia is in dark blue. The average monthly snow is represented in light blue. The average minimum monthly temperatures are in yellow, the average maximum monthly temperatures are in red, and the average of the minimum and maximum monthly temperatures are in orange.

Ronald Reagan Washington National Airport



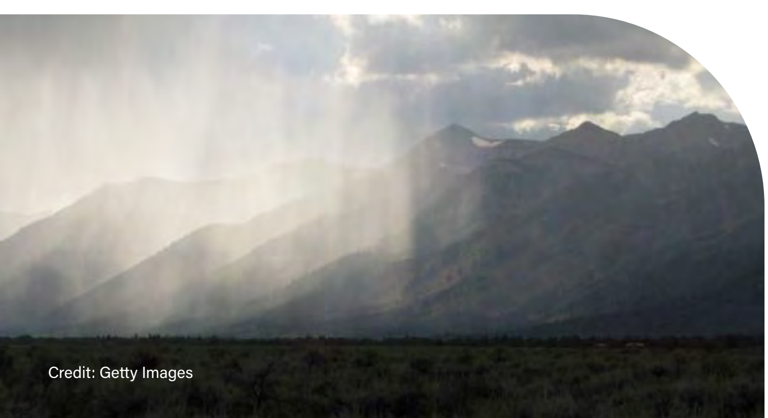
The latitude of a location on the Earth has a primary influence on its climate. This is due to the tilt of the Earth on its axis and the amount of solar radiation reaching it. Other factors that affect climate in a particular region are nearness to large bodies of water, elevation, the rain shadow effect of mountains, global wind and ocean current patterns, and cloud cover.

In general, we expect cities near water to have more moderate temperatures. They experience a smaller range of temperatures between day and night, and their seasons are milder. Cities near water also have more precipitation depending on the prevailing wind patterns. An island's windward side faces the prevailing winds, whereas the island's leeward side faces away from the wind, sheltered by hills and mountains. As winds blow across the ocean, they pick up and transport moisture pulled directly from the water. (Refer to the graphic in the student record sheets.)

Precipitation is also strongly affected by the nearness of mountains. The side of a mountain range that faces the wind, the windward side, will have higher precipitation. The opposite side of the mountain, or leeward side, will often be in a rain shadow, with very little rain. (Refer to the graphic in the student record sheets.)

Lesson Summary

In lesson one, students were introduced to a basic understanding of the difference between weather and climate. In this activity, they will look at the factors that influence precipitation and temperatures of a location, and then make decisions based on climate information.



Credit: Getty Images

Objectives

- Students will investigate weather and climate through maps and archived data.
- Students will examine data from a location and compare it to other locations to determine the effect of geographic features on temperature and precipitation.

Estimated Time

It is estimated that one to two 45-minute class periods are needed for this lesson. This does not include the time required to view Teek and Tom Episode 1: *"What's the Difference Between Weather and Climate?"*, 16:45 minutes (https://oceantoday.noaa.gov/teekandtom/episode-1.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 with a full list in Appendix A (https://oceantoday.noaa.gov/teekandtom/educators-guide/appendix-a.pdf).

Next Generation Science Standards

- **3-ESS2-1: Earth's Systems.** Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.
- **MS-ESS2-5: Earth's Systems.** Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

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

- Pencils (one per student)
- Scissors
- Tape or glue
- Students will need printouts of student record sheets, graphs, and/or maps to carry out the activities. Student record sheets are located at the end of this lesson.
- If you would like to provide the maps/graphics on a projection system, students will only need the student record sheets. Depending on the configuration of your classroom, we recommend one set per student or group.
- All maps/graphics 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-2.zip)

Preparation

1. The teacher notes below include information about finding local maps/data.
2. Teacher notes/extensions, etc., below also include ways to explore the topic or activity further. Additional content to explore is available in the extensions section of the lesson.

InvesTeekation Pathway

ENGAGE

Part 1. Engage

Review the visuals the students made in the previous activity/lesson 1. Give students the sheet of phrases to cut out so that they can arrange these on the student record sheets. This activity is best done in pairs or small groups to encourage discussion. The answer key is below.

WEATHER	CLIMATE
Tells us what kind of clothes to wear today.	*A picture that comes to mind when you think of a faraway place.*
May affect what activities I do outside today.	*We usually have a snowstorm in December.*
Can change from day to day.	*Heat waves have become more common in my area for the past few years.*
Tells us whether to take an umbrella today.	*Tells us what kind of clothes to buy.*
Tells us whether to put on clothes for snow today.	*Summer is usually very hot.*
What you see when you look out the window today.	*There are four seasons where I live.*

EXPLORE

Part 2. Explore

1. Students will learn how weather data collected over time is used to develop climate normals. Using a hypothetical story about Tom Di Liberto, they will use real data and calculate the mean for minimum temperature, maximum temperature, and precipitation for a period of 10 years. Note: Since the date of each year is in July, the precipitation is rain.

Answers to the 10-year mean data table.

Mean Minimum Temperature	Mean Maximum Temperature	Mean Precipitation
67 °F	*87.1 °F*	*0.014 inches*

Ten years of data is not enough to develop a picture of average climate characteristics. The latest 30-year period (1991-2020) is used to create the graphs for this activity.

2. Have students look at the climate normal graphs for temperature and precipitation for Tom's hypothetical home in Beltsville, Maryland. In this case, temperature and precipitation are shown in separate graphs. Usually, temperature and precipitation are shown together. Students are asked a series of questions about the temperature and precipitation graphs.

Discussion questions

1. In July, the mean minimum temperature (climate normal) was 67.6 °F, and the mean maximum temperature (climate normal) was 87.1 °F. In which years were the maximum temperatures that Tom recorded higher than the climate normals?

   1993, 1994, 1997, 1999, 2000.

2. Do Tom's 10-year mean minimum and maximum temperatures in July fit within the 30-year climate normals? Explain.

   The average minimum temperature in Tom's data was 67 °F, which is very close to the 30-year data of 67.6 °F. His mean maximum temperature of 87.1 °F was the same as the 30-year data.

3. The precipitation climate normals for Beltsville between 1991 and 2020 look like the graph below. The dark blue line represents monthly rain, and the lighter blue line represents monthly snow. The average monthly rainfall (climate normal for 1991-2020) in Beltsville in July over 30 years was 4.51 inches. How did the rainfall that Tom recorded in July over 10 years compare to the climate normal?

   Tom's 0.014 inches of rainfall was much less than the average of 4.51 over 30 years.

4. Compare the accuracy of Tom's 10 years of precipitation data and 30 years of climate data.

   There was not much difference in the temperature data, but there was a big difference in the precipitation data. The 10-year time period might have been a particularly dry stretch of years.

Credit: Shutterstock

EXPLAIN

Part 3. Explain

1. Students will look at graphs of climate data (climatographs) for U.S. cities. Temperature and precipitation are influenced by factors such as latitude, where the city is located within a landmass, and the presence of ocean currents. Other factors include the city's proximity to mountain ranges or large bodies of water and prevailing winds. As a class, help students find the location of each of the cities discussed in the activity using the map on their student record sheet, the projection slide, or another means that works for you (e.g., Google Maps).
2. The graphs on the student record sheets show climate normals with temperature data for four cities. They should consider which of four factors is the main influencer of that city's temperature range. They will do the same for four cities and four factors that influence yearly precipitation.
3. Emphasize to the students that they should read the graphs carefully. The months are always along the x-axis, and the temperature and precipitation ranges are on the y-axis. For example, ask students to compare the temperature range of Utqiaġvik and Minneapolis. One city reaches 60 °F and the other 100 °F. Also, compare the precipitation range of Tucson and Salt Lake. The graph for Tucson only reaches 2.4 inches, while Salt Lake reaches 16 inches.
4. Discuss the importance of carefully reading the labels on each axis to make accurate comparisons. Each group of four cities will have one primary factor responsible for differences in temperature or precipitation. Emphasize that weather and climate are complicated, and there may be secondary factors present that affect the temperature and/or precipitation.

Discussion questions

Factors that influence temperature

1. *Latitude – Utqiaġvik*
2. *Landmass – Minneapolis/St. Paul*
3. *Ocean currents – San Diego*
4. *Large bodies of water – Jacksonville*

Factors that influence precipitation

1. *Latitude – Tucson*
2. *Landmass – Salt Lake City*
3. *Large bodies of water – Buffalo*
4. *Mountains – Hilo*

ELABORATE

Part 4. Elaborate

During episode 1, Teek and Tom visit a farm, and Tom introduces the idea of climate outlooks while Teek gets to drive a tractor. In this activity, students are introduced to a new type of map that represents a climate outlook. The map gives probabilities in percentages of how likely precipitation will be above, below, or near average compared to the climate averaged over 30 years. These are shown by colors that represent the following categories: below normal, normal, or above normal.

Credit: Shutterstock

Discussion questions

1. When was this climate outlook map issued?

   July 20, 2023

2. What time period does this climate outlook map cover?

   Dec-Jan-Feb 2023-2024

3. Describe what areas of the country will see "likely above normal" precipitation.

   The far southeast part of the U.S., especially South Carolina, Georgia and Florida.

   Do you think that the precipitation will be rain or snow in those areas?

   It is a warm part of the U.S. in winter, so the precipitation will be rain.

4. Describe what areas will see "leaning below normal" precipitation.

   The far north of the central U.S. and areas around the Great Lakes.

   Do you think that precipitation in those areas during that time period will be rain or snow?

   Precipitation in winter will be as snow.

5. How would this climate outlook map help you if you were responsible for preparing a city for flooding events?

   People in the southeast should prepare for heavy rain and potential flash floods. Since the outlook was released in July, there is time to prepare.

6. How would this climate outlook map help you if you were responsible for preparing a city for snowstorm events?

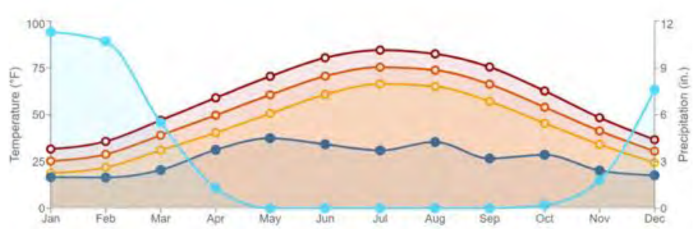
   Cities in the area of leaning below in precipitation, especially snow, might not have to have so many snow plows or salt reservoirs ready.

EVALUATE

Part 5. Evaluate

1. Students will apply what they've learned about the effects of geographic features on temperatures and precipitation. They will make up data and use it to create their own climate graph of temperature and precipitation for an imaginary location. They will describe their imaginary location's climate based on the factors that they have learned about.

2. The students should be able to explain how local geographic features affect both the temperature and the precipitation of their city. For example, in the climate normal graph below (Chicago, Illinois), the monthly precipitation (rain) at Chicago O'Hare International Airport is dark blue. The light blue line is monthly snow. The minimum monthly temperature is yellow, the maximum monthly temperature is red, and the average monthly temperature is orange. Chicago is influenced by its closeness to the Great Lakes and its location in the center of the continental United States.



Chicago O'Hare International Airport

If your students are advanced enough, you can provide them with blank graph paper with no labels to construct the climograph.

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.

Credit: Shutterstock

Extension

Additional information on weather and climate can be found at:

- What's the Difference Between Weather and Climate? NOAA National Centers for Environmental Information (https://www.ncei.noaa.gov/news/weather-vs-climate)
- What is the difference between weather and climate? National Ocean Service (https://oceanservice.noaa.gov/facts/weather_climate.html)

If you want to find temperature or precipitation data for your city, go to NOAA's National Centers for Environmental Information U.S. Climate Normals Quick Access webpage (https://www.ncei.noaa.gov/access/us-climate-normals/#dataset=normals-monthly&timeframe=30&location).

Data is available for climate outlooks of short to longer time periods, as well as archived data. You can find more climate outlook maps on NOAA's National Weather Service Climate Prediction Center webpage (https://www.cpc.ncep.noaa.gov/products/predictions/90day/).

These resources from NOAA's video collections will be helpful for student understanding during discussions regarding their ideas about the influence of temperature and precipitation on climate. The videos show instances of how NOAA provides information about seasonal climate outlooks.

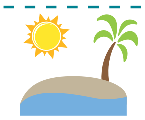
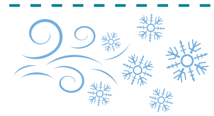
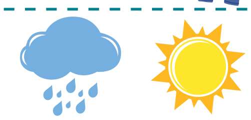
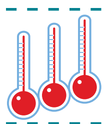
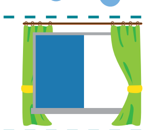
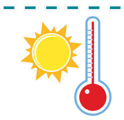
- NOAA Climate YouTube (https://www.youtube.com/user/noaaclimate)
- Videos at Climate.gov (https://www.climate.gov/news-features/videos)

Student Record Sheets

PART 1. In a small group, cut out the phrases below and determine which of them describe climate or weather. Place each phrase in the correct column.

Share your ideas with the class.

WEATHER	CLIMATE

Tells us what kind of clothes to wear today. 	A picture that comes to mind when you think of a faraway place. 
Tells us what kind of clothes to buy. 	We usually have a snowstorm in December. 
Can change from day to day. 	Tells us whether to take an umbrella today. 
Heat waves have become more common in my area for the past few years. 	May affect what activities I do outside today. 
Tells us whether to put on clothes for snow today. 	What you see when you look out the window today. 
Summer is usually very hot. 	There are four seasons where I live. 

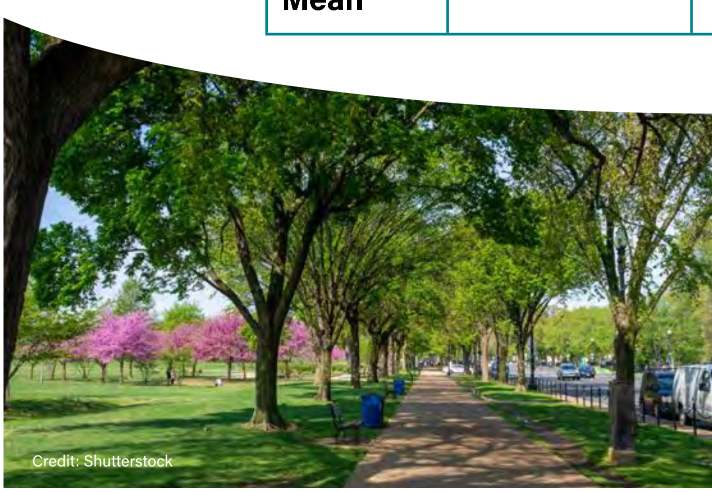
PART 2. STORYTIME!

Tom Di Liberto has always been interested in weather. When he was young, he kept a journal about the weather in Maryland, where he lived. He found weather information in many places, including newspapers, online, or on TV. They always reported the high and low temperatures and the amounts of rain or snow. Weather forecasters use the term precipitation for rain or snow. He started recording that information every day. Over time, he decided to record the weather information on just one day each year: July 4.

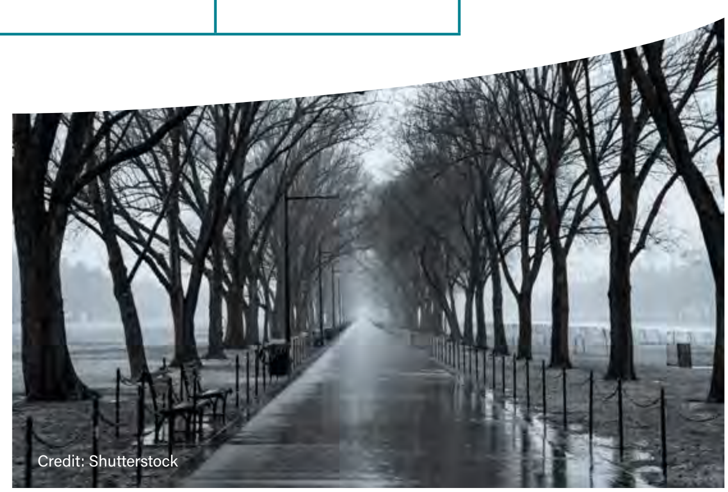
Tom recorded his information for many years until he started working for NOAA as a climate scientist. By that time, his logbook had 10 years of data. Tom wanted to compare his data to NOAA weather records. He found that he needed to find the average (mean) of his data to compare it with NOAA's data.

Calculate the mean for minimum temperature, maximum temperature, and precipitation of Tom's data.

Year	Minimum Temperature (°F)	Maximum Temperature (°F)	Precipitation - Rain (Inches)
1991	70	87	0
1992	66	72	0.12
1993	70	92	0.41
1994	67	90	0.57
1995	66	83	0
1996	58	80	0
1997	65	94	0
1998	63	89	Trace
1999	74	94	0
2000	71	90	0.33
Mean			



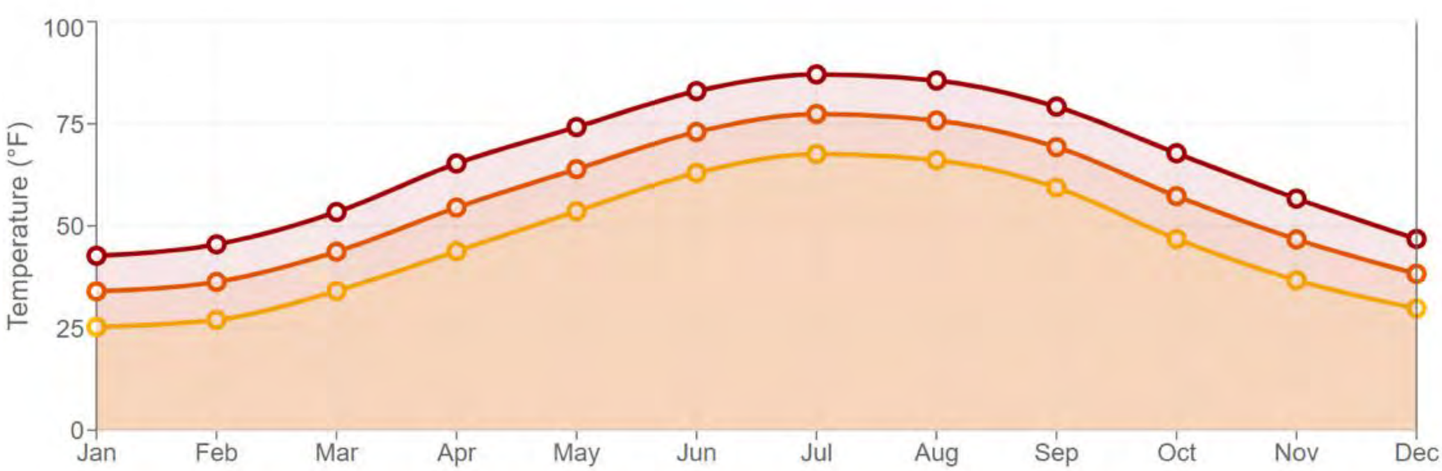
Credit: Shutterstock



Credit: Shutterstock

Scientists use a period of 30 years to show "climate normals." Tom realized that his 10 years of data was not enough to show average climate characteristics. The latest 30-year period (1991-2020) is the most recent "climate normal". Tom found a graph that shows the climate normals for Beltsville, Maryland. (See the graph below.) The dark red top line shows mean maximum temperatures for 30 years. The yellow bottom line is mean minimum temperatures for 30 years, and the middle orange line is the average temperature.

Beltsville, Maryland



1. In July, the mean minimum temperature (climate normal) was 67.6 °F, and the mean maximum temperature (climate normal) was 87.1 °F. In which years were the maximum temperatures that Tom recorded higher than the climate normals?

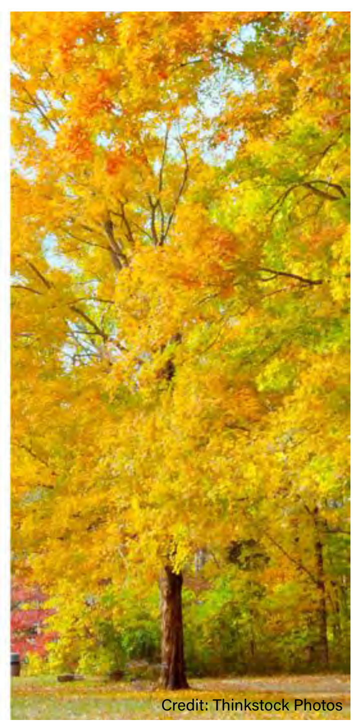
2. Do Tom's 10-year mean minimum and maximum temperatures in July fit within the 30-year climate normals? Explain.

3. The precipitation climate normals for Beltsville between 1991 and 2020 look like the graph below. The dark blue line represents monthly rain, and the lighter blue line represents monthly snow. The average monthly rainfall (climate normal for 1991-2020) in Beltsville in July over 30 years was 4.51 inches. How did the rainfall that Tom recorded in July over 10 years compare to the climate normal?

Beltsville, Maryland

4. Compare the accuracy of Tom's 10 years of data and 30 years of climate data.



Credit: Thinkstock Photos

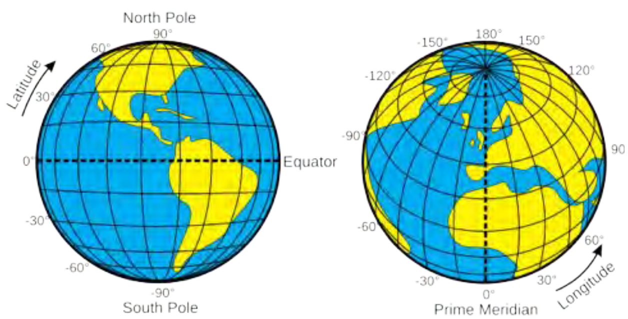
PART 3. The temperatures of a region are affected by many factors. These may include latitude, where the region is within a land mass, or if it is near ocean currents. Below are four factors that influence **temperature.** You will also find four graphs of climate normals for cities in the U.S.

Match the city climate graph with the description of the influencing factor. **Read the graphs carefully.** The months are always along the x-axis. Temperature is on the y-axis. Note that some cities reach higher temperatures, so the y-axis numbers may be different on the graphs.

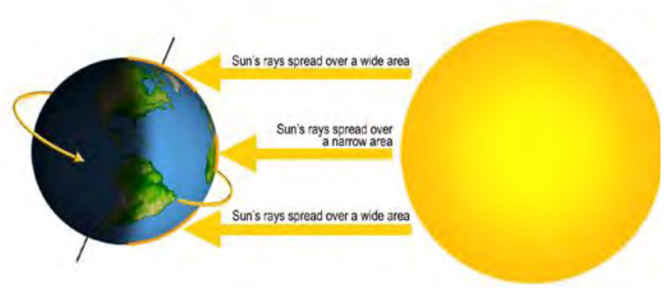
FACTORS THAT INFLUENCE TEMPERATURE

Latitude

Latitude is the measurement of distance north or south of the equator. The equator is the line of 0 degrees latitude. Ninety degrees north of the equator is the North Pole, and 90 degrees south of the equator is the South Pole. Places near the equator are warmer. Places near the poles are colder.



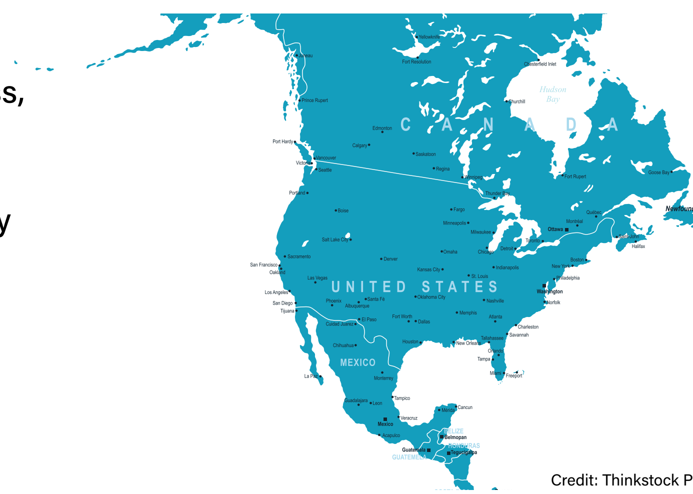
Credit: Wikimedia Commons



Credit: slideshare.net

Landmass

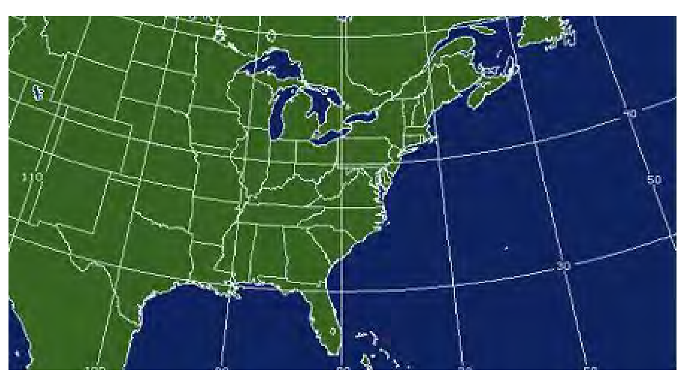
Locations near the center of a large landmass, like a continent, tend to have wide ranges in temperatures. This includes big differences between day and night. Summer may be very hot, and winters may be very cold.



Credit: Thinkstock Photos

Large Bodies of Water

The ocean or the Great Lakes have a moderating effect on temperatures of coastal areas. These regions usually do not have very big differences in temperature between day and night. They also don't have big swings in temperatures during the seasons.

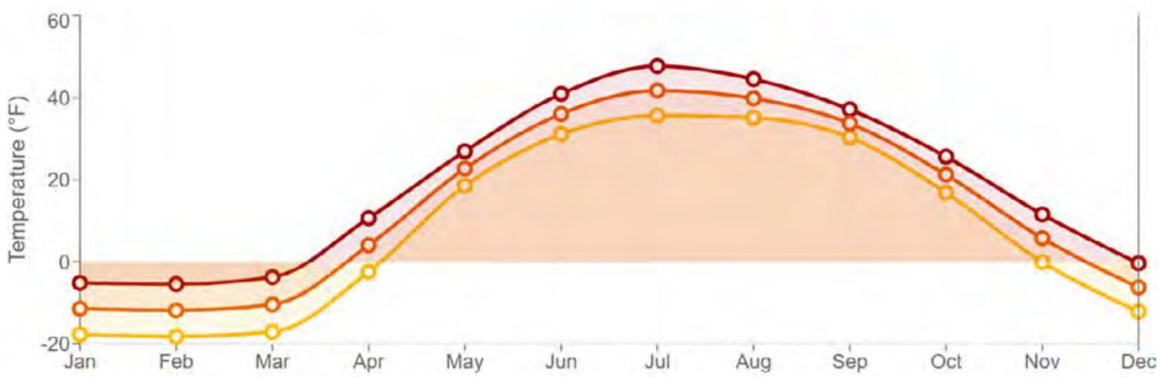


Ocean Currents

Ocean currents are driven by global wind patterns that are fueled by energy from the sun. These currents transfer heat from tropical regions of the Earth to the polar regions, influencing local and global climate. Ocean currents tend to warm temperatures of eastern coastal areas and cool temperatures of western coastal areas.

Credit: Public Domain

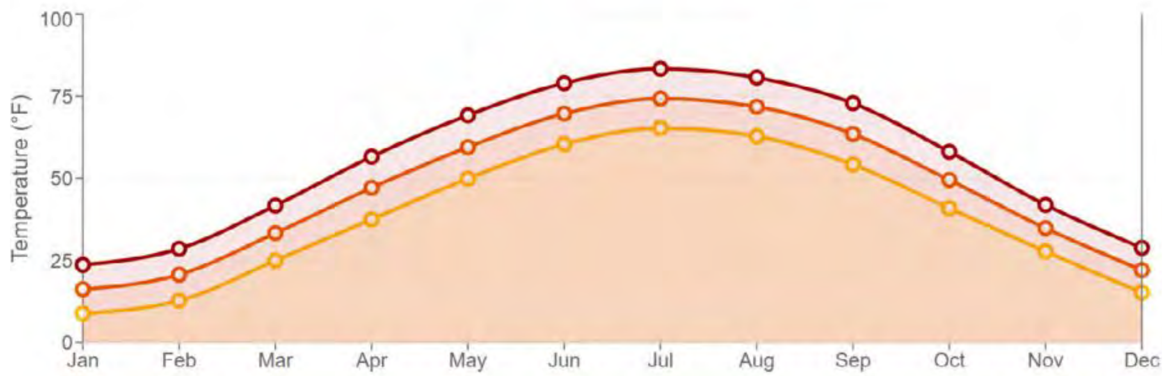
Utqiagvik, AK



1. Which temperature factor do you think affects Utqiagvik, Alaska, the most? Explain.

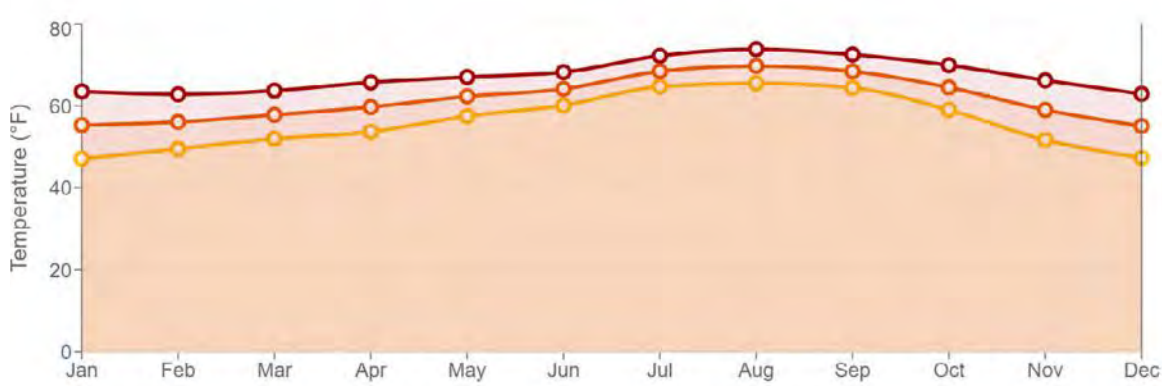
Credit: Shutterstock

Minneapolis/St. Paul, MN



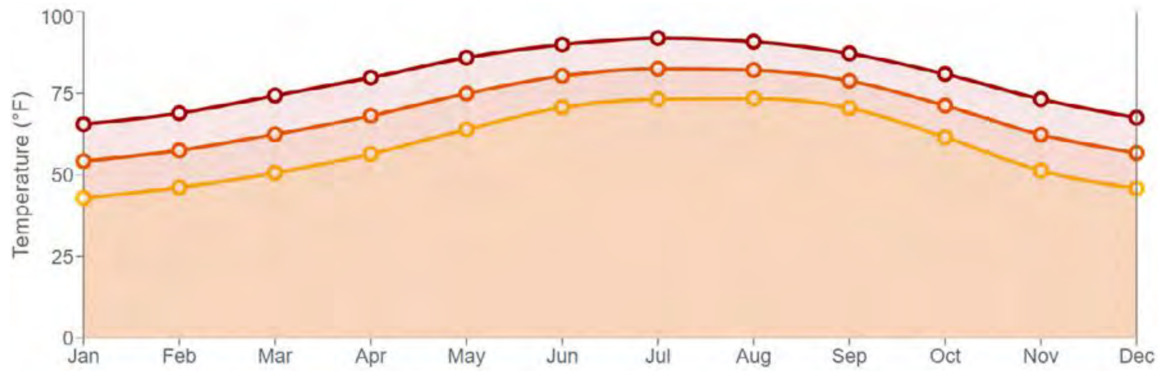
2. Which temperature factor do you think affects Minneapolis/St. Paul, Minnesota, the most? Explain.

San Diego, CA



3. Which temperature factor do you think affects San Diego, California, the most? Explain.

Jacksonville, FL



4. Which temperature factor do you think affects Jacksonville, Florida, the most?

Earth Curiosities

It's a Hot One!

Death Valley in California holds the record for the world's highest surface air temperature ever recorded: 134°F. From May to October, temperatures often reach over 100°F. The valley is a long, narrow basin 282 feet below sea level. It is surrounded by high, steep mountain ranges. The clear, dry air and very few plants allow sunlight to heat the desert surface.

Credit: Shutterstock

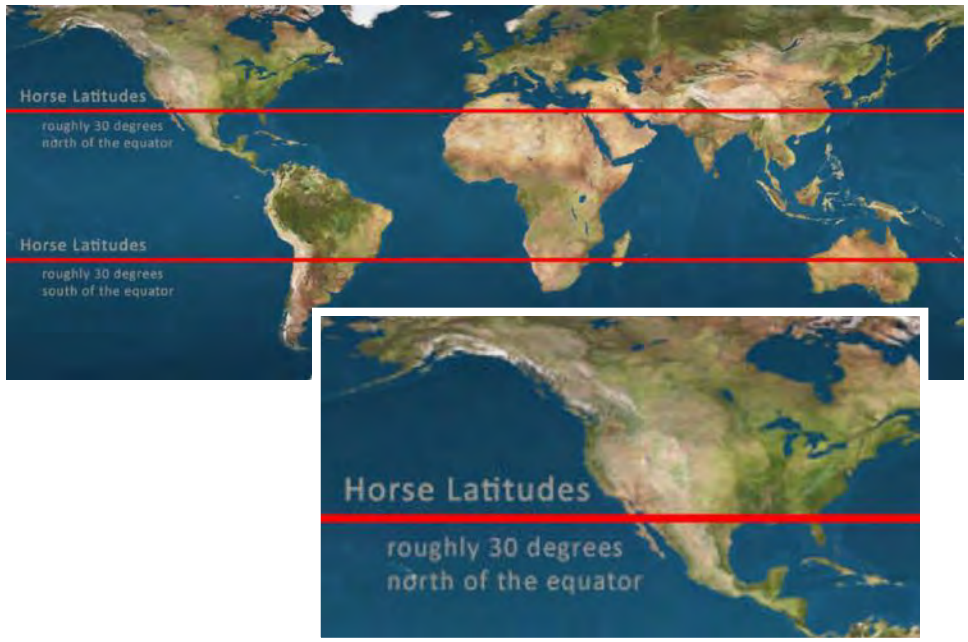
A region's precipitation can be affected by being close to mountain ranges or large bodies of water and the direction of the winds. Below, you will find four factors that influence **precipitation.** You will also find four graphs of climate normals for cities in the U.S. Match the city climate graph with the description of the influencing factor.

NOTE: Read the graphs carefully. The months are always along the x-axis, and the precipitation in inches is on the y-axis. However, depending on the range needed, the numbers may be very different between the graphs. The dark line is rain, and the lighter line is snow.

FACTORS THAT INFLUENCE PRECIPITATION (RAIN OR SNOW)

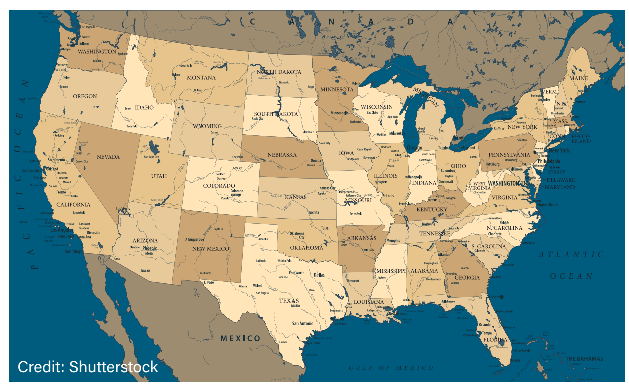
Latitude

The horse latitudes are located at 30 degrees north latitude and 30 degrees south latitude. They are subtropical regions known for calm winds and little precipitation.



Landmass

Locations near the center of a large landmass tend to have drier climates.

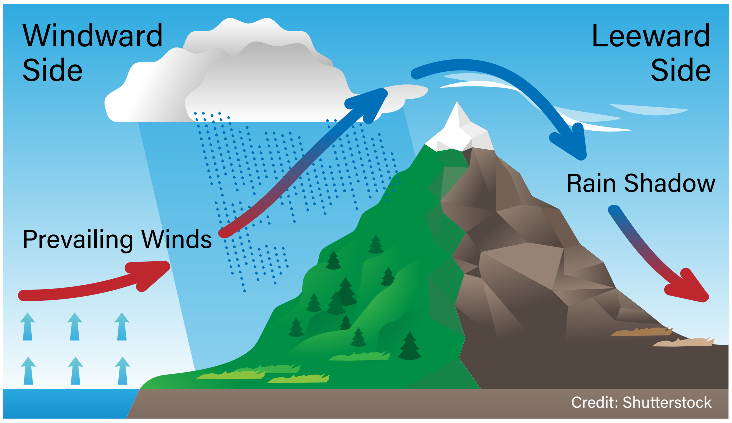


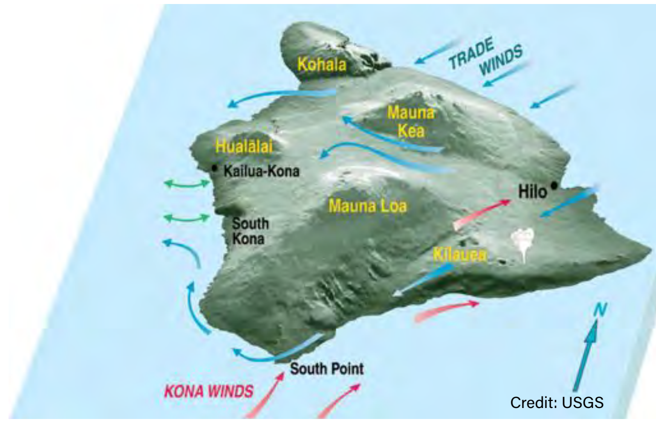
Large Bodies of Water

Areas near large bodies of water like the Great Lakes tend to have higher-than-average precipitation (rain or snow). Moisture is picked up as the wind travels across the water from the west and is released further downwind.

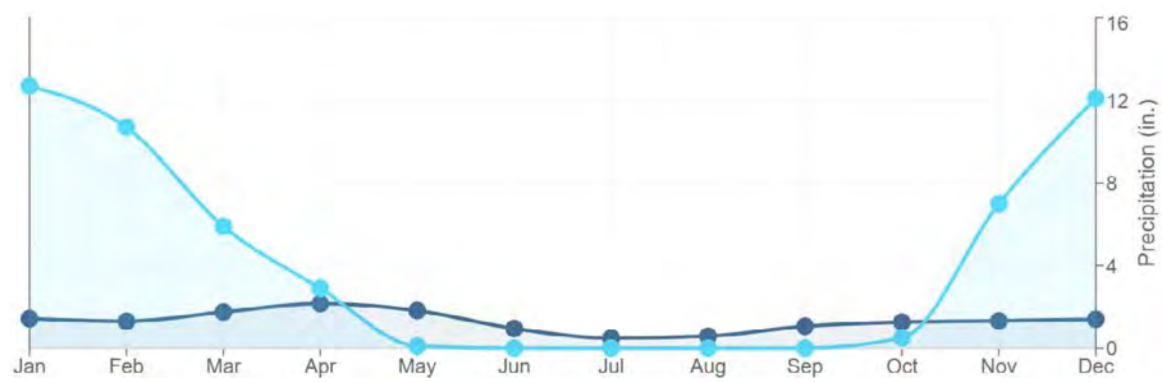
Mountains

An island's windward side faces the prevailing winds. An island's leeward, or downwind side, faces away from the winds and is sheltered from prevailing winds by hills and mountains. As winds blow across the ocean, they pick up moist air from the water. When the moist air reaches an island's hills or mountains, it often releases the moisture as rain. As the air continues to move to the other side of the island, it warms up and dries out. An island's windward side is wetter than its drier leeward side.





Salt Lake City, UT



5. Which precipitation factor do you think affects Salt Lake City, Utah, the most? Explain.

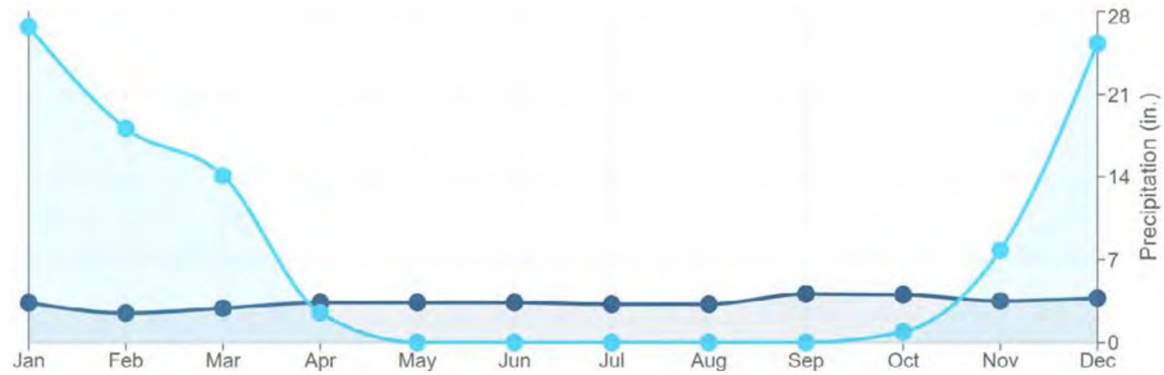
Hilo, HI

6. Which precipitation factor do you think affects Hilo, Hawaii, the most? Explain.

Tucson, AZ

7. Which precipitation factor do you think affects Tucson, Arizona, the most? Explain.

Buffalo, NY



8. Which precipitation factor do you think affects Buffalo, New York, the most? Explain.

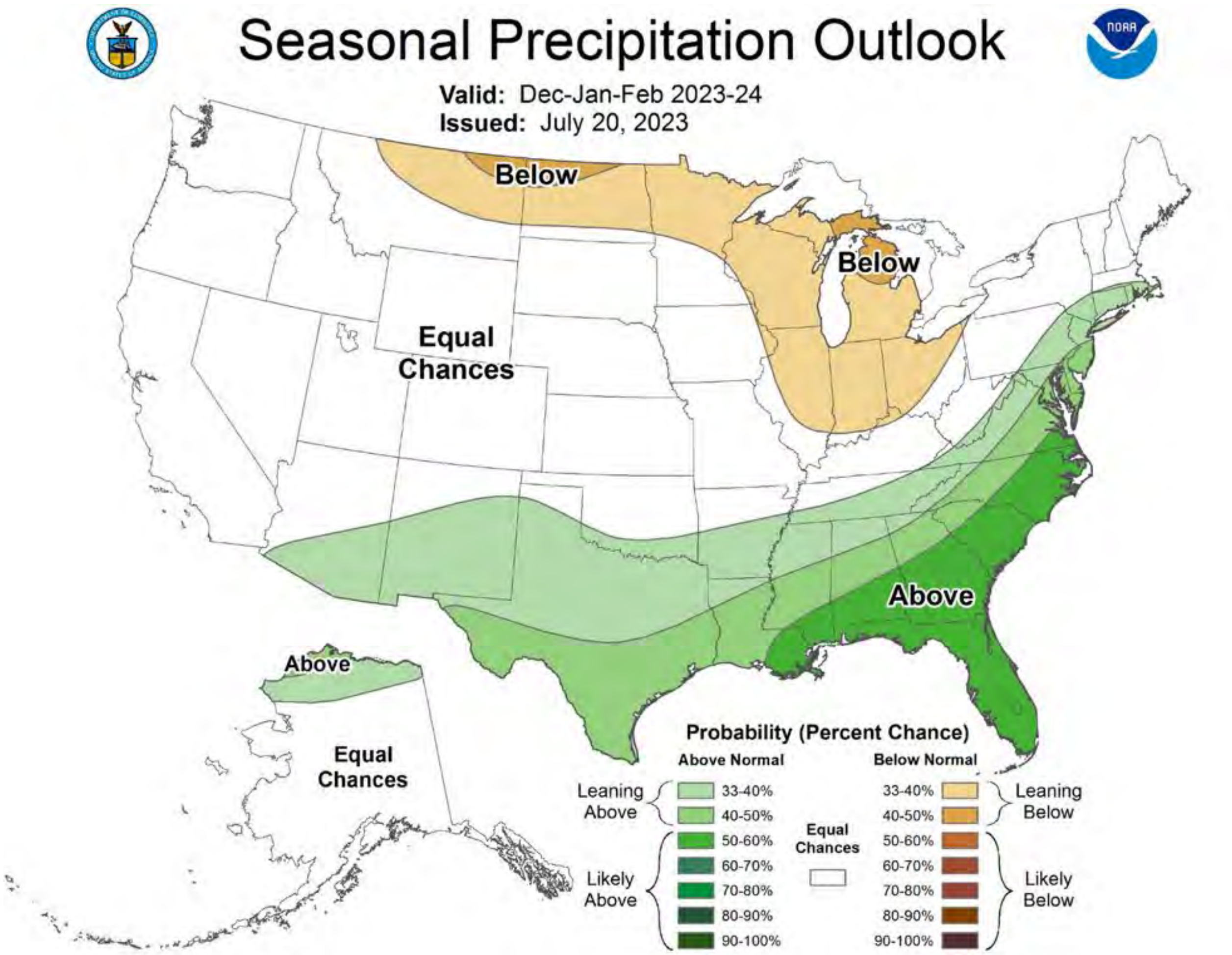
Earth Curiosities

Dust Storms!

Credit: Shutterstock

Dust storms and haboobs can occur anywhere in the United States but are most common in the Southwest. Haboobs occur as a result of winds coming from thunderstorms. These winds can start a dust storm that can drastically reduce visibility. A dust storm usually arrives suddenly in the form of an advancing wall of dust and debris which may be miles long and several thousand feet high. They strike with little warning. Blinding dust can quickly reduce visibility, causing accidents that may involve chain collisions. Dust storms usually last only a few minutes. Don't enter a dust storm area if you can avoid it.

PART 4. During episode 1, Teek and Tom visit a farm, and Tom introduces the idea of climate outlooks. A climate outlook gives the probability that certain temperature or precipitation conditions will be below normal, normal, or above normal. The map below shows a U.S. seasonal outlook for precipitation.



1. When was this climate outlook map issued? _______________

2. What time period does this climate outlook map cover? _________________

3. Describe what areas of the country will see "likely above normal" precipitation. Do you think that the precipitation will be rain or snow in those areas? Explain.

4. Describe what areas will see "leaning below normal" precipitation. Do you think that precipitation in those areas during that time period will be rain or snow? Explain.

5. How would this outlook map help you if you were responsible for preparing a city for heavy rain events?

6. How would this outlook map help you if you were responsible for preparing a city for snowstorm events?

Credit: Shutterstock

PART 5. You will have a chance to envision the climate of a place where you would like to live. You have seen the precipitation and temperature graphs of many cities. You have also seen the factors that can affect temperatures and precipitation.

- Imagine a place with a temperature range and precipitation that you would want to experience year-round.
- Think about whether you like to have four seasons with a wide range of temperatures.
- How much precipitation would you like? Would it fall as rain or snow?

Describe or draw the type of weather that you would like to experience at your imaginary place.

From what you have learned in this lesson, select the temperature and precipitation factors that influence this place. Explain why you chose those factors.

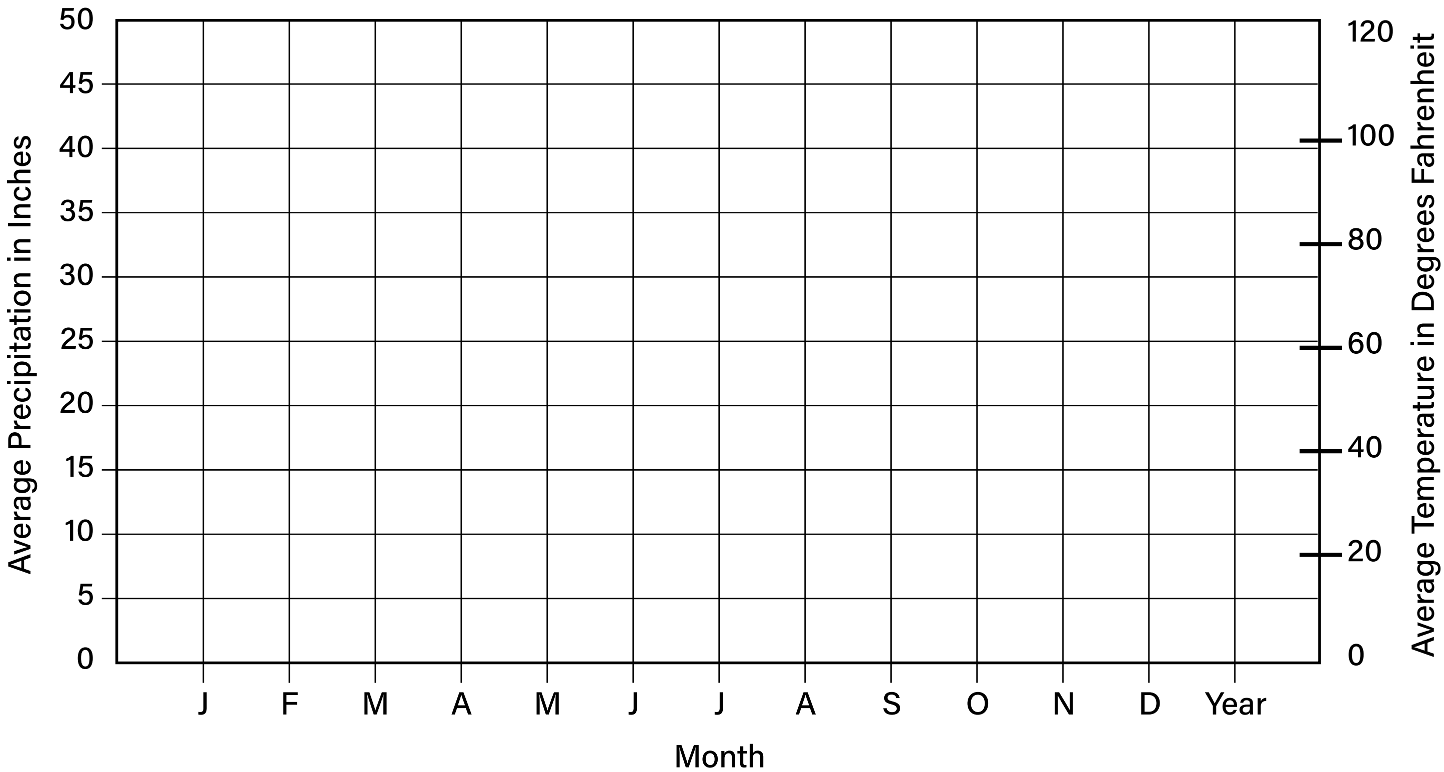
Based on what you know about the factors that influence temperatures and precipitation of your imaginary place, complete the data table below with the minimum and maximum temperatures and precipitation for each month. Imagine that this data represents 30-year averages. Check back with other cities that you have learned about for ideas.

Month	Minimum Temperature (° F)	Maximum Temperature (° F)	Precipitation (Rain in Inches)	Precipitation (Snow in Inches)
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				

Construct a climate graph that includes precipitation and temperature with the data you just created.

1. The x-axis represents the date, labeled with just the first letter of each month (e.g., January is 'J,' February is 'F,' etc.).
2. The left y-axis is "Temperature in degrees Fahrenheit."
3. The right y-axis is "Precipitation in Inches."
4. Using lines of different colors, plot the minimum and maximum temperatures using a line graph. Indicate the colors that you chose in the data table below and on the legend on the side of the graph.
5. Using different colors, plot rainfall and snow using a line graph. Indicate the colors that you chose in the table below and on the legend on the side of the graph.

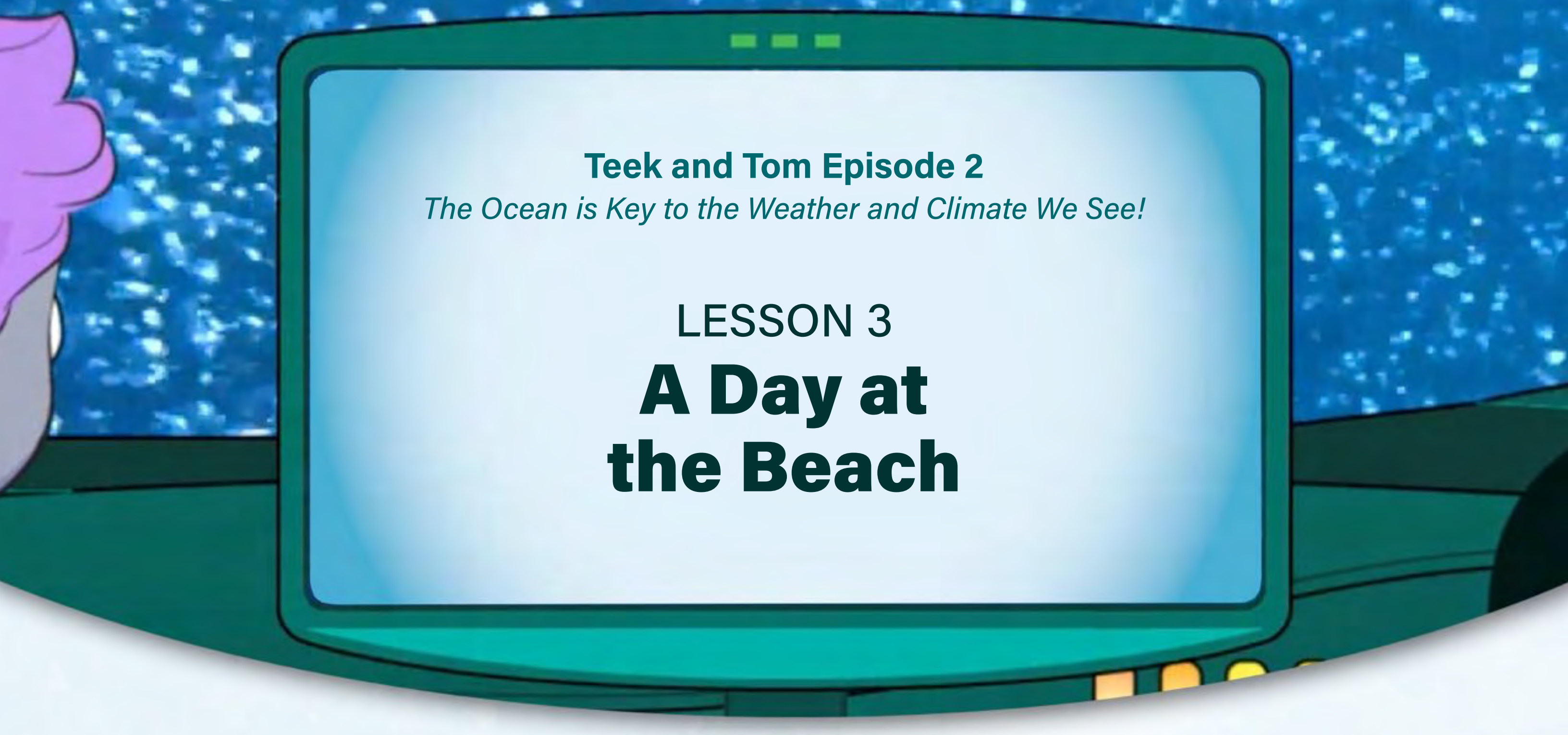
	Line color
Minimum Temperature (°F)	
Maximum Temperature (°F)	
Precipitation as Rain in Inches	
Precipitation as Snow in Inches	



Student Name

Key to Data

Does your imaginary place include precipitation or temperature data that resembles one of the cities that you previously reviewed? Explain.



Teek and Tom Episode 2

The Ocean is Key to the Weather and Climate We See!

LESSON 3

A Day at the Beach

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

The ocean absorbs energy — or heat — from the sun, and this has a major influence on Earth's weather and climate. Earth's ocean is far more important than the land as a source of the heat energy that drives weather and climate. The ocean covers more than two-thirds of the Earth's surface. It absorbs more energy from sunlight and stores heat longer than land. The sun's rays penetrate and heat up the ocean to a depth of many meters. These same rays, however, only heat up the very top layer of sand, soil, or rock on land surfaces. Water is very effective at absorbing and storing heat. These two factors play a big role in how the ocean impacts our weather.

The ocean moderates the climates in coastal areas. Because water does not heat up as easily as land, the ocean helps keep coastal areas cooler during the summer when inland temperatures soar. We can see this by comparing coastal and inland cities in California. The average temperatures of San Francisco, a coastal city, fluctuate very little over the course of a year. This is due to the moderating effect that the ocean has on temperatures. In contrast, the inland city of Sacramento is much cooler in the winter months and warmer in the summer months. This is due to the heating and cooling of its surrounding land mass.

Lesson Summary

Students will conduct a simple activity to demonstrate how water absorbs energy differently than land and air. This is what causes sea breezes, which keep coastal temperatures from getting too hot or cold. Students will then compare coastal and inland city temperature data to look at real-world examples of the ocean's effect on land temperatures.

Components of this lesson were adapted from Radiative Heating of Land and Water from NOAA's Global Monitoring Laboratory (https://gml.noaa.gov/outreach/info_activities/pdfs/LA_radiative_heating_of_land_and_water.pdf).

Objectives

- Students will compare differences in heating and cooling of land and water.
- Students will identify how prevailing winds and the movement of air masses affect weather in their location.

Estimated Time

It is estimated that one or two 45-minute class periods are needed for this lesson. This does not include the time required to view Teek and Tom Episode 2: *"The Ocean is Key to the Weather and Climate We See!"*, 11:15 minutes (https://oceantoday.noaa.gov/teekandtom/episode-2.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 with a full list in Appendix A (https://oceantoday.noaa.gov/teekandtom/educators-guide/appendix-a.pdf).

Next Generation Science Standards

- 3-ESS2-1: Earth's Systems. Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.
- MS-ESS2-4: Earth's Systems. Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.
- MS-ESS2-5: Earth's Systems. Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

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

The following materials allow for the set-up of a single demonstration for a class of approximately 30 students. You will need one setup per group if you want students to do this.

Arrange the pans to receive equal heat from the lamp within the red circle. Measure the temperatures within the red circle.

- Three thermometers
- Three small shallow pans, cups, or containers (small aluminum pans work well). Many options are available, but make sure that the pans or cups are the same size and can hold the soil/sand/water to the same level. The pans should contain at least 1 inch of soil, sand, or water.
- Lamp with heat bulb. If the pans are large, you may need a heat lamp for each of the sample pans. The key is equal light/heat for each of the samples. If your school's food service has food warmers, those

would work, too. The setup pictured includes a clamp heat lamp from the local hardware store. The lamp fixture is rated for 250 watts. The bulb is a 125-watt infrared/heat bulb.

- Stopwatch or timer
- Sand
- Soil (potting soil will work)
- Tap water
- Colored pencils or markers
- Large map of the U.S. You can use the map that is provided in the slide set or display a large paper map. One example of a good map for projection is the U.S. Map from the United States Geological Survey (https://www.usgs.gov/media/images/general-reference-printable-map).
- Students will need printouts of student record sheets, graphs, and/or maps to carry out the activities. Student record sheets are located at the end of this lesson.
- If you would like to provide the maps/graphics on a projection system, students will only need the student record sheets. Depending on the configuration of your classroom, we recommend one set per student or group.
- All maps/graphics 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-3.zip)

Preparation

1. The teacher notes below include information about finding local maps/data.
2. Teacher notes/extensions, etc., below also include ways to explore the topic or activity further.

InvesTeekation Pathway

ENGAGE

Part 1. Engage

1. Ask the students if they have ever visited a beach. Then, have them imagine walking barefoot on that beach on a hot day. If you have students who have not visited a beach, ask them about walking barefoot on a sidewalk or street on a hot day.
2. If you walked on the beach or the sidewalk after sunset, what did the temperature feel like compared to the day under full sunlight? *Students would be expected to say that the cooler air temperatures cause the sidewalk or beach to cool down quickly.*

EXPLORE

Part 2. Explore

1. Show students the experimental setup with containers of soil, sand, and water under a heat lamp. NOTE: Caution students that heat lamps can get very hot. If you are doing this as a class demonstration, ask student helpers to record the time so that temperatures are taken every minute for 10 minutes of heating and every minute for 10 minutes of cooling. Place a thermometer in each container just below the surface. Place the containers 8 inches below the lamp bulb, but leave the lamp off for now. Ask students to predict:
   a. Which substance (soil, sand, or water) do you think will have the greatest rise in temperature after 10 minutes? Why do you think that?

b. Which substance (soil, sand, or water) do you think will cool off the fastest after 10 minutes? Why do you think that?

2. Ask students to record the starting temperature of each material in their data table at "0 minutes." Turn on the lamp and record the temperature of each material every minute until 10 minutes have passed. Turn off the light and move it away from the containers. Continue recording the temperature of the containers every minute for another 10 minutes.

3. Students should plot the data for the three materials on a line graph. Label the x-axis as "Time (minutes)" and the y-axis as "Temperature (°F)." Connect the points for the three datasets using different color lines for each of the three materials. Label the lines appropriately with "water," "sand," and "soil."

Discussion questions

1. Which material heated up the fastest? Support your answer with evidence from the lab.

2. Which material cooled the fastest once the light was turned off? Support your answer with evidence from the lab.

3. How do these results compare to your predictions?

4. Which material was better at storing heat? *This material would be the one that cooled off slowly.*

Typical graphs for the experiment show that the soil and sand heat up faster than the water and cool down faster after the heat is turned off. The soil and sand reach higher temperatures than water during the 10 minutes of heating time. Students should find that water heats up slowly and cools off slowly. Water is very effective at absorbing and storing heat. These two factors play a big role in how the ocean impacts our weather.

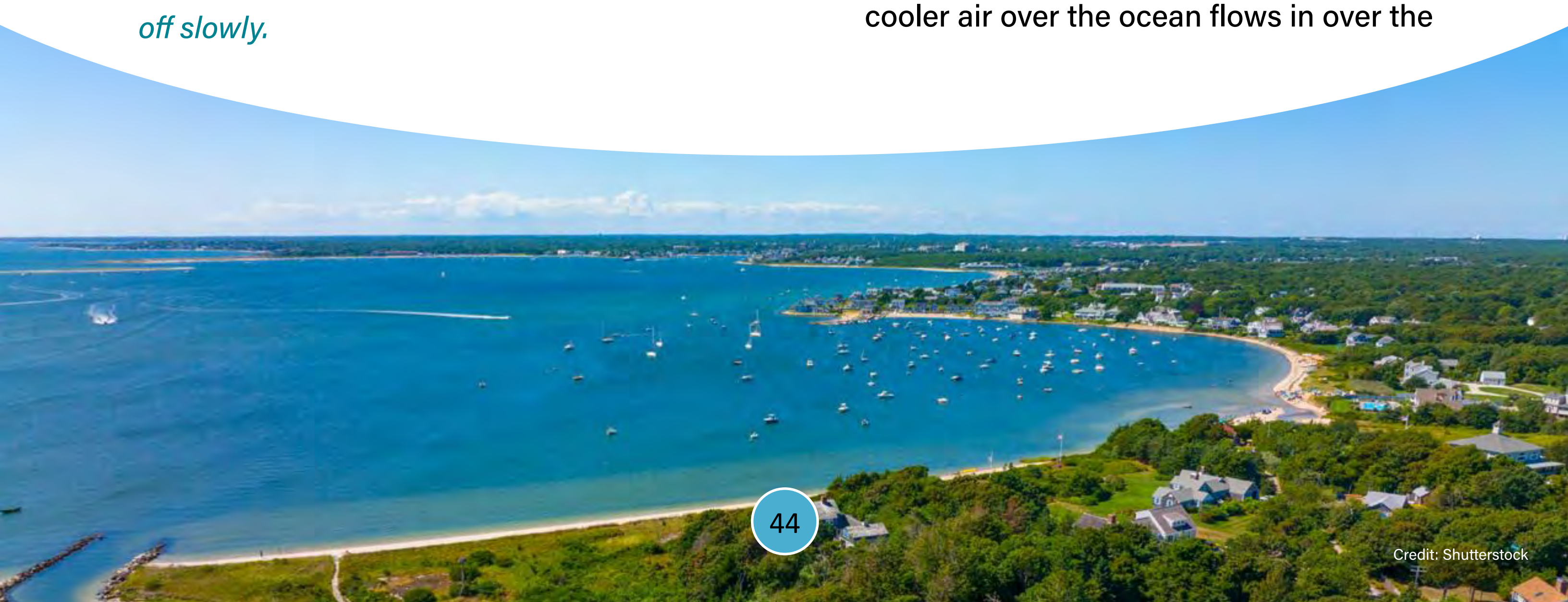
EXPLAIN

Part 3. Explain

1. Ask students to draw an area where land and ocean meet. Have them consider which surface on their drawing will heat up the fastest. Then, ask them to draw arrows to show where they think air will rise fastest when warmed by the sun during the daytime.

2. Show the students simple images illustrating the differences between land and sea breezes. Ask them to identify and label the land breeze and sea breeze.

3. Sea breezes occur during hot summer days because of the unequal heating rates of land and water. During the day, the land's surface heats up faster than the water's surface. As the air above the land is warmer than the air over the water, the air over the land rises. As the warm air over the land rises, cooler air over the ocean flows in over the



Credit: Shutterstock

land's surface to replace the rising warm air. This is what causes the sea breeze. The land breeze image illustrates what occurs at night. In this case, the land's surface cools quicker than the water's surface. The air over the ocean is warmer and still rising. The denser cool air over the land flows offshore to replenish the rising warm air over the ocean. Similar effects can be observed over very, very large lakes.

SEA BREEZE	LAND BREEZE
Air over land is hotter than air over water during the day.	Air cools faster over land at night compared to air over the ocean.
Air rises over the land.	Air rises over the water.
As warm air rises, cooler air is drawn in underneath it from the ocean to take its place over the land.	As warm air rises, cooler air is drawn in underneath it from the land to take its place over the ocean.

ELABORATE

Part 4. Elaborate

In this part of the lesson, we ask students to make predictions about temperature ranges in a coastal and an inland city before we show them actual data. First, have the students locate San Francisco and Sacramento, California, on a projected U.S. map. Ask students to predict:

1. If the sun shines equally on both cities, which location would get hotter during the day?
2. Have them explain why they arrived at that prediction.
3. Based on the results of the experiment, which city would probably experience a greater difference between its daytime and nighttime temperatures?
4. Have them explain their answers based on the results of the experiment.

EVALUATE

Part 5. Evaluate

Ask the students to look at the daily temperature graphs for Sacramento and San Francisco over a 48-hour time period.

1. Ask them to use what they have learned about the moderating effect of being a coastal city to explain the range of temperature differences between the two cities (San Francisco and Sacramento) on the same day.

   As an inland city, Sacramento has a wider range of temperatures than San Francisco, and the daytime temperatures are much higher.

2. Ask the students which city they would rather live in. Ask them to share their reasoning with another student. In a large group, discuss their preferences for weather.
3. How do the daily weather patterns of these cities compare to where you live now?

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.

Extension

If you live near a beach, this might be a good time to emphasize good beach safety. This video might be helpful: Ocean Today Beach and Bay Safe - Checklist (https://oceantoday.noaa.gov/fullmoon-wavesafe-checklist/welcome.html).

These NOAA websites will be helpful for student understanding during discussions about their ideas:

- NOAA JetStream website: The Sea Breeze (https://www.noaa.gov/jetstream/ocean/sea-breeze)
- NOAA National Data Buoy Center (https://www.ndbc.noaa.gov/education/seabreeze.shtml)

Student Record Sheets

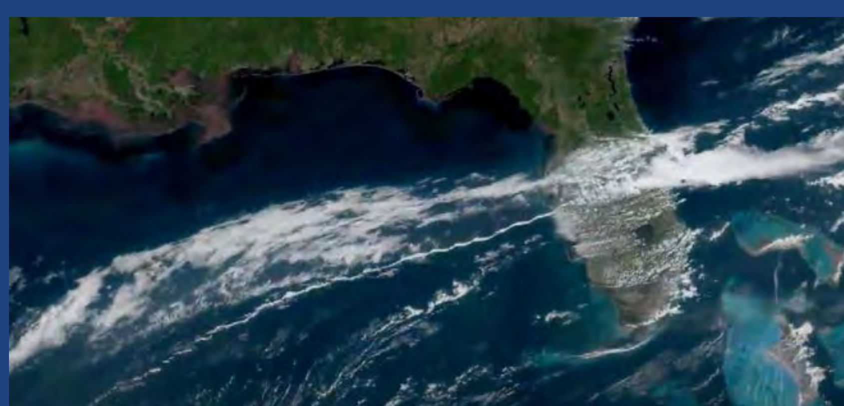
PART 1.

1. In this episode, Teek and Tom enjoy a day at the beach and smores. Have you ever walked barefoot on a beach or sidewalk on a sunny day in the summer? What did the temperature feel like?

2. If you walked on the beach or the sidewalk after sunset, what was the temperature like compared to during the day?

Earth Curiosities — Rope Cloud

On January 25, 2023, NOAA satellites captured an unusually long and long-lived rope cloud produced by a cold front over the Gulf of Mexico near Florida. A rope cloud is a very long, narrow, rope-like band of cumulus cloud formations. Rope clouds tend to form at the dividing line between cooler and warmer air. You can find animations of the rope clouds on the National Environmental Satellite, Data, and Information Service website (https://www.nesdis.noaa.gov/news/earth-orbit-rope-clouds).



PART 2.

We will investigate how different substances change temperatures under a heat lamp. The heat lamp will take the place of the sun in this experiment. We will compare how soil, sand, and water heat up and cool down over time. You will record temperature data on the charts below.

1. Which substance (soil, sand, or water) do you think will have the greatest rise in temperature after 10 minutes? Why do you think that?

2. Which substance (soil, sand, or water) do you think will cool off the fastest after 10 minutes? Why do you think that?

Heating It Up Data

Time (min)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Sand (°F)										
Soil (°F)										
Water (°F)										

Cooling It Down Data

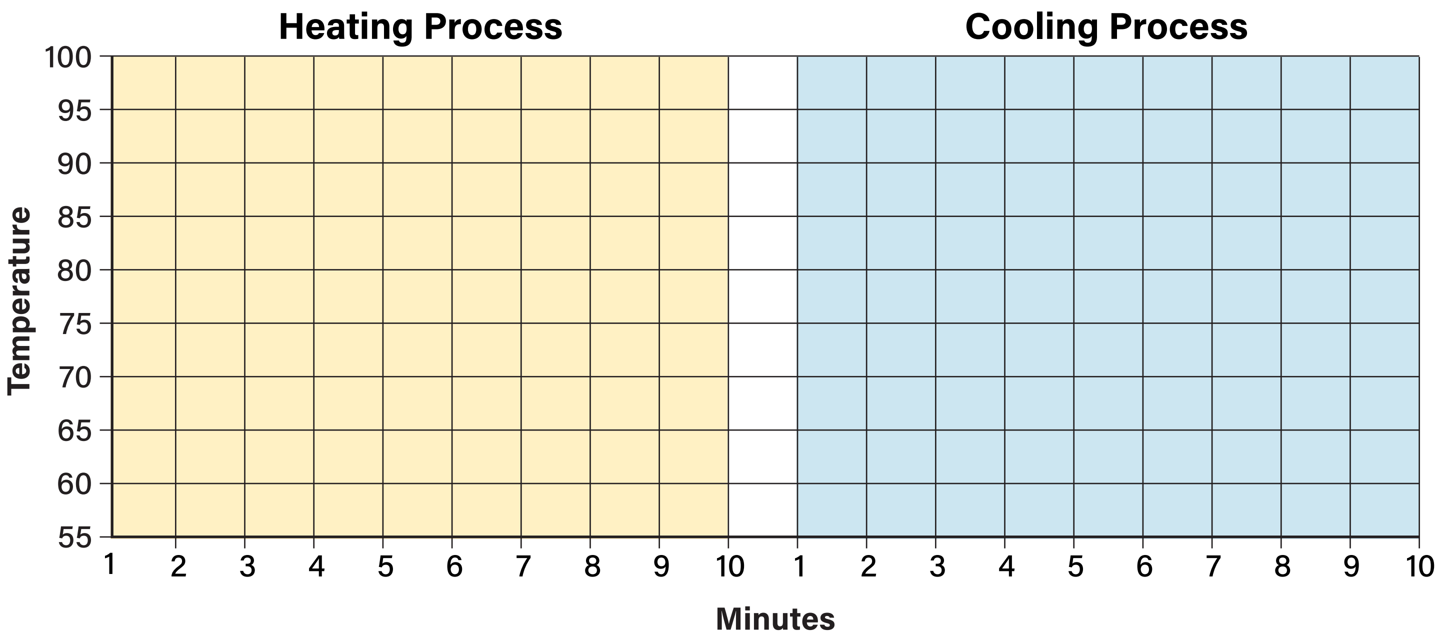
Time (min)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Sand (°F)										
Soil (°F)										
Water (°F)										

Graph it! The graph below will help you visualize the data differently. Plot the heating and cooling process for each of the substances. Use a different line color for each substance and indicate them on the legend below.

Sand line color

Soil line color

Water line color



Your Conclusions

1. Which material heated up the fastest? Support your answer with evidence from the lab.

2. Which material cooled the fastest once the light was turned off? Support your answer with evidence from the lab.

3. How do these results compare to your predictions?

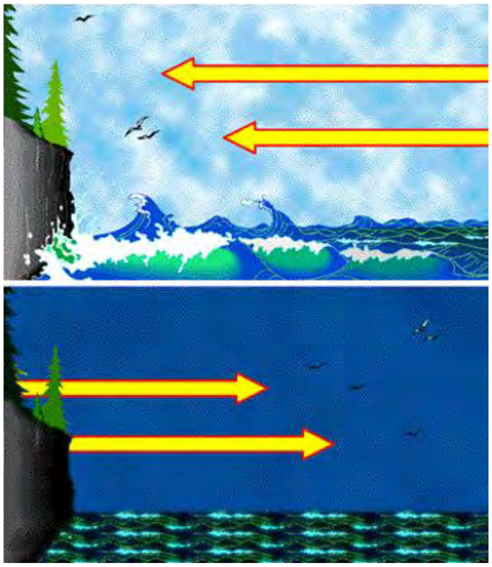
4. Which material was better at storing heat?

PART 3.

Let's compare the results of your experiment to a real-life scale.

1. Draw a small picture of a coastal area where the ocean meets land or beach.
2. Label the ocean and land.
3. Remember the results of the experiment that you just observed. Which surface on your drawing do you think will heat up the fastest? Draw arrows to show where you think air will rise the fastest when warmed by the sun during the daytime.

Take a look at the images. Label which one shows a land breeze and which shows a sea breeze.



Credit: NOAA NCDC

PART 4.

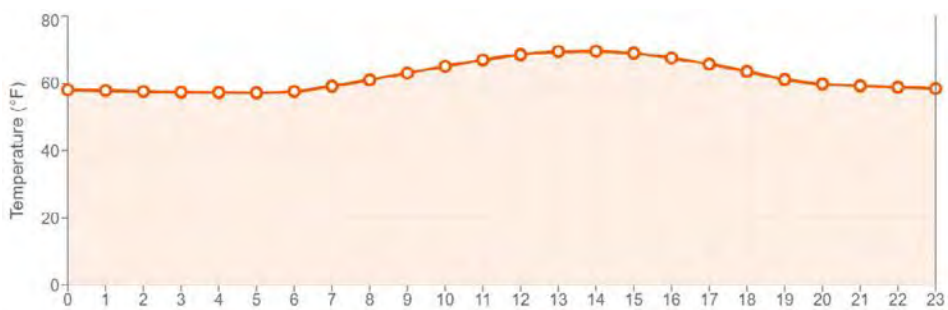
1. On a map, locate San Francisco and Sacramento, California.
2. If the sun shines equally on both cities, predict which location would get hotter during the day.
3. Explain why you made that prediction.
4. Based on the results of the experiment, which city would probably experience a greater difference between its daytime and nighttime temperatures? Explain your reasoning.

Credit: Shutterstock

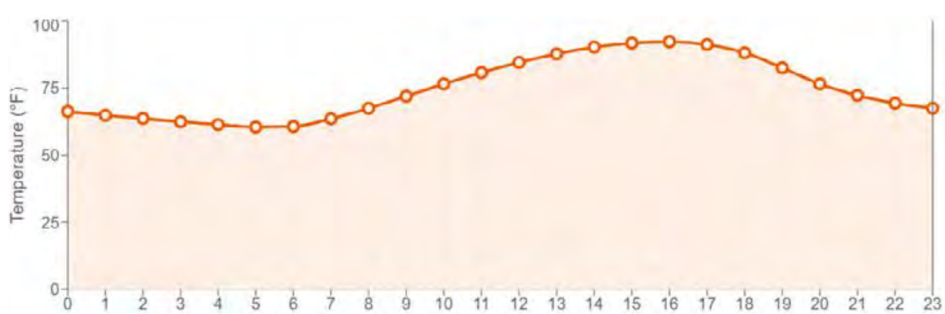
PART 5.

Locate San Francisco and Sacramento on the California map. The graphs below show temperature ranges for night and day over 24 hours. Notice that the temperature ranges on the graphs are different.

San Francisco, California



Sacramento, California

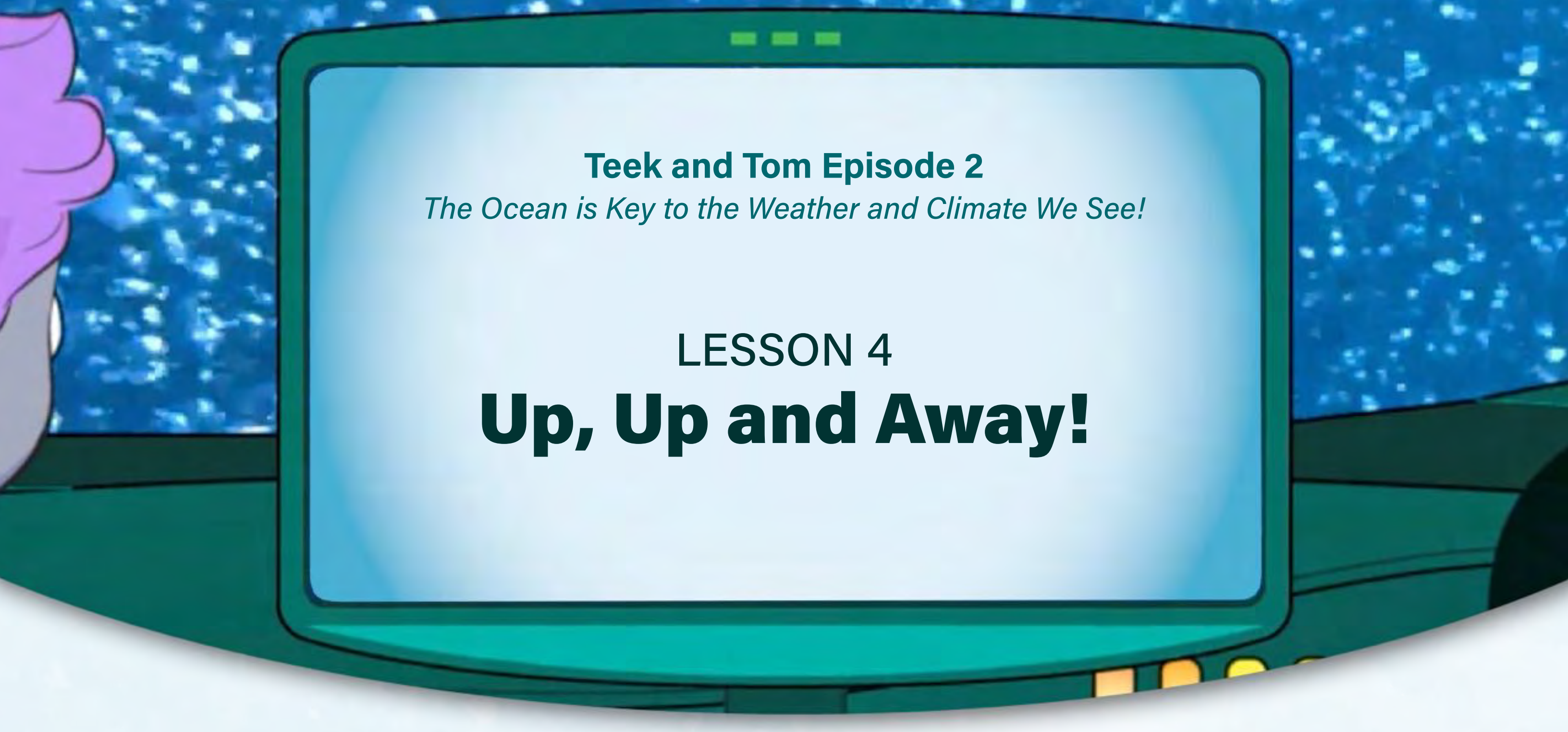


1. Use what you have learned about the moderating effect of being a coastal city to explain the difference in the range of temperatures between the two cities on the same day.

2. Which city would you rather live in? Explain why.

3. How do the daily weather patterns of these cities compare to where you live now?


Credit: Shutterstock



Teek and Tom Episode 2

The Ocean is Key to the Weather and Climate We See!

LESSON 4

Up, Up and Away!

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

Water is a limited resource. The total amount of water in the world does not change over time. It changes form and moves around the Earth in a process called the water cycle. A model globe shows about 70% of the Earth is covered in water. Of the total amount of water on our planet, 97% is in the ocean and is undrinkable — without removing the salt. Of the remaining 3% of water, less than one-half of 1% is available as fresh water in surface sources like lakes, rivers, and swamps.

The atmosphere has a major impact on weather and climate. Evaporation occurs when a liquid changes into a gas. Evaporation from the ocean is the primary mechanism supporting the surface-to-atmosphere portion of the water cycle. The large surface area of the ocean allows for large-scale evaporation to occur. On a global scale, the amount of water evaporating is about the same as the amount of water delivered to the Earth as precipitation (rain, snow, etc.). Most of the water that evaporates from the ocean returns there as precipitation. Only about 10% of the water evaporated from the ocean is transported over land and falls as precipitation. Although the atmosphere does not store a lot of water, it is the superhighway used to move water around the globe. In fact, if all the water in the atmosphere rained down at once, it would only cover the globe to a depth of about 1 inch.

Lesson Summary

Students will investigate the relative amount of salt and fresh water on Earth and then do a simple experiment about water evaporation with covered and uncovered containers. Finally, students will look at the evaporation of water from a salt solution as they paint their name on paper with a salt solution treated with food coloring. The students will find colored salt left behind as the water evaporates overnight. Some of these activities were adapted from the NASA Aquarius Sea Surface Salinity Project, Evaporation Investigation (https://aquarius.oceansciences.org/activities/evap_invest.pdf).

Objectives

- Students will be able to describe the relative amounts of salt and fresh water on Earth.
- Students will compare and contrast their observations before and after an evaporation event.
- Students will describe the process of evaporation through discussion and pictures.

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 2 of Teek and Tom, *"The Ocean is Key to the Weather and Climate We See!"*, 11:15 minutes (https://oceantoday.noaa.gov/teekandtom/episode-2.html).

The activity in part two of this lesson can be set up during the first class period, but daily recording of the water levels in the containers should happen over four to five days.

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-ESS2-1: Earth's Systems. Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.
- 5-ESS2-2: Earth's Systems. Describe and graph the amounts of salt water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth.
- ESS2.C: The Roles of Water in Earth's Surface Processes. Nearly all of Earth's available water is in the ocean. Most fresh water is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere.

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

- One 5-gallon bucket with a sign that says "Ocean"
- Plastic container that will hold 2 cups of water with a sign that says "Fresh water"
- Plastic container that will hold ½ cup of water with a sign that says "Groundwater, Rivers, Lakes"
- Ice cube tray with a sign that says "Glaciers and Ice Caps"
- Sticky note or 4-by-6 card for each student
- Measuring cup that will measure 1 cup of liquid

- Eye dropper
- Hand lens or magnifying glass
- Containers for each group or pair of students. Half of the containers need lids (these might include plastic pint containers from a deli or washed dairy containers)
- Small paper cups (suggest 4 or 5-oz cups for salt paint)
- Popsicle sticks - two for each group or experimental setup
- Small plastic rulers
- Plastic spoons
- Marker for teacher to make signs for the water demo
- Table salt
- Warm water (aids dissolving of the salt)
- Paint brushes
- Food coloring
- Students will need printouts of student record sheets, graphs, and/or maps to carry out the activities. Student record sheets are located at the end of this lesson.
- If you would like to provide the maps on a projection system, students will only need the student record sheets. Depending on the configuration of your classroom, we recommend one set per student or group.
- All maps/graphics 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-4.zip)

Preparation

1. Fill the 5-gallon container with water. Make four large signs labeled "Glaciers and Polar Ice Caps," "Fresh Water," "Groundwater, Rivers, and Lakes," and "Ocean." These should be large enough for the whole class to read what is on each sign. The 5-gallon container should be marked "Ocean." Label the container that will hold 2 cups of water "Fresh Water." Label the plastic container that will hold ½ cup of water with a sign that says "Groundwater, Rivers, Lakes." Label an ice cube tray with a sign that says "Glaciers and Polar Ice Caps."

2. Depending on the availability of materials, you may go through the exercises as a class rather than in small groups or pairs. The visuals can be displayed and discussed as a class. They are available as a slide set to project or present while teaching these activities.

3. Prepare 3 cups of salt water solution for part four of the activity. For each cup of salt water, add ¼ cup of table salt to 1 cup of warm tap water. Gently stir and then add several drops of food coloring. Prepare three different colors of salt water. You can reuse the containers from the first activity or use small paper cups for the salt water paint so that each pair of students has a cup of colored salt water.

InvesTeekation Pathway

ENGAGE

Part 1. Engage

1. In small groups or as a class, have students describe or list how they use water at home, at school, and in their daily activities. Consider having each student write down the specific way they use water and where they use it (e.g., washing hands at home or school) on a 4-by-6 card or sticky notes that can be collected and organized on a classroom board. On another part of the classroom board, gather students' ideas about how water is used in agriculture, industry, electricity generation, and recreation.

2. Ask students to identify the water source that their community uses (e.g., nearby lake, river, underground reservoirs such as a well). Students may not be able to identify where their water comes from. To them, it just streams from their faucet. You may have to do a little research to find out where your local water comes from.

3. **Class Demonstration:** Using a 5-gallon bucket of water marked with a sign that says "Ocean," ask a student to come up and remove 2 cups of water and put it into another container marked "Fresh Water." The 5-gallon bucket of water represents the salt water in the ocean (97%), and the 2 cups of water just removed represents the remainder of the fresh water on the planet (3%). Ask another student to remove 1/2 cup of water from the "Fresh Water" container and put it in a container marked "Groundwater, Rivers, Lakes." Pour the rest of the "Fresh water" (1.5 cups) into an ice cube tray to represent fresh water locked up in glaciers and the polar ice caps. From the container marked "Groundwater, Rivers, and Lakes," use an eyedropper to put one drop in a student's hand, representing the amount of fresh water that is clean and available to humans.

4. Students may understand the water cycle on a local level but struggle to apply the concept on a global scale or understand that the total amount of water on Earth has remained constant and has been conserved throughout time. Students may be aware of bodies of water in their region but have little concept of the vast quantities of salt water that exist on the planet and the relatively small amounts of fresh water.

Discussion questions

1. Compare the amount of salt water and fresh water on Earth. *Students should note that the amount of fresh water on Earth is very small.* Over 97% of the Earth's water is found in the ocean as salt water, and 2% is stored as fresh water in glaciers, ice caps, and snowy mountain ranges. That leaves only 1% of the Earth's water available to us for our daily water supply needs.

2. Why can't we use salt water for agriculture and household uses? *Large amounts of salt water is poisonous for plants and animals, including humans.*

3. If you use a half gallon of water each day for drinking and in your food, how many gallons would you use in a year? *182.5 gallons per year*

4. A person in the United States uses over 100 gallons of water each day for showers, cooking, washing clothes, and other indoor activities.How much water would be used in a year at this rate? *36,400 gallons per year*

5. Water use is very different in other countries. Some countries in Europe use less water,

about 38 gallons each day. Can you think about some ways that we can reduce our personal water use? Some Europeans use 13,870 gallons per year, almost half of what we use in the U.S. *There are many ways Americans can reduce water use. These include taking shorter showers, not letting the water run when brushing teeth, and not using water to defrost frozen foods.*

EXPLORE

Part 2. Explore

1. Provide each student group with two containers (one should have a lid). Each container should be filled with the same amount of water, about half full. The students will cover one of the containers and leave the other one open. Ask each student pair to label the containers with their names.

2. Over the next few days, students will observe the containers to see what happens to the water over time. Ask them how they can use wooden sticks (popsicle sticks) to track changes in the water level over time. They should dip a wooden stick into the water along the side of the container until it touches the bottom. Then, use a ruler to measure the water level on the stick. If the sticks are wide enough, have them mark the water level on the stick with the date of the measurement.

3. The students should record their findings in the table on the student pages. Students should check the containers on a regular basis (daily or every other day).

4. If time allows, have the students complete the first activity using water at different temperatures. Warm water will encourage quicker evaporation, so if there is a warmer place in your room, place one of the containers there. Leave the lids off and place the other container in a cooler place.

EXPLAIN

Part 3. Explain

It is best to allow the containers to sit undisturbed for at least four days so that the students can see a pattern emerge. Once the experiment is complete, ask students to draw an image of their two containers and mark the water levels each day. Ask them to discuss the differences between the conditions experienced in each container and the resulting water levels.

Discussion questions

1. What happened to the level of the water in the closed container?

2. What happened to the level of the water in the open container?

3. Was there a difference in the water levels between the two containers? Explain.

4. Would there be a difference in how fast the water level drops if we had used larger containers? Why or why not?

5. Ask students to draw what happened to the water levels in the two containers over time. Have them share their results with the other groups.

6. If you had a glass of water that you wanted to save, should you leave it open or closed? Why?

ELABORATE

Part 4. Elaborate

Review the results of the water container simulation and circle back to the idea that the ocean covers over 70% of Earth's surface, and evaporation happens over this large area.

Discussion questions

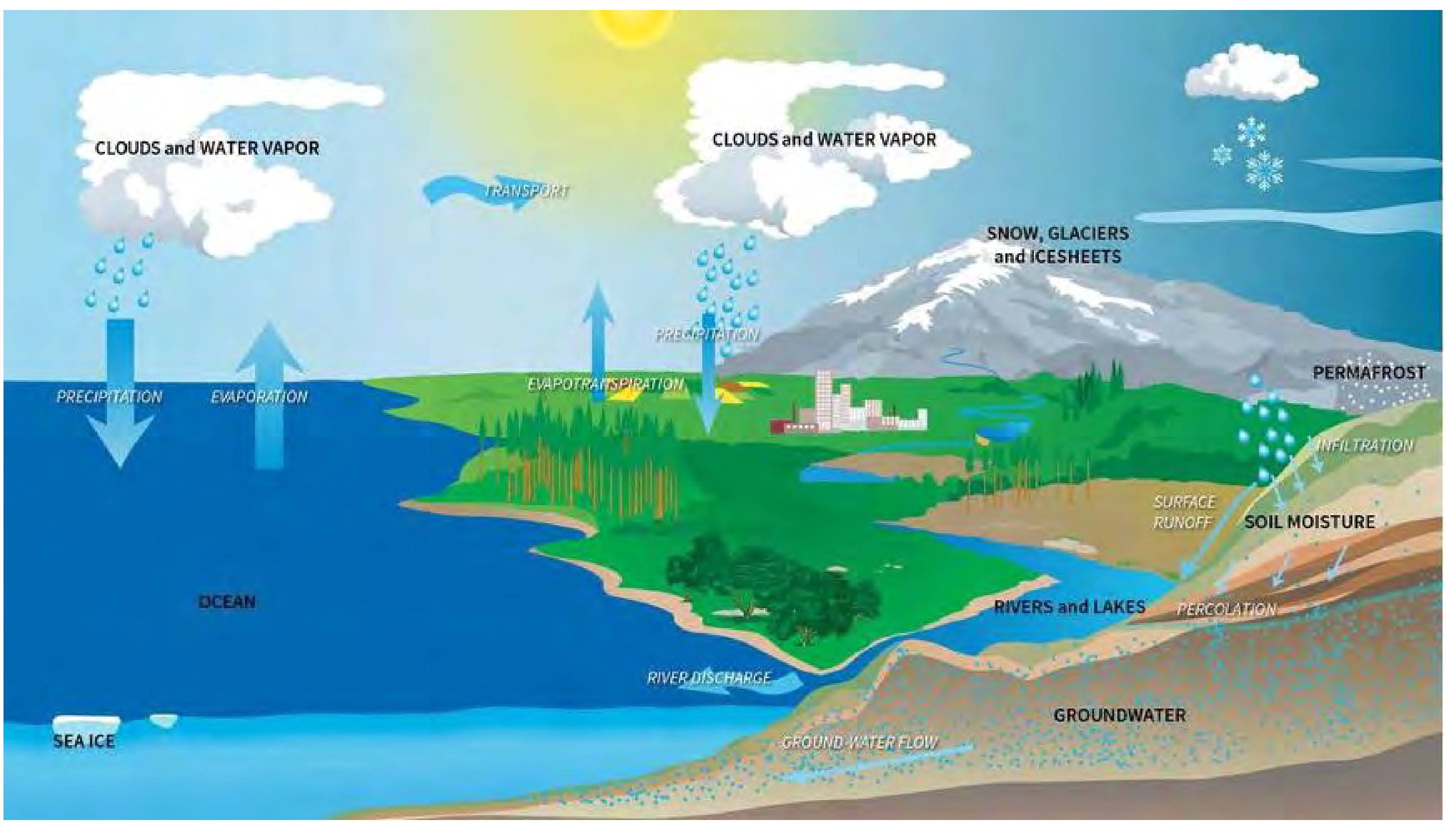
1. Based on the experiment you just finished, what do you think will happen when energy from the sun warms the water in bodies of water like the ocean and lakes? *Help them connect the simulation they did with the containers to what happens on a larger scale on Earth. The water vapor in the air condenses into clouds. The clouds become filled with water, and rain (or snow) falls back into the ocean and onto the land.*
2. Ask students to create their own drawings of the water cycle. *Their drawing should include at least the following parts: Evaporation from the ocean, clouds, precipitation, rivers, or lakes.*

You may want to use an image of the water cycle to assist with the follow-up discussion.

You can review the basics of how the water cycle works with your students in one of Ocean Today's most popular videos, The Water Cycle (2:42) (https://oceantoday.noaa.gov/watercycle/).

The United States Geological Survey offers an interactive water cycle for kids that can help students explore the various interactions within the water cycle (https://water.usgs.gov/edu/watercycle-kids-adv.html). This can be used as a whole class investigation. A more comprehensive water cycle diagram is available as a PDF in English and Spanish (https://www.usgs.gov/media/files/water-cycle-poster-pdf).

The Water Cycle



Credit: NASA

EVALUATE

Part 5. Evaluate

When water evaporates from the ocean, the salt is left behind. This is the principle behind creating fresh water from sea water, known as desalination. Students will paint their names (as elaborate as they wish) with salt water paints and then watch as the water evaporates, leaving the colored salt behind. Provide paper, paintbrushes, and small cups of salt water with food coloring. Once the students have completed their paintings, allow them to dry overnight. The following day, students will examine their paintings to find that the water has evaporated, but the colored salt remains. Provide hand lenses or magnifying glasses so students can see the salt crystals left behind.

Discussion questions

1. What do you observe about the appearance of your name on the paper **before** it dries?
2. What do you observe about the appearance of your name on the paper **after** it dried?
3. Write a brief summary about how evaporation changed your painting. *Their explanation should include the idea that the water has evaporated, but the colored salt was left behind.*
4. When water evaporates from the ocean and forms clouds in the atmosphere, what happens to the salt in the water? *The salt is left behind in the ocean. Water that forms in the clouds is salt-free. Reinforce that this idea is used in processes of desalination. Desalination is becoming more common around the world. The largest desalination plant in the world is located south of Tel Aviv, Israel, and produces over 137 million gallons of fresh water a day. Desalination plants are also running in California, and more are planned.*

Earth Curiosities

Dead Sea Salt Water

This picture shows students from Idaho enjoying the unique experience of "floating high" in the Dead Sea. Located in Israel, the surface of the Dead Sea is 430.5 meters (1,412 feet) below sea level, making its shores the lowest land-based elevation on Earth. Notice how the students seem to be sitting up as if in a chair. The chair is actually very salty water! The Dead Sea has an exceptionally high salt content because the water does not have a way to flow out. It is also very hot in this area, and there is a lot of evaporation. The salt that washes in from the surrounding area concentrates over time. This sea water is much saltier than regular seawater.

Photo Credit: USGS/U.S. Dept. of State

Posted by USGS. Photo Credit: U.S. Dept. of State

Credit: Shutterstock

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.

Extensions

This Ocean Today Video will be helpful for student understanding during discussions about their ideas.

- The Water Cycle (https://oceantoday.noaa.gov/watercycle/)

Fresh water can be in short supply in many parts of the world. As the human population grows, shortages of fresh water will occur more often. Salt water can be turned into fresh water for drinking. An easy method to do this is to heat the sea water, capturing the steam and condensing it back into water (distillation). You can demonstrate this process using a glass bowl, a plastic cup, plastic food wrap, tape or a rubber band large enough to go around the bowl, a small rock or weight, and salty water.

- Put the salty water in the bowl.
- Place the cup in the middle of the bowl and wrap plastic wrap over the top. Secure the wrap with tape.
- Place the rock or weight in the center of the plastic wrap above the cup so that the evaporated water will drip into the cup.
- Set in a sunny and/or warm space and observe.

Illustration from https://www.energy.gov/eere/education/articles/rain-machine-solar-still

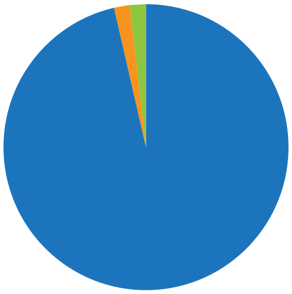
Student Record Sheets

PART 1. WATER ON EARTH

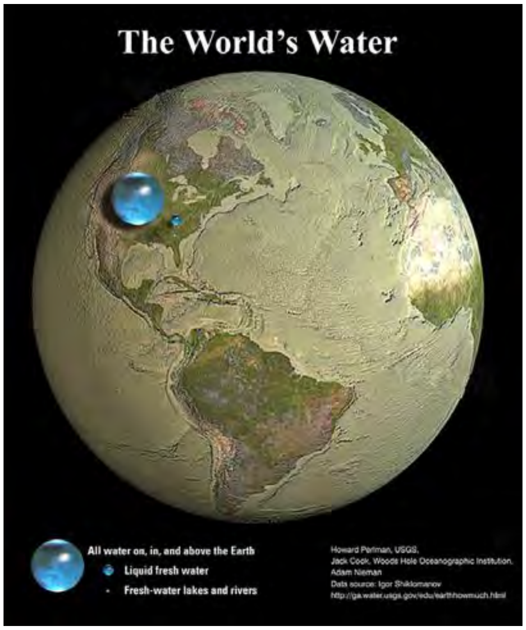
We will model the amount of water on Earth. A full 5-gallon bucket of water will represent all of the water on Earth. Your teacher will ask for someone to remove some water to represent the fresh water available on Earth. The remaining water in the bucket represents salt water, which no animals, plants, or humans on land can use. Complete the chart below as directed by your teacher.

	Total Amount of Fresh Water	Amount of Fresh Water in Glaciers	
5 Gallons			

Percentages of Water on Earth

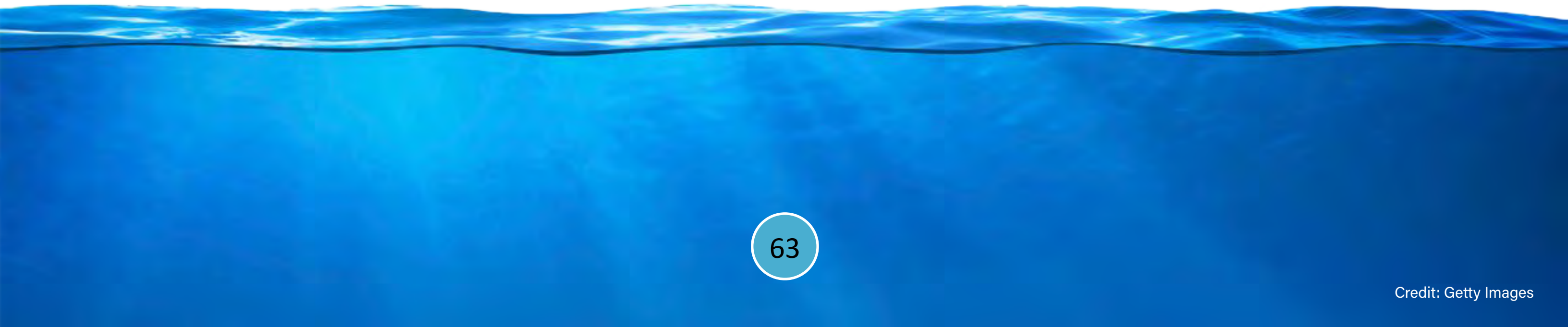


This graph shows the amount of salt and fresh water found in different places on Earth. The ocean contains salt water. Fresh water is made up of groundwater, rivers, lakes, glaciers, and ice at the North and South Poles.



A representation of the amount of water on Earth. This image shows blue spheres representing relative amounts of Earth's water in comparison to the size of the Earth. Are you surprised that these water spheres look so small? They are only small in relation to the size of the Earth.

https://www.usgs.gov/media/images/all-earths-water-a-single-sphere



Credit: Getty Images

Questions

1. Compare the amount of salt water and fresh water on Earth.

2. Why can’t we use salt water for agriculture and household uses?

3. If you use a half gallon of water each day for drinking and in your food, how many gallons would you use in a year?

4. A person in the United States uses over 100 gallons of water each day for showers, cooking, washing clothes, and other indoor activities. How much water would be used in a year at this rate?

5. Water use is very different in other countries. Some countries in Europe use less water, about 38 gallons each day. Can you think about some ways that we can reduce our personal water use?

PART 2.

You will work with another student for this experiment. Label two containers with your names. Fill each container about half full. Cover one of the containers and leave the other one open.

Over the next four or five days, you will observe the containers to see what happens to the water over time. You will use a wooden stick (popsicle stick) to measure the water level in each container by dipping the stick into the water along the side of the container until it touches the bottom. Then, use a ruler to measure the water level on the stick. Mark the water level on the stick for each date. Record your measurements in the table below. Check the containers each day.

Date	Water Level in Closed Container in Centimeters	Water Level in Open Container in Centimeters

PART 3.

1. What happened to the level of the water in the closed container?

2. What happened to the level of the water in the open container?

3. Was there a difference in the water levels between the two containers? Explain.

4. Would there be a difference in how fast the water level drops if we had used larger containers? Why or why not?

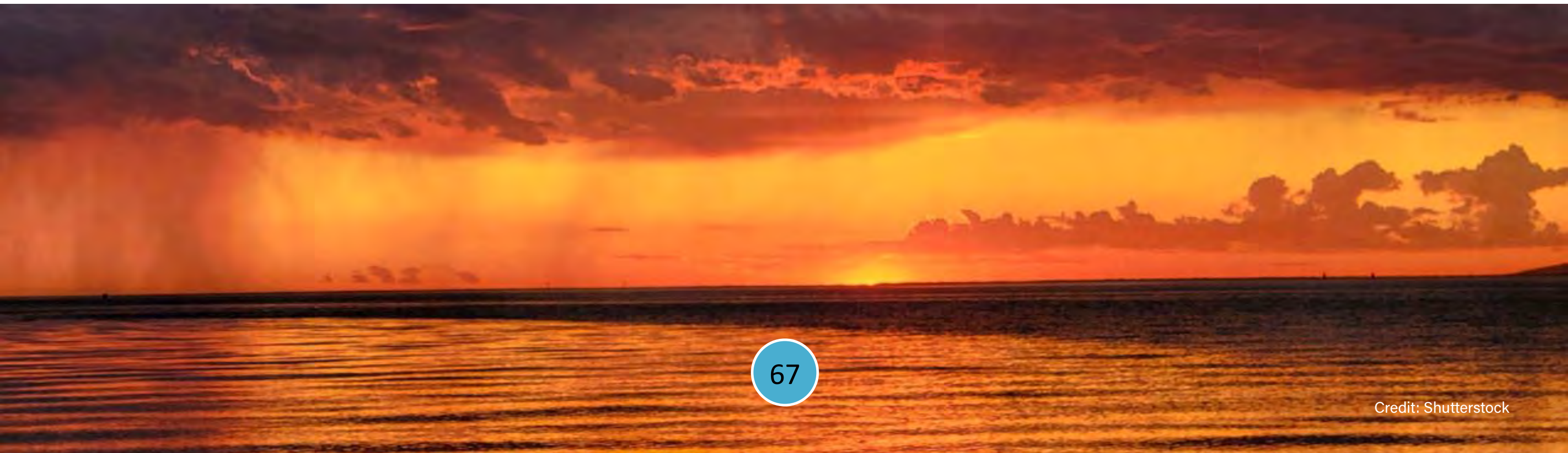
5. Make a drawing that shows what happened to the water levels in the two containers over time. Share your results with the other groups.

6. If you had a glass of water that you wanted to save, should you leave it open or closed? Why?

PART 4.

1. Based on the experiment you just finished, what do you think will happen when energy from the sun warms the water in bodies of water like the ocean and lakes?

2. Make a simple diagram of the water cycle showing the following parts:
   Evaporation from the ocean, clouds, precipitation, rivers, or lakes.



Credit: Shutterstock

PART 5.

You will use paint made from salt water and food coloring. Paint your name on a fresh piece of paper. Let the paper sit overnight to dry.

1. What do you observe about the appearance of your name on the paper before it dries?

2. What do you observe about the appearance of your name on the paper after it dried?

3. Write a brief summary about how evaporation changed your painting.

4. When water evaporates from the ocean and forms clouds in the atmosphere, what happens to the salt in the water?

Teek and Tom Episode 3

Weather and Climate EXTREMES!

LESSON 5

There's Something in the Air

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

The atmosphere, ocean, and land interact with each other in a nonstop cycle, creating daily weather and long-term climate patterns. Storms in the middle of the United States could have started thousands of miles away and with water that was once in the ocean. For example, if cold air from Canada collides with the warm, moist air from the Gulf of Mexico over the central plains of the United States, thunderstorms or snowstorms can result.

Thunderstorms form when warm, moist air meets colder, drier air. As the warm air rises, the water vapor in the air condenses and forms a cloud. As the water vapor condenses, it releases heat, which is a form of energy. Much of a thunderstorm's energy comes from the condensation process that forms the thunderstorm clouds. As the thunderstorm develops, rain falls, cooling things off, and the thunderstorm's energy goes down. Most thunderstorms produce hail, but not all thunderstorms produce hail that ends up on the ground. Temperatures at the upper levels of a thunderstorm are well below freezing, allowing for the creation of hail, but sometimes the hail melts before reaching the ground. Thunderstorms can produce some of nature's most destructive and deadly weather, including tornadoes, hail, strong winds, lightning, and flooding.

Blizzards are dangerous snow storms that occur when a combination of blowing or falling snow and wind results in very low visibility. Heavy snowfall and severe cold often accompany blizzards, but not always. Sometimes, strong winds pick up snow that has already fallen, creating a ground blizzard. NOAA's National Weather Service (NWS) defines a blizzard as a storm that contains large amounts of snow or blowing snow, with winds over 35 mph and visibilities of less than 1/4 mile for an extended period of at least 3 hours.

Lake effect snow is common across the Great Lakes region during the late fall and winter. It occurs when cold air, often originating from Canada, moves across the open waters of the Great Lakes. As the cold air passes over the unfrozen and relatively warm waters of the Great Lakes, warmth and moisture are transferred into the lowest portion of the atmosphere. The air rises, and clouds form, growing into narrow bands that can produce 2 to 3 inches of snow per hour, or more.

A rain shadow effect, common near mountainous regions, is caused when precipitation drops significantly on one side of a mountain. Rainfall and moist air are common on the side of a mountain range facing prevailing winds. Once the rain falls, the air flowing down the mountain's other side is dry. An image of this can be found in the student record sheets.

Atmospheric rivers are long, narrow regions in the atmosphere — like rivers in the sky. They carry most of the water vapor from the tropics. Atmospheric rivers come in all shapes and sizes and are responsible for extreme rainfall and flooding events. The rivers are moved by high-altitude winds that blow from west to east, called the jet stream. These strong winds in the upper levels of the atmosphere are the strongest during winter in both the Northern and Southern hemispheres.

Lesson Summary

Students will investigate four different weather events that are powered by the atmosphere and moisture from the ocean through "recipes" for thunderstorms, snow storms, lake effect snow, and rain shadows. Then, students will be introduced to atmospheric rivers that carry most of the water vapor from the tropics to northern latitudes.

Objectives

- Students will be able to identify how the prevailing winds and air mass movements over the atmosphere, ocean, and land can affect weather and climate far from the ocean.
- Students will be able to explain the impacts of atmospheric rivers in the western United States.

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 Teek and Tom Episode 3: *"Weather and Climate EXTREMES!"*, 9:53 minutes (https://oceantoday.noaa.gov/teekandtom/episode-3.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

- **MS-ESS2-5: Earth's Systems.** Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.
- **ESS2.D: Weather and Climate**. Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.

[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

- Red and blue colored pencils or markers for all students
- Students will need printouts of student record sheets, graphs, and/or maps to carry out the activities. Student record sheets are located at the end of this lesson.
- If you would like to provide the maps/graphics on a projection system, students will only need the student record sheets. Depending on the configuration of your classroom, we recommend one set per student or group.
- All maps/graphics 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-5.zip)

Preparation

No special preparation is needed for this lesson.

InvesTeekation Pathway

Part 1. Engage

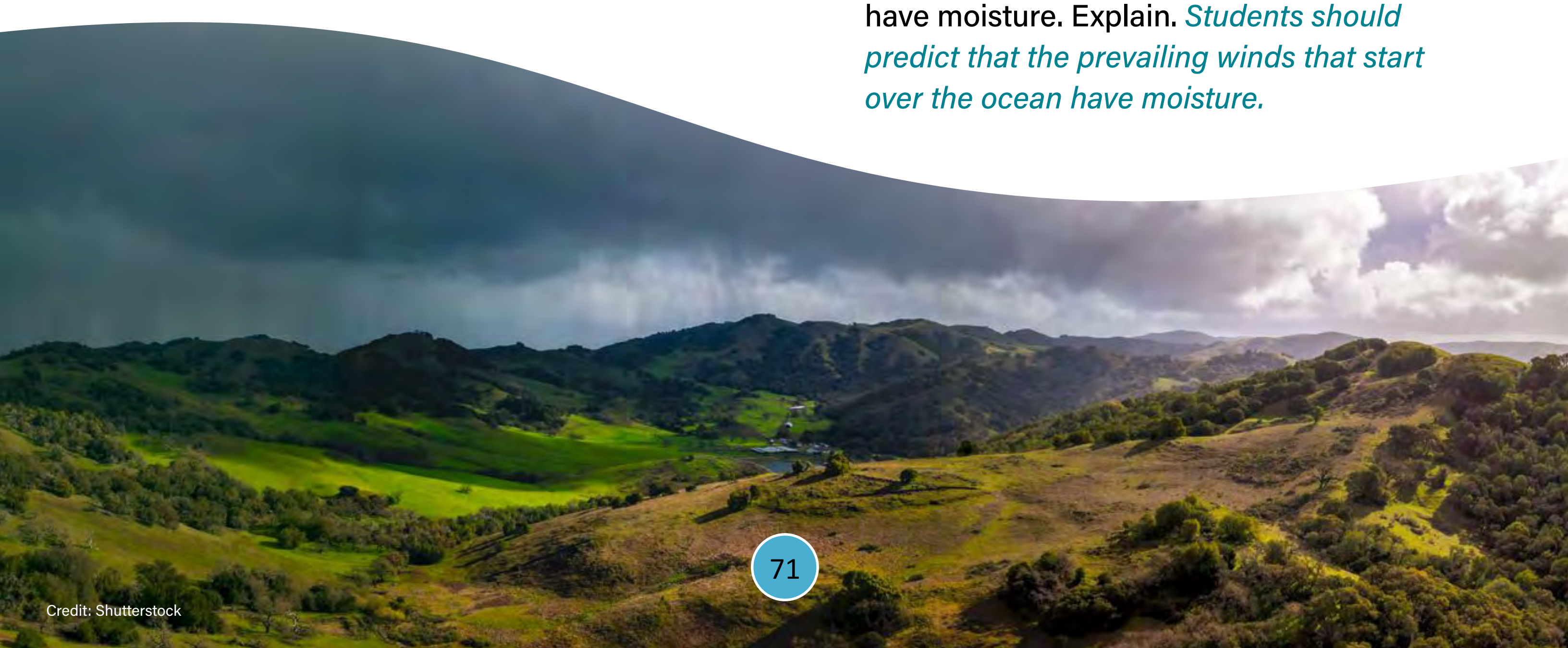
The KWL (Know, Want to Know, Learned) chart is a good way to gauge student ideas before the start of a lesson. Ask students to complete the "What I Know" and "What I Want to Know" sections of the chart before the lesson and save the last one, "What I Learned," for the final part of the lesson. Consider having students complete the columns by themselves first, then in small groups, and finally as a class.

Part 2. Explore

Remind students of what they learned in lesson 3 - on sea and land breezes, and in lesson 2 - that air over the ocean picks up moisture and transports it.

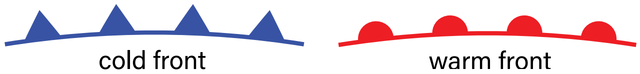
Discussion questions

1. Based on what you learned from the previous lessons, and from Teek & Tom episode two, predict whether the prevailing winds that start over the ocean are dry or have moisture. Explain. *Students should predict that the prevailing winds that start over the ocean have moisture.*



Credit: Shutterstock

2. Draw the symbol that represents the front edge of the cold, dry air. Draw the symbol that represents the front edge of the warm, moist air. How are they different? *The simple graphic of cold, dry air (the blue line represents a cold front) meeting warm, moist air (the red line represents a warm front) shows several common weather symbols typically seen on weather forecasting maps. Each type of front is represented by a different shape.*



3. Based on the image, what kinds of weather can happen when cold air meets warm, moist air in the spring or summer? *Thunderstorms and tornadoes can occur in the summer and spring. Students will investigate tornadoes more in the next lesson.*

4. Now imagine that the same interactions from the image above happen in the winter. What kind of weather do you think will happen then? *In the winter, we might expect snowstorms where the air masses meet.*

EXPLAIN

Part 3. Explain

Students will investigate the conditions (recipes) that cause four different types of weather events to occur. Consider having the students work in pairs or small groups and then discuss the images and questions as a class.

Discussion questions

1. Calculate how far away a storm would be if you saw lightning and heard thunder 15 seconds later. *Sound travels about 1 mile in five seconds, so if you hear thunder 15 seconds after seeing lightning, the storm would be 3 miles (4.8 kilometers) away.*

2. If you are outside and you see a thunderstorm approaching, what actions should you take to protect yourself from lightning? *Ideas might include crouching low to the ground, staying away from metal buildings and trees, and getting off a hill to a lower area.* Appendix C: NOAA NWS Lightning Safety Brochure (https://oceantoday.noaa.gov/teekandtom/educators-guide/appendix-c.pdf).

3. What are the differences between a snowstorm and a blizzard? *A blizzard lasts at least three hours. It has subfreezing temperatures and strong winds of over 35 mph. It may be snowing or blowing around snow that reduces visibility to less than 0.25 miles.*

4. Have students measure how high 70 inches of snow would reach in a doorway to your classroom to visualize how much snow fell during a lake effect storm event in 2022 near Lake Erie in Ohio.

5. Based on what you know about the prevailing winds in the United States, why are the belts of lake effect snow not found all around each lake? *Prevailing winds in the United States usually move from west to east, so the snow would be concentrated on the east side of each lake.*

6. The Buffalo, New York area had a lake effect snow event in November, 2022. Based on the colors from the map, what was the highest amount of snow received in that area? *72-84 inches of snow.*

7. Estimate how much snow the town of Rochester received. *1 to 2 inches*

8. Using the other weather recipes as examples, students should create a recipe for a rain shadow. *Ideas may include warm, moist air rising from the ocean, prevailing*

winds carrying it to land, the moist air rising as it encounters mountains, causing rain or snow to fall on the mountains, and dry air flowing over the other side.

9. *Mojave Desert, California, with 3.5 inches per year, is in a rain shadow.*
10. *Los Angeles, California, with 14 inches of rain per year, is not in a rain shadow.*
11. *Hilo, Hawaii, with 120 inches of rain per year, is not in a rain shadow. Point out that the tradewinds in Hawaii come from the east.*
12. *Captain Cook, Hawaii, with 31 inches of rain per year is in a rain shadow.*

ELABORATE

Part 4. Elaborate

Atmospheric rivers are long, narrow regions in the atmosphere that transport large amounts of moisture, like rivers in the sky. They carry most of the water vapor from the tropics to the northern latitudes. Atmospheric rivers are moved by high-altitude winds that blow from west to east, called the jet stream. Consider having the students work in pairs or small groups and then discuss the images and questions as a class.

Discussion questions

1. Ask the students to look at the graphic of an atmospheric river and write a story about how moist air moves from the tropics to drop as rain in California. We would expect that it would contain these basic ideas:
   - *Warm temperatures in the tropics cause ocean water to evaporate and rise into the atmosphere.*
   - *Winds help carry the water vapor through the atmosphere.*
   - *As atmospheric rivers move over land, the water vapor rises over mountains higher into the atmosphere.*
   - *It then cools into water droplets, which fall as rain or snow in California, depending on the temperatures.*

An animation of the images that are used for this activity can be found at NASA's Scientific Visualization Studio (https://svs.gsfc.nasa.gov/vis/a000000/a004300/a004334/tm_atmosphericRiver_waterVapor_Imerg_4xSlow_0.mp4).

2. How many inches of rain is 50 mm/hr? *50mm/25.4mm per inch = 1.96 inches per hour*
3. How much rain would fall if it were to rain for 5 hours in one place? *1.96 x 5 = 9.84 inches*
4. Compare Map A to the map above, which has western states marked. If you were a weather forecaster looking at Map A, which states would you expect to see rain in the future? *It appears that Washington and Oregon are in the path of the atmospheric river.*
5. Look at Map B. The water vapor map has changed in just 17 hours. Which states are getting the rain now? *It appears that Washington, Oregon, and northern California are affected.*
6. Map C shows the water vapor and precipitation levels at midday on December 11. What was the highest rate of precipitation that fell over northern California on that day? *50 mm per hour*

7. Map D shows the water vapor and precipitation pattern early in the morning of December 12. What changes do you see in the water vapor and precipitation patterns, as well as the states being affected - compared to the day before? *The highest amount of water vapor in the air has moved to include most of California.*

8. Are there areas in your neighborhood or city that flood? *Students may be able to identify roads or low-lying areas where water collects during heavy rains. They may also identify rivers or streams that frequently flood in spring or during heavy rains.*

9. What actions should you take to protect yourself and others when a flood warning is issued? *Student responses may include things like moving to higher ground, staying away from flooded areas, and not driving through roads covered with water.*

   This NOAA NWS website (https://www.weather.gov/safety/flood) is designed to teach about staying safe in a flood event. A NOAA NWS Flood Safety Brochure is available in Appendix D (https://oceantoday.noaa.gov/teekandtom/educators-guide/appendix-d.pdf).

EVALUATE

Part 5. Evaluate

We have looked at weather events like thunderstorms, snow storms, lake effect snow, and rain shadows. Some of these events may be common in your area. However, students may not have previously known the causes of these events. Help them understand that moisture from the ocean can travel long distances and affect the weather even in the center of the country. Once they have completed the final column of the KWL chart, discuss what they have learned. Ask the students to list their questions and what they might be curious about.

Discussion questions

1. Depending on where you live in the United States, have you experienced any of these weather events?
2. Now complete the last column, "What I Learned," from the chart at the beginning of the lesson.
3. What new questions do you have about the ocean, weather and climate connections, and the weather events we have discussed?

Credit: Shutterstock


Credit: Getty Images

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.

Extensions

The University Center for Atmospheric Research's Center for Science Education (https://scied.ucar.edu/globe-weather-curriculum) has developed a free five-week curriculum unit to help middle school students understand weather at local, regional, and global scales.

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

- When Lightning Strikes (https://oceantoday.noaa.gov/lightning/)
- El Niño and La Niña Explained (https://oceantoday.noaa.gov/elninolanina/)

Student Record Sheets

PART 1.

Complete the columns below "What I Know" and "What I Want to Know."
We will complete the last column, "What I Learned," at the end of the lesson.

What do you know about the weather that you experience where you live?

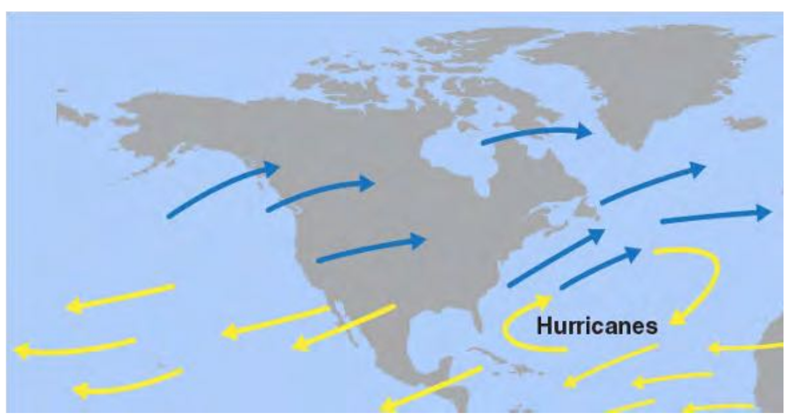
What I Know	What I Want to Know	What I Learned

PART 2.

Prevailing Winds

Winds that move from west to east are called the westerlies. In the United States, it is common for weather patterns to follow winds from west to east.

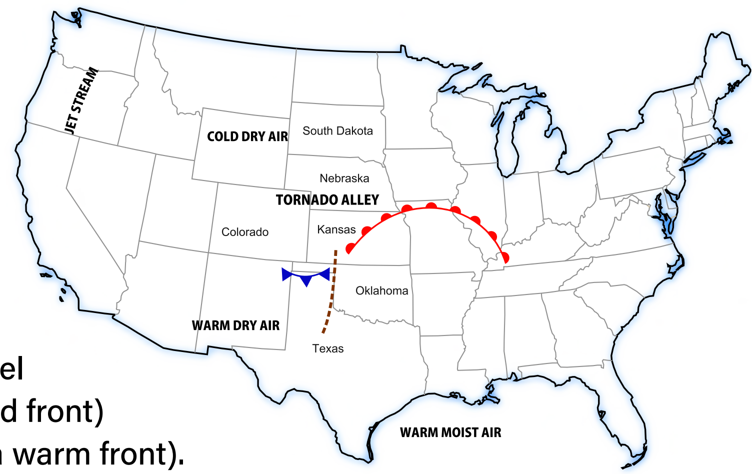
Prevailing winds and weather of North America



Credit: NASA

1. Based on what you have learned from previous lessons, predict whether the prevailing winds that start over the ocean are dry or have moisture. Explain.

Meet Me in the Middle



By Dan Craggs - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=7843081

In previous lessons, we saw that the ocean contains about 97% of Earth's water. It is also Earth's largest reservoir for moisture. We saw that water is very effective at absorbing and storing heat. These two factors play a big role in how the ocean impacts our weather. The middle of the United States is often a meeting place for weather-producing systems. This is a simple model of cold, dry air (the dark blue line represents a cold front) meeting warm, moist air (the red line represents a warm front). Southerly winds coming up from the Gulf of Mexico provide most of the moisture for precipitation in the Midwest. This image represents interactions of air masses in spring or summer.

2. Draw the symbol that represents the front edge of the cold, dry air. Draw the symbol that represents the front edge of the warm, moist air. How are they different?

3. Based on the image, what kinds of weather can happen when these cold fronts meet warm, moist air from a warm front in the spring or summer?

4. Now imagine that the same interactions from the image above happen in the winter. What kind of weather do you think will happen then?

PART 3.

Let's look at how ocean and air movements can cause four types of weather events. We will call them "weather makers." Each weather event has a "recipe" — a set of conditions that help these weather events occur.

Credit: Getty Images

Recipe for a Thunderstorm

- Moisture
- Rising, unstable air
- Lifting force (as the sun heats the surface, air is forced to rise)

Thunderstorm

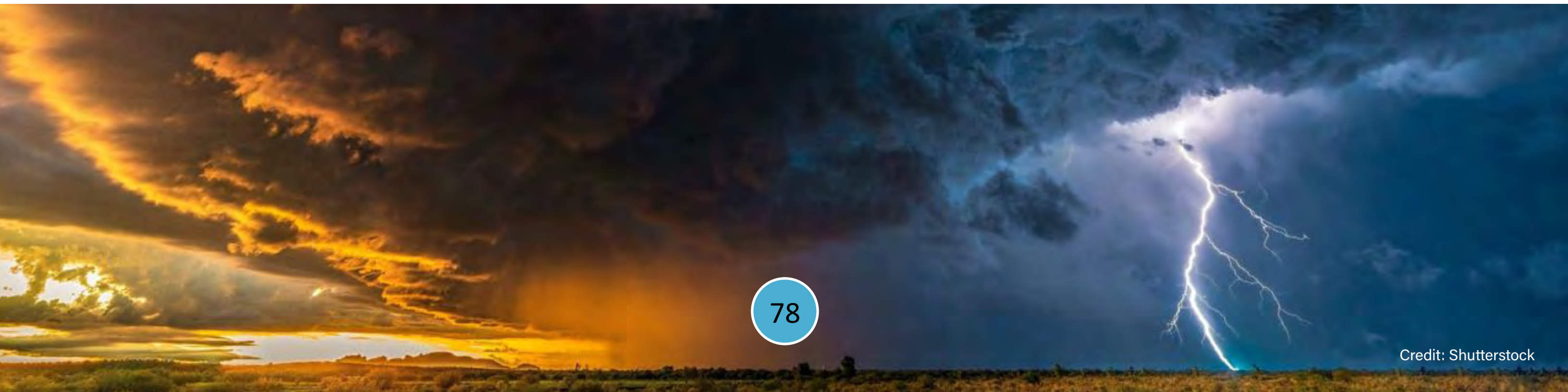
We have seen how winds coming up from the Gulf of Mexico provide moisture for precipitation in the Midwest. In addition, when the sun heats the Earth's surface, the air above it warms. If this warm surface air is forced to rise due to hills or mountains, it will continue to rise as long as it weighs less and stays warmer than the air around it.

As the air rises, the water vapor begins to cool and forms a cloud. The cloud eventually grows upward into areas where the temperature is below freezing. Thunder and lightning usually accompany a thunderstorm. You will see the lightning before you hear the thunder because light moves faster than sound.

Credit: Getty Images

As soon as you see lightning, count the seconds until you hear the thunder. You can count the seconds by saying out loud "1,000, 1,001, 1,002" and so on. Every 5-second gap between the lightning and thunder means that the lighting is about a mile away. Sound travels about 1,000 feet per second (681 miles per hour).

1. Calculate how far away a storm would be if you saw lightning and heard thunder 15 seconds later.



Credit: Shutterstock

Lightning Safety

No place outside is safe when a thunderstorm is in the area. Get inside as soon as you hear thunder. Run to a substantial building or hard-topped metal vehicle as fast as you can. If you can't get to a safe building or vehicle:

- **Avoid open areas.** Don't be the tallest object in the area.
- **Stay away from isolated tall trees, towers or utility poles.** Lightning tends to strike the taller objects in an area.
- **Stay away from metal conductors such as wires or fences.** Metal does not attract lightning, but lightning can travel long distances through it.
- **If you are with a group of people, spread out.** While this actually increases the chance that someone might get struck, it tends to prevent multiple casualties, and increases the chances that someone could help if a person is struck.

What You Might Not Know About Lightning

- **All thunderstorms produce lightning and are dangerous.** Fortunately, people can be safe if they follow some simple guidelines when thunderstorms are forecast.
- **Lightning often strikes outside the area of heavy rain and may strike as far as 10 miles from any rainfall.** Many lightning deaths occur ahead of storms before any rain arrives or after storms have seemingly passed and the rain has ended.
- **If you can hear thunder, you are in danger.** Don't be fooled by blue skies. If you hear thunder, lightning is close enough to pose an immediate threat.
- **Lightning leaves many victims with permanent disabilities.** While only about 10% of lightning victims die, many survivors must live the rest of their lives with intense pain, neurological disabilities, depression, and other health problems.

If you see lightning and hear thunder at the same time, the storm is right above you. Each year, lightning kills 20-30 people in the United States. It injures hundreds more. Tornadoes, hail, and wind gusts get the most attention, but only lightning can strike outside of the storm itself. It is the first thunderstorm hazard to arrive and the last to leave.

2. If you are outside and you see a thunderstorm approaching, what actions should you take to protect yourself from lightning?

Snowstorms and Blizzards


Credit: Getty Images/iStockphoto

Recipe for a Snowstorm

- Moisture
- Cold air in the clouds and on the ground
- Lifting force (something to raise the moist air such as warm air colliding with cold air)

The winter storms that bring precipitation to the western U.S. originate over the North Pacific. As warm, moist air rises, clouds form and cause precipitation. Snow forms when the atmospheric temperature is at or below freezing. The snow will reach the ground if the ground temperature is at or below freezing.

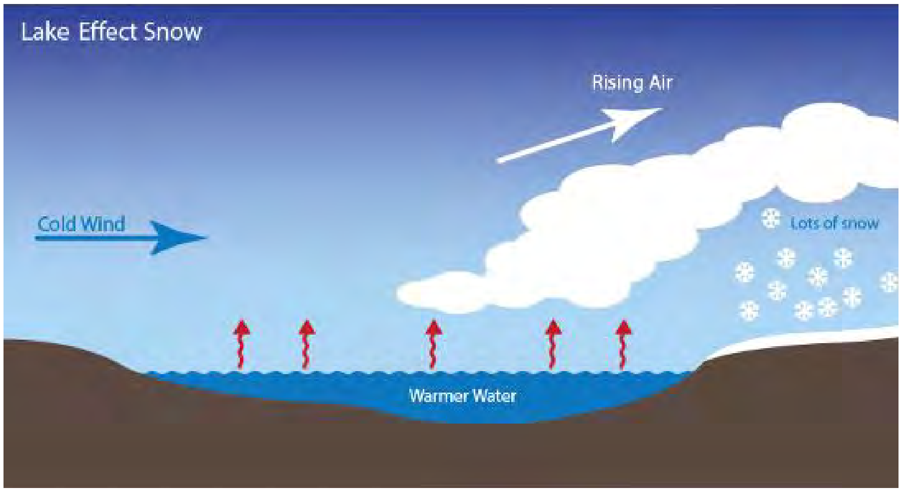
The Blizzard – A special type of snowstorm

A blizzard is a violent winter storm, lasting at least three hours. It has subfreezing temperatures and strong winds over 35 mph (56 kilometers per hour). It may be snowing or blowing around snow that reduces visibility to less than 0.25 miles (0.4 kilometers). Blizzards can create life-threatening conditions. Traveling by automobile can become difficult or even impossible due to “whiteout” conditions and drifting snow.

The strong winds and cold temperatures accompanying blizzards can combine to create another danger. The wind chill is the amount of cooling one “feels” due to the combination of wind and temperature. During blizzards, with the combination of cold temperatures and strong winds, very low wind chill values can occur. It is not uncommon in the Midwest to have wind chills below -60 °F during blizzard conditions.

3. What are the differences between a snowstorm and a blizzard?

Lake Effect Snow



Recipe for Lake Effect Snow

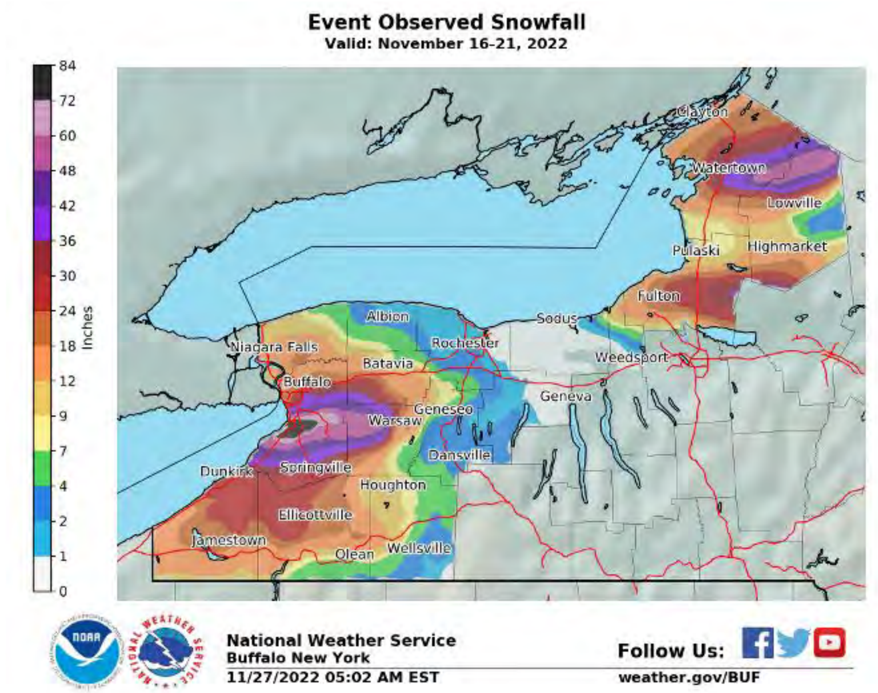
- Cold air passes over a warmer lake
- Air warms up as it passes over the lake and picks up moisture from it
- Air cools down when it passes over land again, and releases its moisture as snow

Lake effect snow forms when cold, below-freezing air passes over a lake's warmer waters. Some lake water evaporates and warms the air. Then, the warmer moist air moves away from the lake. As the air passes back over the colder land, it cools, "dumping" its moisture on the ground as snow.

This image shows belts of lake effect snow in the Great Lakes. In the U.S., lake effect snow commonly occurs across parts of Wisconsin, Michigan, New York, Ohio, Pennsylvania, and the Great Salt Lake in Utah. A storm in 1996 in Ohio caused power outages for 160,000 customers as the storm produced isolated snowfall of almost 70 inches (1.78 meters).

Dept. of Geography at Hunter College, CUNY

4. Measure how high 70 inches of snow would reach in a doorway to your classroom.
5. Based on what you know about the prevailing winds in the United States, why are the belts of lake effect snow not found all around each lake?

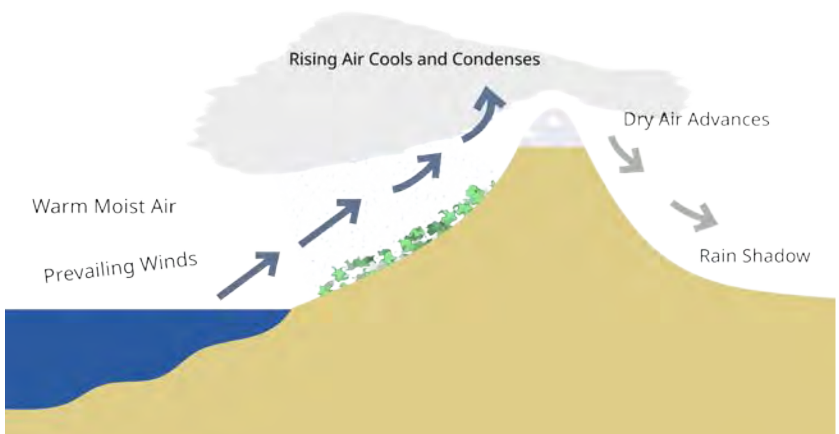


6. The Buffalo, New York area had a lake effect snow event in November 2022. Based on the colors from the map, what was the highest amount of snow received in that area?

7. Estimate how much snow the city of Rochester received.

Rain Shadows

8. From the image, make a recipe for a rain shadow. Notice that when rising air cools, the water vapor condenses and falls as rain or snow.



Credit: By domdomegg - Own work, CC BY 4.0, https://commons.wikimedia.org/w/index.php?curid=45877009

Recipe for a Rain Shadow

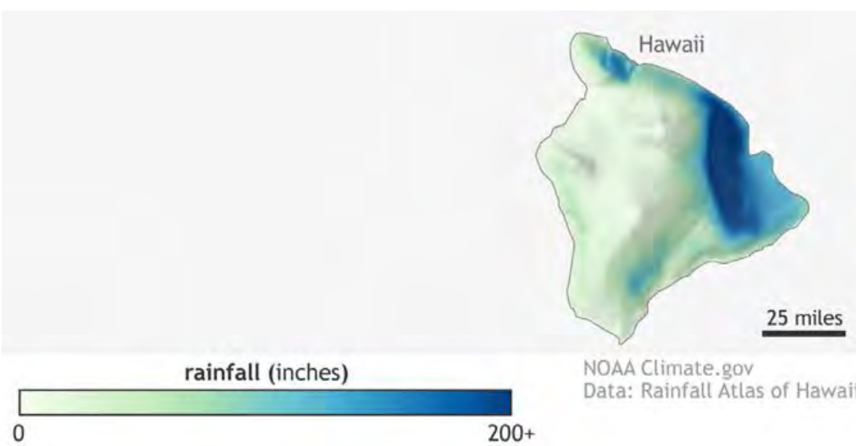
The map below shows cities and areas near a mountain range. Based on the amount of rain that each region receives in a year and the map of prevailing winds, identify whether you think the city lies in a rain shadow.

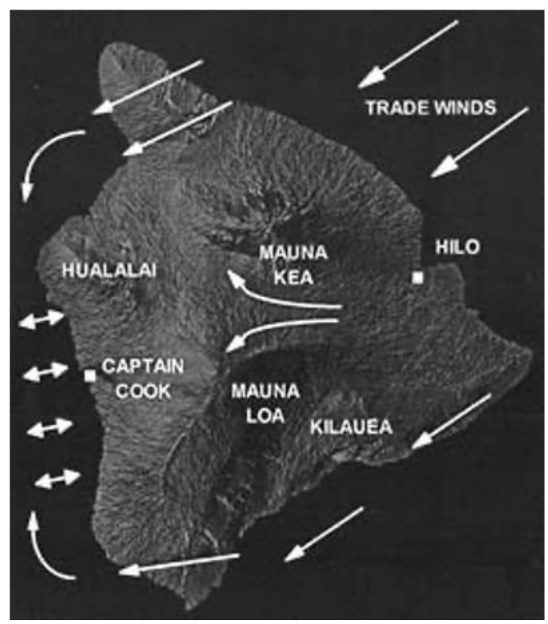
Credit: Kmusser at Wikimedia Commons

9. Mojave Desert, California – 3.5 inches per year

10. Los Angeles, California – 14 inches per year

These Hawaii Island maps show prevailing winds called tradewinds and the rainfall that results. Based on the amount of rain that each city receives in a year, identify whether you think the city is in a rain shadow.





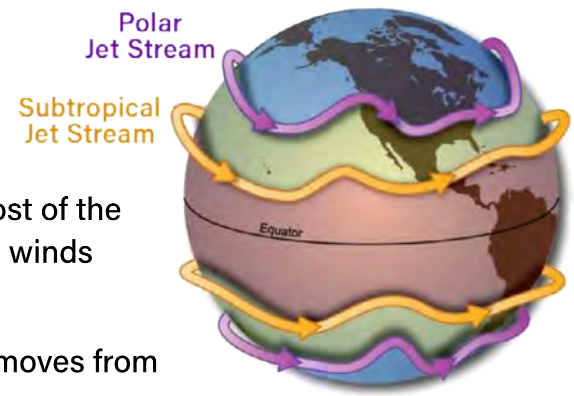
Credit: USGS

11. Hilo, Hawaii – 120 inches per year

12. Captain Cook, Hawaii – 31 inches per year

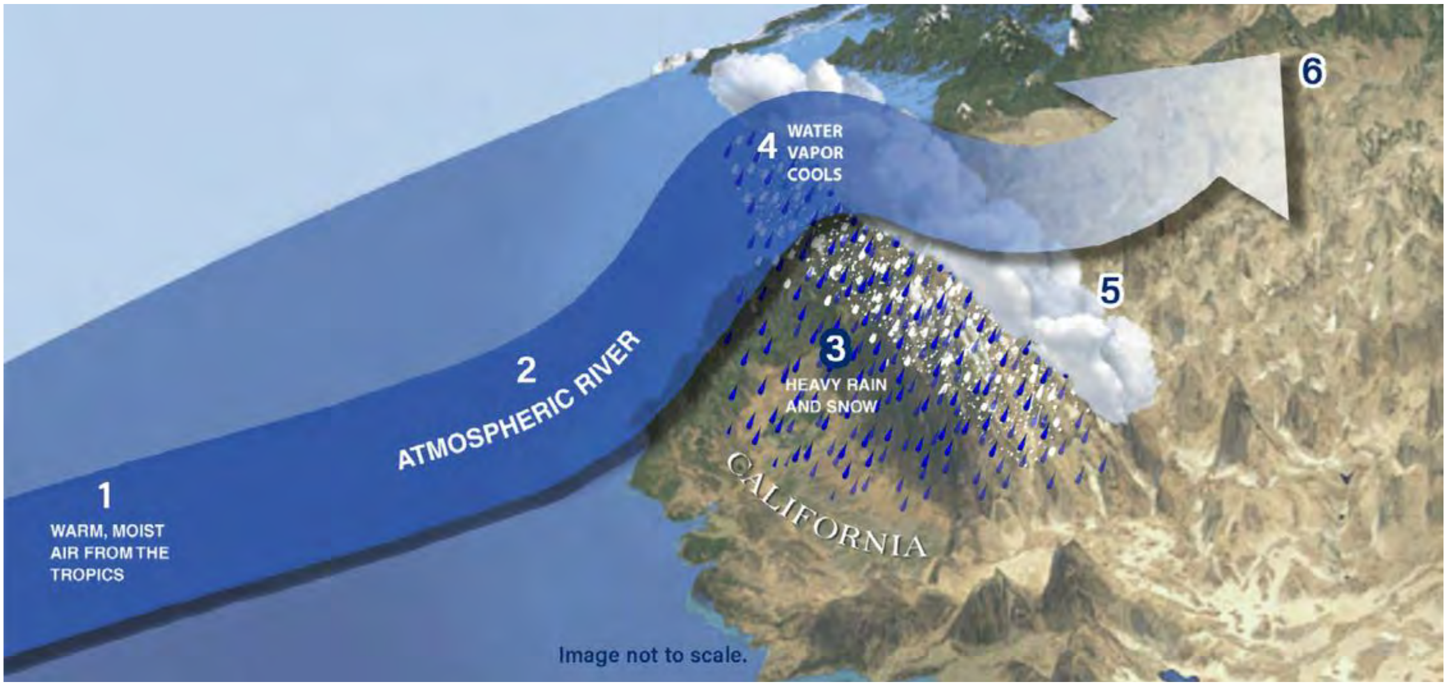
PART 4.

Atmospheric Rivers



Let's investigate how the moisture from the ocean moves toward land to cause events like thunderstorms, snow storms, and flooding. Atmospheric rivers are long, narrow regions in the atmosphere, like rivers in the sky. They carry most of the water vapor from the tropics. They are moved by high-altitude winds that blow from west to east, called the jet stream.

1. Look at the graphic and write a story about how moist air moves from the tropics to drop as rain in California.



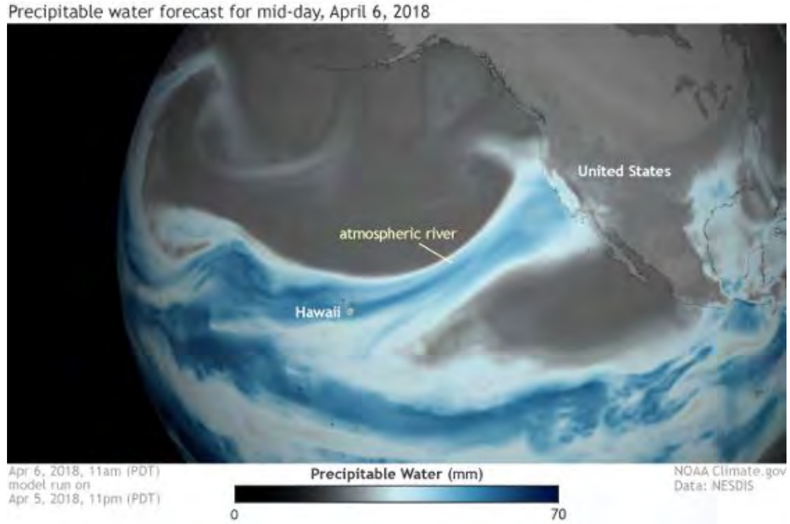
My story about how water moves in an atmospheric river.

Atmospheric rivers come in different sizes and strengths. The average atmospheric river carries the same amount of water vapor as the average water flow at the mouth of the Mississippi River. That is 4,435,973 gallons per second! When the atmospheric rivers reach land, they release their water vapor in the form of rain or snow. Strong atmospheric rivers can create extreme rainfall and floods. These events can disrupt travel, start mudslides, and cause catastrophic damage to life and property.

A well-known example of a strong atmospheric river is called the "Pineapple Express" because moisture builds up in the tropical Pacific around Hawaii and can wallop the U.S. and Canada's west coasts with heavy rainfall and snow.

Prevailing winds cross over warm bands of tropical water vapor to form this "river," which travels across the Pacific. When it reaches the West Coast, the Pineapple Express can dump as much as 5 inches of rain in one day.

Precipitable water forecast for mid-day, April 6, 2018



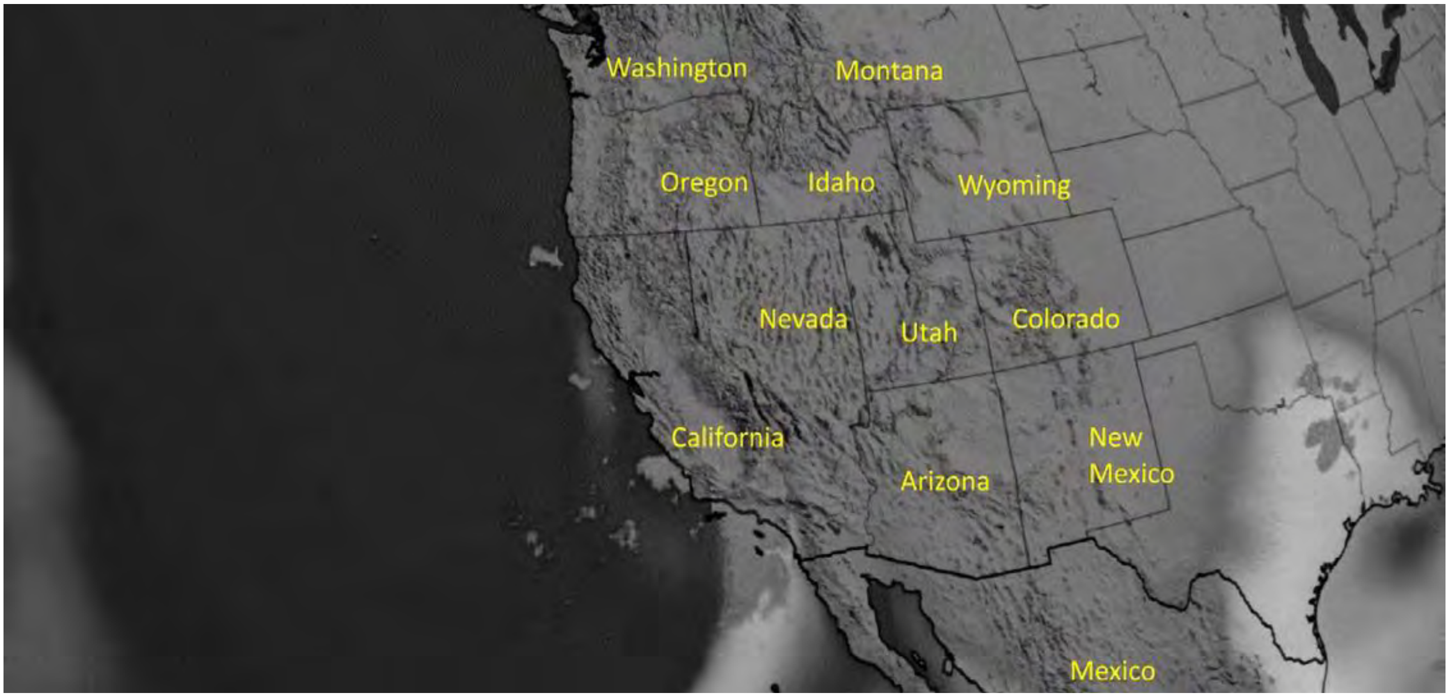
Earth Curiosities

Tornado Alley

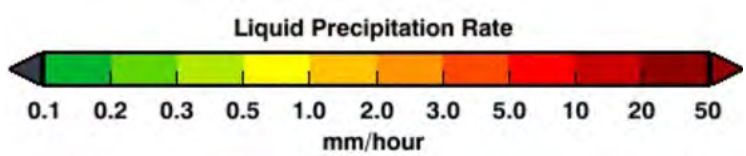
A ten state area of the Midwest has been named "Tornado Alley" in recognition of its attractiveness to tornadoes. The peak "tornado season" for Texas, Oklahoma, and Kansas is from May into early June. In North Dakota, South Dakota, Nebraska, Iowa, and Minnesota, tornado season is in June or July. But remember, tornadoes can happen at any time of year and in any state. Tornadoes can also happen at any time of day or night, but most tornadoes occur between 4–9 p.m.


Credit: iStockphoto

The atmospheric river shown in the images below occurred December 10-12, 2014, over the Pacific Ocean and southwest U.S. (Credit: NASA's Scientific Visualization Studio)



The maps below show how much water vapor is in the atmosphere and the rate of precipitation in the atmosphere. It is a measurement of the amount of water in the air, measured in millimeters (mm) as if it were liquid. There are 25.4 millimeters in an inch. To convert millimeters into inches, divide the length in millimeters by 25.4.



2. How many inches of rain is 50 mm/hr?

3. How much rain would fall if it were to rain that much for five hours in one place?

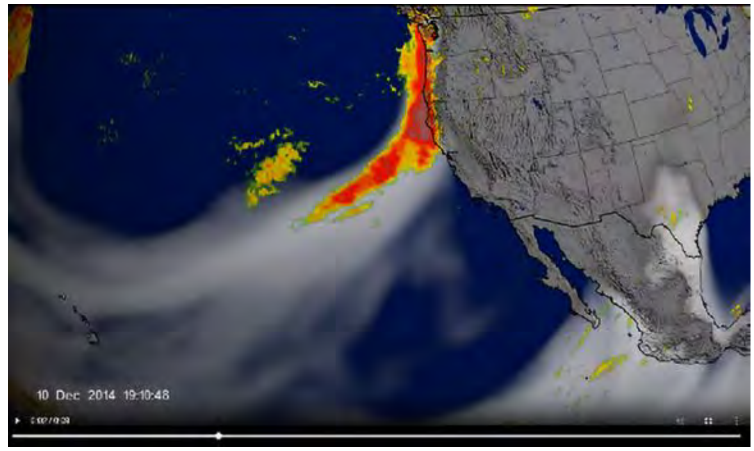
4. Compare Map A to the map above, which has western states marked. If you were a weather forecaster looking at Map A, which states would you expect to see rain in the future?

Map A. Water Vapor & Precipitation Map morning December 10, 2014

Credit: NASA

5. Look at Map B. The water vapor and precipitation map has changed in just 17 hours. Which states are getting the rain now?

Map B. Water Vapor & Precipitation Map evening December 10, 2014



Credit: NASA

6. Map C shows the water vapor and precipitation levels at midday on December 11. What was the highest rate of precipitation over northern California on that day?

Map C. Water Vapor & Precipitation Map December 11, 2014

Credit: NASA

7. Map D shows the water vapor and precipitation pattern for the early morning of December 12. What changes do you see in the water vapor pattern and the states being affected compared to the day before?

Map D. Water Vapor & Precipitation Map December 12, 2014

Credit: NASA

Effects of Atmospheric Rivers

Flooding occurs in every U.S. state and territory and is a threat anywhere in the world that receives rain. In the U.S., floods kill more people each year than tornadoes, hurricanes, or lightning. When atmospheric rivers reach land, they often release a lot of rain or snow over short periods of time. The heavy rain has caused rivers to rise and reach major flood levels.

Flash floods are the most dangerous kind of floods because they combine the destructive power of a flood with incredible speed. Flash floods occur when heavy rainfall exceeds the ability of the ground to absorb it. They also occur when water fills normally dry creeks or streams or enough water accumulates for streams to overtop their banks. This rapid rise can happen in a short amount of time, within minutes of the rainfall. People underestimate the force and power of water. Six inches of fast-moving flood water can knock over an adult. Twelve inches of rushing water can carry away most cars, and 2 feet of rushing water can carry away SUVs and trucks. It is NEVER safe to drive or walk into flood waters.

8. Are there areas in your neighborhood or city that flood?

9. What actions should you take to protect yourself and others when a flood warning is issued?

Credit: Shutterstock

PART 5.

We have looked at weather events like thunderstorms, snow storms, lake effect snow, and rain shadows.

1. Depending on where you live in the United States, have you experienced any of these weather events?

2. Now complete the last column, "What I Learned," from the chart at the beginning of the lesson.

3. What new questions do you have about the ocean, weather and climate connections, and the weather events we have discussed?

Credit: Shutterstock

Credit: Thinkstock Photos

Teek and Tom Episode 3

Weather and Climate EXTREMES!

LESSON 6

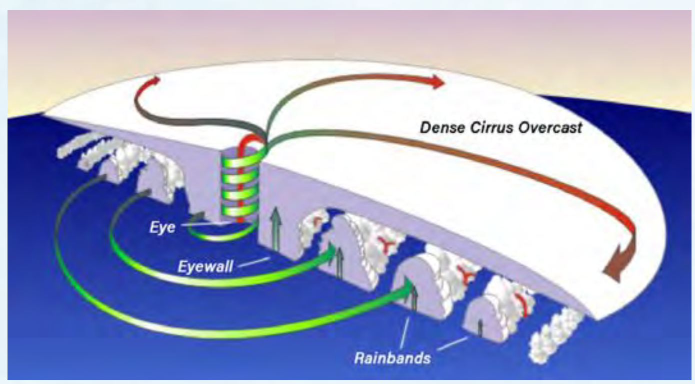
Recipes for Disasters: Tornadoes and Hurricanes

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

In the third episode of Teek and Tom, they discuss weather and climate extremes. In this lesson, we will look at two of the most severe types of weather events: the tornado and the hurricane. A tornado is a narrow, violently rotating column of air that extends from a thunderstorm to the ground. Inside the huge thundercloud, warm and humid air rises, while cool air falls, along with rain or hail. All these conditions can result in rolling, spinning air currents inside the cloud. Although this spinning column of air starts out horizontally, it can easily turn vertically and drop down out of the cloud. When it touches the ground, it's a tornado.

Hurricanes are extremely powerful weather events that form over the ocean. The heat from tropical waters provides the hurricane with energy, allowing it to turn into a violent storm. Hurricanes start as a low-pressure area that moves westward through the moisture-rich tropics. As the warm ocean air rises, more air rushes in beneath it. The rising air then cools, forming clouds and thunderstorms.



Up in the clouds, water condenses and forms droplets, releasing even more heat to power the storm. When wind speeds within such a storm reach 74 mph, it's classified as a hurricane. The terms "hurricane" and "tropical cyclone" refer to the same kind of storm: a rotating system of clouds and thunderstorms that originate over tropical or subtropical waters and have closed low-level circulation. The same type of weather event in the northwest Pacific is called a "typhoon," and "cyclones" occur in the South Pacific and Indian Ocean. Global warming increases ocean temperatures, which increase the ferocity of hurricanes.

Weather and climate extremes are conditions, such as temperature, precipitation, drought, or flooding, that are above or below the range of historical measurements. More intense droughts, stronger hurricanes, and more intense rains are all signs of a warming climate. Extreme weather events often cause a lot of physical damage and can be very costly to the areas they impact. When weather extremes become more frequent, they may reflect a change in the climate. NOAA's National Centers for Environmental Information Climate Extremes Index (https://www.ncei.noaa.gov/access/monitoring/cei/) tracks extreme weather events by combining six indicators related to temperature, drought, precipitation events, and tropical cyclone activity. Scientists determine a percentage of the contiguous U.S. that is above or below these normal climate conditions to calculate the extremes.

Lesson Summary

Students will learn about the atmospheric conditions needed for extreme weather events like tornadoes and hurricanes. They will track the path of Hurricane Ian from 2022. Finally, students will review a climate extreme map to find whether their local area is above or below normal climate conditions and what weather extremes might impact them.

Objectives

- Students will be able to identify the basic conditions of tornado formation and where they commonly occur.
- Students will be able to identify the conditions needed for hurricane formation, as well as the impacts of landfall.
- Students will be able to identify the impacts of a warming ocean on extreme weather events.
- Students will be able to explain the difference between weather and climate extremes and give an example of each.

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 Teek and Tom Episode 3: *"Weather and Climate EXTREMES!"*, 9:53 minutes (https://oceantoday.noaa.gov/teekandtom/episode-3.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/teek-and-tom-educators-guide-appendix-a.pdf).

Next Generation Science Standards

- **3-ESS2-1: Earth's Systems**. Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.
- **MS-ESS2-5: Earth's Systems**. Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.
- **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.

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

- Students will need printouts of student record sheets, graphs, and/or maps to carry out the activities. Student record sheets are located at the end of this lesson.
- If you would like to provide the maps/graphics on a projection system, students will only need the student record sheets. Depending on the configuration of your classroom, we recommend one set per student or group.
- All maps/graphics 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-6.zip)

Preparation

No special preparation is needed for this lesson.

Credit: Shutterstock

InvesTeekation Pathway

ENGAGE

Part 1. Engage

Two images display the before and after of the 2011 tornado in Joplin, Missouri. This was a particularly destructive event, causing damage for 13 miles. At its widest point, the path of the tornado stretched a full mile. As the storm moved through Joplin, it gained strength, with winds peaking at more than 200 mph. Note: Shortly after the May 22, 2011 tornado, NOAA dispatched its King Air 350CER aircraft, equipped with specialized remote sensing equipment, to take imagery after the event. The time of day might be a factor in finding differences. The cars in the lot before the tornado may have been reflective of a work day. Since the tornado and the image taken after the event were after 5 p.m., many people may have left for the day.

Before the tornado	After the tornado
Roads are visible	*Roads are still present*
Trees dot the landscape	*Most trees are gone*
Many cars are present in parking lots	*The cars are gone*
Large building complex in the middle with many smaller houses around the streets	*The houses and building complexes are gone*

EXPLORE

Part 2. Explore

Review the recipe for a tornado with students, then ask them to review the two U.S. maps that show monthly tornado events in May and June from 1998-2022. Extension: You can see additional months at NOAA's National Weather Service (NWS) Storm Prediction Center 25-Year Average Number of Tornadoes per State by Month webpage (https://www.spc.noaa.gov/wcm/permonth_by_state/), which provides all tornados from 1997 through 2023.

Discussion questions

1. Find your state and compare the average number of tornadoes in April and May. *These answers will vary, but the overall trend would be for more tornadoes in the central part of the U.S.*

2. Compare the images for April and May. What trends do you see happening from April to May? *The trend is that as spring progresses, the high number of tornadoes moves more north and more west.*

3. Next, students are introduced to hurricanes as an extreme weather event. They look at a series of images showing a hurricane's development path and then are asked to characterize whether a storm would be a tropical depression, a tropical storm, or a hurricane based on its wind speeds. The storms are from 2022. Additional information can be found at NOAA's National Hurricane Center 2022 Atlantic Hurricane webpage (https://www.nhc.noaa.gov/data/tcr/index.php?season=2022&basin=atl).

Gaston	55	*Tropical storm*
Eleven	30	*Tropical depression*
Bonnie	95	*Hurricane*

You may find interest in these two sites if you live in an area that has been affected by hurricanes.

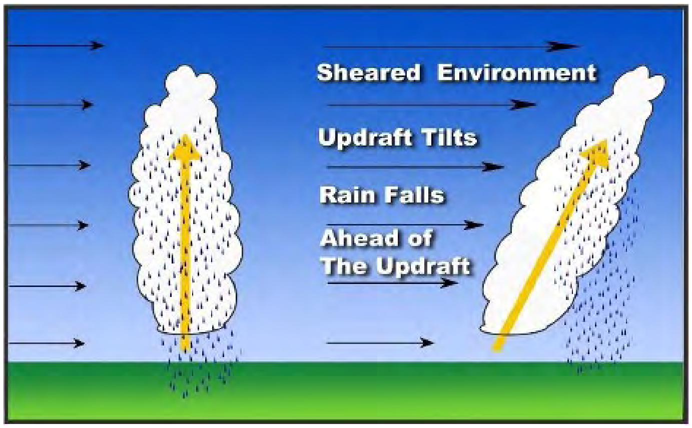
- NOAA's National Hurricane Center, Hurricanes in History (https://www.nhc.noaa.gov/outreach/history/)
- NOAA's National Hurricane Center Yearly Maps of Hurricane Tracks (https://www.nhc.noaa.gov/data/tcr/index.php)

EXPLAIN

Part 3. Explain

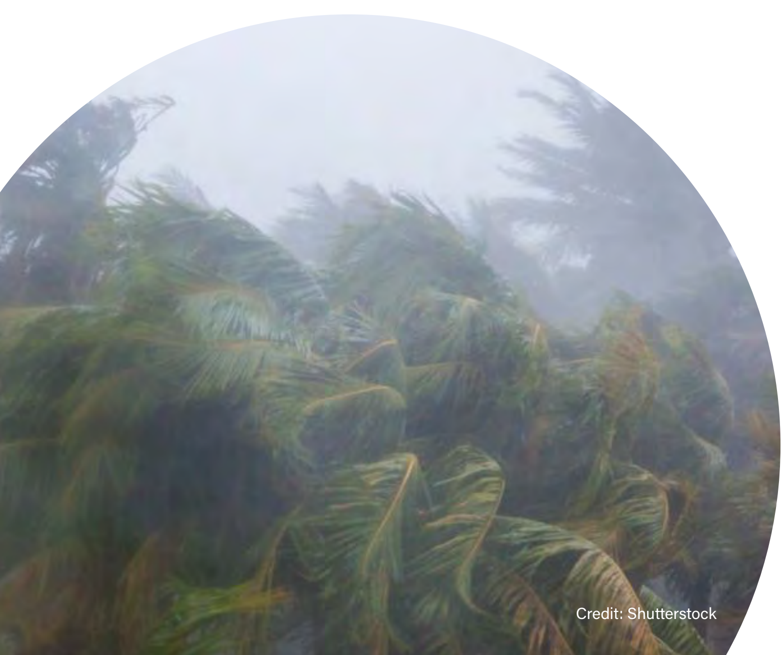
Students are given an infographic to develop a recipe for a hurricane. Overall, these ingredients are needed:

- A preexisting weather disturbance. A hurricane often starts as an area of low pressure in the atmosphere that moves west from Africa.
- Warm water of at least 80 degrees Fahrenheit, extending to a depth of at least 165 feet, powers the storm.
- Low wind shear. Wind shear describes how the wind changes speed and/or direction with height. The image below shows two storms, one in a very weakly sheared environment on the left and another in a strongly sheared environment on the right. The storm experiencing little or no wind shear will produce a vertical updraft. A large difference in wind speed and direction around or near the storm can weaken it.



Discussion questions

1. Where do hurricanes form that impact the United States? *Disturbances over Africa in tropical regions.*
2. What water temperature is needed? *Tropical places where the water is at least 80 degrees Fahrenheit.*
3. What kind of air is needed? *Moist, warm air forms disturbances over the warm water.*
4. When is the storm considered a hurricane? *When spinning winds reach 74 miles per hour, it is considered a hurricane.*
5. How big are the storms? *Ten miles high and 1,000 miles across.*
6. How does a hurricane become less powerful? *When a hurricane hits land, when it moves over colder water, or when wind shear increases.*


Credit: Shutterstock

ELABORATE

Part 4. Elaborate

Hurricane Ian was a major hurricane of the 2022 North Atlantic hurricane season. Students will track part of the path of Hurricane Ian over eight days. They will use the information provided to answer the following questions.

1. When was Ian classified as a tropical storm? *September 24*
2. When was Ian upgraded to a hurricane? *September 27*
3. How long was Ian classified as a hurricane? *Four days*
4. What state felt the greatest impact of the hurricane? *Florida*

EVALUATE

Part 5. Evaluate

1. Show students the NOAA Ocean Today video, "Fuel for the Storm: How warming oceans lead to bigger hurricanes in the future." (https://oceantoday.noaa.gov/every-full-moon/episode11-hurricane/).
2. If time permits, this NOAA Ocean Today video shows a snapshot of the formation of Hurricane Sandy in 2012. The Making of a Super Storm (https://oceantoday.noaa.gov/fullmoon-makingofasuperstorm/).
3. Have students work in small groups or pairs and ask them to highlight the impacts of a warmer ocean on hurricanes, atmospheric rivers, and inland storms. Potential impacts include:
   - More moisture in atmospheric rivers
   - Longer and more intense heat waves
   - More moisture in hurricanes
   - More moisture moving inland for storms
   - Increased rainfall
   - More flooding with storms
   - Increased storm surge on coasts
   - Stronger hurricanes
4. Finally, have students look carefully at the climate extremes map and identify the index percentages for each region. Encourage discussion about what they have learned so far about atmospheric rivers and weather on the coasts and inland that can bring heavy rain and flooding. Remind them how increased moisture in the atmosphere powers storms like snow storms, tornadoes, and hurricanes. The provided list will help remind them about potential weather extremes.
   - More heat waves
   - Heavy rain from atmospheric rivers
   - More flooding from increased rainfall
   - Severe snow storms from atmospheric rivers
   - Tornadoes
   - Hurricanes bring more rainfall and flooding

   Have students work in small groups or discuss the Climate Extremes Index map as a class and complete the chart provided to them. (answer key on next page)

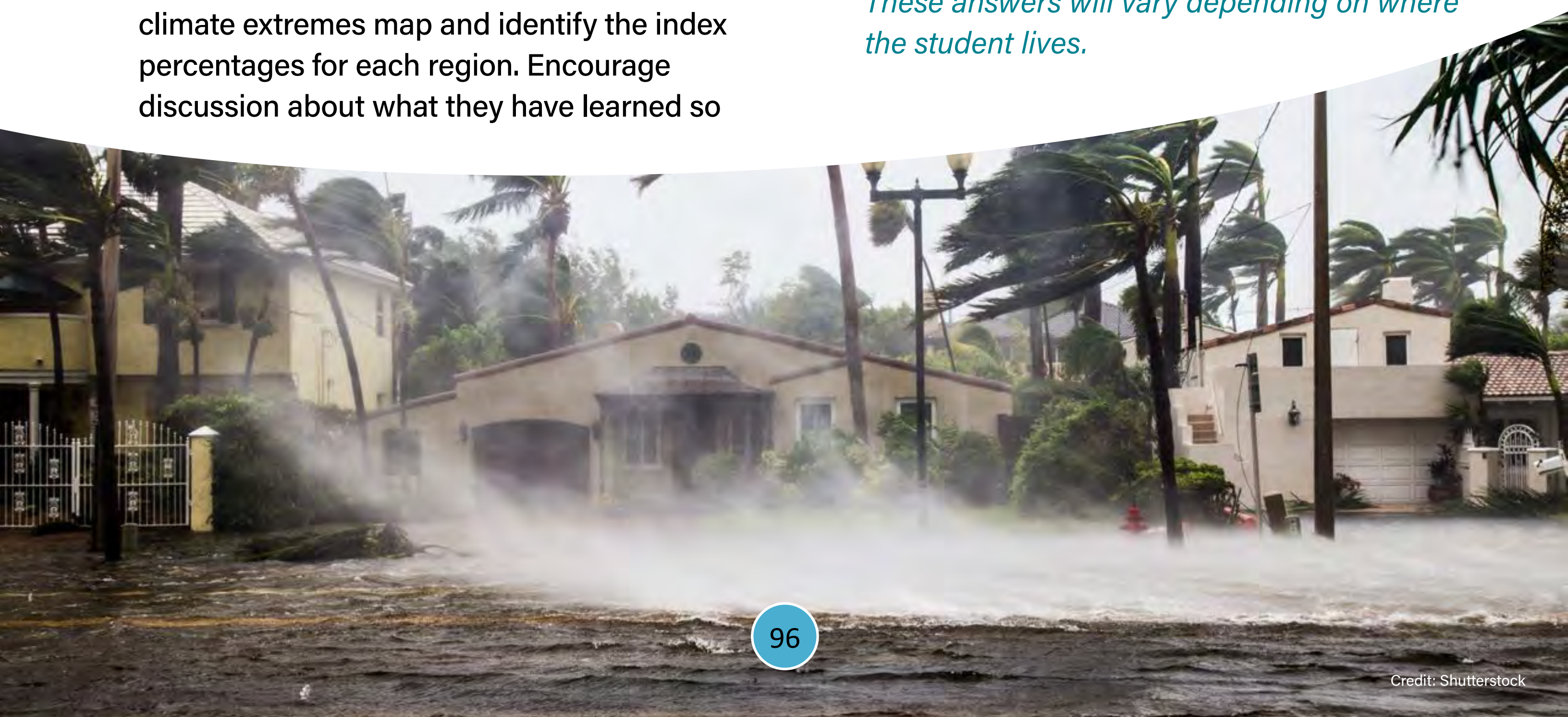
Discussion questions

1. Why do you think the Ohio Valley and the Upper Midwest have such low percentages?

   These regions get some moisture from passing storms and have some tornadoes, but they have less severe heat waves and little impact from hurricanes.

2. What is the climate index for your state? What weather extremes impact your area?

   These answers will vary depending on where the student lives.



Credit: Shutterstock

Region	Index percentage	Weather extremes that impact the region
West	*45.36%*	*Heavy rain from atmospheric rivers* *More flooding from increased rainfall* *Severe snow storms from atmospheric rivers* *More heat waves*
Northeast	*22.16%*	*More flooding from increased rainfall* *Hurricanes bring more rainfall and flooding* *More heat waves*
Upper Midwest and Ohio Valley	*8.78%* *7.10%*	*More heat waves* *Tornadoes* *More flooding from increased rainfall*
Southwest	*16.80%*	*More heat waves* *Hurricanes bring more rainfall and flooding*
South	*24.10%*	*Hurricanes bring more rainfall and flooding* *More heat waves* *Tornadoes* *More flooding from increased rainfall*
Southeast	*18.84%*	*Hurricanes bring more rainfall and flooding* *More heat waves* *More flooding from increased rainfall*
Northwest	*19.48%*	*More flooding from increased rainfall* *Severe snow storms from atmospheric rivers* *More heat waves*
Northern Rockies and Plains	*18.32%*	*More heat waves* *Severe snow storms from atmospheric rivers* *More flooding from increased rainfall*

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.

Credit: NASA

Extensions

The University Center for Atmospheric Research's Center for Science Education has a series of lessons on worldwide hurricane incidence and the effects of increasing sea surface temperatures (https://scied.ucar.edu/activity/hurricanes-and-climate).

These NOAA Ocean Today Videos will be helpful for student understanding during discussions about hurricanes.

- Hurricane Storm Surge (https://oceantoday.noaa.gov/hurricanestormsurge/)
- Hurricane Survival (https://oceantoday.noaa.gov/hurricanesurvival/)

Student Record Sheets

PART 1. A Bad Night in Joplin

A tornado began in Joplin, Missouri, at 5:41 p.m. local time on May 22, 2011, and lasted for 32 minutes. It caused damage for 13 miles. At its widest point, the path of the tornado stretched a full mile. As the storm moved through Joplin, it gained strength, with winds peaking at more than 200 mph. Look at the two images below and identify four features that changed after the storm.

Before

After

Before the Tornado	After the Tornado

"Before-and-after" images like this are important in helping federal and local officials and emergency responders understand a tornado's damage and what hazards still exist. This tornado caused 161 fatalities and more than 1,000 injuries, making it one of the deadliest single tornadoes on record in the U.S. since official records began in 1950. Over 3,000 residences were heavily damaged or completely destroyed, and 15,000 vehicles, including heavy buses and tractor trailers, were picked up and carried by the winds — some for hundreds of yards. A team from NOAA's National Weather Service (NWS) found vehicles that had been rolled into balls of bent metal and broken glass by the storm's force.

Credit: Shutterstock

Earth Curiosities

Amazing Precipitation Records

Type of Precipitation	Date	Place	Record Amount
Rain in 24 hours	January 7, 1968	Réunion Island (in the Indian Ocean, off the coast of Madagascar)	71.9 inches
Rain in 1 hour	July 3, 1975	Inner Mongolia, China	15.8 inches
Hailstone	July 23, 2010	Vivian, South Dakota	8 inches & 1.9 pounds
Snow total in 24 hours	April 15, 1921	Silver Lake, Colorado	75.6 inches

8-inch hailstone, Vivan, South Dakota (NWS)

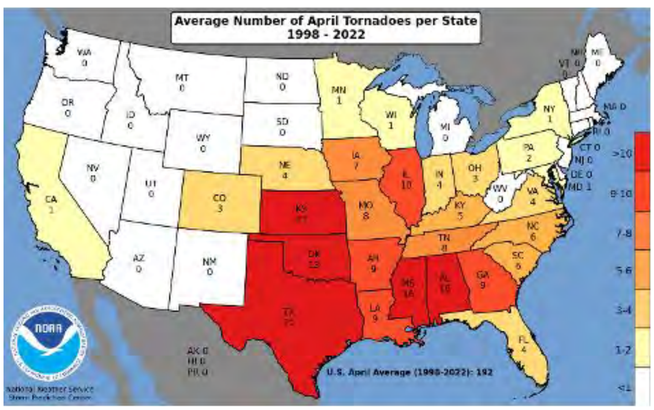
PART 2.

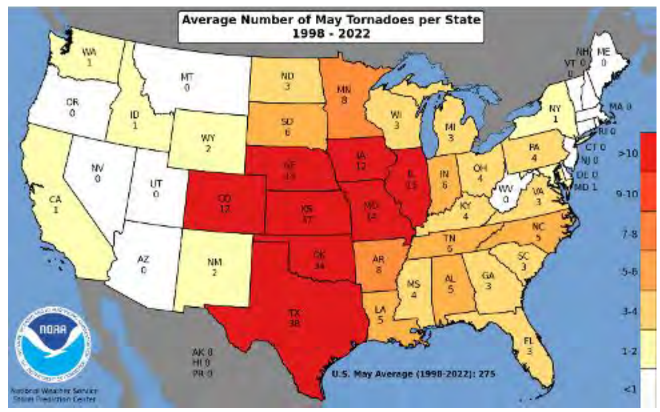
Tornadoes

Recipe for a Tornado

- Warm, moist air near the ground
- Cooler dry air above in the atmosphere
- Wind shear – a change in wind speed or direction the higher you go in the atmosphere

Tornadoes can be among the most violent phenomena of all atmospheric storms we experience. Because wind is invisible, it is hard to see a tornado unless it forms a condensation funnel made up of water droplets, dust, and debris. About 1,200 tornadoes hit the U.S. each year, and 15,000 severe storm and tornado watches and warnings are issued by NOAA NWS each year.



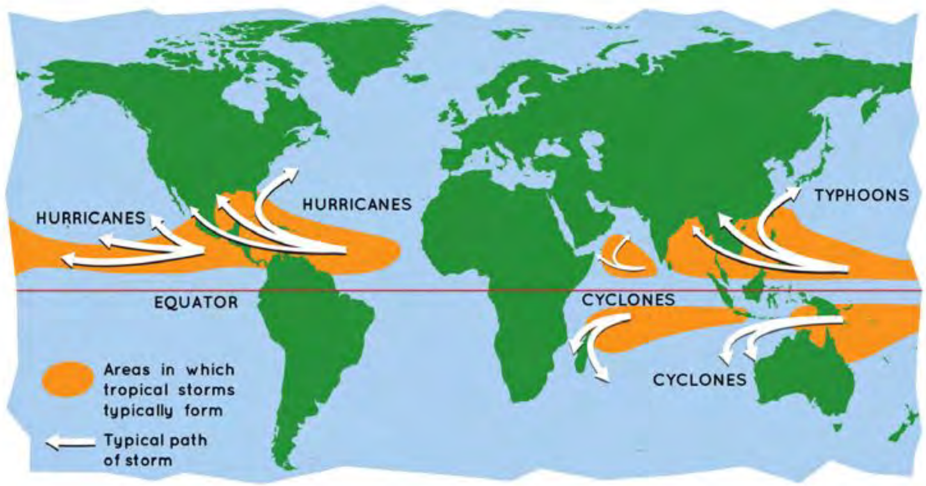


1. These maps show the average number of tornadoes in April and May for each state from 1998 to 2022. Notice that the left map is April, and the right map is May. Since 1950, there have only been four tornadoes in Alaska. From 1950 to 2018, only 42 tornadoes were reported in the state of Hawaii. That is an average of 0.05 each month. Find your state and compare the average number of tornadoes in April and May.

2. Compare the images for April and May. What trends do you see happening from April to May?

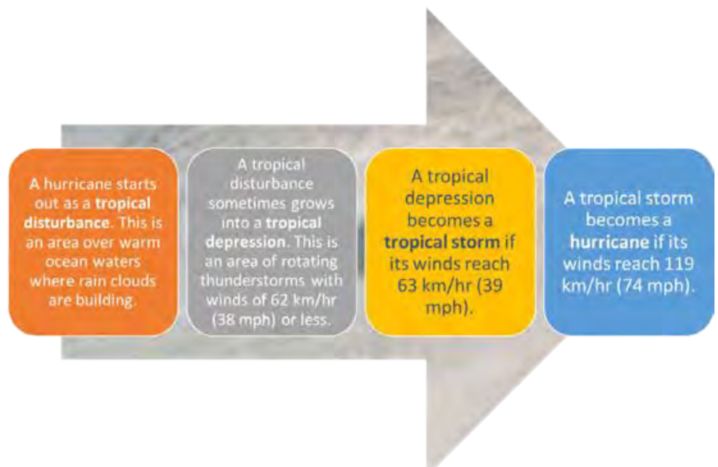
Hurricanes

Hurricanes are severe tropical storms that form in the southern Atlantic Ocean, Caribbean Sea, Gulf of Mexico, and the eastern Pacific Ocean. They collect heat and energy through contact with warm ocean waters and then move toward land. Evaporation from the ocean water increases their power. Hurricanes rotate in a counterclockwise direction around an "eye," which is the center of the hurricane. Hurricanes are called "typhoons" in the northwest Pacific and "cyclones" in the South Pacific and Indian Ocean.



Credit: https://mynasadata.larc.nasa.gov/

Many hurricanes start out as tropical disturbances and then become tropical depressions off the west coast of Africa. As the disturbance moves west due to prevailing winds, it becomes a tropical storm with winds between 39 and 73 mph. It is called a hurricane when the winds reach at least 74 mph. When this storm comes onto land, the heavy rain, strong winds, and large waves can damage buildings, trees, and cars. Hurricanes are most common between June and November. The Atlantic and Gulf coasts can get hit, and the effects can be felt more than 100 miles inland. People who live on the coast may experience extreme winds and flooding from rain and storm surge. People who live inland are at risk for wind, thunderstorms, and flooding.



3. Determine whether the following storms from 2022 would be considered a tropical depression, a tropical storm, or a hurricane.

Storm name	Wind speed	Tropical depression, tropical storm, or hurricane
Gaston	55	
Eleven	30	
Bonnie	95	

PART 3.

Recipe for a Hurricane

Whipping up a hurricane calls for a number of ingredients readily available in tropical areas.

Look at the informational poster and find the key ingredients needed for a hurricane to develop.

Put your findings in the recipe form below.

Recipe for a Hurricane

1. Where do hurricanes form that impact the United States?

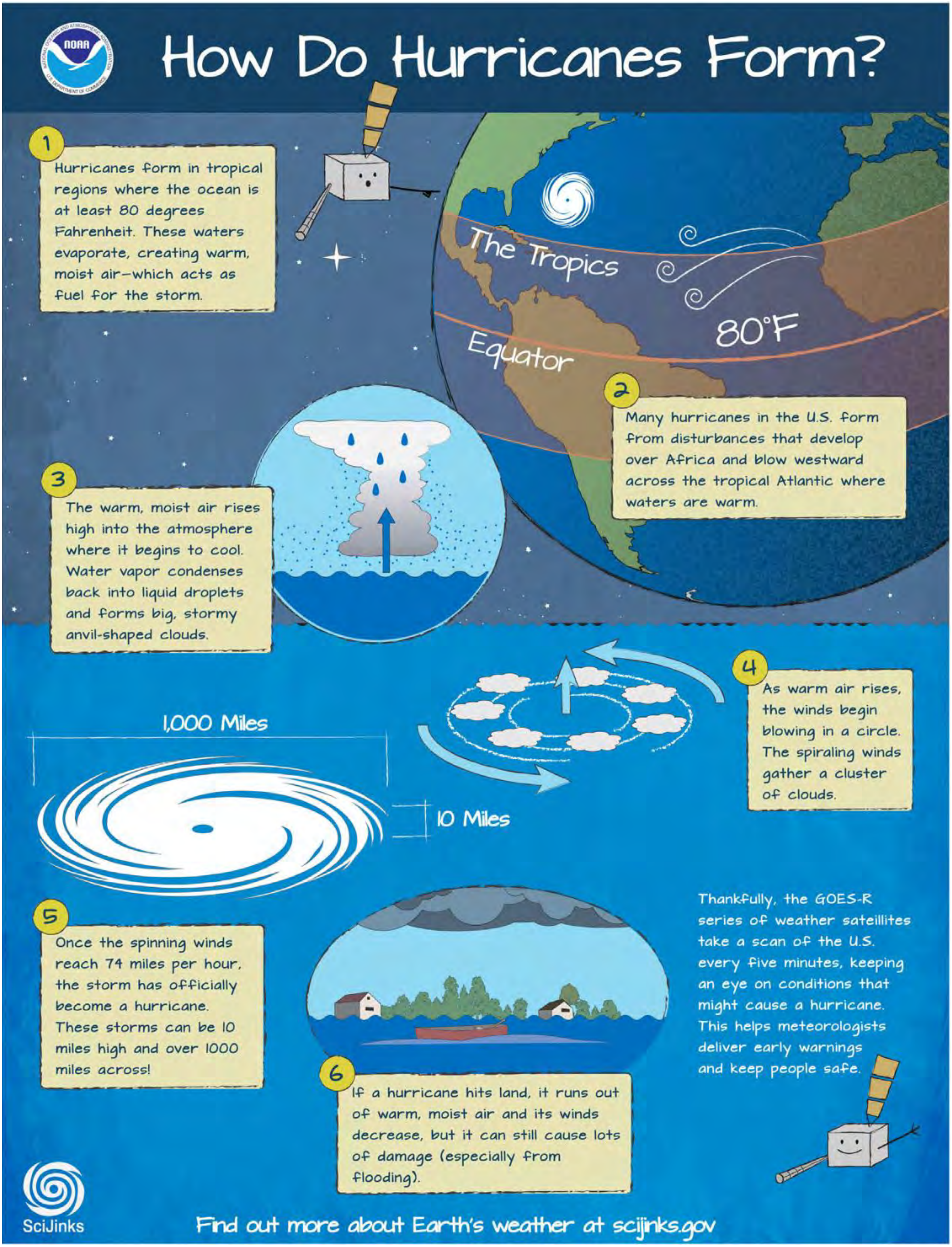
2. What water temperature is needed?

3. What kind of air is needed?

4. When is the storm considered a hurricane?

5. How big are the storms?

6. How does a hurricane become less powerful?


How Do Hurricanes Form?
1
Hurricanes form in tropical regions where the ocean is at least 80 degrees Fahrenheit. These waters evaporate, creating warm, moist air—which acts as fuel for the storm.
The Tropics
80°F
Equator
2
Many hurricanes in the U.S. form from disturbances that develop over Africa and blow westward across the tropical Atlantic where waters are warm.
3
The warm, moist air rises high into the atmosphere where it begins to cool. Water vapor condenses back into liquid droplets and forms big, stormy anvil-shaped clouds.
4
As warm air rises, the winds begin blowing in a circle. The spiraling winds gather a cluster of clouds.
1,000 Miles
10 Miles
5
Once the spinning winds reach 74 miles per hour, the storm has officially become a hurricane. These storms can be 10 miles high and over 1000 miles across!
6
If a hurricane hits land, it runs out of warm, moist air and its winds decrease, but it can still cause lots of damage (especially from flooding).
Thankfully, the GOES-R series of weather sateillites take a scan of the U.S. every five minutes, keeping an eye on conditions that might cause a hurricane. This helps meteorologists deliver early warnings and keep people safe.
SciJinks
Find out more about Earth's weather at scijinks.gov

PART 4.

A 2022 Disaster

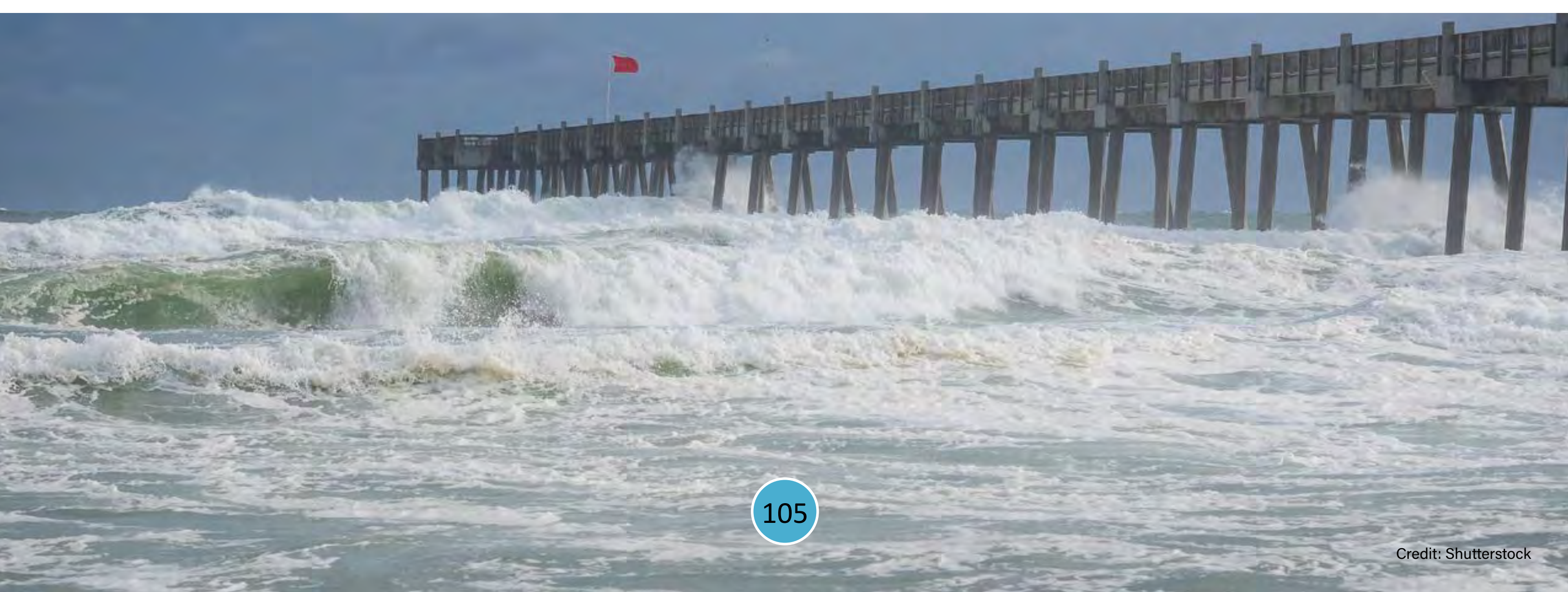
Satellite image of Hurricane Ian on September 28, 2022 (NOAA)

Hurricane Ian was a major hurricane of the 2022 North Atlantic hurricane season. Warm ocean sea surface temperatures across the region aided the hurricane's formation. As Ian approached the central Florida coast, it continued to strengthen with winds of 155 mph. The combination of Ian's excessive rainfall, severe winds, and storm surge contributed to widespread damage and loss of property. More than 2.6 million people lost electricity. Many coastal communities were washed away by the winds and storm surge.

You will track the path of Hurricane Ian as it traveled up from the Caribbean to impact Florida and other states. The map shows an area of the Atlantic Ocean and Caribbean Sea off the east coast of North America. Use the map to track the path of Hurricane Ian from the positions given in the accompanying table.

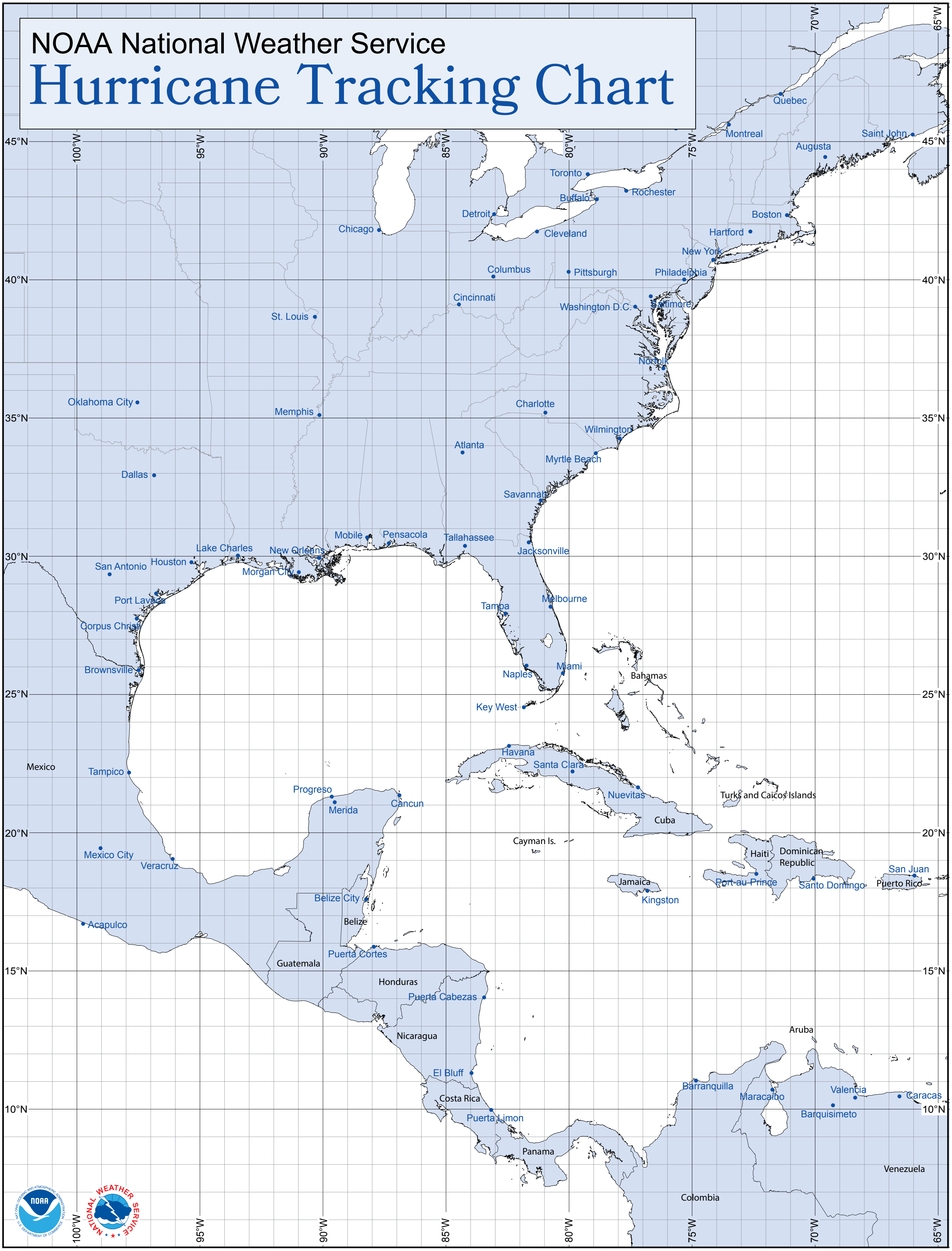
Each position shows the storm's center for the time indicated in the table. These positions are given as latitude and longitude. Longitude increases toward the left (west), and latitude increases upward (north).

Plot each of the eight positions from the table and mark them on the map with corresponding numbers to compare the map with the numbered positions to the information on the data table. Connect your plotted points with line segments and answer the follow-up questions.



Credit: Shutterstock

NOAA National Weather Service
Hurricane Tracking Chart



NATIONAL WEATHER SERVICE: Building a Weather-Ready Nation www.weather.gov

To learn more about tropical cyclones, and how to protect yourself, visit JetStream - an Online School for Weather at www.weather.gov/jetstream

Track for Hurricane Ian, September 2022

Position	Date	West Longitude	North Latitude	Winds in miles per hour
1	September 24	72	15	40
2	September 25	79	15	50
3	September 26	83	20	100
4	September 27	84	23	125
5	September 28	83	26	155
6	September 29	80	30	80
7	September 30	79	34	70
8	October 1	79	35	50

1. When was Ian classified as a tropical storm?

2. When was Ian upgraded to a hurricane?

3. How long was Ian classified as a hurricane?

4. What state felt the greatest impact of the hurricane?

Credit: Shutterstock

PART 5.

After you view the video "Fuel for the Storm," (https://oceantoday.noaa.gov/every-full-moon/episode11-hurricane/welcome.html) work in small groups or pairs to summarize the impacts of a warmer ocean on hurricanes, atmospheric rivers, and inland storms. Share your findings with the class.

Climate Extremes

We have seen many examples of weather extremes, from snowstorms to tornadoes and hurricanes. When the number of these events increases or decreases, it may reflect a changing climate. Scientists track extreme weather events by collecting data related to temperature, drought, flooding, precipitation events, and tropical cyclone activity. They use this to determine what parts of the U.S. are above or below normal climate conditions to calculate the extremes.

Look at the map below and identify the index percentages for each region. Choose from the following list of weather extremes that might impact the climate for each region.

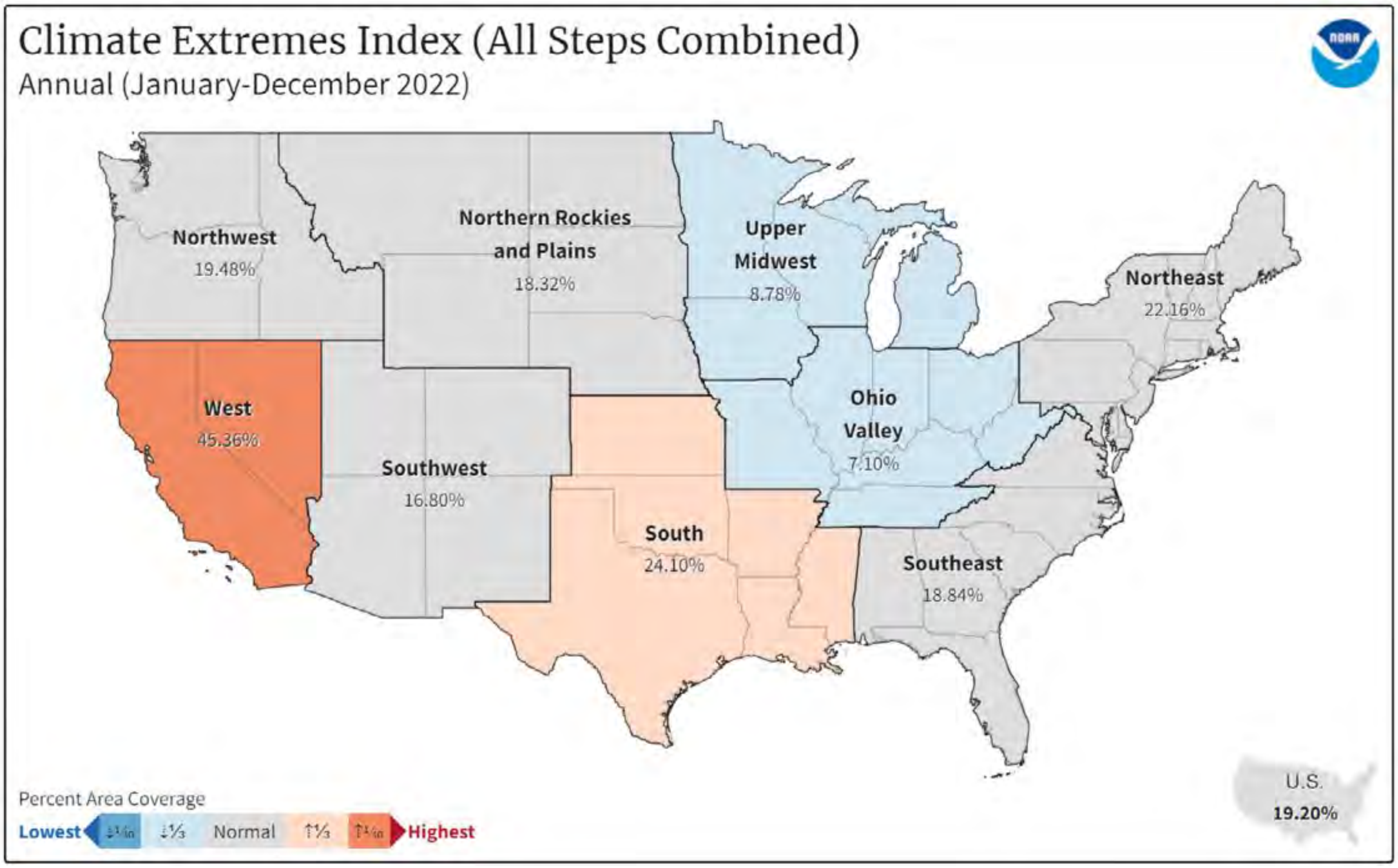
- More heat waves
- Heavy rain from atmospheric rivers
- More flooding from increased rainfall
- Severe snow storms from atmospheric rivers
- Tornadoes
- Hurricanes bring more rainfall and flooding

Region	Index percentage	Weather extremes that impact the region
West		
Northeast		
Upper Midwest and Ohio Valley		

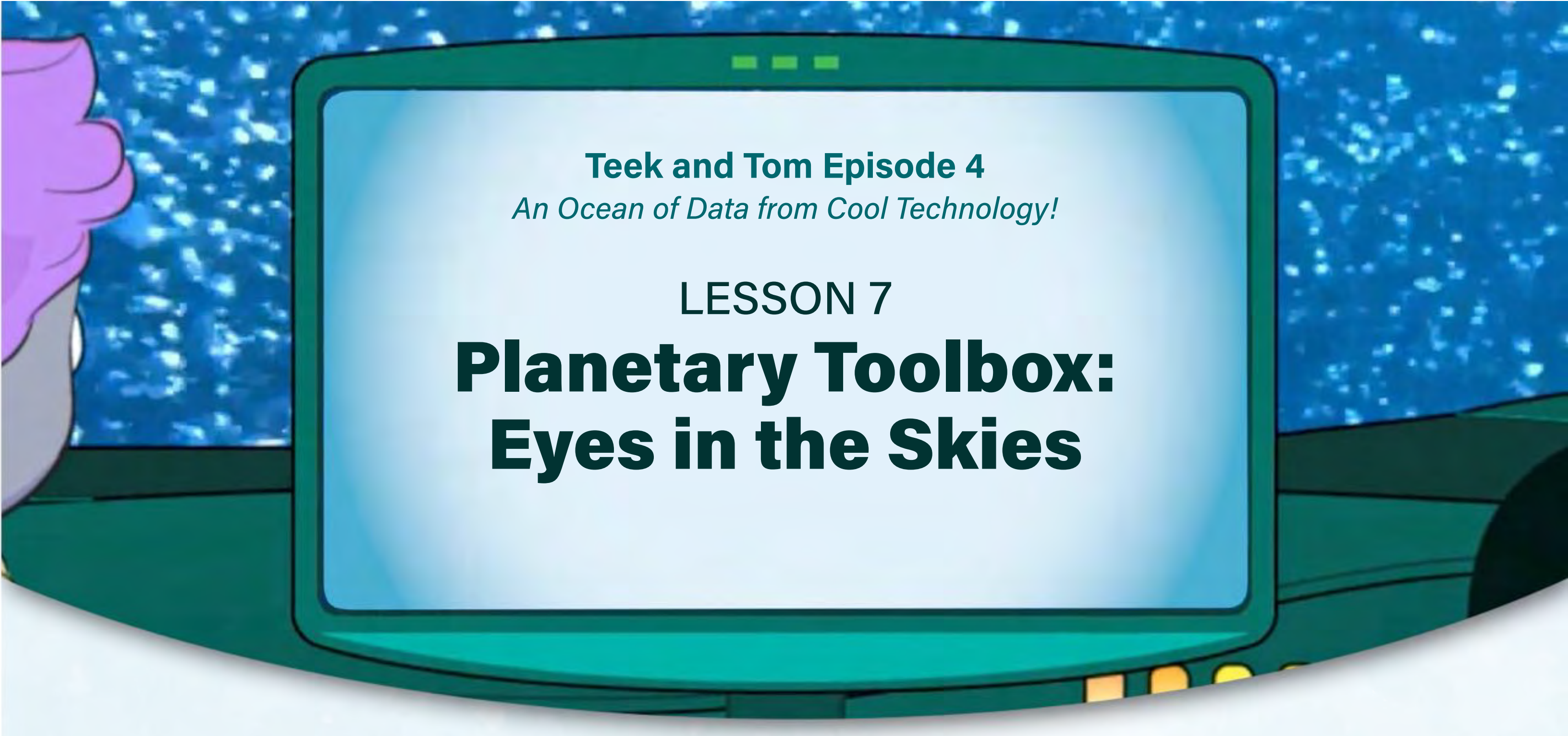
Region	Index percentage	Weather extremes that impact the region
Southwest		
South		
Southeast		
Northwest		
Northern Rockies and Plains		

1. Why do you think the Ohio Valley and the Upper Midwest have such low percentages?

2. What is the climate index for your state? What weather extremes impact your area?



Climate Extremes Index (All Steps Combined)
Annual (January-December 2022)
Northwest
19.48%
Northern Rockies
and Plains
18.32%
Upper
Midwest
8.78%
Northeast
22.16%
West
45.36%
Ohio
Valley
7.10%
Southwest
16.80%
South
24.10%
Southeast
18.84%
U.S.
19.20%
Percent Area Coverage
Lowest
Normal
Highest



Teek and Tom Episode 4

An Ocean of Data from Cool Technology!

LESSON 7

Planetary Toolbox: Eyes in the Skies

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

In episode 4, scientist Tom introduced technology that NOAA uses to study the Earth's atmosphere. He discussed satellites that monitor Earth from space, hurricane hunter aircraft that use dropsondes, the RAAVEN drone, and weather balloons that measure atmospheric properties.

Earth-orbiting satellites provide continuous images and data on atmospheric conditions. They allow scientists to make more accurate and timely weather forecasts and better understand long-term climate conditions. Atlantic and Pacific geostationary satellites (GOES) can continuously observe hurricanes from formation to dissipation. They orbit 22,236 miles above Earth's equator at speeds equal to the Earth's rotation. This allows them to maintain their positions over specific geographic regions so they can provide continuous coverage of that area over time.

Two polar-orbiting satellites (POES) circle the Earth in north-south orbits, passing close to the North and South Poles. The POES satellite system makes 14 polar orbits per day, traveling approximately 520 miles above the Earth. As the POES satellites circle the Earth, the planet rotates beneath them. This allows the satellites to see a different view with each orbit, with each satellite providing two complete views of weather around the world every day. Often called the backbone of global weather forecasting, polar-orbiting weather satellites fly closer to the Earth than geostationary satellites. They provide as much as 85% of the data used by weather models.

GOES and POES satellites allow scientists to track atmospheric variables such as temperature and cloud formation, providing data necessary to track and understand normal weather patterns, as well as extreme weather events like hurricanes.

To gather data around, within, and above hurricanes, NOAA uses its own aircraft as well as aircraft operated by the U.S. Air Force. These planes routinely fly into potentially threatening storms where their radar and sensors measure a cross-section of the hurricane. They also use dropsondes to gather information about the layers of the hurricane.

There are 122 NOAA National Weather Service (NWS) weather forecast offices around the country. Meteorologists at these offices supplement the information provided by NOAA and U.S. Air Force aircraft with data provided by ground weather radar stations. Together, these systems let meteorologists measure the motion inside storms and hurricanes and record their precipitation intensity, movement, and a variety of wind data.

The NOAA NWS also launches weather balloons to collect information about atmospheric conditions and improve weather forecasts — especially those involving extreme weather like hurricanes. A small expendable box of instruments connected to the balloons called a radiosonde measures air temperature, pressure, humidity, as well as wind speed and direction. A radio signal sends data back to scientists on the ground. During its flight, a weather balloon can reach over 100,000 feet in altitude. Eventually, at a very high altitude, the balloon bursts. About 70,000 balloons are released by the NWS each year. Radiosondes provide valuable information to better understand the general behavior of the atmosphere and the formation of extreme weather.

The RAAVEN (**R**obust **A**utonomous **A**erial **V**ehicle-**E**ndurant and **N**imble) aircraft has been used in tropical places like Barbados. It is launched from a catapult and has sensors installed to measure wind and turbulence in the local clouds. The data it collects helps us to better understand how tropical clouds form. These cloud systems contain moisture and heat that are transported into the atmosphere around the globe. They can also form tropical cyclones and hurricanes that can affect coasts.

Lesson Summary

Students will learn about tools routinely used to observe general atmospheric conditions, as well as track and predict the impacts of hurricanes. Using data from a real hurricane event, they will work in teams to share information about a storm event and then develop emergency actions that should be taken before the hurricane makes landfall.

Objectives

- Students will be able to identify instruments that provide data about general atmospheric conditions as well as the development and movement of hurricanes.
- Students will be able to explain how teams work together to gather data and issue warnings to local populations about severe weather events like hurricanes.

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 4 of Teek and Tom *"An Ocean of Data from Cool Technology!"*, 12:23 minutes (https://oceantoday.noaa.gov/teekandtom/episode-4.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.
- [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.

[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

- Team data sheets for the simulation
- Small rulers that measure up to 6 inches
- Students will need printouts of student record sheets, graphs, and/or maps to carry out the activities. Student record sheets are located at the end of this lesson.
- If you would like to provide the maps/graphics on a projection system, students will only need the student record sheets. Depending on the configuration of your classroom, we recommend one set per student or group.
- All maps/graphics 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-7.zip)

Preparation

No special preparation is needed for this lesson.

InvesTeekation Pathway

ENGAGE

Part 1. Engage

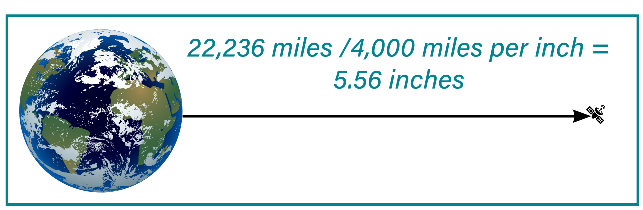
NOAA NWS watches and warnings may be issued for a wide variety of weather events. These include wind, hurricanes, thunderstorms, tornadoes, floods, heat, fog, wind chill, frost, freeze, ice storms, and fire. Students should compare the information provided for a severe thunderstorm watch versus a warning and then discuss their thoughts in small groups.

EXPLORE

Part 2. Explore

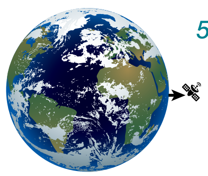
Students will be introduced to the technology tools highlighted in episode 4 of Teek and Tom and will answer questions about each. The answers are below.

1. Geostationary satellites hold their position above Earth. The 2-inch Earth image represents our planet's 8,000-mile (12,874 kilometers) diameter. Each inch represents 4,000 miles. How many inches away would the geostationary satellite be? In the answer box, measure that distance from the Earth and mark where the (tiny) satellite would be.



Credit: Shutterstock

2. If we use the same 2-inch Earth, calculate how far away a polar-orbiting satellite would orbit at 520 miles. Remember, each inch represents 4,000 miles. In the answer box, measure that distance from the Earth and mark where the (tiny) satellite would be.



520 miles /4,000 miles per inch = 0.13 inches

Credit: Shutterstock

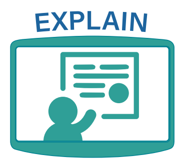
3. A map of the U.S. shows the locations and names of NOAA National Weather Service (NWS) forecast offices around the country and the regions they cover. Find the name of the NWS forecast office in your area. *Answers will vary.*

4. During its flight, a weather balloon can reach an altitude of over 100,000 feet (19 miles). Balloons rise about 4 meters per second (9 miles per hour). How long would it take a weather balloon to rise 19 miles? *19 miles / 9 miles per hour = 2.1 hours.*

5. If a weather balloon sends back two measurements of the atmosphere each second, calculate how many measurements it would collect from the time it's launched from the ground until it reaches an altitude of 19 miles. *2 measurements x 60 seconds x 60 minutes x 2.1 hours = 15,120 measurements*

6. The RAAVEN (**R**obust **A**utonomous **A**erial **V**ehicle-**E**ndurant and **N**imble) aircraft is launched from a catapult and has sensors installed to measure wind and turbulence in the local clouds. What is one advantage and one disadvantage of using drones like RAAVEN compared to larger aircraft or satellites for gathering data? *ROVs like RAAVEN are cheaper to operate and can be launched from many places. RAAVEN cannot withstand the intense conditions present in a hurricane.*

7. Show students this video: NOAA's Hurricane Hunters Fly Into the Eye of a Monster (https://oceantoday.noaa.gov/hurricanehunters/). What are the similarities and differences in the information provided by hurricane hunters compared to satellites, the RAAVEN, and weather balloons? *Hurricane hunters can record temperature, pressure, and wind speed from individual layers within the hurricane. Satellites can only show the top of the hurricane. Weather balloons have a limited area to collect data. RAAVEN and hurricane hunters gather data on winds and conditions inside cloud formations. Satellites can derive temperature, pressure, and wind speed from other variables.*



Part 3. Explain

Hurricane Florence, a large and slow-moving hurricane, made landfall during the morning of September 14, 2018. The storm spent two days producing record-breaking rainfall (30 inches) across eastern North Carolina and a portion of northeastern South Carolina. Record river flooding destroyed roads and damaged thousands of homes and businesses. Although Florence will be remembered primarily for its record-breaking flooding, wind gusts over 100 mph caused significant damage to buildings, trees, and electrical service. Your students will use actual data collected from this hurricane to predict the impacts of this event. Additional information about Hurricane Florence can be found in the slide set that accompanies this lesson.

Divide your students into five teams, assigning each team to one of the five roles below.

- NOAA Satellite team will report the location of the hurricane.
- NOAA Hurricane Hunter team will report the top wind speeds of the hurricane.

- NOAA NWS office in Wilmington, North Carolina, will report the wind speed and rainfall amounts.
- NOAA NWS National Hurricane Center team 1 will issue hurricane watches and warnings.
- NOAA NWS National Hurricane Center team 2 will issue storm surge and tornado watches and warnings.

During the hurricane, NOAA Hurricane Hunters conducted nine flights. Data and imagery from land-based NOAA Doppler weather radars and satellites, like the NOAA polar-orbiting satellites, were used to construct Hurricane Florence's best track and impact. Point out the eye at the center of the hurricane image.

Provide each team with the six daily reports relevant to their team for September 9-14. Each team will share their data with the class. Students will also complete a data table and map the hurricane's progress. You can provide a sheet containing the six days of reports or cut the sheets apart so that each team gets a small stack of six reports.

The slide set for this lesson (https://oceantoday.noaa.gov/teekandtom/educators-guide/slide-set-7.zip) includes images of the hurricane's path and its anticipated track, as well as storm surge and rainfall information. You can present the relevant information to the class for each date of the simulation. The images include:

- September 9 – Hurricane track with anticipated path
- September 10 – Hurricane track with anticipated path
- September 11 – Hurricane track with anticipated path
- September 12 – Hurricane track with anticipated path and estimated storm surge map
- September 13 – Hurricane track with anticipated path and rainfall map
- September 14 – Hurricane track with anticipated path

Earth Curiosities

Killer Hurricane

The 1900 Galveston Hurricane was the deadliest weather disaster in United States history. On September 8 the storm hit the Texas coast south of Galveston as a Category 4 hurricane. Storm tides, a combination of regular tides and storm surge, of 8 to 15 feet swamped Galveston Island and other parts of the Texas coast. These storm tides were the primary cause of the 8,000 deaths on record, though death toll estimates from the storm range from 6,000 to 12,000. Photo Credit: Library of Congress

Storm surge is a rise in coastal water levels due to a hurricane. It is the greatest threat to life and property from a hurricane. Extreme flooding in coastal areas happens when normal high tides combine with a storm surge.

NOAA Satellite Team

September 9

Hurricane is located at 24.5 north latitude and 55.8 west longitude

NOAA Satellite Team

September 10

Hurricane is located at 24.9 north latitude and 58.9 west longitude

NOAA Satellite Team

September 11

Hurricane is located at 26.4 north latitude and 64.1 west longitude

NOAA Satellite Team

September 12

Hurricane is located at 28.5 north latitude and 69.5 west longitude

NOAA Satellite Team

September 13

Hurricane is located at 32.5 north latitude and 74.3 west longitude

NOAA Satellite Team

September 14

Hurricane is located at 34.1 north latitude and 77.2 west longitude

NOAA Hurricane Hunters	NOAA Hurricane Hunters
September 9	**September 10**
Hurricane top wind speeds of 76 mph Hurricane eye has a diameter of 12 miles	Hurricane top wind speeds of 140 mph Hurricane eye has a diameter of 12 miles

NOAA Hurricane Hunters	NOAA Hurricane Hunters
September 11	**September 12**
Hurricane top wind speeds of 140 mph Hurricane eye has a diameter of 36 miles	Hurricane top wind speeds of 140 mph Hurricane eye has a diameter of 34 miles Storm is 400 miles in diameter

NOAA Hurricane Hunters	NOAA Hurricane Hunters
September 13	**September 14**
Hurricane top wind speeds of 110 mph Hurricane eye collapses	Hurricane top wind speeds of 90 mph There is no eye to report

NOAA National Weather Service Office

Wilmington, NC – September 9

Average ground wind speed of 4-10 mph

Precipitation: 0 inches of rain

NOAA National Weather Service Office

Wilmington, NC – September 10

Average ground wind speed of 5-13 mph

Precipitation: 0 inches of rain

NOAA National Weather Service Office

Wilmington, NC – September 11

Average ground wind speed of 6-12 mph

Precipitation: 0.02 inches inches of rain

NOAA National Weather Service Office

Wilmington, NC – September 12

Average ground wind speed of 5-15 mph

Precipitation: 0.60 inches inches of rain

NOAA National Weather Service Office

Wilmington, NC – September 13

Average ground wind speed of 30-40 mph

Precipitation: 1.50 inches inches of rain

NOAA National Weather Service Office

Wilmington, NC – September 14

Average ground wind speed of 60-105 mph

Precipitation: 9.58 inches of rain with over 30 inches in some areas

National Hurricane Center – Team 1

September 9

Tropical storm watch issued for coastal North Carolina

National Hurricane Center – Team 1

September 10

Hurricane watch issued for coastal North Carolina and Virginia

National Hurricane Center – Team 1

September 11

Hurricane warning issued for coastal North Carolina and Virginia

National Hurricane Center – Team 1

September 12

Hurricane warning issued for coastal North Carolina and Virginia

National Hurricane Center – Team 1

September 13

Hurricane warning issued for coastal North Carolina and Virginia

National Hurricane Center – Team 1

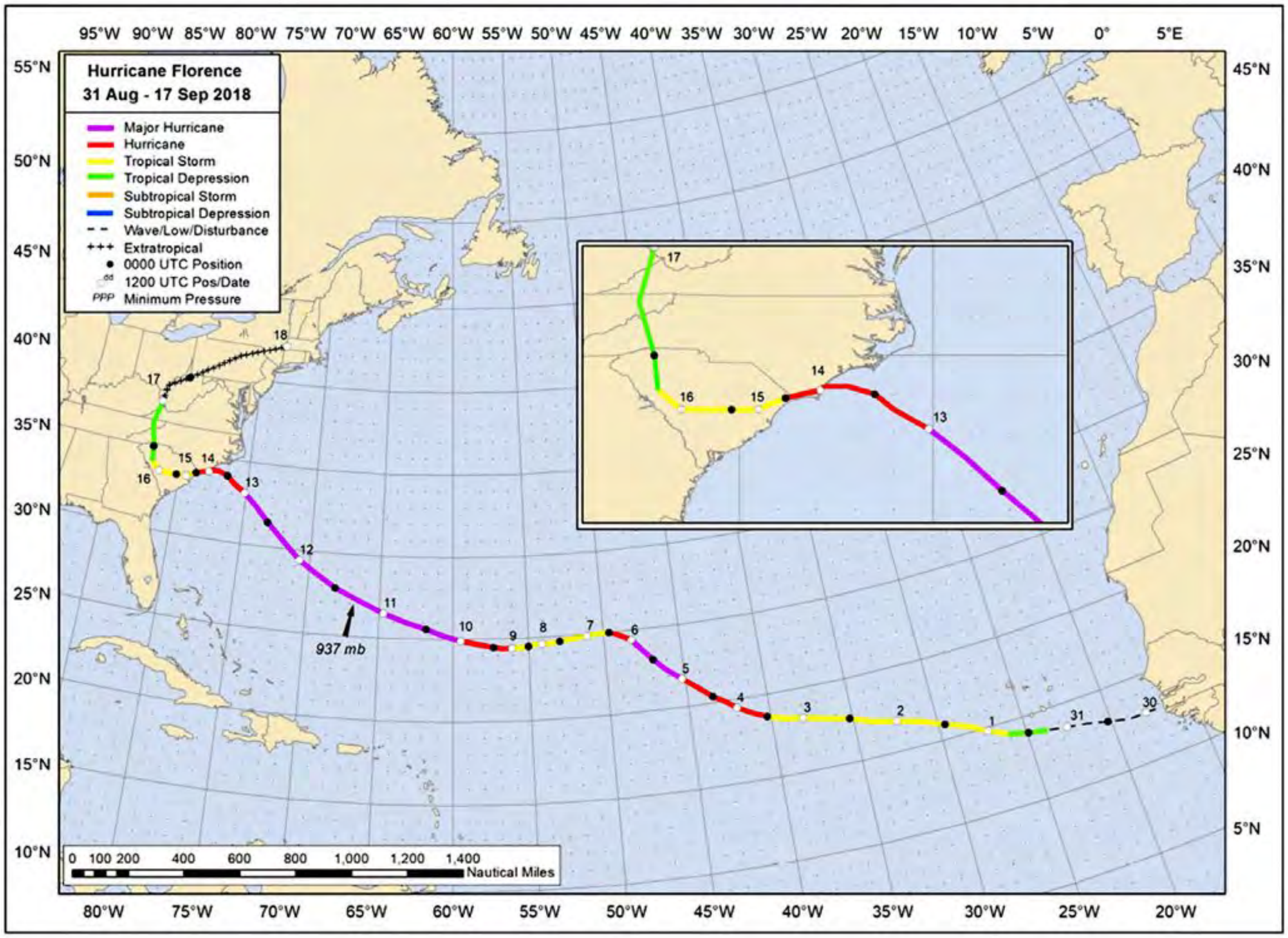
September 14

Hurricane warning replaced with tropical storm warning coastal North Carolina and Virginia

National Hurricane Center – Team 2 **September 9** Storm surge watch issued for coastal North Carolina	**National Hurricane Center – Team 2** **September 10** Storm surge watch predicted 8 to 11 feet above ground level for coastal areas of North Carolina and South Carolina
National Hurricane Center – Team 2 **September 11** Rainfall exceeding 10 inches predicted for coastal North Carolina	**National Hurricane Center – Team 2** **September 12** Tornado watch for coastal and inland North Carolina Storm surge warning for coastal areas of North Carolina and South Carolina
National Hurricane Center – Team 2 **September 13** Tornado watch for coastal and inland North Carolina Storm surge warning for coastal areas of North Carolina and South Carolina	**National Hurricane Center – Team 2** **September 14** Tornadoes warnings over North Carolina and South Carolina Storm surge warning of 4 feet above normal levels for coastal areas of North Carolina and South Carolina

The table below shows team information for all dates.

Team	NOAA Satellite	NOAA Hurricane Hunter	NOAA NWS office Wilmington, NC	NOAA National Hurricane Center team 1	NOAA National Hurricane Center team 2
Date	**Location**	**Hurricane wind speed; Size of the hurricane's eye or size of the whole hurricane**	**Wind speed on the ground; Precipitation**	**Tropical depression, tropical storm, or hurricane**	**Storm surge, anticipated rainfall, and wind warnings**
Sept 9	*24.5 N 55.8 W*	*76 mph* *Eye diameter: 12 miles*	*Wind speed: 4-10 mph* *Precipitation: 0*	*Tropical storm watch NC*	*Storm surge watch issued for SC/NC*
Sept 10	*24.9 N 58.9 W*	*140 mph* *Eye diameter: 12 miles*	*Wind speed: 5-13 mph* *Precipitation: 0*	*Hurricane watch NC/VA*	*Storm surge watch predicted 8 to 11 ft above ground level for SC/NC*
Sept 11	*26.4 N 64.1 W*	*140 mph* *Eye diameter: 36 miles*	*Wind speed: 6-12 mph* *Precipitation: 0.02 inches*	*Hurricane warning NC/VA*	*Rainfall exceeding 10 inches predicted for NC*
Sept 12	*28.5 N 69.5 W*	*140 mph* *Eye diameter: 34 miles* *Storm diameter: 400 miles*	*Wind speed:* *5-15 mph* *Precipitation: 0.60 inches*	*Hurricane warning NC/VA*	*Tornado watch for NC* *Storm surge warning for SC/NC*
Sept 13	*32.5 N 74.3 W*	*110 mph* *Eye collapses*	*Wind speed: 30-40 mph* *Precipitation: 1.50 inches*	*Hurricane warning NC/VA*	*Tornado watch for NC* *Storm surge warning for SC/NC*
Sept 14	*34.1 N 77.2 W*	*90 mph*	*Wind speed: 60-105 mph* *Precipitation: 9.58 inches* *30 inches in some areas*	*Hurricane warning replaced with tropical storm warning NC/VA*	*Tornado warnings SC/NC* *Storm surge warning SC/NC* *Storm produced 31 tornadoes over North Carolina and South Carolina September 15-16.*



By the end of the storm, wind gusts over 100 mph caused significant damage to buildings, trees, and electrical service. A storm surge of over 4 feet eroded beaches and damaged property. The hurricane caused 42 fatalities. An estimated 74,563 structures were flooded, and 5,214 people were rescued from flooding.

Once the data has been collected from each team, ask the students to work in their small groups to complete the table about emergency responses for each day. Based on the data collected each day, what actions do they think should be taken to prepare for the storm and keep everyone safe? The hurricane affected a large area over several states. Ask students to consider the actions that individuals and state and local officials should take, how hospitals and airports should prepare, and who should evacuate to be safe. Think about the need for fresh water, food, electricity, and shelter in a tornado. Also, ask students how they would prepare for flash flooding, which happens when heavy rainfall occurs over a short amount of time, such as several hours or successive days, filling streams and rivers. Brainstorm some potential actions with students that can be taken each day for emergency preparations. These might include:

- Make plans to evacuate
- Evacuate
- Move to higher ground
- Stock up on water, groceries, gas, and supplies
- Prepare for high winds
- Prepare for flash floods
- Prepare for loss of power
- Hospitals and nursing homes should be ready with a generator
- Airports may need to shut down
- Move to tornado shelters

Date	Emergency Response and Preparation
September 9	*People in North Carolina should stock up on water, groceries, and supplies. They should make plans in case they need to evacuate.*
September 10	*People who live close to the coast should evacuate. People who live farther inland should stock up on groceries, gas, and supplies.*
September 11	*People in low-lying areas that can flood should evacuate. Coastal areas of North Carolina and South Carolina should evacuate.*
September 12	*People should prepare for high winds, flood waters, and losing power. People who live in low-lying areas or on the coast should move to shelter in higher areas or in special community centers.*
September 13	*People should prepare for high winds, flood waters, and losing power. People in mobile homes should be prepared to go to tornado shelters. Hospitals and nursing homes should be ready with generators. Airports may need to shut down.*
September 14	*Residents and visitors should remain indoors until local officials decide it is safe to go outside. If a tornado warning is issued, people should take shelter in the lower part of their houses, and people in mobile homes should go to tornado shelters.*

ELABORATE

Part 4. Elaborate

Debrief Questions

1. Why is taking multiple measurements of the wind speed, precipitation in the clouds, storm direction, and other data important?

   More data means that scientists can make more accurate predictions and provide information many days ahead of time for emergency preparations.

2. Why is coordination critical between the different data sources, such as hurricane hunters, satellite teams, local weather stations, and the National Hurricane Center?

   Each team collects different information. When combined, the results provide a more accurate and complete picture of the storm and its effects.

3. Why is it important to inform the local population about the various effects of approaching severe weather?

   The storm affects people differently depending on where they live. Watches and warnings need to be issued to everyone for all impacts of the storm so they can take action and help those who might not be aware of the warnings.

EVALUATE

Part 5. Evaluate

The students have a self-assessment to evaluate how well they think they performed in the simulation. The rubric below is for evaluating student performance by the teacher.

CATEGORY	Exemplary	Proficient	Partially Proficient	Unsatisfactory	Points
Focus on the Task	**3 points**	**2 points**	**1 point**	**0 points**	
	Stayed on task all of the time without reminders.	Stayed on task most of the time. Group members can count on this person.	Stayed on task some of the time. Group members must sometimes remind this person to do the work.	Hardly ever stays on task. Will let others do the work.	
Work Habits	**3 points**	**2 points**	**1 point**	**0 points**	
	Completed assigned tasks and does not depend on others to do the work.	Completed most assigned tasks.	Does not follow through on most tasks and sometimes counts on others to do the work	Does not complete tasks. Depends on others to do all of the work.	
Listening, Questioning, and Discussing	**3 points**	**2 points**	**1 point**	**0 points**	
	Respectfully listens, discusses, asks questions, and helps the group.	Respectfully listens, discusses, and asks questions.	Has trouble listening with respect and does not take turns.	Does not listen with respect, argues with teammates, and does not consider other ideas.	
Information-Sharing	**3 points**	**2 points**	**1 point**	**0 points**	
	Gathered information and shared useful ideas.	Usually provided useful information and ideas for discussion.	Sometimes provided useful information and ideas for discussion.	Almost never provided useful information or ideas for discussion.	
Group/Partner Teamwork	**3 points**	**2 points**	**1 point**	**0 points**	
	All team members contributed equally.	Assisted group/ partner in the finished project.	Finished individual tasks but did not assist the group/ partner during the project.	Contributed little to the group effort during the project.	
				TOTAL POINTS	____/15

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.

Extensions

These additional Ocean Today Videos will be helpful for student understanding during discussions about hurricanes.

- Hurricane Survival Guide (https://oceantoday.noaa.gov/fullmoon-hurricanesurvival/welcome.html)
- Hurricane Storm Surge (https://oceantoday.noaa.gov/fullmoon-stormsurge/welcome.htm)

Student Record Sheets

PART 1.

You have probably experienced weather watches and warnings. NOAA's National Weather Service (NWS) issues watches and warnings for local areas. These may be issued for a wide variety of weather events. including wind, hurricanes, thunderstorms, tornadoes, floods, heat, fog, wind chill, frost, freeze, ice storms, and fire. Below are examples of a severe thunderstorm watch and a warning.

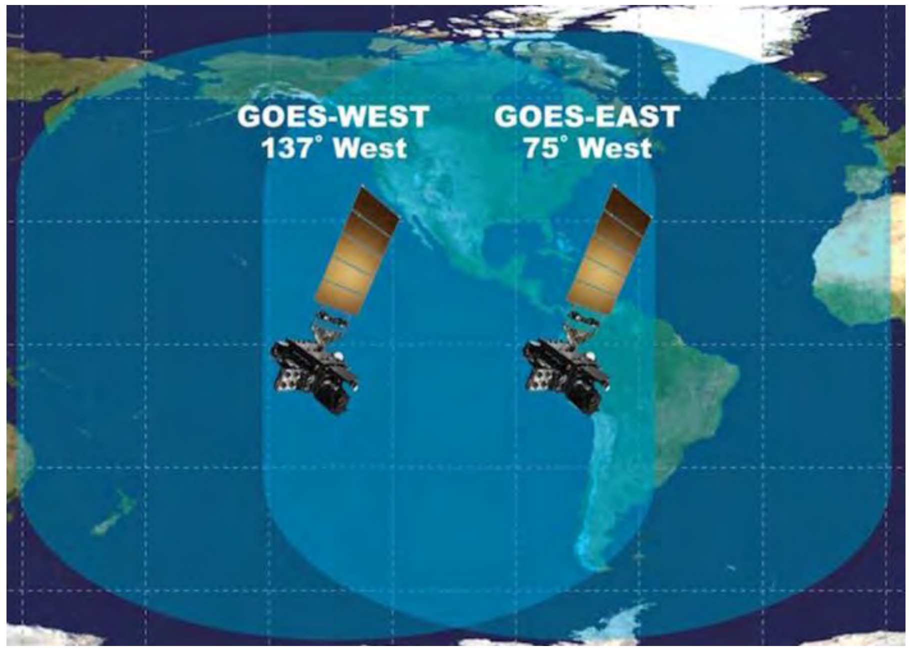
Severe Thunderstorm WATCH **Be Prepared!**	Severe thunderstorms are possible in and near the watch area. Weather conditions favor thunderstorms, damaging wind, and hail. The watch area is typically large, covering numerous counties or even states. The risk of hazardous weather has increased, but its occurrence, location, or timing is still uncertain. A watch is intended to give people enough advance notice to be prepared with a plan of action in case a storm threatens. Listen for later information and possible warnings, especially when planning travel or outdoor activities.
Severe Thunderstorm WARNING **Take Action!**	Severe weather has been reported by spotters or indicated by radar. Seek shelter. A warning means weather conditions pose a threat to life or property. People in the path of the storm need to take protective action. Large hail or damaging wind is occurring or will occur in this location. Take shelter in a substantial building. Get out of mobile homes that can blow over in high winds. Warnings typically are posted in a much smaller area — around the size of a city or small county — that may be impacted by a large hail or damaging wind identified by an NWS forecaster on radar or by a trained spotter/law enforcement watching the storm.

Compare the differences between a watch and a warning.

In a small group, discuss how you think a watch and a warning are different, and be prepared to explain your thinking.

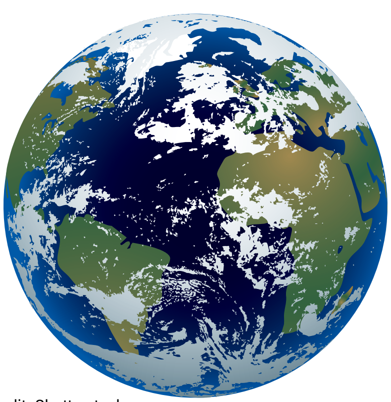
PART 2.

In episode 4, scientist Tom introduced technology that NOAA uses to study the Earth's atmosphere. He discussed satellites that monitor Earth from space, hurricane hunter aircraft that use dropsondes, the RAAVEN drone, and weather balloons that measure atmospheric properties. Two kinds of satellites allow scientists to collect data on atmospheric variables such as temperature and cloud formation. The information they provide allows scientists to track and understand weather patterns, as well as extreme weather events like hurricanes.



1. Geostationary satellites (GOES) orbit 22,236 miles above Earth's equator. Two of these GOES satellites provide imagery over North and South America as well as the Atlantic and Pacific oceans. During severe weather, geostationary satellites can be commanded to take images every 30 seconds to 1 minute. The image shows the two satellites hovering directly over North and South America.

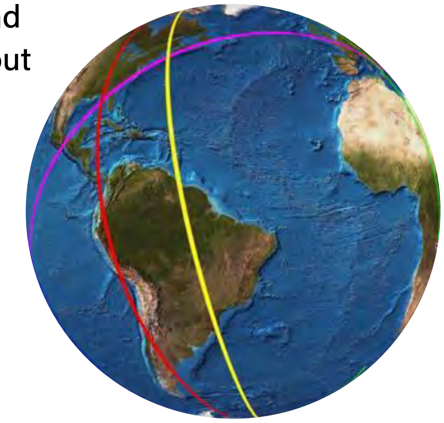
   Let's model the distance that geostationary satellites hold above Earth. This 2-inch image of the Earth represents our planet's 8,000-mile diameter. Each inch represents 4,000 miles. How many inches away would the geostationary satellites be? In the answer box, measure that distance away from the Earth and mark where the (tiny) satellite would be.

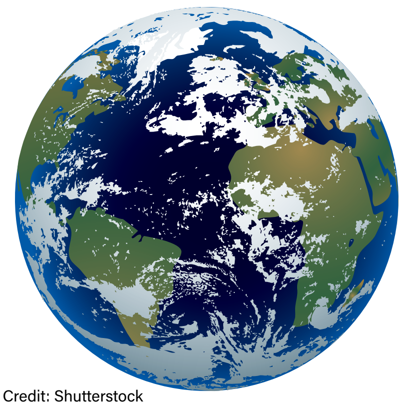


Credit: Shutterstock

2. Polar-orbiting satellites (POES) make orbits that circle the North and South Poles. They make nearly 14 polar orbits per day, traveling about 520 miles above the surface of the Earth. As the POES satellites circle the Earth, the planet rotates beneath them. This allows the satellites to see a different view with each orbit.

   If we use the same 2-inch Earth, calculate how far away a polar-orbiting satellite would orbit at 520 miles. Remember, each inch represents 4,000 miles. In the answer box, measure that distance away from the Earth and mark where the (tiny) satellite would be.

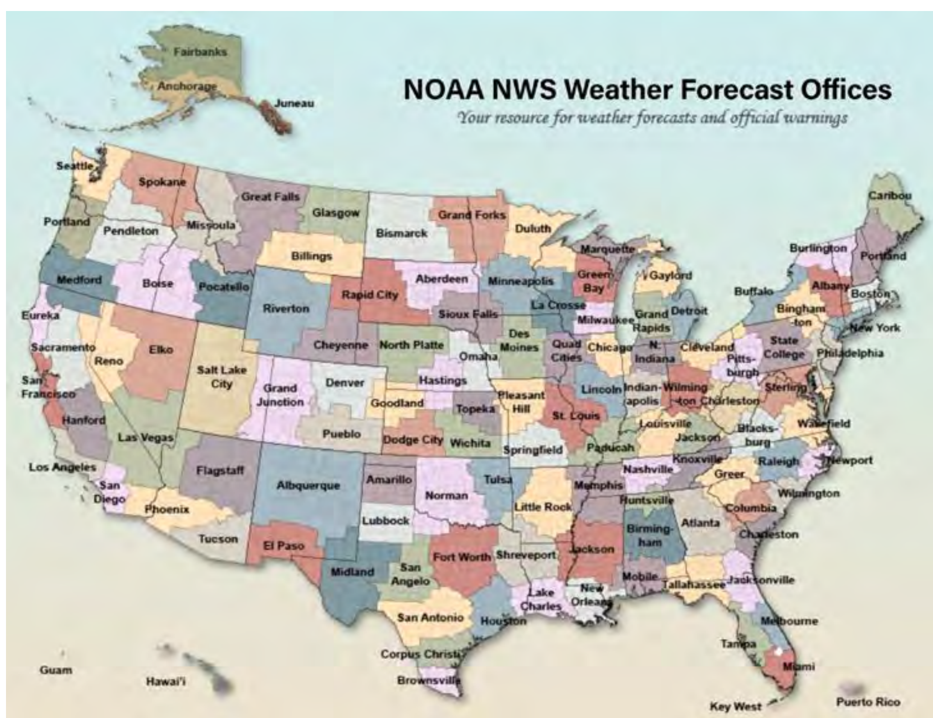




Credit: Shutterstock

3. There are 122 NOAA NWS forecast offices around the country. Local offices monitor local weather around the clock. They issue forecasts for their specific regions two to four times a day. They also provide information on hazardous weather that might impact their area. Local offices issue weather watches and/or warnings to alert people to any threats.

   Find the name of the NOAA NWS forecast office in your area.



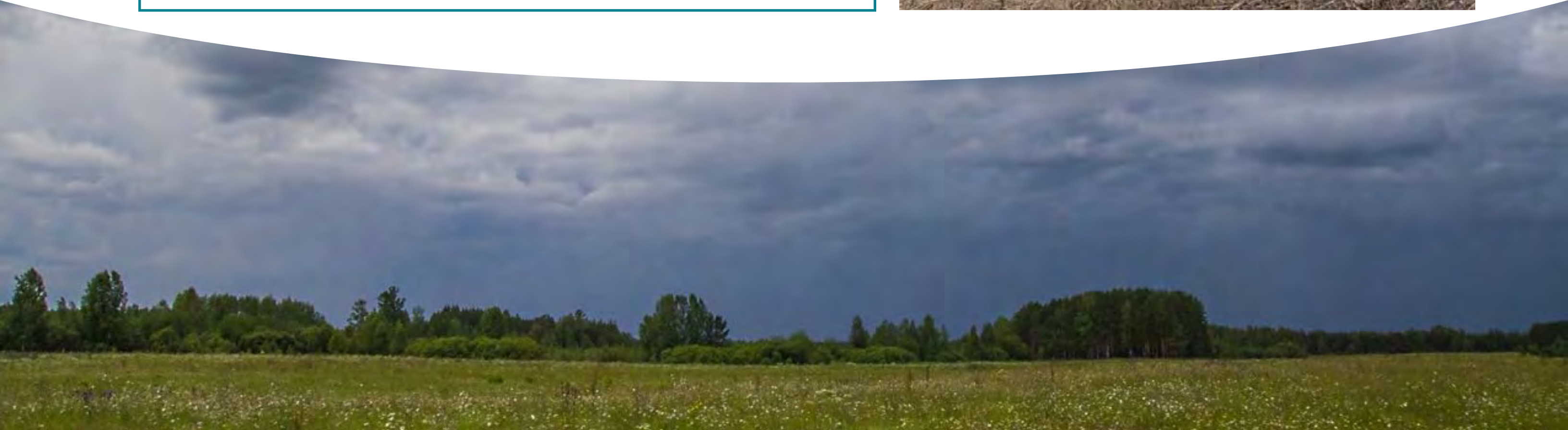
4. NOAA NWS regularly launches thousands of weather balloons from local offices to collect information that improves weather forecasts. These balloons carry instruments that measure temperature, air pressure, humidity, wind speed, and direction. A radio signal sends the data back to scientists on the ground. During its flight, a weather balloon can reach over 100,000 feet (19 miles) in altitude. Balloons rise about 4 meters per second (9 miles per hour). How long would it take a weather balloon to rise 19 miles?

A weather balloon is shown completely inflated, along with its parachute and the instrument package, known as a radiosonde.

5. If a weather balloon sends back two measurements of the atmosphere each second, calculate how many measurements it would collect from the time it's launched from the ground until it reaches an altitude of 19 miles.

6. The RAAVEN (**R**obust **A**utonomous **A**erial **V**ehicle-**E**ndurant and **N**imble) aircraft is launched from a catapult and has sensors installed to measure wind and turbulence in the local clouds. What is one advantage and one disadvantage of using drones like RAAVEN compared to larger aircraft or satellites for gathering data?

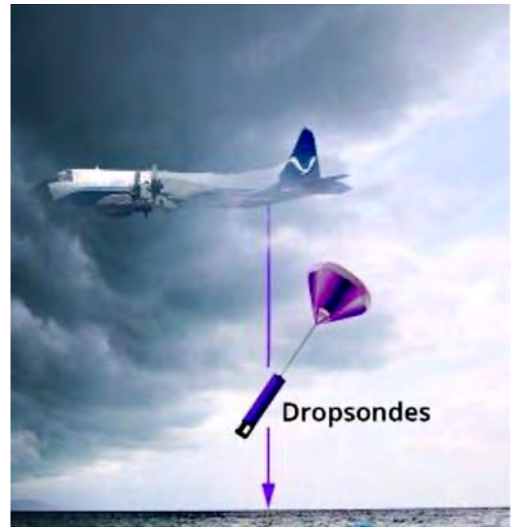
Credit: CIRES/NOAA



7. Hurricane Hunter aircraft fly into the world's worst weather. Data collected by these high-flying meteorological stations help forecasters make accurate predictions during a hurricane. They also help hurricane researchers develop a better understanding of storm processes to improve their forecast models.

   Watch the short video NOAA's Hurricane Hunters Fly Into the Eye of a Monster (https://oceantoday.noaa.gov/hurricanehunters/).

   What are the similarities and differences in the information provided by hurricane hunters compared to satellites, the RAAVEN, and weather balloons?



Fun Fact: NOAA has nicknamed their three hurricane hunter aircraft Miss Piggy, Kermit, and Gonzo, after the Muppets characters.

PART 3.

Hurricane!

You will be part of a team studying a weather disturbance in the Atlantic Ocean. You will work with that team to provide information using one of the technology tools that you've been learning about. The teams are:

- **NOAA Satellite team** – will report the location of the hurricane.
- **NOAA Hurricane Hunter team** – will report the top wind speeds of the hurricane.
- **NOAA National Weather Service office in Wilmington, North Carolina** – will report the wind speed and rainfall amounts.
- **NOAA National Weather Service National Hurricane Center team 1** – will issue hurricane watches and warnings.
- **NOAA National Weather Service National Hurricane Center team 2** – will issue storm surge and tornado watches and warnings.

The NOAA Hurricane Hunter team uses dropsondes during its flights to collect information from within the hurricane, such as the wind speed and the size of the eye. The eye is a circular area of fair weather found at the center of a severe tropical storm.

The NOAA Satellite team collects information from the GOES and POES satellites.

The NOAA National Weather Service local office sends weather balloons to collect localized data about the atmosphere. All of the information is fed to computers at NOAA's NWS National Hurricane Center.

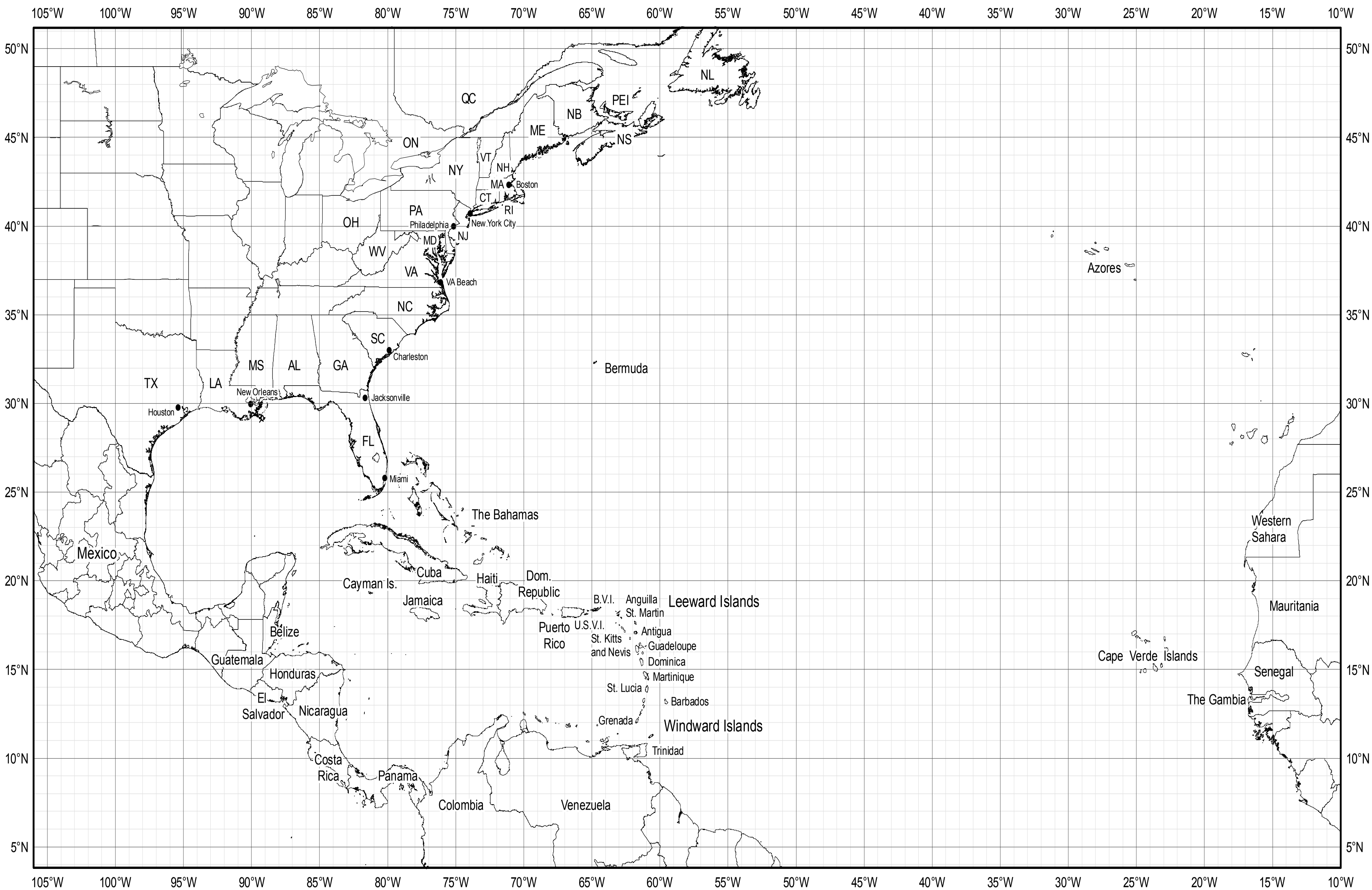
The NOAA National Hurricane Center issues watches and warnings to the places that need to know about approaching severe weather associated with hurricanes. They also predict the impacts of storm surge, rain, and wind. This simulation will help you see some of the work needed to warn people about the effects of an approaching hurricane.

Each team will be given information for six days of the simulation from September 9-14. Each team will share each day's information with the rest of the class. Everyone will record all of the information from each team so that you can help guide the emergency response needed to keep people safe. You should also map the location of the approaching storm on the Atlantic Hurricane Tracking Map.

Team	NOAA Satellite	NOAA Hurricane Hunter	NOAA NWS office Wilmington, NC	NOAA National Hurricane Center team 1	NOAA National Hurricane Center team 2
Date	Location	Hurricane wind speed; Size of the hurricane's eye or size of the whole hurricane	Wind speed on the ground; Precipitation	Tropical depression, tropical storm, or hurricane	Storm surge, anticipated rainfall, and wind warnings
Sept 9					
Sept 10					
Sept 11					
Sept 12					
Sept 13					
Sept 14					

Atlantic Basin Hurricane Tracking Chart

National Hurricane Center, Miami, Florida



Once the data has been collected from each team, work in your group to discuss and complete the table about emergency responses for each day.

Think about what actions should be taken by individuals or families to prepare for the storm and keep everyone safe. They may need fresh water and food for several days. They should be prepared to be without electricity. Safe places and shelters need to be identified for tornadoes.

What actions should local officials take to prepare hospitals and airports? Finally, consider who might help with repairs, restoring power, and helping clear the debris after the storm. Be prepared to share your advice with the class.

Date	Emergency Response and Preparation
September 9	
September 10	
September 11	
September 12	
September 13	
September 14	

PART 4.

Debrief Questions

1. Why is taking multiple measurements of the wind speed, precipitation in the clouds, storm direction, and other data important?

2. Why is coordination critical between the different data sources, such as hurricane hunters, satellite teams, local weather stations, and the National Hurricane Center?

3. Why is it important to inform the local population about the various effects of approaching severe weather?

PART 5.

Finally, think about how well your team did in the simulation and what you contributed to the group effort. Select the points in each category and record how you think you did. Select 0-3 points for each category and then total the points you think you earned.

CATEGORY	Exemplary	Proficient	Partially Proficient	Unsatisfactory	Points
Focus on the Task	**3 points**	**2 points**	**1 point**	**0 points**	
	Stayed on task all of the time without reminders.	Stayed on task most of the time. Group members can count on this person.	Stayed on task some of the time. Group members must sometimes remind this person to do the work.	Hardly ever stays on task. Will let others do the work.	
Work Habits	**3 points**	**2 points**	**1 point**	**0 points**	
	Completed assigned tasks and does not depend on others to do the work.	Completed most assigned tasks.	Does not follow through on most tasks and sometimes counts on others to do the work	Does not complete tasks. Depends on others to do all of the work.	
Listening, Questioning, and Discussing	**3 points**	**2 points**	**1 point**	**0 points**	
	Respectfully listens, discusses, asks questions, and helps the group.	Respectfully listens, discusses, and asks questions.	Has trouble listening with respect and does not take turns.	Does not listen with respect, argues with teammates, and does not consider other ideas.	
Information-Sharing	**3 points**	**2 points**	**1 point**	**0 points**	
	Gathered information and shared useful ideas.	Usually provided useful information and ideas for discussion.	Sometimes provided useful information and ideas for discussion.	Almost never provided useful information or ideas for discussion.	
Group/Partner Teamwork	**3 points**	**2 points**	**1 point**	**0 points**	
	All team members contributed equally.	Assisted group/ partner in the finished project.	Finished individual tasks but did not assist the group/ partner during the project.	Contributed little to the group effort during the project.	
				TOTAL POINTS	_____/15

Teek and Tom Episode 4

An Ocean of Data from Cool Technology!

LESSON 8

Planetary Toolbox: Eyes in the Ocean

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

In episode 4, scientist Tom introduced technology NOAA uses to study the ocean. He discussed satellites that monitor Earth from space, using sonar and wave gliders, as well as the remotely operated vehicle (ROV) *Deep Discoverer.*

Oceanographic tools such as buoys, gliders, and floats provide a variety of data, including air and water temperature, wave height, wind direction, and speed at and below the ocean surface. All of the data provided by these technologies are brought together in computer models to predict severe weather and to provide information for ocean shipping.

Hydrography is the science that deals with measuring and describing the physical features of bodies of water (AKA mapping the seafloor). Since the ocean floor is not visible to us, it can be difficult to map, so scientists must use sonar. Sonar stands for **So**und **Na**vigation and **R**anging. Active sonar systems emit a pulse of sound into the water, which bounces off the seafloor, creating an "echo." Seafloor depth is calculated based on the length of time between the sonar emitting a pulse of sound and how long it takes to receive its "echo." Contemporary seafloor mapping is often conducted using multibeam sonar systems on marine vessels. The data that a multibeam sonar provides allows scientists to collect a very detailed view of the ocean floor. Even with today's technology, only 26% of the ocean floor has been mapped with modern high-resolution technology.

The NOAA Ship *Okeanos Explorer* is the only federal vessel dedicated to exploring our largely unknown ocean. From this 224-foot-long ship, data are collected using a variety of advanced technologies to explore and characterize unknown or poorly known deepwater ocean areas, features, and phenomena at depths of 250 to 6,000 meters (820 to 19,700 feet). Most of the scientists participating in expeditions on *Okeanos Explorer* can remain on shore thanks to telepresence technology.

Since the ocean is not a convenient place to conduct research, scientists collect samples of water, sediment, flora, and fauna to study in laboratories aboard the ship or ashore. Scientists also create instruments and automated laboratories to operate autonomously on the seafloor or at different ocean depths. Water sampling at sea can be as simple as dropping a bucket over the side of a ship or as technical as sending large water bottles thousands of meters toward the seafloor on a wire. Electronic instruments called CTDs measure the water's conductivity, which reflects its salinity, and temperature at various depths as it descends through the water, taking continuous measurements.

Research vessels like the *Okeanos Explorer* also transport ROVs to study sites and provide staging, servicing, and monitoring platforms for them. ROVs can be lowered alone on a cable or in a protective vehicle. Cameras on the ROV serve as "eyes" for researchers, who receive video signals and control the vehicle via a fiber-optic cable. An ROV can explore, take photographs, collect samples, or handle instruments, operating around the clock for many consecutive days — something that scientists in a small research submersible just can't do.

The ROV *Deep Discoverer* carries no passengers and is connected to research vessels like the *Okeanos Explorer* via a long cable. It is remotely piloted by engineers on the ship and capable of diving to depths of 3.7 miles (6,000 meters). The *Deep Discoverer* can record high-definition video, collect biological, geological, and water samples, and measure physical characteristics of the ocean such as salinity, water temperature, depth, and dissolved oxygen. All of this information helps us better understand the deep ocean environment.

Live video from *Deep Discoverer* travels from the seafloor to the ship and then via satellite connection to scientists on shore who use the real-time video to guide the ROV's pilots on where to go and which samples to collect.

Lesson Summary

Students will investigate ocean exploration tools used to monitor the physical parameters of the ocean floor, water temperature and salinity, ocean currents, and biological components. They will compare the tools' weaknesses and strengths, then select tools to investigate a remote part of the ocean. Finally, they will select a tool that might be used to explore Saturn's moon, Titan.

Objectives

- Students will be able to identify several instruments that provide data about the ocean at its surface and at different depths.
- Students will be able to explain how sonar is used to map the ocean floor and find natural and man-made features.

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 4 of Teek and Tom, *"An Ocean of Data from Cool Technology!"*, 12:23 minutes (https://oceantoday.noaa.gov/teekandtom/episode-4.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

- 3-5-ETS1: Engineering Design. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- MS-ETS1-2: Engineering Design. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

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

- Students will need printouts of student record sheets, graphs, and/or maps to carry out the activities. Student record sheets are located at the end of this lesson.
- If you would like to provide the maps/graphics on a projection system, students will only need the student record sheets. Depending on the configuration of your classroom, we recommend one set per student or group.
- All maps/graphics 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-8.zip)

Preparation

No special preparation is needed for this lesson.

Earth Curiosities

A New Hawaiian Island?

Loihi is the newest member of the Hawaiian volcanoes. It is an undersea mountain rising more than 3000 meters above the floor of the Pacific Ocean. Both Loihi and Kilauea volcanoes sit near Mauna Loa volcano, an older, larger, and still active volcano on the Big Island of Hawaii. Loihi (in the red circle on the map) sits submerged in the Pacific off the southeastern coast of the Big Island of Hawaii. Don't plan on visiting soon. Loihi won't appear above the surface of the sea for tens of thousands of years.

Credit: Hawaii_Island_topographic_map en.svg: *Hawaii_Island_topographic_map-fr.svg: Sémhurderivative work: Kmusser (talk)derivative work: Kmusser (talk) - Hawaii_Island_topographic_map en.svg, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=6085217

InvesTeekation Pathway

ENGAGE

Part 1. Engage

This shipwreck mystery activity is based on real wrecks in Thunder Bay National Marine Sanctuary. The GPS location recorded for the mystery wreck is N45°14.058′ W83°16.707′ if you and your students would like to find the wreck on a chart. These coordinates are enunciated: 45 degrees 14.058 minutes north, by 83 degrees 16.707 minutes west. Here is a little more information about each potential shipwreck option. You can share this information after the students identify which ship they think Teek and Tom found.

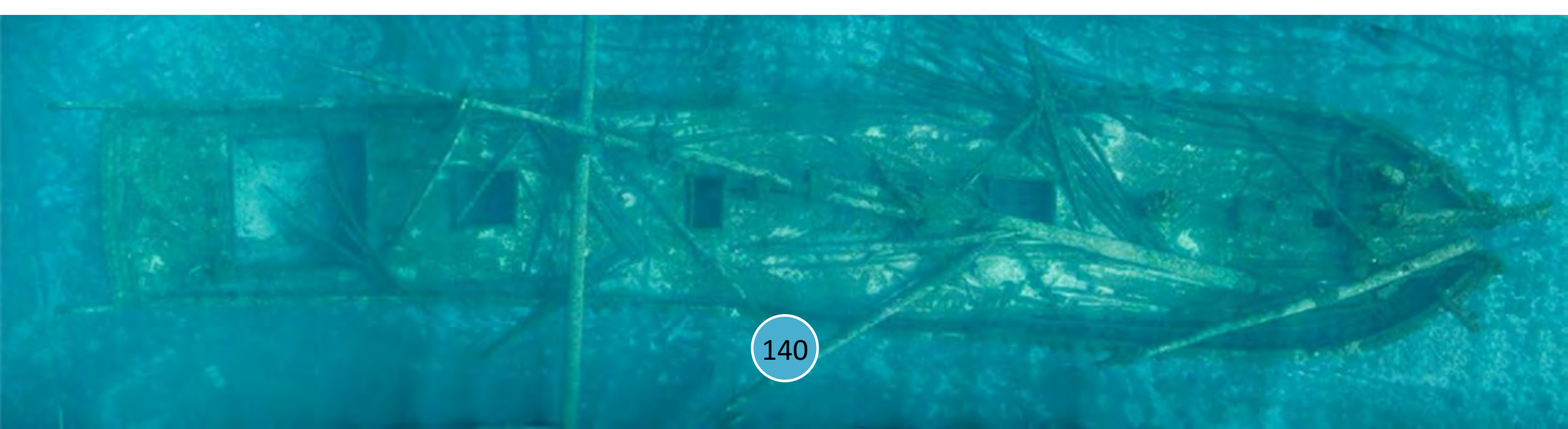
Maid of the Mist
This small schooner encountered a strong gale off Huron Beach while awaiting a load of cedar posts. The ship dragged anchor, grounded, and broke its keel.

John J. Audubon
On October 20, 1854, the *Audubon* sailed north for Chicago with a load of iron railroad tracks. At 1:30 a.m., the southbound *Defiance* emerged from the darkness and fog, striking *Audubon*'s midsection. The collision cut a hole deep in Audubon's hull, and she sank quickly. The crew survived.

Defiance
On October 20, 1854, *Audubon* and *Defiance* collided and fatally damaged both vessels. The *Defiance* sank a few miles away. The crew survived. *Defiance* and *Audubon* rest intact in more than 170 feet of water. Dr. Robert Ballard and Jean-Michel Cousteau have studied the pair of wrecks, helping to bring national attention to these underwater treasures.

Pewabic
The loss of the steamer *Pewabic* due to a collision with its sister ship *Meteor* resulted from bad decisions and not bad weather. A few miles south of Thunder Bay Island, *Pewabic*'s wheelsman suddenly turned his vessel into the path of the oncoming *Meteor,* cutting a huge gash into the side of *Pewabic*. Although Meteor rescued many of the estimated 150 passengers, at least 35 drowned in Thunder Bay's worst maritime disaster. Today, *Pewabic* is a gravesite and silent memorial to those who died in its sinking and salvage.

D.R. Hanna
This ship was carrying wheat from Duluth, Minnesota, to Buffalo, New York. The steamer *Quincy A. Shaw* collided with and sank the steel freighter. The *Hanna* rolled over and now rests upside down on the lake bottom. It is the largest wreck in Thunder Bay National Marine Sanctuary.

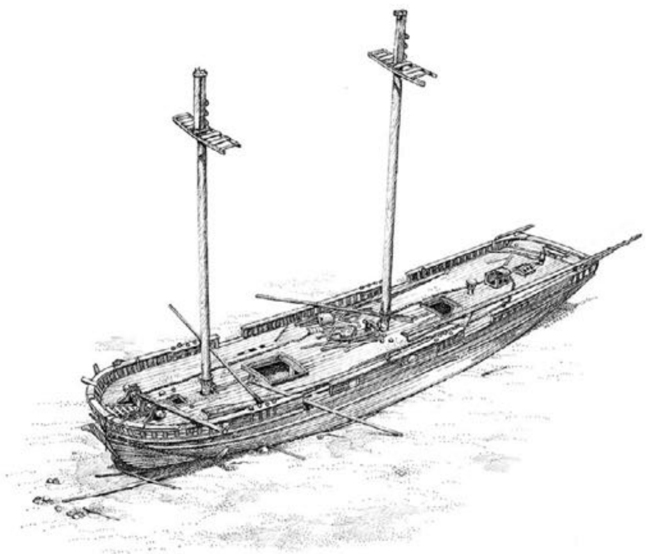


1. Which ship do you think Teek and Tom found?

   Defiance

2. What evidence leads you to think this is the correct ship?

   Maid of the Mist was too short. D.R. Hanna was made of metal and built in the 1900's. Of the wooden ships left, the Defiance was the only one with a cargo of grain that would "disappear" over time. The rail iron from John J. Audubon and the ore from the Pewabic would have been left behind for divers to find.



The Defiance

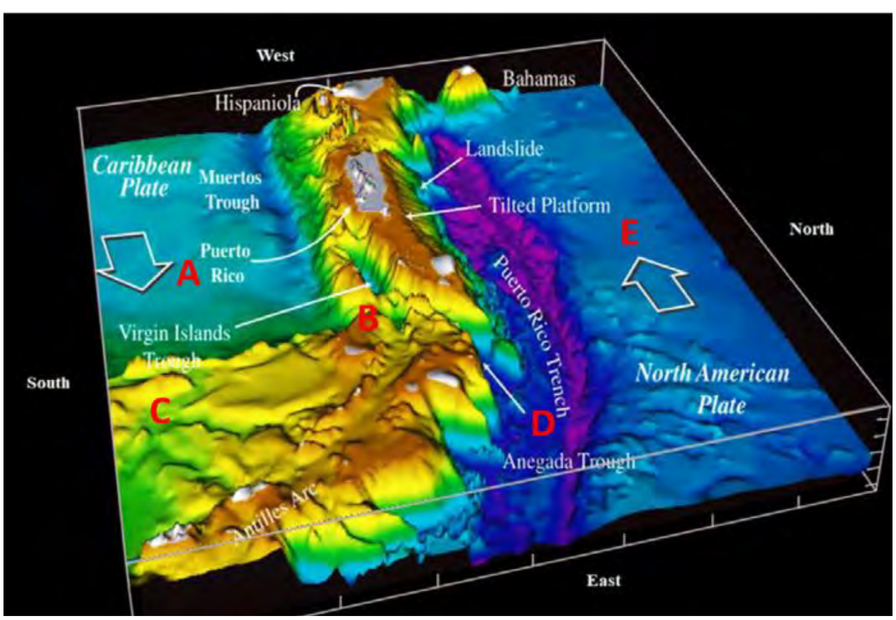
EXPLORE

Part 2. Explore

Students will examine several sonar images, looking for clues to identify each mystery.

1. *The images include a crane that fell to the ocean floor and a lost WWII B-25 Mitchell aircraft in New Guinea.*

2. The seafloor image that the students use is a color-shaded bathymetry map of the northeastern Caribbean. The white tips of the mountains show islands like Puerto Rico, the Virgin Islands, and the Bahamas. The features of this map are indicated below.



A. Island
B. Mountain range
C. Valley
D. Trench
E. Plain

3. What is the shallowest depth in this image? *0 meters (sea level or above)* What kind of feature does this represent? *Island*

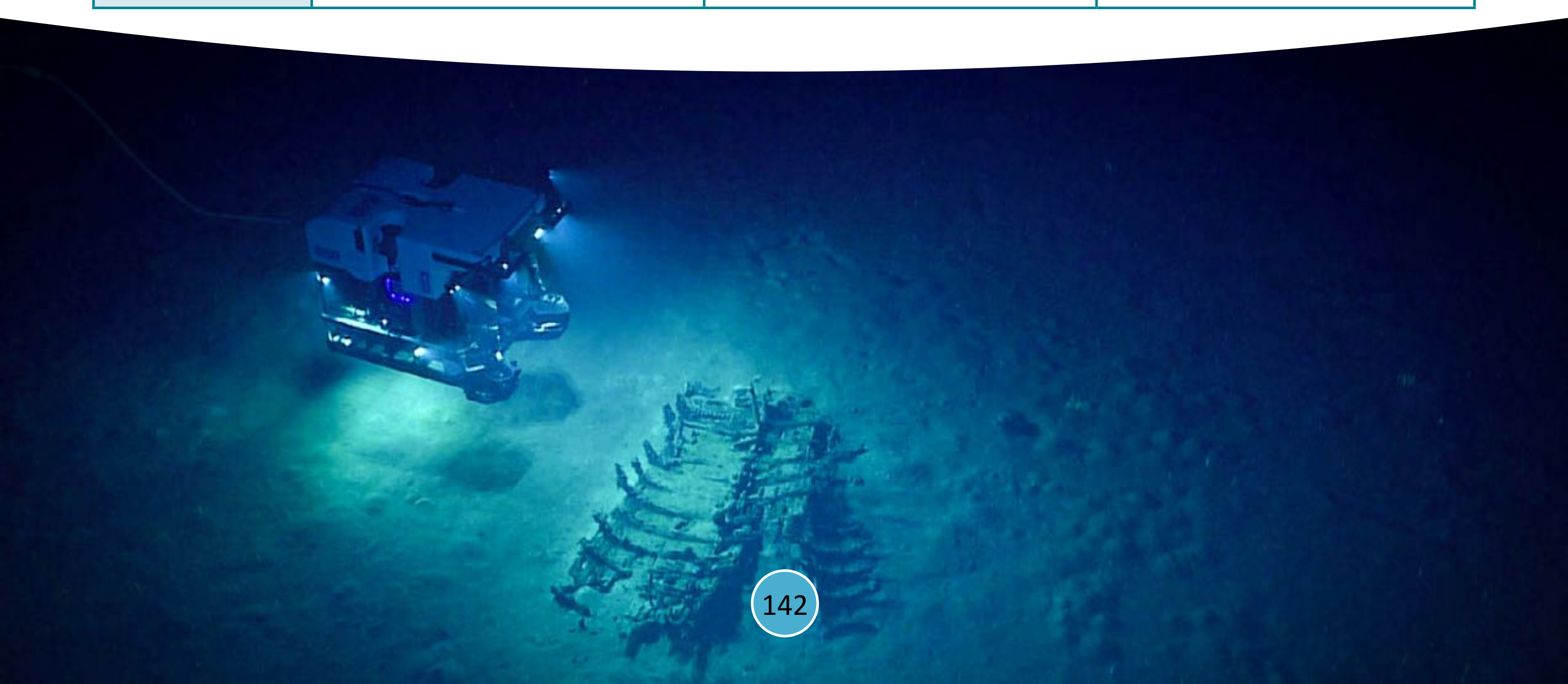
4. How deep does the trench go? *4400 meters*

EXPLAIN

Part 3. Explain

Many tools can be used to collect data about the ocean. Some tools can be operated remotely, some autonomously, and some require human interaction. Students may have some of these responses.

Exploration Tool	Type of data collected	Strength of this tool for collecting ocean data	Weakness of this tool for collecting ocean data
Sonar	*Depth and contours of the ocean bottom*	*Very detailed maps of the ocean floor and its features*	*Need a ship for this tool*
Ocean Glider	*Monitor temperature, currents, and other ocean conditions*	*Can collect data in remote locations safely and at relatively low cost*	*Cannot go very deep into the ocean , only 1,000 meters*
Ocean Drifter	*Sink to a particular depth and remain there collecting data about temperature and salinity*	*Low cost and can collect data down to 2,000 meters. Can be programmed*	*Cannot go very deep into the ocean*
Wave Glider Surfboard	*Ocean temperatures, currents, and salt content*	*Low-cost, autonomous robots that travel at the ocean surface*	*Only collects information at the surface*
Okeanos Explorer	*Sonar, CTD instruments that collect conductivity, temperature, and depth*	*Carries ROVs that can collect additional data. Can travel anywhere in the ocean*	*Ships require a crew and are costly*
ROV *Deep Discoverer*	*Can take high-definition video and has many tools to collect data*	*Can collect water and biological samples from very deep*	*Must be launched from a ship*



ELABORATE

Part 4. Elaborate

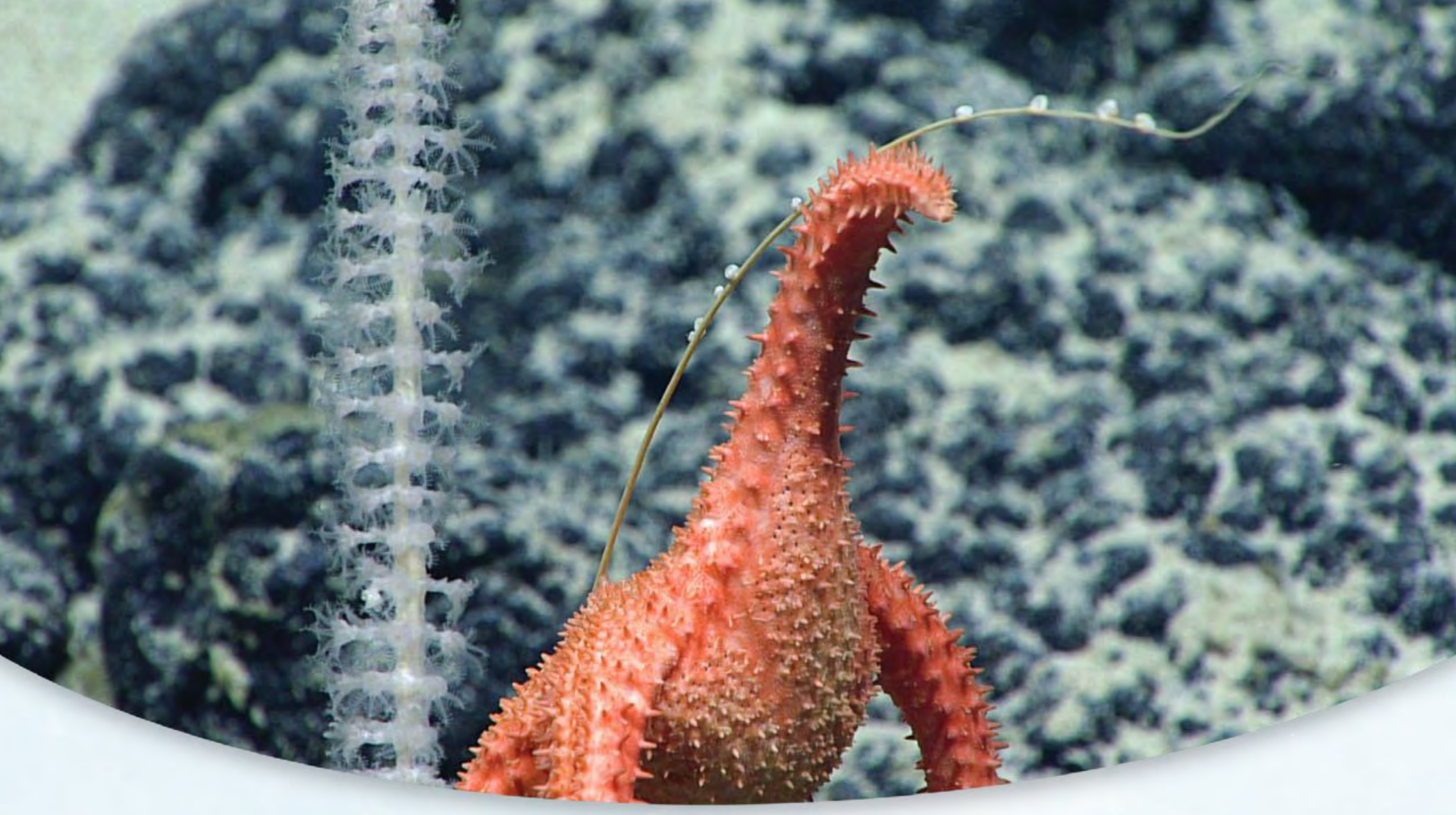
The description of the remote ocean in this activity is actually in the Pacific Remote Islands Marine National Monument. This area of 495,189 square miles (1,282,534 square kilometers) is in the central Pacific Ocean and has seven islands and atolls: Baker, Howland, and Jarvis Island; Johnston, Wake, and Palmyra Atoll; and Kingman Reef. You might recall some of these names from World War II history. It is one of the most pristine tropical marine environments in the world. Forty-five coral species and large populations of seabirds, sea turtles, whales, and reef sharks are found here as well. Many nationally and internationally threatened, endangered, and depleted species thrive at Palmyra and Kingman, including sea turtles, pearl oysters, giant clams, reef sharks, coconut crabs, fishes, and dolphins. Both Palmyra Atoll and Kingman Reef support higher levels of coral diversity (180–190 species) than any other atoll or reef island in the central Pacific. Students may record responses similar to the ones below about the exploration tasks in this remote part of the ocean.

Task	Tool	Why did you choose this tool?
Investigate the ocean currents around the surface of the islands	*Wave glider or drifter*	*Both of these float and record data about the currents*
Map the geologic features of the deep ocean floor	*Sonar on the Okeanos Explorer*	*Sonar can map the ocean floor but is done on a ship*
Record water temperatures from the surface to the ocean floor	*Ocean glider, drifter, or CTD on the Okeanos Explorer*	*All of these tools can be programmed to record temperatures at different depths and send the data back*
Identify and sample the creatures of the deep ocean	*ROV Deep Discoverer*	*The ROV has 2 manipulator arms for collecting samples.*

EVALUATE

Part 5. Evaluate

Saturn's largest moon, Titan, is bigger than Earth's moon and even larger than the planet Mercury. Titan has a dense atmosphere, and it's the only world besides Earth with standing bodies of liquid, including rivers, lakes, and seas, on its surface. Like Earth, Titan's atmosphere is primarily nitrogen. Liquids rain down from clouds, flow across its surface, fill lakes and seas, and then evaporate back into the sky, similar to Earth's water cycle. Scientists also think that Titan has an ocean of water. So far, we have only been able to look at Titan from the atmosphere. Students should consider what they have learned about tools for ocean exploration and design a probe that might be useful to collect data on a remote place like Titan. They are asked to write a description and then draw a diagram of the instrument that could be used to explore Titan.



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.

Extensions

A number of locations, technologies, and information are noted in this lesson. Some links to explore this content in greater depth are located below.

Thunder Bay National Marine Sanctuary (https://thunderbay.noaa.gov/)

2017 Laulima O Ka Moana: Exploring Deep Monument Waters Around Johnston Atoll (https://oceanexplorer.noaa.gov/okeanos/explorations/ex1706/dailyupdates/dailyupdates.html#cbpi=july25.html). Scroll down the page and view the video: "July 27, 2017: Dive 11."

ROV Deep Discoverer: Voyage to the Ridge 2022 (https://oceanexplorer.noaa.gov/okeanos/explorations/22voyage-to-the-ridge/welcome.html).

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

- Ocean Time Capsules (https://oceantoday.noaa.gov/oceantimecapsules/)
- Explore with Us (https://oceantoday.noaa.gov/explorewithus/)
- Ocean as a Lab: ROVs (https://oceantoday.noaa.gov/oceanasalab_rovs/)
- Ocean Science Robots (https://oceantoday.noaa.gov/oceanrobots/)
- Mission: Exploration (https://oceantoday.noaa.gov/missionexploration/)

Student Record Sheets

PART 1. It's a Mystery Shipwreck!

While Teek and Tom were exploring the Great Lakes in the spaceship *BARY*, they found a shipwreck in 185 feet of water in Lake Huron.

There are some clues about the ship from the site.

- The ship was over 100 feet long.
- It was constructed out of wood.
- The ship was built in the mid-1800s.
- The cargo disappeared quickly because no trace was left.

Good records exist for the shipwrecks in Lake Huron. Teek did some research and identified five ships that are believed to have sunk near this area. Take a look at the clues and decide which of these shipwrecks might be the mystery ship that Teek and Tom found.

Ship Name	Vessel Type	Construction Information	Cargo	Length
Maid of the Mist	Sail: wooden two-masted schooner	Launched in 1863	Cedar posts	90 feet
John J. Audubon	Sail: wooden two-masted schooner	Launched in 1854	Rail iron	148 feet
Defiance	Sail: wooden two-masted schooner	Launched in 1848	Grain	115 feet
Pewabic	Wooden passenger and freight steamship	Launched in 1863	Copper and iron ore; passengers	200 feet
D.R. Hanna	Steel freighter	Launched in 1906	Grain	532 feet

1. Which ship do you think Teek and Tom found?

2. What evidence leads you to think this is the correct ship?

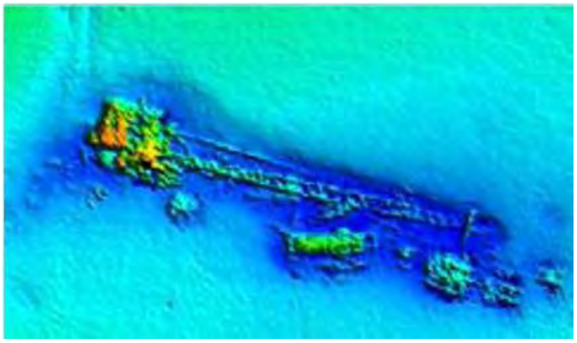
PART 2.

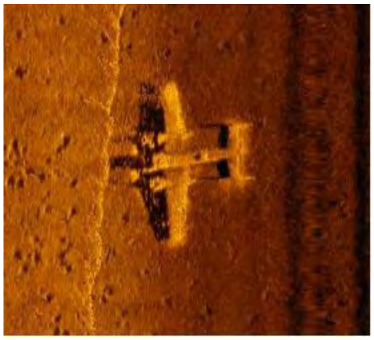
The image that Teek and Tom took of the mystery shipwreck was a sonar image. In episode 4, scientist Tom introduced technology like sonar that NOAA uses to study Earth's ocean. Sonar is short for Sound Navigation and Ranging.


Illustration courtesy of NOAA Ocean Exploration.

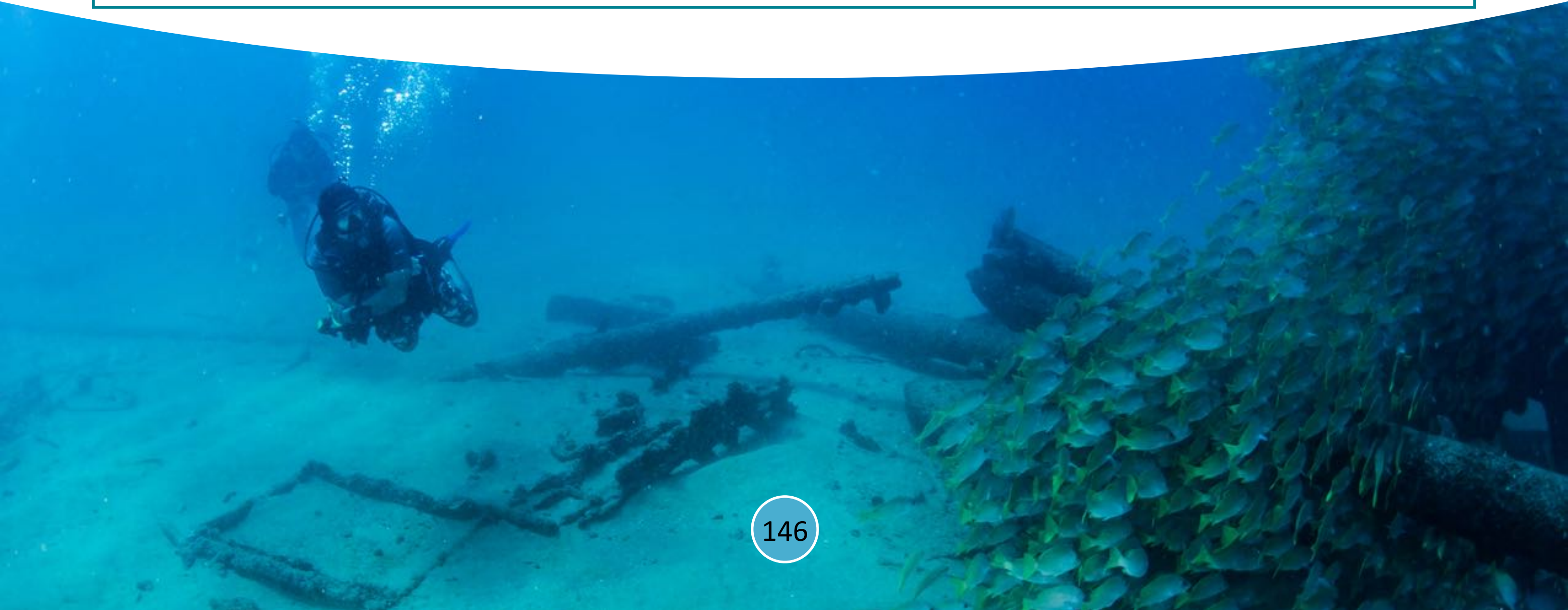
Sonar systems emit a pulse of sound into the water, which bounces off the seafloor, creating an "echo." Seafloor depth is calculated based on the length of time between the sonar emitting a pulse of sound and how long it takes for it to receive its echo.

Sometimes, when the seafloor is being mapped, other objects are found. Here are a couple of items found using sonar.

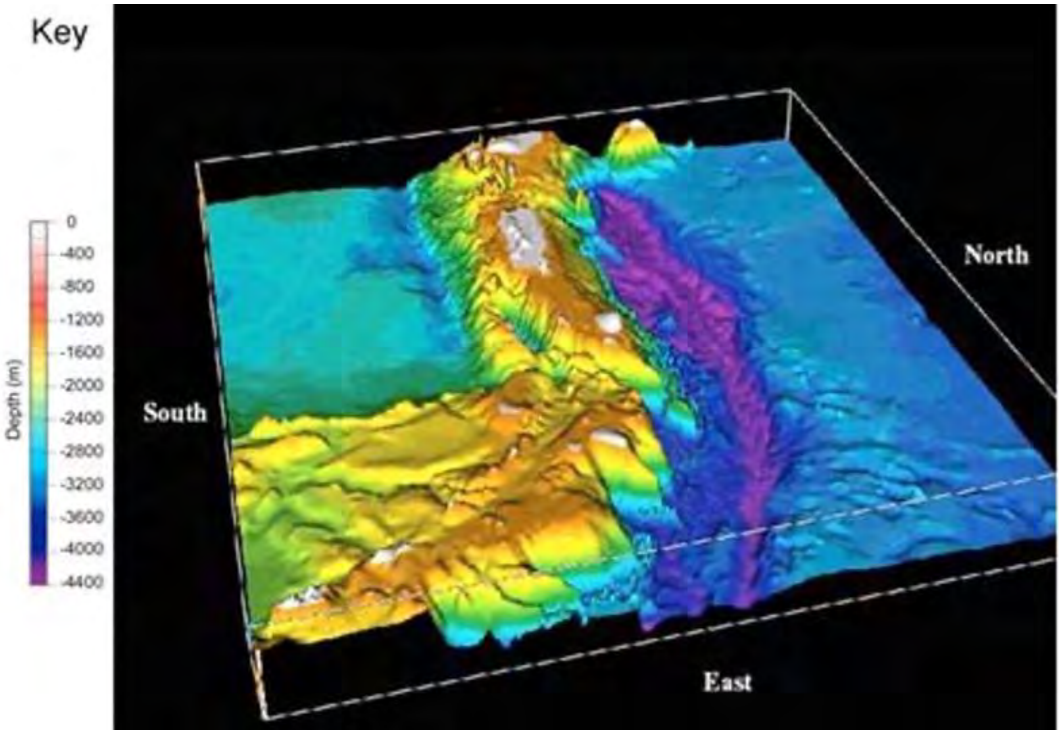

Mystery object #1


Mystery object #2

1. Discuss with a partner what you think these objects are. What evidence supports your ideas?



2. The seafloor contains many physical features like mountains, valleys, trenches, and plains. The use of sonar can map these features. Take a look at this seafloor image in the Caribbean region of the Atlantic, and identify an island, a mountain range, a valley, a trench, and a plain. Draw a line to the feature on the map from the list on the right.



A. Island

B. Mountain range

C. Valley

D. Trench

E. Plain

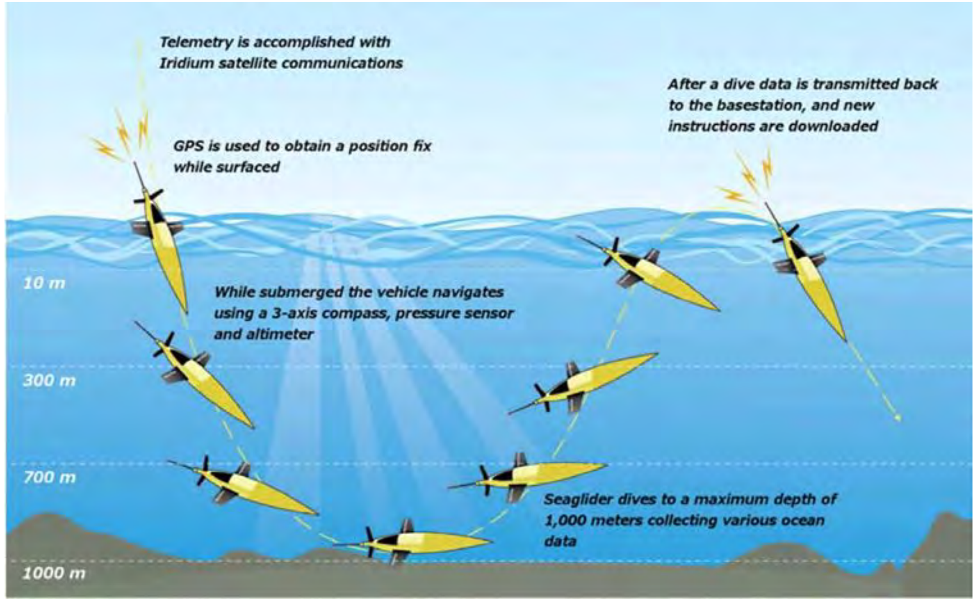
3. What is the shallowest depth in this image? What kind of feature does this represent?

4. How deep does the trench go?

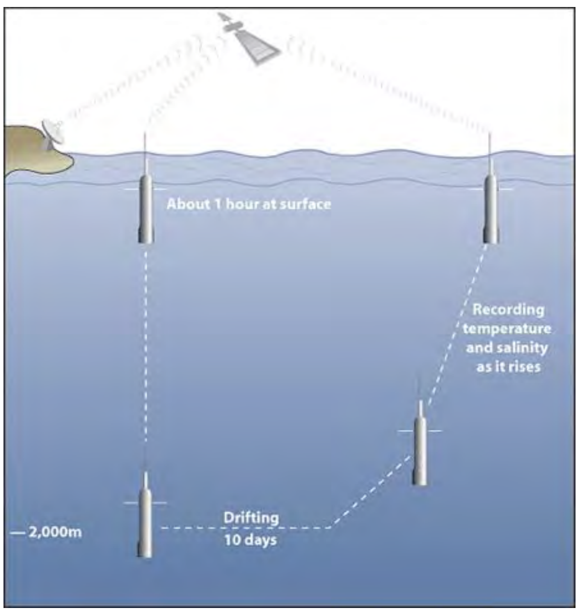
Credit: Shutterstock

PART 3.

Sonar has been used for many years to map the ocean floor, but there are other tools that Teek and Tom discussed in episode 4 that can help explore the ocean. One example is an **ocean glider** that does not need human assistance while traveling. These little robots can collect data in remote locations safely and at a relatively low cost. Glider sensors can monitor temperature, currents, and other ocean conditions.



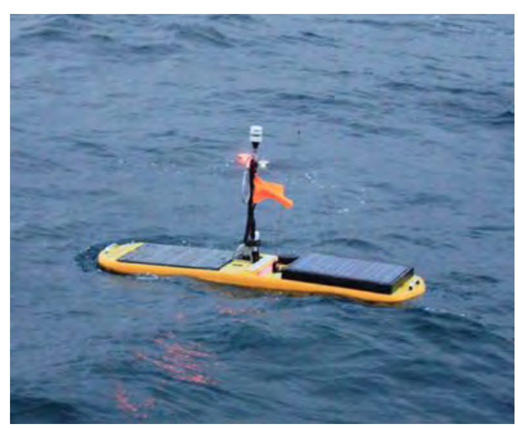
Ocean Glider



Ocean Drifter

Ocean drifters are programmed to sink to a particular depth and remain there for a specific period of time. At that depth, which scientists call a "parking depth," the profiling float drifts with the currents, collecting data it sends back to the scientists via satellite when it returns to the ocean's surface.

Wave gliders are small autonomous robot surfboards that travel at the ocean surface through wave energy, collecting ocean temperatures, currents, and salt content. Solar panels on top of the gliders power the sensors, which transmit the data back to satellites.

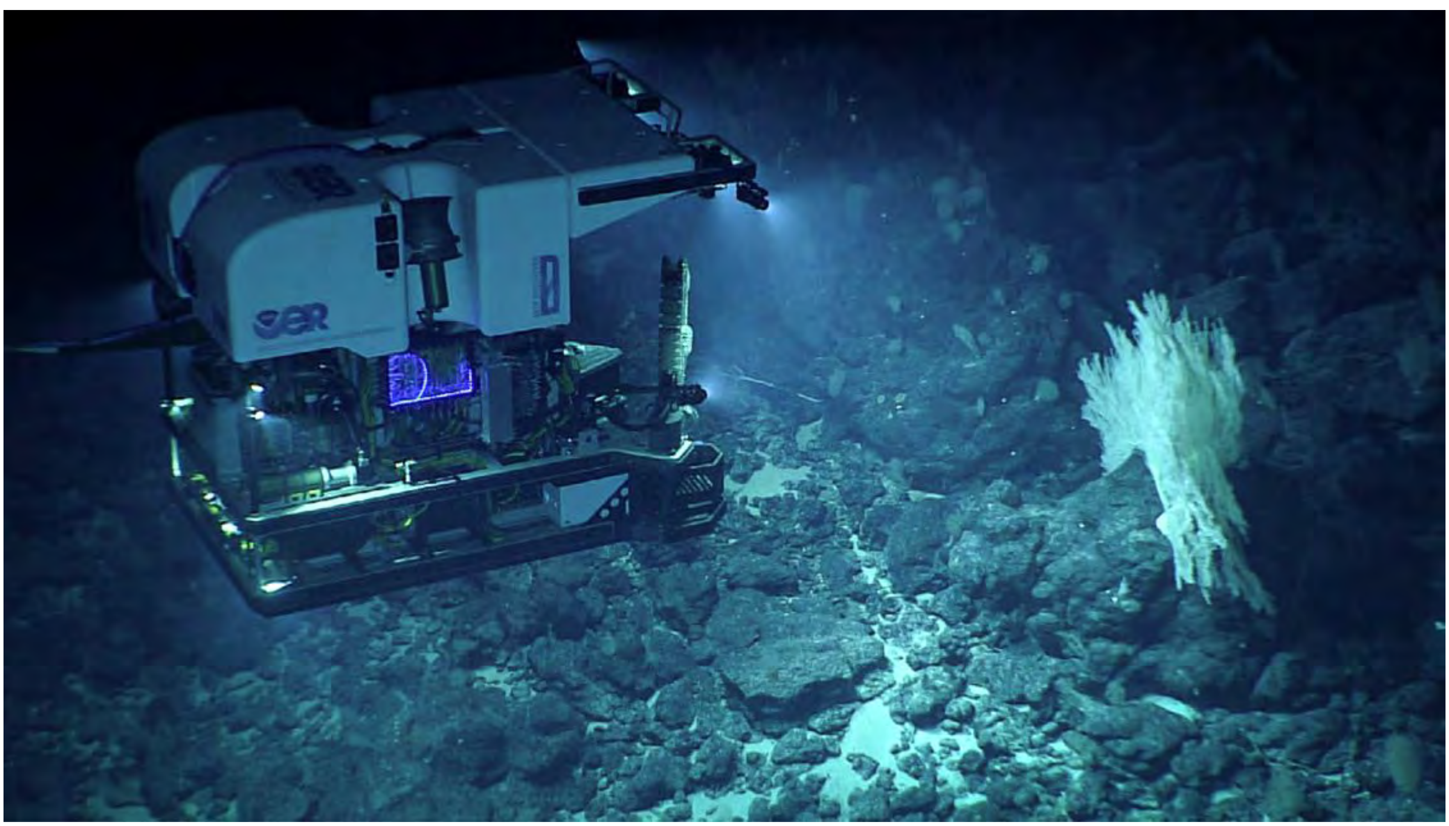

Wave glider surfboard

Okeanos Explorer

CTD instrument

The NOAA Ship ***Okeanos Explorer*** is equipped with mapping sonars and CTDs, which measure conductivity, temperature, and depth. This equipment is put into the water from the ship to measure the chemical and physical properties of the water at many depths.

The ***Okeanos Explorer*** also carries a remotely operated vehicle (ROV), the ***Deep Discoverer,*** capable of diving to depths of 3.7 miles. It cannot carry people, but it can capture high-definition video. It also has many tools to collect samples to help us better understand the deep-ocean environment. It is equipped with two manipulator arms and bottles for water collection, as well as sampler jars for collecting delicate biological samples.



ROV *Deep Discoverer*

Complete the chart below about some of the tools used for ocean exploration.

Exploration Tool	Type of data collected	Strength of this tool for collecting ocean data	Weakness of this tool for collecting ocean data
Sonar			
Ocean Glider			
Ocean Drifter			
Wave Glider Surfboard			
Okeanos Explorer			
ROV *Deep Discoverer*			

PART 4.

We have only mapped 26% of the ocean floor and explored 5% of the world's ocean. That means that **95%** of our ocean is unexplored. Teek would like to use some of NOAA's exploration tools to investigate a new area he and Tom discovered in a remote place on Earth. You and a small team will develop a plan to study this part of the ocean using some of the tools you have learned about in this lesson. Here is a description of the area that was found.

This remote part of the Pacific Ocean has several islands surrounded by shallow coral reefs. The islands are old volcanoes that drop off sharply to the deep floor of the Pacific Ocean. The coral reefs and ocean floor are home to a wide variety of animal and plant life.

Record the tools for ocean exploration that you suggest Teek and Tom might use to complete some tasks in this remote part of the ocean.

Task	Tool	
Investigate the ocean currents around the surface of the islands		
Map the geologic features of the deep ocean floor		
Record water temperatures from the surface to the ocean floor		
Identify and sample the creatures of the deep ocean		

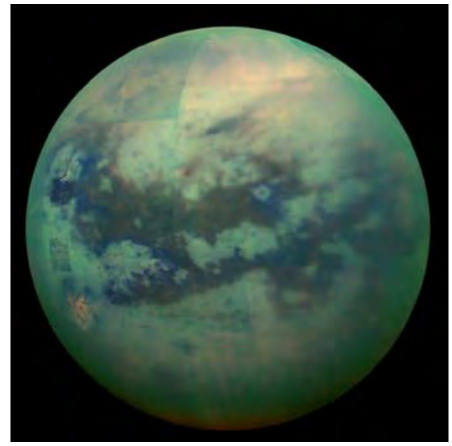
Credit: Shutterstock

PART 5.

Titan is a moon of Saturn that has an ocean of water. So far, we have only been able to look at Titan from the atmosphere as spacecraft fly by. In the future, spacecraft will be sent to land on Titan to take a closer look at its surface and ocean.

This image shows an infrared view of Titan from NASA's Cassini spacecraft. It was taken during Cassini's flyby on November 13, 2015.

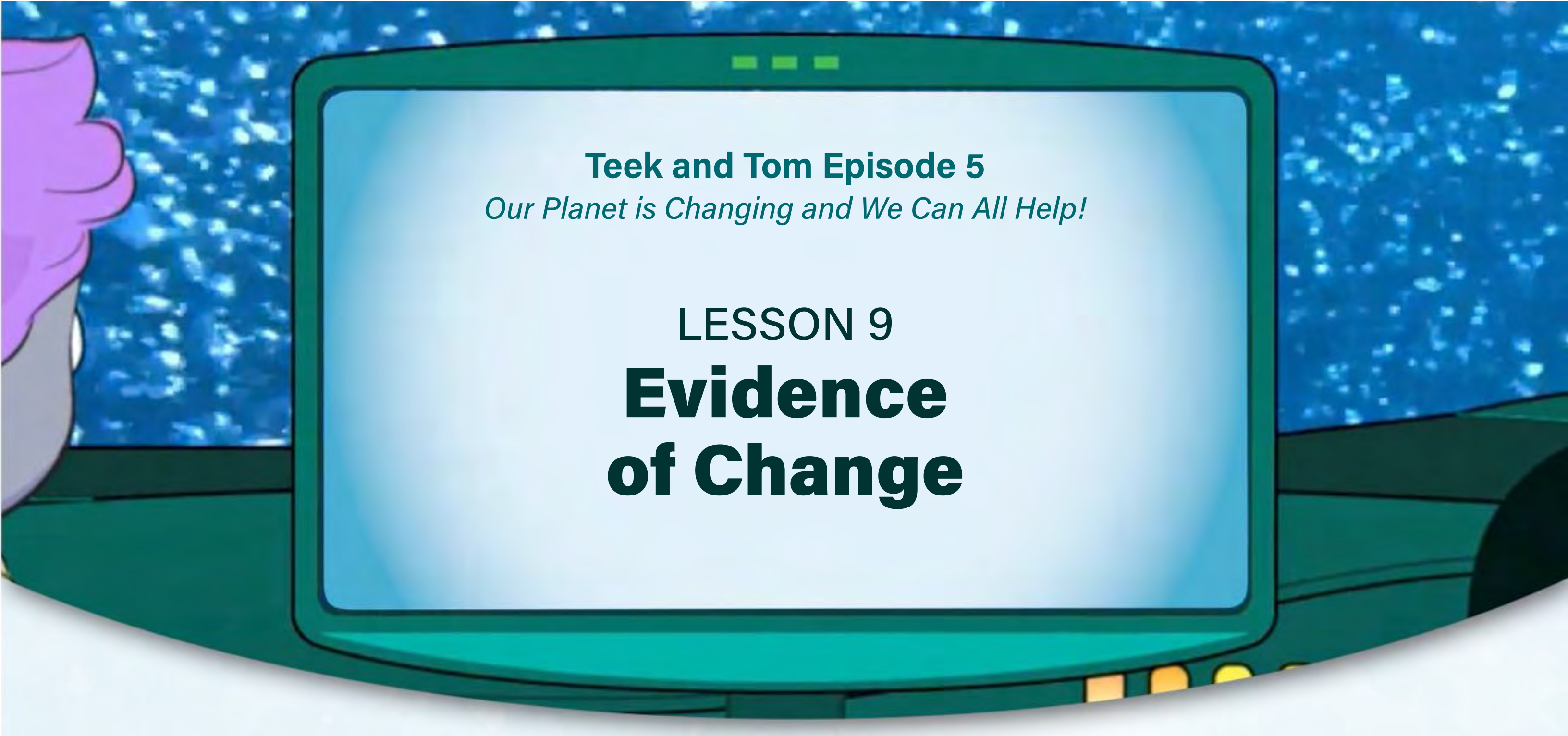
Consider what you have learned about tools for ocean exploration and design a probe that might be useful to collect data on a remote place like Titan.



Credit: NASA. A composite image of Saturn's moon Titan taken by the Cassini spacecraft.

Write a description of your probe and explain why you chose this type of instrument.

Now, draw a diagram of your probe. Be sure to label the instruments that will collect data.



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

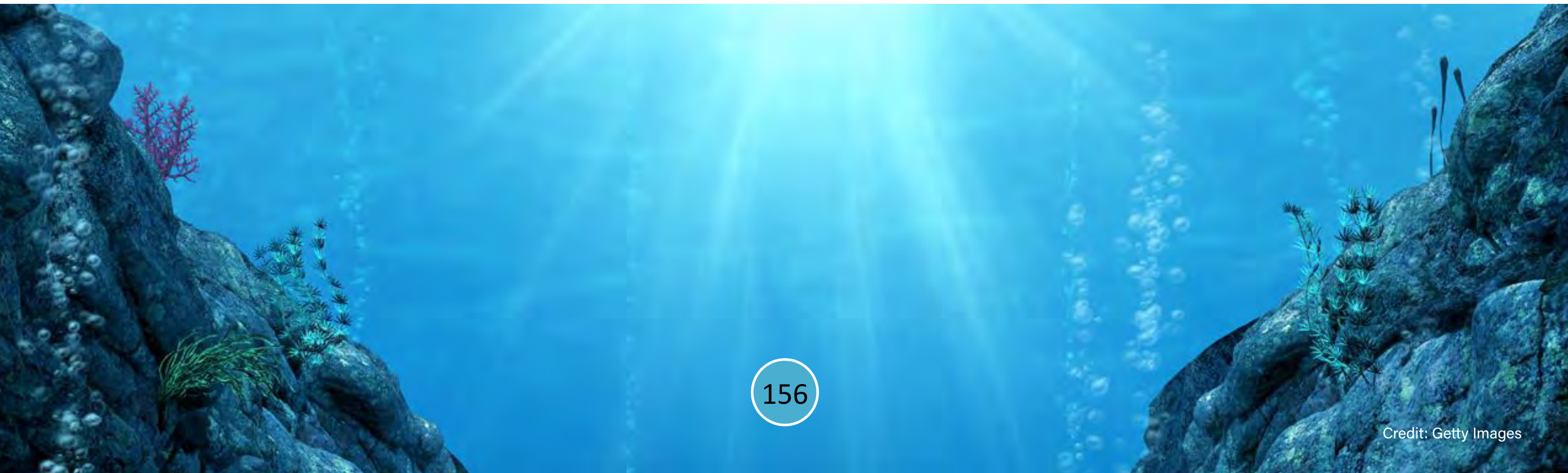
Part 2. Explore

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."*



Credit: Getty Images

EXPLAIN

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:

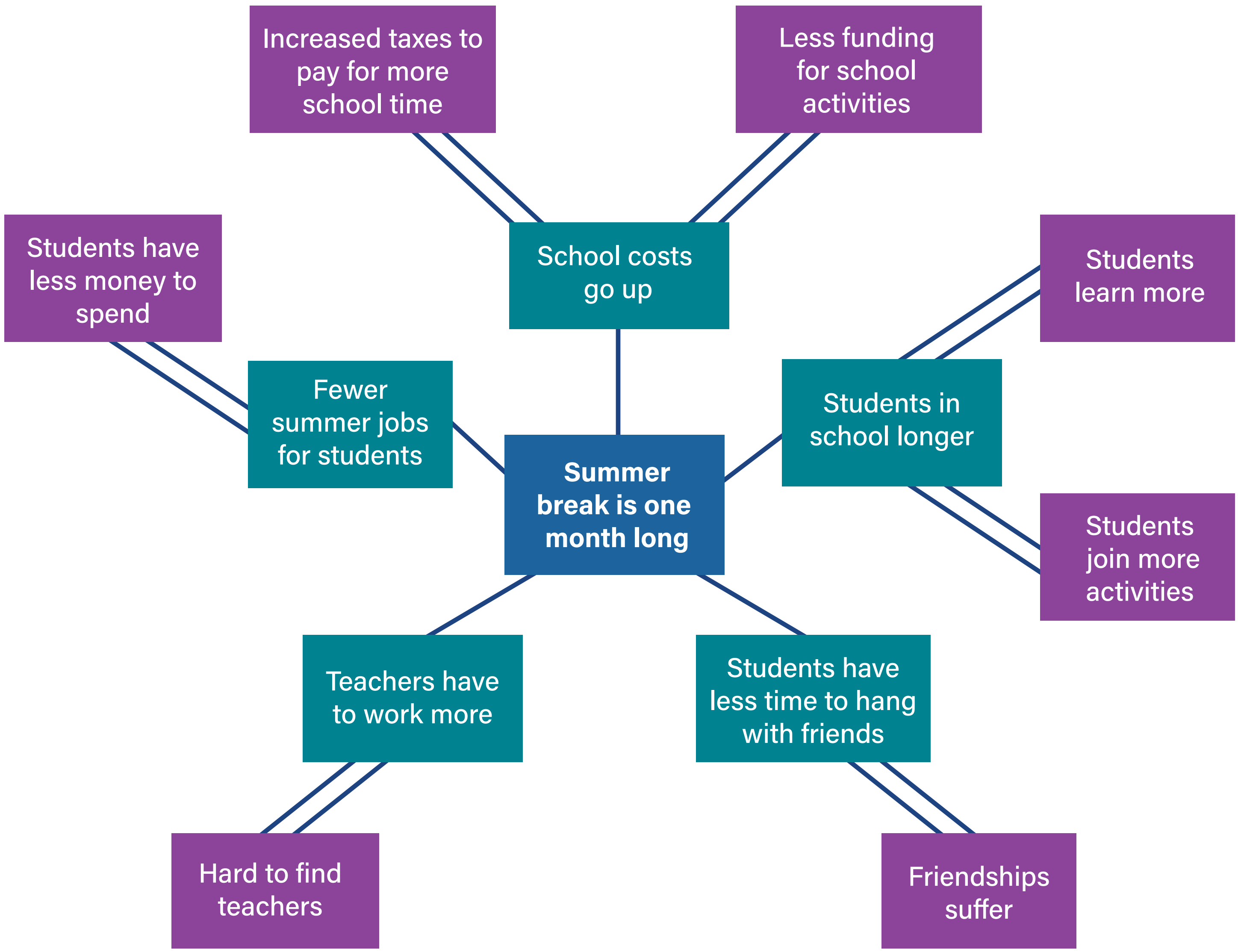
   - Prevailing winds move air masses and moisture from the ocean or Great Lakes. The warmer the water, the more moisture is in the air, which could mean wetter and stronger hurricanes and rainstorms. Hurricanes are expected to cause more intense rainfall, coastal floods, and higher storm surge caused by 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?

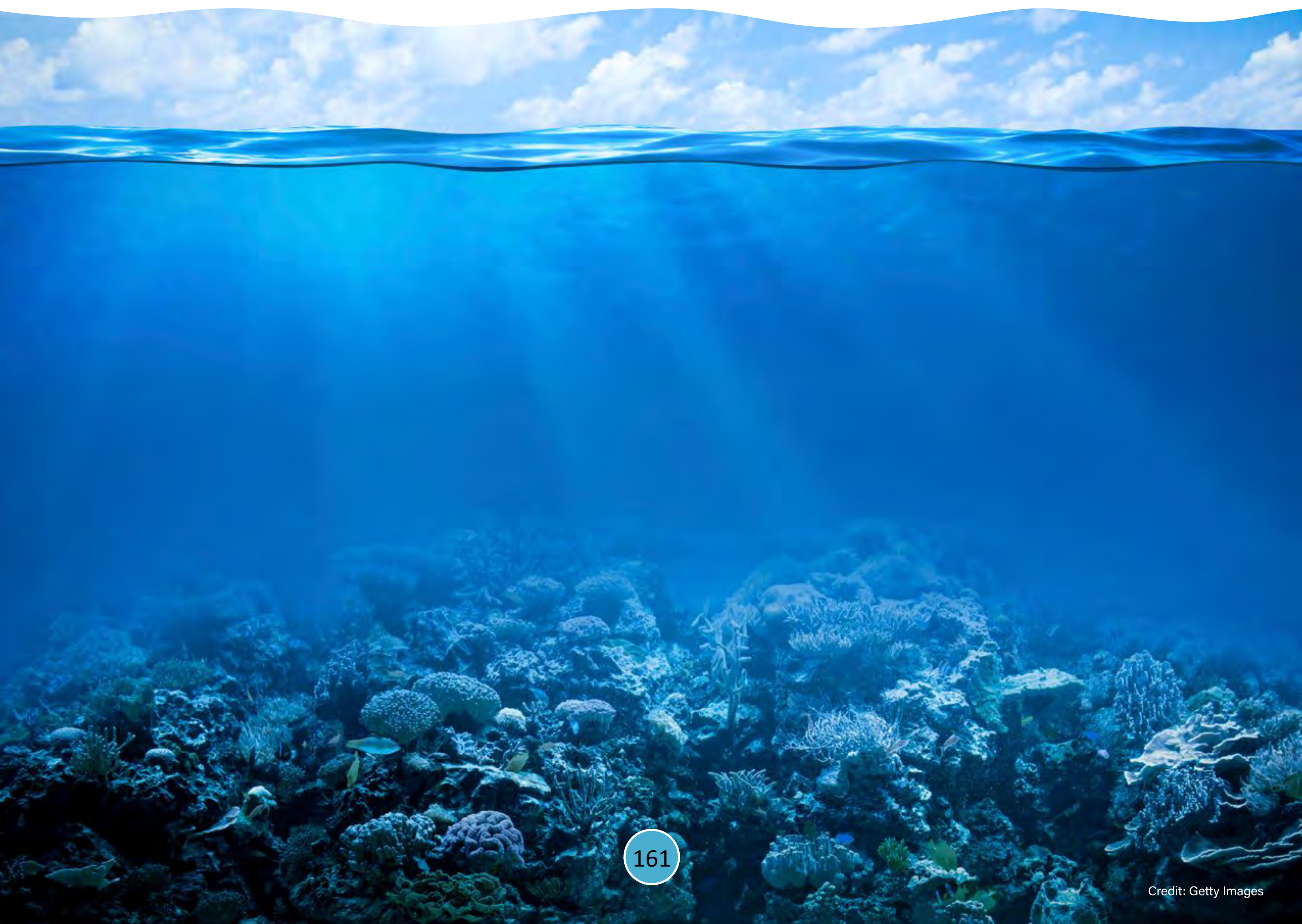
   Answers will vary, but students should be able to identify that they might be affected by more severe storms, heat waves, coastal flooding, or drought.

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: Getty Images

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.

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).

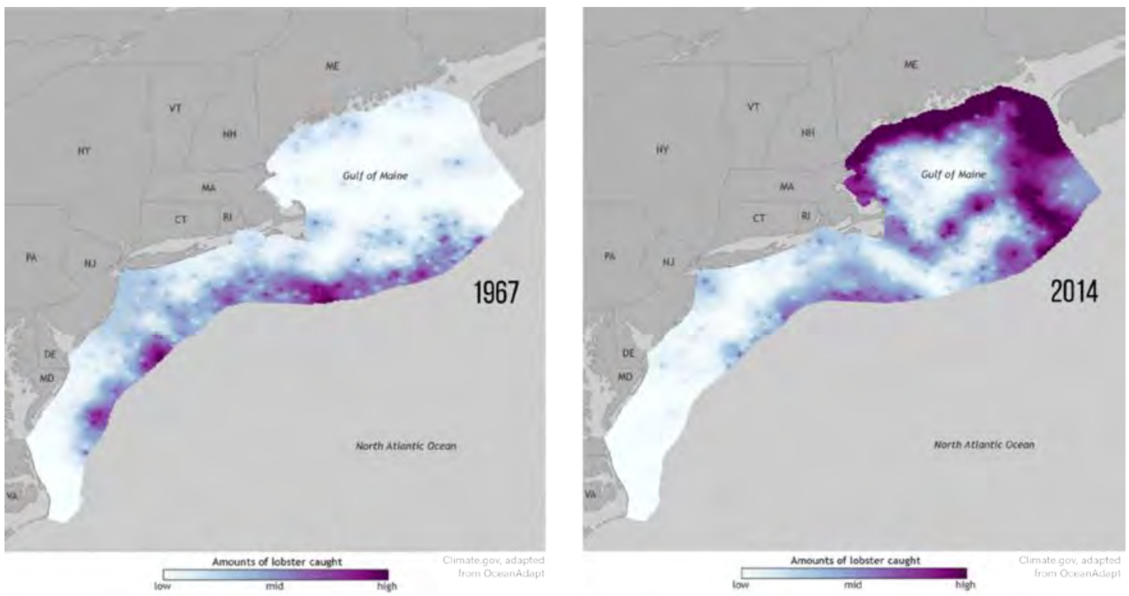
These Ocean Today Videos will be helpful for student understanding during discussions about their ideas.

- 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?

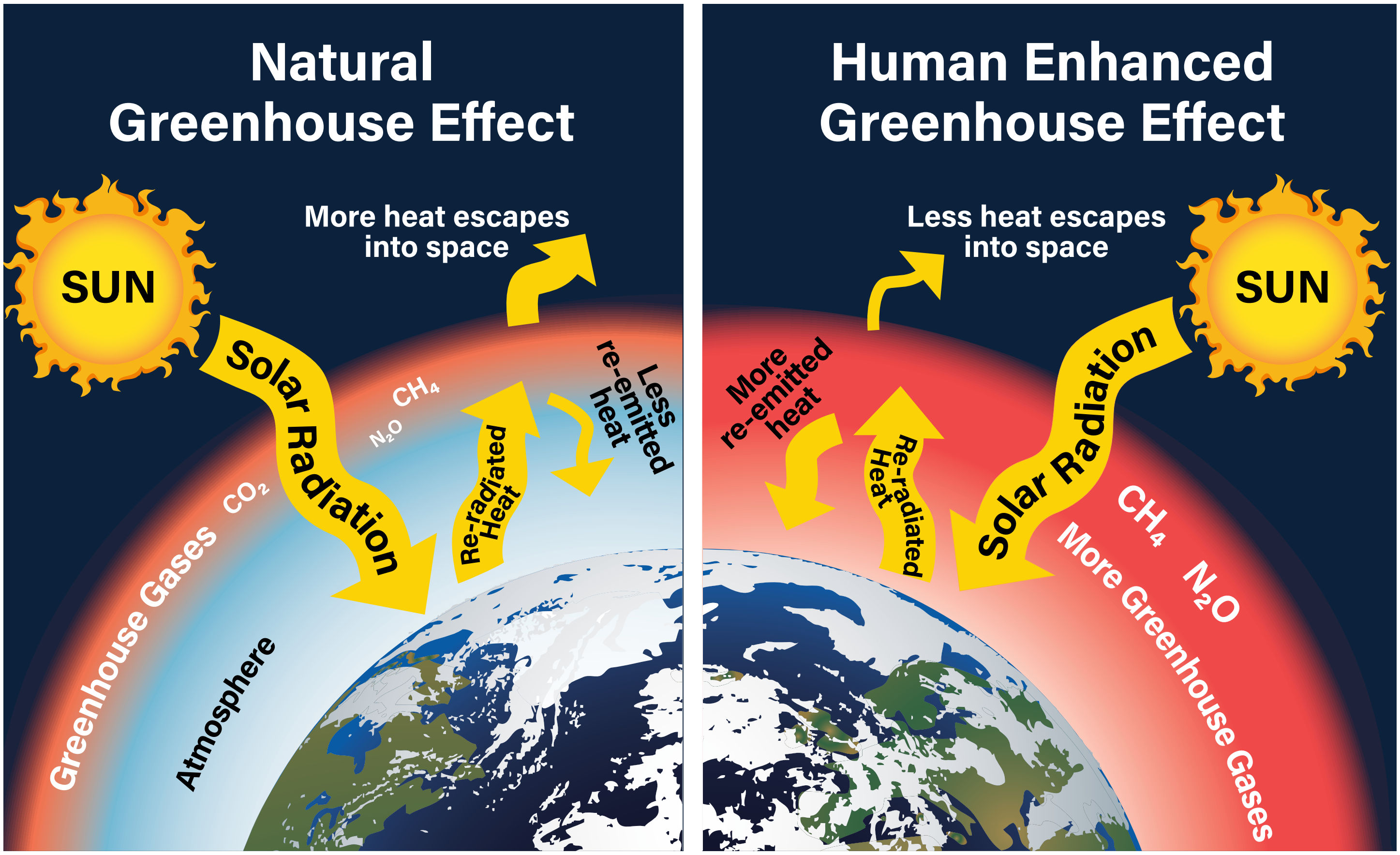
2. Where do you think the highest number of lobsters will be found in another 50 years?

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.



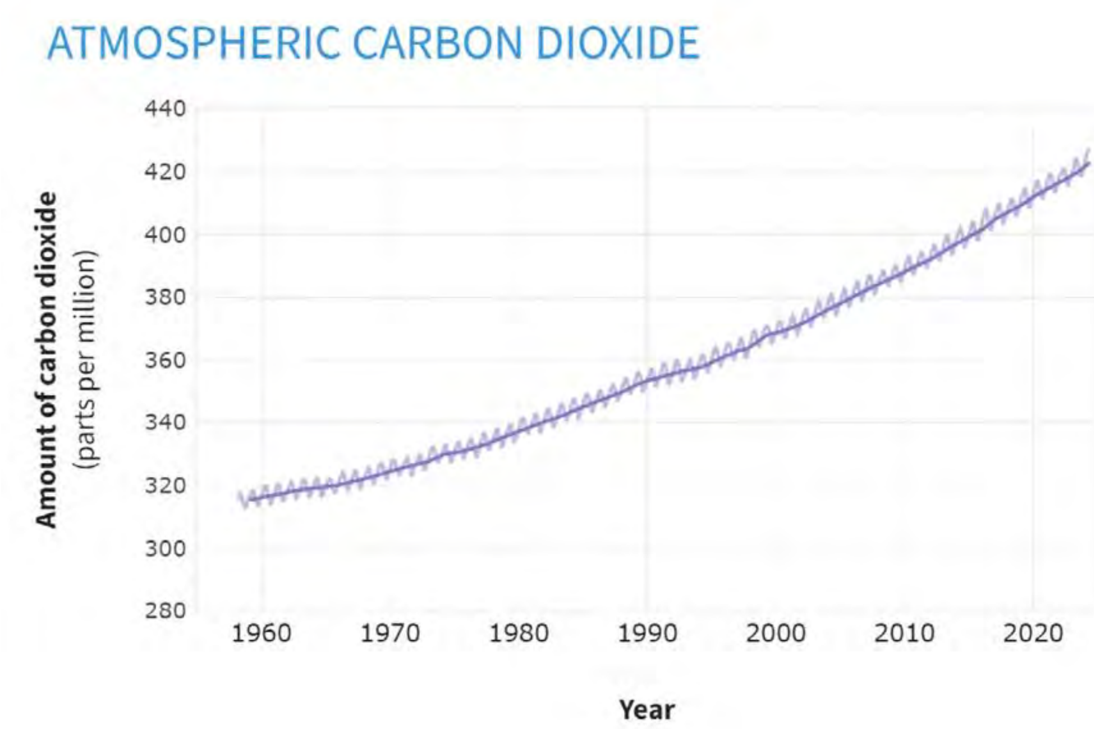
Compare	Natural Greenhouse Effect	Human-enhanced Greenhouse Effect
Amount of solar radiation entering the atmosphere from the sun		
Amount of reradiated heat from the Earth's surface		
Amount of heat that escapes into space		
Thickness of the greenhouse gas blanket		
Amount of heat that bounces off the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

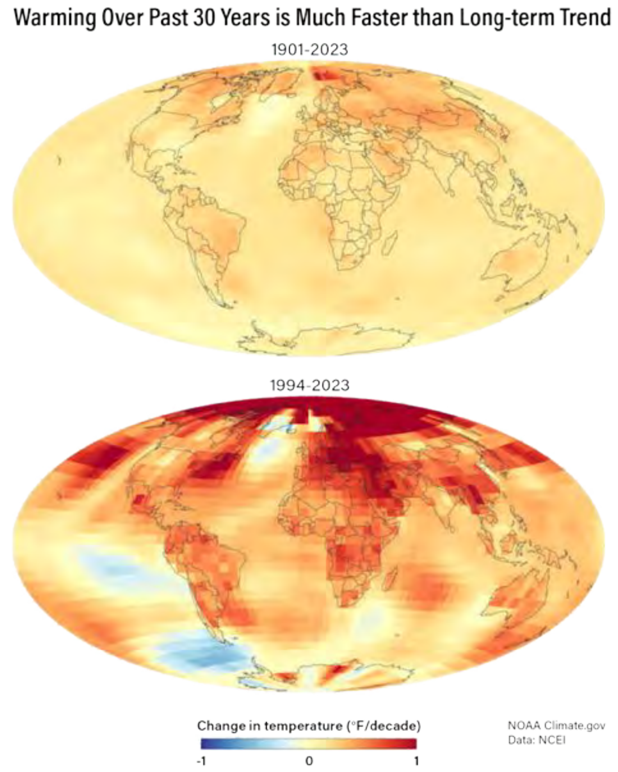
2. What do you predict will happen in the next 10 years?

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?

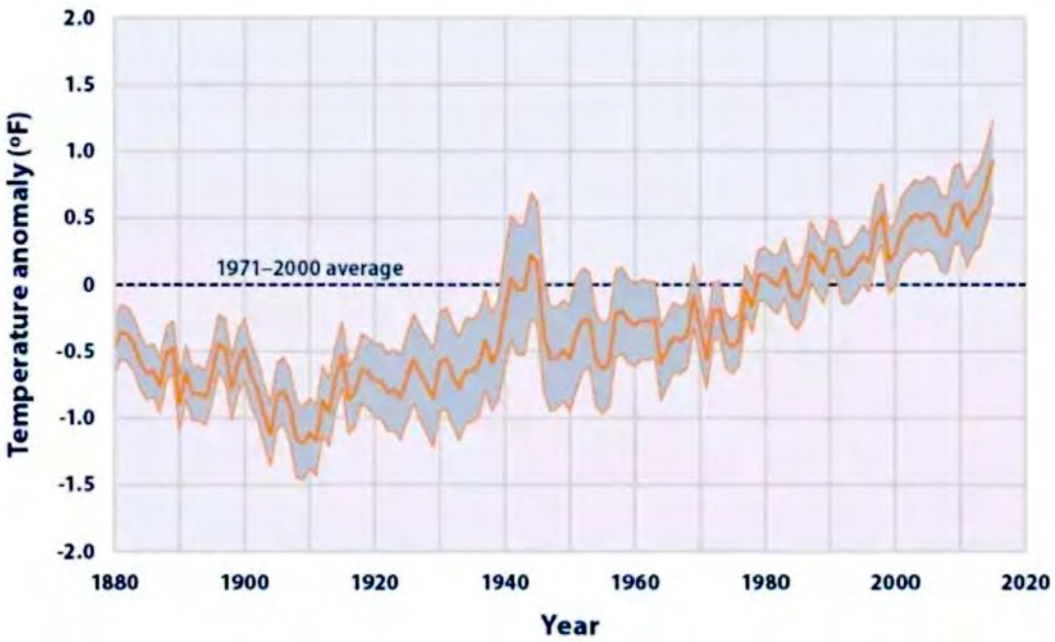
6. Which image shows a higher warming trend **per year**? What evidence supports your idea?



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.



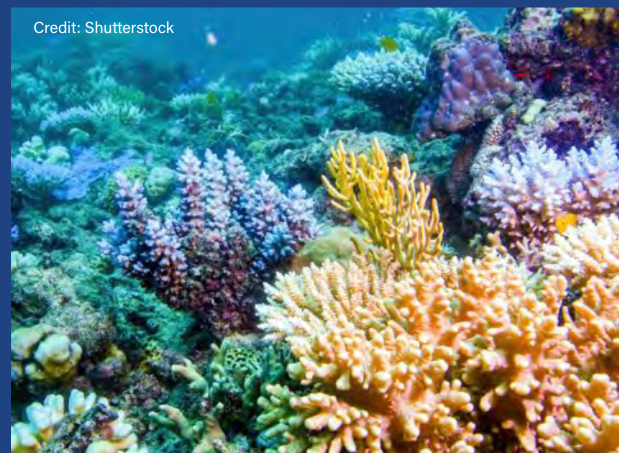
8. What differences do you observe between the temperature anomalies in (differences from the average) in 1960 and 2020 compared to the 1971-2000 average ocean surface temperature?

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

Credit: iStockphoto

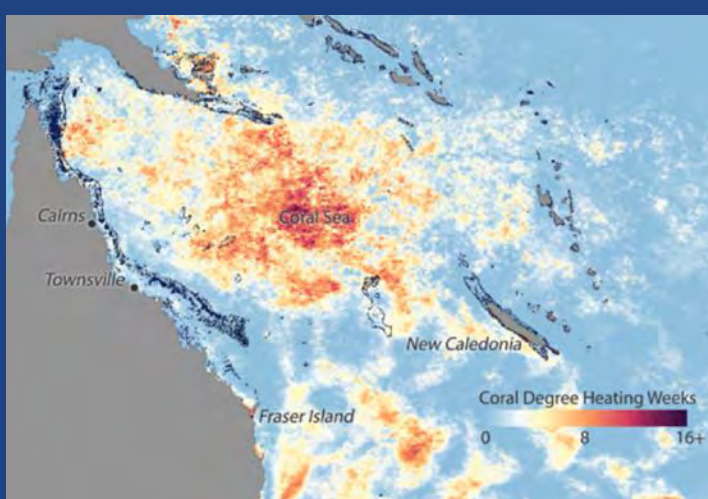
Earth Curiosities

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.



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.

Ocean water is getting warmer

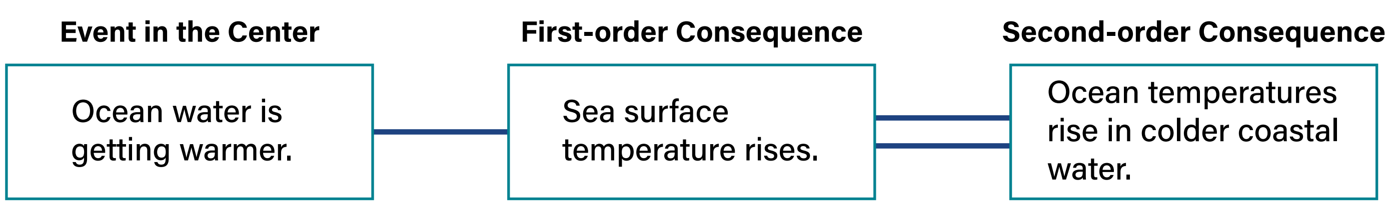
First-order Consequences	Second-order Consequence	Third-order Consequences	Fourth-order Consequences
Sea surface temperature rises	Higher temperatures for coral reef ecosystems		
	Ocean temperatures rise in colder coastal water		
More water vapor in the air	Stronger and wetter hurricanes		
	More intense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

Teek and Tom Episode 5

Our Planet is Changing and We Can All Help!

LESSON 10

Taking Care of Earth

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

In this series of videos and lessons with Teek and Tom, we learned how ocean and atmosphere interactions affect weather and climate and how humans influence the system. Along the way, we discussed severe weather and the impacts of climate change. Knowing the facts and taking action either personally or with others helps eliminate the fear of these issues which are frequently colored by doom and gloom in the public arena. People need a strong knowledge base around the causes of a warming climate, but also the opportunity to develop a strong set of skills to apply their knowledge in the real world, including problem-solving, critical thinking, teamwork, coping with uncertainty, empathy, and negotiation.

Educating children and early adolescents about global problems within local, regional, and national contexts helps them develop skills in making informed decisions and motivating action. It can have a consequential impact on students' daily behaviors and decision-making that reduces their overall lifetime carbon footprint. Here are some simple methods educators can implement in the classroom to promote positive experiences surrounding climate education:

1. Encourage your students to develop a care for the environment. Outside activities and investigations are important for students to learn more about the natural world and help them connect with nature regardless of where they live. People with strong connections to nature are more likely to engage in planet-friendly actions like recycling.

2. Encourage students to take collective action. While students can make significant environmental impacts through individual actions, focus on how their efforts can be magnified when they work with their families, their friends, and others in the community. Encourage them to join a club or connect with a local organization to create campaigns or take actions that will have a local impact.

3. Help students investigate how to make simple choices to save energy on their own, with their families at home, as well as at school. This will help to reduce greenhouse gases and the consequences of global warming.
4. Work with your students to convince the people around you to save energy. This includes reusing and recycling, which reduces the need for new manufacturing.
5. Encourage your students to keep learning to be responsible stewards of planet Earth and to make good decisions.

The hardest part of becoming an environmental steward is coming up with ideas to take action. NOAA Planet Stewards (https://oceanservice.noaa.gov/education/planet-stewards/psep-supporting.html) provides teachers with resources to design their own projects. These programs support educators to carry out hands-on projects that conserve, restore, and protect human communities and natural resources with federal funding. You can find more information on getting started with the *Planet Stewards Project Development Guide* (https://oceanservice.noaa.gov/education/planet-stewards/Planet-Stewards-Project-Development.pdf) and examples of *Planet Stewards Successful Projects* (https://oceanservice.noaa.gov/education/planet-stewards/earthscientists/).

Lesson Summary

Students will have an opportunity to demonstrate what they have learned about the connections between the ocean and atmosphere from previous lessons through a report or presentation to an imaginary Milky Way Galactic Council.

Objectives

- Students will be able to explain how the changes to Earth's atmosphere and ocean affect weather and climate.
- Students will be able to give examples of how climate change impacts humans and other species.
- Students will be able to provide several ways that humans can reduce the stress on the ocean and the atmosphere.

Estimated Time

It is estimated that three 45-minute class periods are needed for this lesson. Students will need one or two class periods to prepare and one class period for the presentations. 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-ESS3-3: Earth and Human Activity. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- ESS3.C: Human Impacts on Earth Systems. Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.

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

- Printouts of the student record sheet will need to be provided to the students to help them organize their reports. It is located at the end of this lesson.
- Depending on the format of the report or presentation that you have the students employ, they may need materials to develop visuals, such as large paper, poster board, markers, and scissors.
- The rubrics used 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-10.zip)

Preparation

There is no special preparation needed for this activity other than gathering materials that students may need to create visuals for their presentation.

InvesTeekation Pathway

There is no new content for this lesson. Students are asked to prepare and present a report about what they have learned to an imaginary Milky Way Galactic Council. They are asked to use a creative method to showcase their knowledge about the ocean and atmosphere connections to weather and climate and how the changes affect humans. Finally, they report on potential actions that could be taken to address climate change.

Presentation to the Milky Way Galactic Council

A scenario has been designed to challenge your students to present what they have learned to the Milky Way Galactic Council using one of several methods. Depending on your students' capabilities and your classroom's composition, assign the work individually, in pairs, or in small groups. You can ask your students to use various formats for their reports. It is up to you whether to allow them to use any of the options below or to just use one strategy. Consider limiting the students to 10 minutes of presentation time.

- Presentation with slides or visual aids
- News update similar to what you would see on TV
- Poster
- Storyline or comic book

Regardless of the strategies that the students use, ask several other staff to be part of the review team (the Milky Way Galactic Council representatives) for the completed project reports. This will give students an authentic audience and an opportunity to showcase their knowledge. Discuss possible ways that students can measure the effectiveness of their actions. This might include reviewing their family's electricity bill over several months after starting reduction strategies, increasing recycling, or starting to compost at home and seeing how it affects their weekly garbage production. Ask students to determine ways to measure the impact of their efforts by quantifying the amount of recycling, composting, or energy savings.

Questions	Student Responses
What are the causes of current changes to Earth's atmosphere and ocean?	*People started burning fossil fuels for electricity, heat, transportation, and manufacturing. This released greenhouse gases, especially carbon dioxide, into the atmosphere, causing increased land and ocean temperatures. This increase in air and water temperature increases the moisture in the atmosphere and fuels changes in climate and weather.*
How are the changes in the ocean and atmosphere affecting weather and climate?	*Higher ocean temperatures are causing many problems on our planet, such as sea level rise, rapid melting of massive glaciers and ice sheets, changes in weather patterns leading to drought and flooding, and increases in extreme weather like heat waves and heavy rain. Over time, changes in weather lead to changes in overall climate.*
How are these changes impacting plants and animals, including people, on the planet?	*Warming sea surface temperatures are forcing populations of ocean animals like the lobster to shift to higher latitudes. Coral reef systems are affected by large-scale bleaching, which damages or kills the corals and causes devastating effects on the whole ecosystem. Land plant and animal species habitats are all being affected. Increased heat waves, rising sea levels, and an increase in severe weather like flash floods, more severe hurricanes, and drought affect humans all over the planet.*
What actions can communities like schools, states, and countries take to reduce the stress on the atmosphere and the ocean?	*Increase green spaces and trees in urban places. Plants remove carbon dioxide from the air naturally, and trees are especially good at storing CO_2. Reduce deforestation in tropical countries. Switch to renewable energy sources such as solar, wind, or hydroelectric. Reduce dependence on fossil fuel vehicles and increase use of mass transportation. Reduce plastic use. Retrofit buildings to be more energy efficient.*
What actions can you personally take to reduce the stress on the atmosphere and the ocean?	• *Walk or ride your bike to school or events if it is safe* • *Use car pools or mass transportation* • *Use reusable water bottles instead of plastic water bottles* • *If you bring lunch, use reusable containers or food wrapping* • *If you buy lunch, encourage the use of bamboo or metal silverware rather than disposable.* • *Recycle paper, clothing, aluminum, and food scraps* • *Reduce energy, take short showers rather than a bath* • *Consider eating less meat and relying more on a vegetable or grain-based diet*

The rubric below may be used to provide students with feedback on their reports. You can decide if the other invited members of the review team are expected to give feedback as well. It is especially important for any reviewers to provide comments on the reports to help students understand where they excelled and where they can improve.

Student(s) Names____

Reports/presentations cannot be longer than 10 minutes and must address the following questions.

1. What are the causes of current changes to Earth's atmosphere and ocean?
2. How are the changes to Earth's atmosphere and ocean affecting weather and climate?
3. How are these changes impacting plants and animals, including people, on the planet?
4. What actions can communities like schools, states, and countries take to reduce the stress on the atmosphere and the ocean?
5. What actions can **you** personally take to reduce the stress on the atmosphere and the ocean?

Report/Presentation Rubric				
Points	**3**	**2**	**1**	**Total**
Subject Knowledge	Answered all five required questions clearly and completely	Answered 2-3 of the required questions	Had difficulty answering the questions or omitted 2-4 of the required questions	
Content	Presented major points and fully supported them with convincing arguments, ideas, and data	Presented major points and partially supported them with convincing arguments, ideas, and data	Important information is left out	
Organization	Presented complete information in a logical, interesting way	Presented most of the information in a logical sequence that the audience could follow	Audience had difficulty following the presentation	
Use of Slides/Props or Visual Aids	Added significant value and information to the report	Reason for use was clear, and its contribution was worth the time to introduce it	Visuals not present or did not add value	
Effective Use of Time	Time allocated effectively	Finished on time but seemed rushed or incomplete	Did not finish on time or did not use the time well	
			Total Points:	**/15**
How was this report/presentation successful?				
How might this report/presentation be improved?				

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.

Extensions

There are many participatory science and stewardship projects that provide a local or regional focus on a wide variety of science fields. This encourages people of all ages to participate in scientific research. Projects are designed to crowdsource information, collecting data from volunteers across large areas and over long timescales — something a single researcher could never do on their own. Teachers can use participatory science projects to show students they can work together to learn more about climate change and take collective action.

1. CoCoRaHS (https://www.cocorahs.org/) is an acronym for the Community Collaborative Rain, Hail, and Snow Network, a unique, nonprofit, community-based network of volunteers of all ages and backgrounds working together to measure and map precipitation (rain, hail, and snow). By using low-cost measurement tools, stressing training and education, and utilizing an interactive website, the aim is to provide the highest quality data for natural resources, education, and research applications. They are now in all fifty states.

2. An Ocean Guardian School (https://sanctuaries.noaa.gov/education/ocean_guardian/) makes a commitment to the protection and conservation of its local watersheds, the world's ocean, and special ocean areas, like national marine sanctuaries. The school makes this commitment by proposing and then implementing a school- or community-based conservation project. It is managed by NOAA's Office of National Marine Sanctuaries.

3. At the NOAA Water Level Reporter (https://noaa.maps.arcgis.com/apps/MapSeries/index.html?appid=8e4a278576964f47b4fc050e51f344ca), anyone can submit a water level report from their mobile device. Observations you and your students share will be used to map water levels (flooded, normal, and low) regionally. Flooding or other elevated water level impacts from storm events, such as hurricanes and inland floods, can be reported. Weather forecast offices will use the contributions to help communicate impacts and potential risks for future storm events.

4. The National Phytoplankton Monitoring Network (PMN) (https://coastalscience.noaa.gov/monitoring-and-assessments/pmn/) is a community-based network of volunteers monitoring marine phytoplankton and harmful algal blooms. The PMN helps NOAA respond to the growing threat posed by these microorganisms by collecting important data about species and their distribution in coastal waters, the Great Lakes and inland waters, and on tribal lands.

5. The GLOBE (**G**lobal **L**earning and **O**bservations to **B**enefit the **E**nvironment) project (https://www.globe.gov/) is an international science and education program that focuses on increasing environmental awareness and contributing to increased scientific understanding of the Earth. The GLOBE Observer allows users to contribute to the measurement databases about clouds, mosquito habitat, land cover, and trees.

Earth Curiosities

Earth's Place in Space

The Milky Way is a large spiral galaxy dominated by just two arms wrapping off the ends of a central bar of stars. The major arms consist of many young and old stars. The smaller arms are mostly filled with gas and pockets of star-forming activity. Our sun lies near a small, partial arm called the Orion Spur, which lies between the Sagittarius and the Perseus arms. The Earth is part of the Solar system that orbits the sun and consists of a group of eight planets. The solar system also includes numerous comets, asteroids, and dwarf planets that orbit the sun.

This image is an artist's conception of the Milky Way Galaxy. NASA/JPL-Caltech/R. Hurt (SSC/Caltech)

Student Record Sheet

To: Planet Earth Members

From: The Milky Way Galactic Council

Special Request: Update about Planet Earth

Earth and Queloz lie within the Milky Way galaxy and have been automatically added to the Galactic Federation because of the presence of intelligent beings. The Milky Way Galactic Council oversees the conditions of each planet to make sure that the planets are not changed by their intelligent species to the point that living things cannot survive. It has come to our attention that your planet, Earth, is experiencing stress related to conditions of the ocean and atmosphere. We are requesting that you provide a report about this situation to members of the Milky Way Galactic Council so that you can stay a valued member of the Federation. Your report should respond to the questions in the table below.

Questions	Student Responses
What are the causes of current changes to Earth's atmosphere and ocean?	
How are the changes in the ocean and atmosphere affecting weather and climate?	
How are these changes impacting plants and animals, including people, on the planet?	

Questions	Student Responses
What actions can communities like schools, states, and countries take to reduce the stress on the atmosphere and the ocean?	
What actions can you personally take to reduce the stress on the atmosphere and the ocean?	

Credit: iStockphoto

Appendix A

National Education Standards

Episode 1, Lesson 1: *What Should I Wear Today?*

Next Generation Science Standards

Performance Expectations

- 3-ESS2-1: Earth's Systems. Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.
- 5-ESS2-1: Earth's Systems. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.

Disciplinary Core Ideas

- ESS2.A: Earth Materials and Systems. Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes.
- ESS2.D: Weather and Climate. Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years.

Science and Engineering Practices

- Analyze and interpret data
- Use mathematics and computational thinking

Crosscutting Concepts

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- Patterns can be used to make predictions.

Common Core English and Language Arts

- Writing Standards Grades 4-5: Use precise language and domain-specific vocabulary to inform about or explain the topic.
- College and Career Readiness Grades 6-12: Presentation of Knowledge and Ideas - Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes.

Common Core Mathematics

- Summarize numerical data sets in relation to their context, such as by describing the nature of the attribute under investigation, including how it was measured and its units of measurement.
- Informally assess the degree of visual overlap of two numerical data distributions with similar variabilities.

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

- D2.Geo.2.3-5: Use maps, satellite images, photographs, and other representations to explain relationships between the locations of places and regions and their environmental characteristics.
- D3.4.3-5: Use evidence to develop claims in response to compelling questions.

Episode 1, Lesson 2: *It's All about the Weather...and the Climate*

Next Generation Science Standards

Performance Expectations

- 3-ESS2-1: Earth's Systems. Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.
- 5-ESS2-1: Earth's Systems. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.
- MS-ESS2-5: Earth's Systems. Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

Disciplinary Core Ideas

- ESS2.C: The Roles of Water in Earth's Surface Processes. The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.
- ESS2.D: Weather and Climate. Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years.

Science and Engineering Practices

- Analyze and interpret data
- Use mathematics and computational thinking
- Develop and use models

Crosscutting Concepts

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- Patterns can be used to make predictions.
- A system can be described in terms of the components and their interactions.

Common Core English and Language Arts

Writing Standards Grades 4-5.

- Use precise language and domain-specific vocabulary to inform about or explain the topic. Provide a concluding statement or section related to the information or explanation presented.

Common Core Mathematics

- Summarize numerical data sets in relation to their context, such as by describing the nature of the attribute under investigation, including how it was measured and its units of measurement.

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

- D2.Geo.2.3-5: Use maps, satellite images, photographs, and other representations to explain relationships between the locations of places and regions.

Episode 2, Lesson 3: *A Day at the Beach*

Next Generation Science Standards

Performance Expectations

- 3-ESS2-1: Earth's Systems. Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.
- MS-ESS2-4: Earth's Systems. Develop a model to describe the cycling of water from Earth's systems driven by the energy of the Sun and Earth's gravity.
- MS-ESS2-5: Earth's Systems. Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

Disciplinary Core Ideas

- ESS2.A: Earth Materials and Systems. Earth's major systems are the geosphere, the hydrosphere, the atmosphere, and the biosphere. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather.
- ESS2.C: The Roles of Water in Earth's Surface Processes. The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.
- ESS2.D: Weather and Climate. Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.

Science and Engineering Practices

- Analyze and interpret data
- Develop and use models

Crosscutting Concepts

- Patterns can be used to make predictions.
- A system can be described in terms of the components and their interactions.
- The transfer of energy drives the motion and/or cycling of matter.

Common Core English and Language Arts

- Writing Standards Grades 4-5. Use precise language and domain-specific vocabulary to inform about or explain the topic. Provide a concluding statement or section related to the information or explanation presented.

Common Core Mathematics

- Summarize numerical data sets in relation to their context, such as by describing the nature of the attribute under investigation, including how it was measured and its units of measurement.

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

- D3.4.3-5. Use evidence to develop claims in response to compelling questions.

Episode 2, Lesson 4: *Up, Up, and Away!*

Next Generation Science Standards

Performance Expectation

- 3-ESS2-1: Earth's Systems. Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.
- 5-ESS2-2: Earth's Systems. Describe and graph the amounts of salt water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth.

Disciplinary Core Ideas

- ESS2.C: The Roles of Water in Earth's Surface Processes. Nearly all of Earth's available water is in the ocean. Most freshwater is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere.

Science and Engineering Practices

- Analyze and interpret data
- Develop and use models
- Use mathematics and computational thinking

Crosscutting Concepts

- Patterns can be used to make predictions.
- Standard units are used to measure and describe physical quantities such as weight and volume.

Common Core English and Language Arts

Writing Standards Grades 4-5.

- Use precise language and domain-specific vocabulary to inform about or explain the topic. Provide a concluding statement or section related to the information or explanation presented.

Common Core Mathematics

- Summarize numerical data sets in relation to their context, such as by describing the nature of the attribute under investigation, including how it was measured and its units of measurement.
- Model with mathematics.

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

- D3.4.3-5. Use evidence to develop claims in response to compelling questions.
- D4.2.3-5. Construct explanations using reasoning, correct sequence, examples, and details with relevant information and data.

Episode 3, Lesson 5: *There's Something in the Air*

Next Generation Science Standards

Performance Expectation

- MS-ESS2-5: Earth's Systems. Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

Disciplinary Core Ideas

- ESS2.C: The Roles of Water in Earth's Surface Processes. The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.
- ESS2.D: Weather and Climate. Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. Because these patterns are so complex, weather can only be predicted probabilistically.

Science and Engineering Practices

- Analyze and interpret data
- Develop and use models
- Use mathematics and computational thinking

Crosscutting Concepts

- Patterns can be used to make predictions.
- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Common Core English and Language Arts

Writing Standards Grades 4-5.

- Use precise language and domain-specific vocabulary to inform about or explain the topic. Provide a concluding statement or section related to the information or explanation presented.

Common Core Mathematics

- Summarize numerical data sets in relation to their context, such as by describing the nature of the attribute under investigation, including how it was measured and its units of measurement.

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

- D3.4.3-5. Use evidence to develop claims in response to compelling questions.
- D4.2.3-5. Construct explanations using reasoning, correct sequence, examples, and details with relevant information and data.

Episode 3, Lesson 6:
Recipes for Disasters: Tornadoes and Hurricanes

Next Generation Science Standards

Performance Expectations

- 3-ESS2-1: Earth's Systems. Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.
- MS-ESS2-5: Earth's Systems. Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.
- 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.

Disciplinary Core Ideas

- ESS2.D: Weather and Climate. Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. Because these patterns are so complex, weather can only be predicted probabilistically.
- ESS3.B: Natural Hazards. A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards but can take steps to reduce their impacts. Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events.

Science and Engineering Practices

- Analyze and interpret data
- Use mathematics and computational thinking

Crosscutting Concepts

- Patterns can be used to make predictions.
- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Common Core English and Language Arts

Writing Standards Grades 4-5.

- Use precise language and domain-specific vocabulary to inform about or explain the topic. Provide a concluding statement or section related to the information or explanation presented.

Common Core Mathematics

- Summarize numerical data sets in relation to their context, such as by describing the nature of the attribute under investigation, including how it was measured and its units of measurement.
- Reason abstractly and quantitatively.

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

- D3.4.3-5. Use evidence to develop claims in response to compelling questions.
- D4.2.3-5. Construct explanations using reasoning, correct sequence, examples, and details with relevant information and data.

Episode 4, Lesson 7: *Planetary Toolbox: Eyes in the Skies*

Next Generation Science Standards

Performance Expectations

- 3-ESS3-1: Earth and Human Activity. Make a claim about the merit of a design solution that reduces the impact of a weather-related hazard.
- 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.

Disciplinary Core Ideas

- ESS3.B: Natural Hazards. A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards but can take steps to reduce their impacts. Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events.

Science and Engineering Practices

- Analyze and interpret data
- Use mathematics and computational thinking

Crosscutting Concepts

- Patterns can be used to make predictions.
- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Common Core English and Language Arts

Writing Standards Grades 4-5.

- Use precise language and domain-specific vocabulary to inform about or explain the topic. Provide a concluding statement or section related to the information or explanation presented.
- Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually.

Common Core Mathematics

- Summarize numerical data sets in relation to their context, such as by describing the nature of the attribute under investigation, including how it was measured and its units of measurement.
- Reason abstractly and quantitatively.

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

- D3.4.3-5. Use evidence to develop claims in response to compelling questions.
- D4.2.3-5. Construct explanations using reasoning, correct sequence, examples, and details with relevant information and data.

Episode 4, Lesson 8: *Planetary Toolbox: Eyes in the Ocean*

Next Generation Science Standards

Performance Expectations

- 3-5 ETS1-1: Engineering Design. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time or cost.
- MS-ETS1-2: Engineering Design. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Disciplinary Core Ideas

- ETS1.A: Defining and delimiting engineering problems. Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.
- ETS1.B: Developing Possible Solutions. Research on a problem should be carried out before beginning to design a solution. An often productive way to generate ideas is for people to work together to brainstorm, test, and refine possible solutions. Testing a solution involves investigating how well it performs under a range of likely conditions. Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. Communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs.
- ETS1.C: Optimizing the design solutions. Multiple solutions to an engineering design problem are always possible because there is more than one way to meet the criteria and satisfy the constraints. But the aim of engineering is not simply to design a solution to a problem but to design the best solution.

Science and Engineering Practices

- Ask question and define problems
- Plan and carry out an investigation
- Construct explanations and design solutions
- Develop and use models

Crosscutting Concepts

- Influence of Science, Engineering, and Technology on Society and the Natural World

Common Core English and Language Arts

Writing Standards Grades 4-5

- Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually.

Episode 4, Lesson 8: *Planetary Toolbox: Eyes in the Ocean*

Common Core Mathematics

- Summarize numerical data sets in relation to their context, such as by describing the nature of the attribute under investigation, including how it was measured and its units of measurement.
- Reason abstractly and quantitatively.

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

- D3.4.3-5. Use evidence to develop claims in response to compelling questions.
- D4.2.3-5. Construct explanations using reasoning, correct sequence, examples, and details with relevant information and data.

Episode 5, Lesson 9: *Evidence of Change*

Next Generation Science Standards

Performance Expectations

- 3-ESS3-1: Earth and Human Activity. Make a claim about the merit of a design solution that reduces the impact 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.

Disciplinary Core Ideas

- ESS3.C: Human Impacts on Earth Systems. Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.
- 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). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

Science and Engineering Practices

- Ask questions and define problems
- Engage in argument from evidence
- Obtain, evaluate and communicate information

Episode 5, Lesson 9: *Evidence of Change*

Crosscutting Concepts

- Patterns can be used to make predictions.
- Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- Systems and system models
- Stability and change

Common Core English and Language Arts

Writing Standards Grades 4-5

- Use precise language and domain-specific vocabulary to inform about or explain the topic. Provide a concluding statement or section related to the information or explanation presented.
- Write opinion pieces on topics or texts, supporting a point of view with reasons and information.
- Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually.

Common Core Mathematics

- Summarize numerical data sets in relation to their context, such as by describing the nature of the attribute under investigation, including how it was measured and its units of measurement.
- Reason abstractly and quantitatively.

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

- D3.4.3-5. Use evidence to develop claims in response to compelling questions.
- D4.2.3-5. Construct explanations using reasoning, correct sequence, examples, and details with relevant information and data.

Episode 5, Lesson 10: *Taking Care of the Earth*

Next Generation Science Standards

Performance Expectations

- 3-ESS3-1: Earth and Human Activity. Make a claim about the merit of a design solution that reduces the impact 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-ESS3-3: Earth and Human Activity. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

Disciplinary Core Ideas

- ESS3.B: Natural Hazards. A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards but can take steps to reduce their impacts. Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events.

- ESS3.C: Human Impacts on Earth Systems. Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.
- 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). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

Science and Engineering Practices

- Engage in argument from evidence
- Obtain, evaluate and communicate information

Crosscutting Concepts

- Patterns can be used to make predictions.
- Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- Systems and system models
- Stability and change

Common Core English and Language Arts

Writing Standards Grades 4-5

- Use precise language and domain-specific vocabulary to inform about or explain the topic. Provide a concluding statement or section related to the information or explanation presented.
- Write opinion pieces on topics or texts, supporting a point of view with reasons and information.
- Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually.

Common Core Mathematics

- Reason abstractly and quantitatively.

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

- D3.4.3-5. Use evidence to develop claims in response to compelling questions.
- D4.2.3-5. Construct explanations using reasoning, correct sequence, examples, and details with relevant information and data.

Washington D.C. Temperatures
*** PLEASE NOTE ***
Climate data on this page are PRELIMINARY (unofficial).
CERTIFIED (official) climate data are available from the
National Centers for Environmental Information (NCEI) - http://www.ncdc.noaa.gov/
*** PLEASE NOTE ***

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	WINTER	SPRING	SUMMER	AUTUMN	1ST HALF	2ND HALF
1871	32.6	35.9	48.0	58.2	63.9	73.2	74.0	76.8	62.3	58.1	42.3	32.1	54.8	M	56.7	74.7	54.2	52.0	57.6
1872	31.7	33.7	35.4	56.0	67.4	75.4	81.1	79.0	69.0	55.5	42.5	31.0	54.8	32.5	52.9	78.5	55.7	49.9	59.7
1873	32.2	34.8	41.8	53.1	63.6	75.1	79.8	74.8	68.0	54.9	40.8	40.5	54.8	32.7	52.8	76.6	54.6	50.1	59.8
1874	39.4	37.2	44.5	47.1	63.8	77.5	78.9	72.7	70.1	55.9	44.6	39.2	56.0	39.0	51.8	76.4	56.9	51.6	60.2
1875	28.5	28.8	39.1	48.0	63.6	72.9	77.0	71.9	64.6	53.6	41.0	36.8	52.2	32.2	50.2	73.9	53.1	46.8	57.5
1876	40.4	36.7	39.4	51.4	64.5	75.8	80.4	75.5	65.2	50.7	45.2	27.1	54.3	38.0	51.8	77.2	53.7	51.4	57.4
1877	29.4	39.4	41.0	52.9	61.9	73.9	77.8	76.3	66.9	58.6	46.2	41.8	55.5	32.0	51.9	76.0	57.2	49.8	61.3
1878	33.5	39.8	49.4	58.3	62.5	69.1	80.2	75.0	68.9	57.0	45.4	33.3	56.0	38.4	56.7	74.8	57.1	52.1	60.0
1879	30.8	32.2	43.8	52.8	65.7	73.3	79.0	75.3	65.2	63.0	46.7	41.9	55.8	32.1	54.1	75.9	58.3	49.8	61.9
1880	41.9	40.8	41.8	55.5	70.5	74.3	76.7	74.9	67.9	54.9	40.2	29.0	55.6	41.5	55.9	75.3	54.3	54.1	57.3
1881	27.6	32.8	40.1	50.3	67.0	70.7	77.4	76.5	78.2	62.9	47.5	41.7	56.0	29.8	52.5	74.9	62.9	48.1	64.0
1882	33.2	40.4	44.1	50.8	59.2	73.8	76.0	73.9	69.1	60.9	42.9	34.1	54.9	38.4	51.4	74.6	57.6	50.3	59.5
1883	29.6	37.5	37.6	50.9	63.6	74.4	76.8	72.1	65.1	56.9	47.2	36.9	54.0	33.7	50.7	74.4	56.4	48.9	59.2
1884	29.4	40.9	42.2	50.9	64.4	72.5	74.2	74.2	71.7	59.6	44.7	36.0	55.1	35.7	52.5	73.6	58.7	50.1	60.1
1885	32.9	26.9	34.5	53.1	62.3	71.1	77.8	73.4	66.1	54.7	45.3	37.5	53.0	31.9	50.0	74.1	55.4	46.8	59.1
1886	28.9	32.1	42.0	55.5	62.1	69.9	73.9	73.1	69.3	57.6	46.1	30.7	53.4	32.8	53.2	72.3	57.7	48.4	58.5
1887	32.9	38.9	38.5	51.6	67.9	72.1	80.5	73.2	65.0	55.4	41.9	37.2	54.8	34.2	52.7	75.3	54.1	50.3	58.9
1888	30.2	35.7	37.4	52.9	62.7	73.0	73.6	75.8	64.8	52.6	47.4	37.5	53.6	34.4	51.0	74.1	54.9	48.7	58.6
1889	39.2	31.1	43.4	54.4	64.6	70.8	75.8	72.4	65.6	52.5	46.2	45.6	55.1	35.9	54.1	73.0	54.8	50.6	59.7
1890	43.8	43.4	41.4	53.6	63.8	74.8	75.0	73.6	67.8	56.4	48.0	34.2	56.3	44.3	52.9	74.5	57.4	53.5	59.2
1891	37.4	41.4	38.6	55.4	61.4	71.6	72.0	74.5	70.3	54.4	44.0	43.2	55.4	37.7	51.8	72.7	56.2	51.0	59.7
1892	31.6	37.0	37.7	51.4	63.8	76.2	75.8	76.2	66.1	55.4	43.7	33.2	54.0	37.3	51.0	76.1	55.1	49.6	58.4
1893	24.6	35.1	41.1	53.8	61.6	72.5	77.0	74.6	66.0	56.5	43.6	38.3	53.7	31.0	52.2	74.7	55.4	48.1	59.3
1894	37.8	35.2	48.5	53.2	65.9	73.6	77.9	74.0	71.4	57.9	44.0	37.4	56.4	37.1	55.9	75.2	57.8	52.4	60.4
1895	31.6	26.2	41.8	53.8	62.6	74.6	72.8	77.2	72.4	52.1	46.4	38.8	54.2	31.7	52.7	74.9	57.0	48.4	60.0
1896	33.3	36.7	38.5	56.6	68.8	71.3	76.7	75.8	67.8	54.0	50.6	35.6	55.5	36.3	54.6	74.6	57.5	50.9	60.1

Washington D.C. Temperatures

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	WINTER	SPRING	SUMMER	AUTUMN	1ST HALF	2ND HALF
1897	31.0	36.6	46.0	52.9	62.4	69.6	76.9	73.4	68.2	58.0	46.0	38.1	54.9	34.4	53.8	73.3	57.4	49.8	60.1
1898	36.6	35.0	48.8	50.9	64.4	73.5	78.8	76.9	71.0	57.8	44.0	35.6	56.1	36.6	54.7	76.4	57.6	51.5	60.7
1899	33.4	27.4	42.2	54.0	64.4	74.3	76.6	74.8	65.8	58.5	45.3	36.2	54.4	32.1	53.5	75.2	56.5	49.3	59.5
1900	35.2	33.7	38.8	54.2	64.4	72.2	78.7	79.6	73.6	61.6	49.2	36.5	56.5	35.0	52.5	76.8	61.5	49.8	63.2
1901	34.9	29.8	45.0	50.6	62.5	72.4	79.8	76.0	67.4	55.6	40.6	34.8	54.1	33.7	52.7	76.1	54.5	49.2	59.0
1902	31.8	29.8	46.7	52.9	65.4	71.8	77.0	72.6	66.8	57.6	51.3	34.4	54.8	32.1	55.0	73.8	58.6	49.7	60.0
1903	33.4	37.4	50.0	54.0	64.4	67.0	76.0	71.8	67.2	56.8	41.6	32.2	54.3	35.1	56.1	71.6	55.2	51.0	57.6
1904	27.5	28.4	42.2	49.7	65.0	71.0	74.4	72.3	67.4	54.1	43.1	30.9	52.2	29.4	52.3	72.6	54.9	47.3	57.0
1905	29.8	26.4	45.0	54.0	65.2	71.8	76.4	73.6	68.2	56.9	44.4	37.5	54.1	29.0	54.7	73.9	56.5	48.7	59.5
1906	40.0	34.0	37.6	55.5	64.4	72.8	75.2	76.4	72.9	56.9	47.8	37.0	55.9	37.2	52.5	74.8	59.2	50.7	61.0
1907	37.2	30.2	48.8	48.4	59.2	65.9	75.8	72.4	69.4	52.0	44.5	38.1	53.5	34.8	52.1	71.4	55.3	48.3	58.7
1908	34.2	30.8	47.4	56.4	65.3	71.8	78.0	73.2	66.6	58.2	46.0	37.0	55.4	34.4	56.4	74.3	56.9	51.0	59.8
1909	36.0	43.0	42.1	54.2	64.4	73.9	74.7	73.0	66.4	53.2	50.8	31.8	55.2	38.7	53.6	73.9	56.8	52.3	58.3
1910	33.6	34.6	51.2	57.9	61.4	69.7	77.6	73.8	71.0	60.2	41.4	30.5	55.2	33.3	56.8	73.7	57.5	51.4	59.1
1911	38.2	37.0	41.0	51.2	70.0	73.0	78.7	76.6	70.4	57.2	42.8	41.0	56.4	35.2	54.1	76.1	56.8	51.7	61.1
1912	25.0	31.0	40.9	55.6	65.1	70.4	75.8	73.4	70.4	59.3	46.9	40.0	54.5	32.3	53.9	73.2	58.9	48.0	61.0
1913	43.6	36.6	49.0	55.5	64.4	72.8	77.6	74.2	67.4	58.8	47.8	40.4	57.3	40.1	56.3	74.9	58.0	53.7	61.0
1914	38.6	30.1	39.4	53.5	67.0	73.8	75.9	76.4	66.0	60.2	45.4	32.8	54.9	36.4	53.3	75.4	57.2	50.4	59.5
1915	35.6	38.8	38.8	59.4	62.5	70.6	76.1	74.0	71.0	58.6	46.2	35.2	55.6	35.7	53.6	73.6	58.6	51.0	60.2
1916	39.8	34.2	37.9	53.4	66.7	69.7	77.8	75.2	66.6	56.6	46.3	35.5	55.0	36.4	52.7	74.2	56.5	50.3	59.7
1917	35.0	32.8	43.4	54.2	59.6	72.6	76.6	75.9	63.8	52.0	42.8	27.9	53.0	34.4	52.4	75.0	52.9	49.6	56.5
1918	23.7	36.8	48.4	53.2	69.6	70.8	74.4	77.6	64.2	60.6	46.3	41.6	55.6	29.5	57.1	74.3	57.0	50.4	60.8
1919	38.1	37.2	46.4	53.8	64.6	73.9	77.2	73.6	69.4	63.2	46.8	32.6	56.4	39.0	54.9	74.9	59.8	52.3	60.5
1920	28.7	32.7	45.5	52.6	60.0	71.6	75.0	74.8	68.8	61.2	45.9	39.3	54.7	31.3	52.7	73.8	58.6	48.5	60.8
1921	36.6	39.0	55.5	59.2	62.3	74.2	79.3	72.8	74.4	57.0	47.5	37.9	58.0	38.3	59.0	75.4	59.6	54.5	61.5
1922	32.0	38.6	45.4	55.6	66.8	74.5	76.6	73.1	69.9	59.4	47.9	37.6	56.4	36.2	55.9	74.7	59.1	52.2	60.8
1923	36.8	32.6	45.4	53.6	63.4	75.6	75.7	74.4	69.6	56.1	45.1	45.0	56.1	35.7	54.1	75.2	56.9	51.2	61.0
1924	35.0	34.2	42.6	51.9	60.0	71.3	75.0	74.8	64.3	57.4	46.0	36.4	54.1	38.1	51.5	73.7	55.9	49.2	59.0
1925	32.9	43.0	46.4	56.9	60.6	77.4	76.8	73.0	72.8	52.0	44.3	37.0	56.1	37.4	54.6	75.7	56.4	52.9	59.3
1926	33.8	36.5	40.1	51.1	64.3	69.1	76.7	76.4	69.0	57.2	45.1	33.8	54.5	35.8	51.8	74.1	57.1	49.2	59.7
1927	34.0	42.1	47.6	51.9	64.0	68.6	76.4	70.0	70.1	60.4	51.0	39.1	56.3	36.6	54.5	71.7	60.5	51.4	61.2
1928	35.9	37.6	44.1	51.9	63.1	71.0	78.1	77.0	64.9	59.9	49.4	39.2	56.0	37.5	53.0	75.4	58.1	50.6	61.4
1929	34.9	35.0	50.2	57.6	64.5	72.9	76.9	74.4	70.2	55.6	47.6	38.4	56.5	36.4	57.4	74.7	57.8	52.5	60.5

Washington D.C. Temperatures

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	WINTER	SPRING	SUMMER	AUTUMN	1ST HALF	2ND HALF
1930	35.6	41.9	45.0	53.2	67.3	75.1	80.4	76.8	76.0	56.2	46.7	35.7	57.5	38.6	55.2	77.4	59.6	53.0	62.0
1931	37.0	39.4	41.3	54.2	65.1	73.3	79.6	75.6	74.1	61.2	54.0	44.2	58.2	37.4	53.5	76.2	63.1	51.7	64.8
1932	46.8	42.9	40.0	52.6	64.2	73.2	77.4	77.8	70.3	58.0	44.7	39.6	57.3	44.6	52.3	76.1	57.7	53.3	61.3
1933	42.6	38.4	43.0	55.7	67.2	74.7	76.1	76.0	71.8	56.5	45.0	38.6	57.1	40.2	55.3	75.6	57.8	53.6	60.7
1934	39.1	24.6	41.2	53.9	66.5	77.2	80.8	74.1	70.6	56.2	49.6	37.3	55.9	34.1	53.9	77.4	58.8	50.4	61.4
1935	33.3	35.4	50.2	51.9	61.8	73.4	79.4	76.8	67.0	58.2	50.2	32.1	55.8	35.3	54.6	76.5	58.5	51.0	60.6
1936	30.6	29.6	50.3	52.2	67.4	72.8	78.4	77.9	71.4	59.7	45.0	39.8	56.3	30.8	56.6	76.4	58.7	50.5	62.0
1937	43.8	36.6	42.1	53.4	65.8	75.1	77.2	77.8	65.9	55.3	46.6	37.0	56.4	40.1	53.8	76.7	55.9	52.8	60.0
1938	35.7	40.9	49.8	57.1	63.4	72.8	78.4	78.6	67.4	58.8	49.8	38.4	57.6	37.9	56.8	76.6	58.7	53.3	61.9
1939	37.8	42.3	46.4	53.4	68.0	75.4	76.2	78.8	71.0	58.4	46.0	40.1	57.8	39.5	55.9	76.8	58.5	53.9	61.8
1940	24.9	37.1	40.7	50.8	64.4	74.8	77.5	73.4	66.8	55.7	48.2	42.8	54.8	34.0	52.0	75.2	56.9	48.8	60.7
1941	34.8	33.8	39.8	60.6	66.8	73.2	77.0	76.1	72.8	64.4	50.4	41.9	57.6	37.1	55.7	75.4	62.5	51.5	63.8
1942	34.9	34.2	47.4	59.0	69.1	74.4	78.8	75.1	70.4	60.3	48.3	34.9	57.2	37.0	58.5	76.1	59.7	53.2	61.3
1943	36.2	38.8	45.4	51.2	67.1	79.2	78.5	79.0	67.6	56.4	46.7	36.4	56.9	36.6	54.6	78.9	56.9	53.0	60.8
1944	37.4	38.2	43.0	53.8	71.6	74.8	79.2	76.2	70.5	56.4	47.4	34.4	56.9	37.3	56.1	76.7	58.1	53.1	60.7
1945	30.8	38.4	56.2	59.5	62.8	74.5	76.4	74.8	72.8	57.6	49.3	32.9	57.1	34.5	59.5	75.2	59.9	53.7	60.6
1946	36.8	39.2	53.0	56.0	65.2	72.4	76.2	72.6	70.0	61.4	51.8	41.4	58.0	36.3	58.1	73.7	61.1	53.8	62.2
1947	41.7	31.4	40.0	57.2	64.6	71.6	75.5	79.0	69.8	64.5	46.2	36.6	56.5	38.2	53.9	75.4	60.2	51.1	61.9
1948	28.8	36.8	48.0	55.9	64.6	74.0	78.0	75.8	69.4	56.2	51.4	40.2	56.6	34.1	56.2	75.9	59.0	51.4	61.8
1949	42.6	43.8	46.6	55.0	66.0	75.1	81.0	77.6	67.1	63.4	48.1	41.9	59.0	42.2	55.9	77.9	59.5	54.9	63.2
1950	48.0	38.7	41.7	52.4	64.5	73.9	76.2	75.6	66.9	61.0	47.9	35.6	56.9	42.9	52.9	75.2	58.6	53.2	60.5
1951	39.3	38.6	45.6	55.9	64.9	73.4	78.7	76.8	70.3	62.1	44.1	40.9	57.6	37.8	55.5	76.3	58.8	53.0	62.2
1952	40.7	41.1	43.3	57.0	64.2	76.9	80.5	76.2	68.9	55.3	48.2	38.9	57.6	40.9	54.8	77.9	57.5	53.9	61.3
1953	40.7	42.6	47.5	56.1	70.1	74.6	79.6	76.3	69.7	60.5	48.1	40.9	58.9	40.7	57.9	76.8	59.4	55.3	62.5
1954	35.9	43.5	44.5	59.6	62.6	74.4	78.8	75.2	73.3	62.0	45.2	37.1	57.7	40.1	55.6	76.1	60.2	53.4	61.9
1955	35.4	37.8	47.1	58.2	67.1	70.2	82.1	78.3	69.9	59.6	45.5	33.6	57.1	36.8	57.5	76.9	58.3	52.6	61.5
1956	34.5	41.1	43.2	53.6	63.6	73.3	75.6	75.0	66.6	59.0	46.1	44.2	56.3	36.4	53.5	74.6	57.2	51.6	61.1
1957	32.9	41.4	45.8	59.2	67.2	76.6	79.2	75.7	71.9	55.4	49.6	41.4	58.0	39.5	57.4	77.2	59.0	53.9	62.2
1958	34.4	31.2	41.4	57.1	65.2	71.3	79.1	75.4	69.1	59.1	49.9	32.9	55.5	35.7	54.6	75.3	59.4	50.1	60.9
1959	34.9	39.0	45.4	58.5	69.8	76.0	78.5	80.3	73.2	62.2	46.8	42.0	58.9	35.6	57.9	78.3	60.7	53.9	63.8
1960	38.2	38.3	35.6	61.2	63.7	74.1	77.0	78.5	71.3	58.7	48.5	31.0	56.3	39.5	53.5	76.5	59.5	51.9	60.8
1961	29.8	38.3	47.6	52.0	62.2	73.2	78.6	77.6	74.8	59.9	50.2	36.4	56.7	33.0	53.9	76.5	61.6	50.5	62.9

Washington D.C. Temperatures

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	WINTER	SPRING	SUMMER	AUTUMN	1ST HALF	2ND HALF
1962	34.6	34.6	44.2	56.3	68.7	73.8	75.3	76.8	67.0	60.3	44.9	33.2	55.8	35.2	56.4	75.3	57.4	52.0	59.6
1963	31.4	31.0	48.5	57.8	64.9	73.7	77.6	75.4	66.5	61.2	49.8	31.1	55.7	31.9	57.1	75.6	59.2	51.2	60.3
1964	36.3	36.9	47.5	54.1	68.1	76.0	79.1	75.5	69.9	55.1	51.0	39.9	57.5	34.8	56.6	76.9	58.7	53.2	61.8
1965	33.4	36.8	41.4	51.8	69.1	72.6	78.2	77.2	72.6	57.5	49.5	41.5	56.8	36.7	54.1	76.0	59.9	50.9	62.8
1966	32.4	36.2	47.5	52.7	65.0	76.0	80.9	78.7	68.6	57.0	49.5	37.6	56.8	36.7	55.1	78.5	58.4	51.6	62.1
1967	41.0	34.0	45.0	57.6	60.0	74.7	77.2	76.2	68.0	57.9	45.0	39.9	56.4	37.5	54.2	76.0	57.0	52.1	60.7
1968	31.4	34.3	49.7	58.0	63.7	74.1	79.9	79.2	72.0	61.3	50.0	36.6	57.5	35.2	57.1	77.7	61.1	51.9	63.2
1969	34.2	36.9	43.0	58.7	68.4	77.1	79.5	76.3	70.1	58.8	47.2	36.3	57.2	35.9	56.7	77.6	58.7	53.1	61.4
1970	30.0	37.1	41.9	55.3	68.3	75.2	79.2	79.0	75.0	62.5	49.3	39.7	57.7	34.5	55.2	77.8	62.3	51.3	64.1
1971	31.3	39.1	43.2	55.0	63.7	75.9	78.3	76.7	73.0	64.7	48.2	45.5	57.9	36.7	54.0	77.0	62.0	51.4	64.4
1972	38.5	36.5	45.6	54.1	64.6	70.2	77.5	75.9	71.0	56.0	46.8	43.6	56.7	40.2	54.8	74.5	57.9	51.6	61.8
1973	37.6	37.0	51.1	56.0	62.8	77.1	79.2	79.9	74.3	63.3	51.6	41.9	59.3	39.4	56.6	78.7	63.1	53.6	65.0
1974	42.9	39.2	49.2	58.3	65.1	71.5	79.0	78.4	70.2	57.3	50.9	43.1	58.8	41.3	57.5	76.3	59.5	54.4	63.2
1975	40.9	40.6	45.2	53.6	69.7	76.4	79.3	80.1	68.5	63.2	54.4	40.5	59.4	41.5	56.2	78.6	62.0	54.4	64.3
1976	33.9	46.9	51.3	59.9	65.0	77.6	78.4	76.7	70.4	55.4	43.0	35.5	57.9	40.4	58.7	77.6	56.3	55.8	59.9
1977	25.4	38.8	52.7	60.1	69.4	74.3	80.9	78.8	73.9	59.0	51.8	38.1	58.6	33.2	60.7	78.0	61.6	53.5	63.8
1978	32.5	31.4	44.4	57.7	65.8	76.7	78.8	81.3	73.6	59.4	52.2	43.1	58.1	34.0	56.0	78.9	61.7	51.4	64.7
1979	35.1	28.4	51.5	56.0	67.7	72.4	78.6	78.5	71.6	58.6	54.4	43.7	58.1	35.5	58.4	76.5	61.5	51.9	64.2
1980	37.2	36.1	46.2	60.1	69.5	74.8	82.3	82.8	77.1	59.9	48.6	39.8	59.5	39.0	58.6	80.0	61.9	54.0	65.1
1981	33.0	43.7	47.6	62.1	66.2	78.7	80.2	77.0	71.0	58.3	51.4	38.5	59.0	38.8	58.6	78.6	60.2	55.2	62.7
1982	28.1	38.3	45.7	54.0	69.0	72.8	80.3	75.4	70.6	60.2	51.8	45.5	57.7	35.0	56.2	76.2	60.9	51.3	64.0
1983	38.1	38.7	48.8	53.3	64.9	75.0	81.2	81.0	72.6	60.5	50.3	36.0	58.4	40.8	55.7	79.1	61.1	53.1	63.6
1984	32.2	43.8	41.8	54.9	64.9	76.9	76.5	77.8	68.3	65.2	46.0	45.6	57.8	37.3	53.9	77.1	59.8	52.4	63.2
1985	30.8	37.8	47.7	61.6	68.1	72.3	79.0	76.7	71.9	61.2	54.3	36.4	58.2	38.1	59.1	76.0	62.5	53.1	63.3
1986	35.4	35.3	47.4	56.2	68.1	76.6	81.1	74.6	70.9	61.1	46.5	39.8	57.8	35.7	57.2	77.4	59.5	53.2	62.3
1987	34.7	37.0	47.7	54.8	67.2	76.4	82.6	78.7	72.1	54.4	49.9	41.5	58.1	37.2	56.6	79.2	58.8	53.0	63.2
1988	31.0	37.3	47.2	54.4	65.8	74.4	81.9	80.7	68.9	54.4	49.9	38.7	57.1	36.6	55.8	79.0	57.7	51.7	62.4
1989	39.9	37.8	46.1	55.4	64.1	76.8	78.3	77.1	71.4	60.5	48.0	27.9	56.9	38.8	55.2	77.4	60.0	53.4	60.5
1990	43.6	45.2	50.2	56.8	64.3	75.0	79.4	76.5	69.6	62.8	52.0	44.5	60.0	38.9	57.1	77.0	61.5	55.9	64.1
1991	38.6	43.0	48.8	58.2	73.0	76.8	81.4	80.0	71.0	60.4	48.8	42.3	60.2	42.0	60.0	79.4	60.1	56.4	64.0
1992	38.2	41.2	45.0	55.4	62.3	71.7	79.5	74.0	69.2	56.0	48.8	39.6	56.7	40.6	54.2	75.1	58.0	52.3	61.2
1993	39.7	34.3	42.2	54.8	67.4	75.3	83.1	79.6	71.0	58.1	48.8	38.1	57.7	37.9	54.8	79.3	59.3	52.3	63.1
1994	28.8	36.3	45.4	62.0	63.1	79.4	81.8	75.5	70.2	59.1	53.3	44.2	58.3	34.4	56.8	78.9	60.9	52.5	64.0

Washington D.C. Temperatures

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	WINTER	SPRING	SUMMER	AUTUMN	1ST HALF	2ND HALF	
1995	39.6	34.3	49.2	56.3	65.8	74.6	81.5	81.3	70.9	62.3	43.1	35.6	57.9	39.4	57.1	79.1	58.8	53.3	62.5	
1996	32.9	37.3	42.9	56.8	63.9	77.2	77.6	76.5	70.6	59.4	44.1	43.0	56.9	35.3	54.5	77.1	58.0	51.8	61.9	
1997	37.0	44.7	48.7	54.0	62.9	73.1	80.4	77.6	70.5	59.6	46.2	41.0	58.0	41.6	55.2	77.0	58.8	53.4	62.6	
1998	43.0	43.4	46.9	57.4	67.5	73.0	78.9	79.4	75.4	60.1	50.3	44.4	60.0	42.5	57.3	77.1	61.9	55.2	64.8	
1999	38.2	41.0	44.5	56.5	67.3	74.7	83.0	79.7	70.0	57.2	53.1	42.0	58.9	41.2	56.1	79.1	60.1	53.7	64.2	
2000	35.9	42.5	51.7	55.6	67.8	74.7	74.7	75.1	67.6	60.2	46.7	31.8	57.0	40.1	58.4	74.8	58.2	54.7	59.4	
2001	35.5	40.9	43.8	57.6	65.9	75.2	75.3	78.9	68.9	59.7	54.8	45.5	58.5	36.1	55.8	76.5	61.1	53.2	63.9	
2002	41.6	42.6	47.7	60.0	65.2	76.1	80.9	81.1	73.0	58.7	47.1	37.2	59.3	43.2	57.6	79.4	59.6	55.5	63.0	
2003	31.1	33.7	47.1	55.1	61.7	71.4	77.8	78.8	70.5	57.5	53.1	39.2	56.4	34.0	54.6	76.0	60.4	50.0	62.8	
2004	30.6	38.2	48.8	57.4	71.8	73.4	78.6	75.9	71.6	58.3	51.0	40.1	58.0	36.0	59.3	76.0	60.3	53.4	62.6	
2005	36.1	39.6	43.1	57.3	61.9	75.7	80.5	80.1	75.0	60.5	50.2	36.4	58.0	38.6	54.1	78.8	61.9	52.3	63.8	
2006	43.1	38.6	47.9	59.5	65.1	74.5	80.4	80.6	67.8	57.3	50.7	44.2	59.1	39.4	57.5	78.5	58.6	54.8	63.5	
2007	40.7	30.9	47.7	53.6	67.8	76.1	79.3	79.7	72.9	67.1	49.8	41.8	59.0	38.6	56.4	78.4	63.3	52.8	65.1	
2008	40.0	41.0	49.0	58.9	64.7	77.9	80.8	77.9	74.0	58.9	46.6	40.3	59.2	40.9	57.5	78.9	59.8	55.3	63.1	
2009	31.7	39.8	45.2	57.0	65.5	73.7	76.9	79.9	70.2	58.5	52.2	37.9	57.4	37.3	55.9	76.8	60.3	52.2	62.6	
2010	35.3	34.2	51.2	60.9	69.4	80.6	83.1	80.2	75.5	61.6	50.5	34.6	59.8	35.8	60.5	81.3	62.5	55.3	64.3	
2011	33.7	41.8	45.6	58.8	68.4	78.8	84.5	80.0	71.3	58.4	52.4	45.0	59.9	36.7	57.6	81.1	60.7	54.5	65.3	
2012	40.8	44.4	56.8	58.3	71.4	76.3	84.0	81.0	72.2	61.0	46.6	45.4	61.5	43.4	62.2	80.4	59.9	58.0	65.0	
2013	40.3	38.4	43.8	58.9	66.7	76.5	81.2	77.1	71.3	62.4	46.6	42.3	58.8	41.4	56.5	78.3	60.1	54.1	63.5	
2014	32.2	37.8	42.9	57.3	68.5	77.2	79.4	77.7	73.8	62.9	48.0	43.7	58.5	37.4	56.2	78.1	61.6	52.7	64.3	
2015	35.6	30.3	45.3	59.4	73.2	78.1	81.5	79.3	74.9	58.9	53.7	51.2	60.1	36.5	59.3	79.6	62.5	53.7	66.6	
2016	34.9	39.9	53.5	56.9	63.9	76.2	82.7	82.7	76.0	63.1	52.6	41.8	60.4	42.0	58.1	80.5	63.9	54.2	66.5	
2017	42.1	47.7	47.2	63.8	65.5	77.3	81.7	77.4	72.5	64.9	49.8	39.2	60.8	43.9	58.8	78.8	62.4	57.3	64.3	
2018	35.7	45.3	43.6	54.9	72.4	76.2	80.7	81.0	75.5	62.6	46.5	43.5	59.8	40.1	57.0	79.3	61.5	54.7	65.0	
2019	37.2	42.2	46.8	62.4	71.0	76.4	82.1	80.1	76.5	64.1	46.1	42.2	60.6	41.0	60.1	79.5	62.2	56.0	65.2	
2020	42.4	43.8	53.2	55.3	63.8	77.0	83.9	79.6	70.2	61.9	54.3	41.4	60.6	42.8	57.4	80.2	62.1	55.9	65.2	
2021	38.6	37.8	51.2	58.2	66.1	76.6	80.9	80.9	73.2	66.3	47.9	47.6	60.4	39.3	58.5	79.5	62.5	54.8	66.1	
2022	34.6	42.6	50.4	56.9	67.8	76.0	81.1	80.4	72.7	58.2	52.6	40.1	59.5	41.6	58.4	79.2	61.2	54.7	64.2	
2023	45.2	46.7	49.1	62.1	65.0										58.7					
NORM	37.5	40.0	47.6	58.2	67.2	76.3	81.0	79.4	72.4	60.8	49.9	41.7	59.3	39.7	57.7	78.9	61.0	54.5	64.2	1991-2020
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	WINTER	SPRING	SUMMER	AUTUMN	1ST HALF	2ND HALF	

DON'T GET CAUGHT OUTSIDE

No place outside is safe when a thunderstorm is in the area. Get inside as soon as you hear thunder. Run to a substantial building or hard-topped metal vehicle as fast as you can. If you can't get to a safe building or vehicle:

- ✓ Avoid open areas. Don't be the tallest object in the area.
- ✓ Stay away from isolated tall trees, towers or utility poles. Lightning tends to strike the taller objects in an area.
- ✓ Stay away from metal conductors such as wires or fences. Metal does not attract lightning, but lightning can travel long distances through it.
- ✓ If you are with a group of people, spread out. While this actually increases the chance that someone might get struck, it tends to prevent multiple casualties, and increases the chances that someone could help if a person is struck.

IF SOMEONE IS STRUCK

Cardiac arrest is the immediate cause of death for those who die. Lightning victims do not carry an electrical charge and may need first aid immediately.

- ✓ Call for help. Call 9-1-1.
- ✓ Give first aid. Begin CPR if you are trained.
- ✓ Use an Automatic External Defibrillator if one is available. These units are lifesavers!
- ✓ Don't be a victim. If possible, move the victim to a safer place. Lightning CAN strike twice.

NOAA PA 201752

ORGANIZED OUTDOOR ACTIVITIES

It's essential that people in charge of organized outdoor activities understand the dangers of lightning and have a lightning safety plan. Don't be afraid to ask. If you hear thunder, it's time to get to a safe building or vehicle. Speak out!

LEARN MORE ABOUT LIGHTNING SAFETY AT:

www.weather.gov/lightning

NATIONAL WEATHER SERVICE

LIGHTNING SAFETY

FOR YOU AND YOUR FAMILY

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

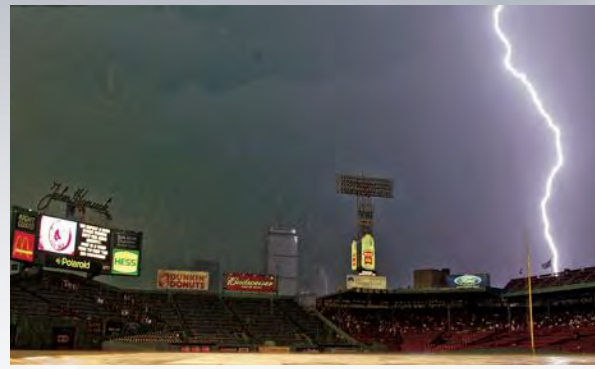
WHEN THUNDER ROARS, GO INDOORS!

Each year in the United States, there are about 25 million cloud-to-ground lightning flashes and about 300 people struck by lightning. Of those struck, about 30 people are killed and others suffer lifelong disabilities. Most of these tragedies can be prevented. When thunderstorms threaten, get inside a building with plumbing and electricity, or a hard-topped metal vehicle!

The National Weather Service collects information on weather-related deaths to learn how to prevent these tragedies. Many lightning victims say they were "caught" outside in the storm and couldn't get to a safe place. Other victims simply waited too long before seeking shelter. With proper planning, similar tragedies can be avoided.

Some people were struck because they went back outside too soon. Stay inside a safe building or vehicle for at least 30 minutes after you hear the last thunder. While 30 minutes may seem like a long time, it is necessary to be safe.

Finally, some victims were struck inside homes or buildings while they were using electrical equipment or corded phones. Others were in contact with plumbing, outside doors, or window frames. Avoid contact with these electrical conductors when a thunderstorm is nearby!



Stadiums and other outdoor venues should have a lightning safety plan. Photo: NOAA

WHAT YOU MIGHT NOT KNOW ABOUT LIGHTNING

- ✓ **All thunderstorms produce lightning and are dangerous.** Fortunately, people can be safe if they follow some simple guidelines when thunderstorms are forecast.
- ✓ **Lightning often strikes outside the area of heavy rain and may strike as far as 10 miles from any rainfall.** Many lightning deaths occur ahead of storms before any rain arrives or after storms have seemingly passed and the rain has ended.
- ✓ **If you can hear thunder, you are in danger.** Don't be fooled by blue skies. If you hear thunder, lightning is close enough to pose an immediate threat.
- ✓ **Lightning leaves many victims with permanent disabilities.** While only about 10% of lightning victims die, many survivors must live the rest of their lives with intense pain, neurological disabilities, depression, and other health problems.

AVOID THE LIGHTNING THREAT

- ✓ **Have a lightning safety plan.** Know where you'll go for safety and ensure you'll have enough time to get there.
- ✓ **Postpone activities.** Consider postponing activities if thunderstorms are forecast.
- ✓ **Monitor the weather.** Once outside, look for signs of a developing or approaching thunderstorm such as towering clouds, darkening skies, or flashes of lightning.
- ✓ **Get to a safe place.** If you hear thunder, even a distant rumble, seek safety immediately. Fully enclosed buildings with wiring and plumbing are best. A hard-topped metal vehicle with the windows closed is also safe. Stay inside until 30 minutes after the last rumble of thunder. Sheds, picnic shelters, tents or covered porches do NOT protect you from lightning.
- ✓ **If you hear thunder, don't use a corded phone except in an emergency.** Cordless phones and cell phones are safe to use.
- ✓ **Keep away from electrical equipment and plumbling.** Lightning will travel through the wiring and plumbing if your building is struck. Don't take a bath or shower, or wash dishes during a storm.

Lightning discharge on a golf green. Photo: E. Philip Krider

For more information, visit www.weather.gov/lightning

National Weather Service

FLOOD SAFETY

FOR YOU AND YOUR FAMILY

BEFORE A FLOOD

- Stay informed: Visit weather.gov or tune into your local news for the latest forecast.
- Determine whether your home, school or work is in an area likely to flood.
- Learn which roadways are likely to flood and find an alternative route so you can avoid them.
- Create a communications plan so your family will know how to connect during an emergency.
- Assemble an emergency kit.
- Prepare for possible evacuation. Pack your bags and include items for your pets so you are ready to leave at a moment's notice.
- Charge all essential electronics.
- Be Proactive: Leave before the flooding starts to avoid getting stranded.

DURING A FLOOD

- Stay informed: Tune into your local news for updates on flooding in progress.
- Get to higher ground if you are in an area that is subject to flooding.
- Follow evacuation orders and heed warning signs.
- If you have time before you evacuate, disconnect utilities and appliances.
- Avoid floodwaters: It is NEVER safe to drive or walk through them.

AFTER A FLOOD

- Stay informed: Tune into your local news for updates on affected areas and the safety of your drinking water.
- Avoid floodwaters: Standing water can hide chemicals that can make you sick, power lines that can cause electrocution and sharp debris that can seriously harm you.
- Avoid disaster areas: Your presence may hamper emergency operations.
- Heed road closure and cautionary signs.
- Wait for the "all-clear" before returning to an area that was impacted by flooding.
- Contact your family and loved ones to let them know you are okay.

Image from the FEMA Photo Library

For more information, visit **weather.gov/safety/flood**

National Weather Service

TURN AROUND DON'T DROWN ®

MOST FLOOD-RELATED DEATHS AND INJURIES COULD BE AVOIDED IF PEOPLE FOLLOWED THIS SIMPLE ADVICE:

Turn Around Don't Drown®. More than 50 percent of flood-related deaths are due to someone driving or walking into floodwaters.

- ✓ **6 INCHES OF FAST-MOVING WATER** can knock adults off their feet and sweep them away.
- ✓ **12 INCHES OF MOVING WATER** can carry off a small car.
- ✓ **18 TO 24 INCHES OF MOVING WATER** can carry away larger vehicles including trucks, vans and SUVs.

If you come to an area that is covered with water, you may not know the depth of the water or the condition of the road or ground underneath. This is especially true at night, when your vision is limited. Play it safe. Whether driving or walking, any time you come to a flooded area, Turn Around Don't Drown®.

For more information, visit **weather.gov/safety/flood**

This Educator's Guide is supported by NOAA Planet Stewards

https://oceanservice.noaa.gov/education/planet-stewards