
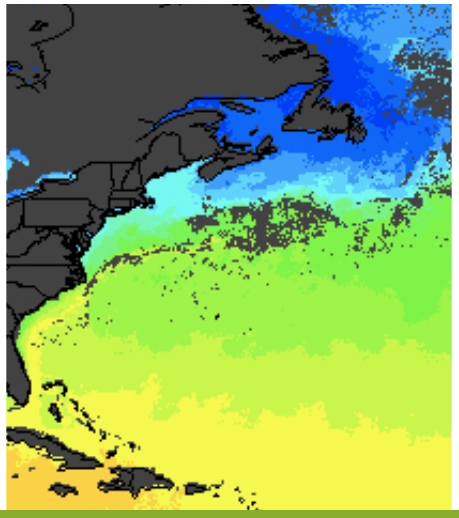


2 How Warm Is the Ocean?
Currents and Sea Surface Temperature

By Steven Moore, Jennifer Vuturo-Brady, and Hedley Bond

Guiding Question
How do ocean currents impact seasonal sea surface temperatures?

Project Duration
Two 45-minute class periods

Grade Level
Grades 9-12+ (ages 14-18)

Learning Objectives
Students will be able to:

- describe how technological advances have impacted the field of oceanography, focusing on the use of satellites
- observe seasonal changes in sea surface temperatures (SSTs) throughout the year, identifying months with the warmest and coldest coastal SSTs

Subjects
- Earth and Space Science
- Physical Geography

How Warm Is the Ocean?

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How do ocean currents impact seasonal sea surface temperatures?

Activity Overview

In this activity, students will use satellite imagery to learn more about ocean circulation and the major currents impacting the East and West Coasts of the United States. Through this investigation, they will gain a stronger understanding of circulation patterns within the ocean and the significance of those patterns.

Background Information

Today, Earth's oceans are studied intensively from afar. Technologies such as remote-sensing satellites and offshore stationary and drifting buoys collect and transmit data via satellite to computers in researchers' laboratories and interested citizens' homes. Imaging sensors mounted on orbiting satellites transmit data that can be used to determine sea surface temperatures (SSTs), chlorophyll levels, ice coverage, sediment plumes, and other oceanic conditions on a global scale.

Remote sensing is the process of obtaining information about an object or phenomenon without actually touching it. Although the distance between the object and the data-gathering sensor can be large or small, most remote-sensing equipment is located some distance above the surface of Earth. Sensors may be mounted on orbiting satellites, airplanes, or raised platforms.

Background Knowledge

Students will be able to make better sense of the data analysis if they have a basic understanding of ocean currents, latitude, and seasons as key factors influencing sea surface temperature.

Connections to National Standards

NATIONAL GEOGRAPHY STANDARDS

- Standard 1: How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective
- Standard 4: The physical and human characteristics of places
- Standard 7: The physical processes that shape the patterns of Earth's surfaces

NATIONAL SCIENCE EDUCATION STANDARDS GRADES 9-12

- Energy in the Earth system (D-1)
- The origin and evolution of the Earth system (D-3)
- Science and technology in local, national, and global challenges (F-6)
- Environmental quality (F-4)
- Abilities of technological design (E-1)
- Historical perspectives (G-3)

Vocabulary

boundary current, *noun*—a deep ocean current that develops as a result of changes in temperature and salinity.
latitude, *noun*—distance north or south of the Equator, measured in degrees.
longitude, *noun*—distance east or west of the prime meridian, measured in degrees.
ocean current, *noun*—stream of water flowing near the ocean's surface or far below it.
remote sensing, *noun*—information gathering about the Earth's surface from a distance.
sea surface temperature (SST)—temperature of the water film at the sea surface.
sensor, *noun*—instrument that receives a signal and

transmits data about that signal, such as data on light and heat.

thermal radiation, *noun*—electromagnetic radiation emitted from a heat or light source as a consequence of its temperature.

transmitters, *noun*—an electronic device which, with the aid of an antenna, produces radio waves.

Extending the Learning

Have students explore stationary and drifting buoys, which float on the ocean surface. Stationary buoys, such as those maintained by the National Weather Service (NWS) and the National Oceanic and Atmospheric Administration's (NOAA) National Data Buoy Center (NDBC), provide real-time information about offshore conditions. A buoy's sensors may measure wind speed, direction and gust, barometric pressure, air temperature, SST, wave height, and wave periods. While the sensors transmit data continuously, public updates are posted hourly on the Web. Both current and historical data are available from the NDBC website: http://www.ndbc.noaa.gov.

In the My World project, turn on the **All buoys** layer. Zoom in to a coastline of interest to you. Find the name or Station ID of some stationary buoys in your area of interest.

Turn off the **All buoys** layer, and turn on the **Four Buoys** layer. Zoom out to show the entire United States and all four buoys. Each buoy provides monthly SST data from a National Marine Sanctuary. Examine the data and compare the SSTs from the four sites.

Researchers also use satellite-tracked buoys to study surface currents and local ocean conditions. Each is composed of a float and a tail. The float portion contains a radio transmitter and a buoy, while the submerged tail portion causes the buoy to move with the current. The sensors attached to drifting buoys acquire data continuously and calculate hourly averages. When a satellite passes overhead, roughly every six hours, the data sets are transmitted from the drifting buoy to the satellite, and from there to a receiving station on Earth.

Turn on both of the drifting buoy layers, **Buoy 41630** and **Buoy 41631.** Examine the data table for Buoy 4130. *How many records are there? When was this buoy deployed? When was it retrieved?* Zoom in to view the path of the buoy. Identify start and end points by applying a color scheme, such as Rainbow 2, to latitude. Choose **Edit the Appearance Of the Active Layer > Color.** Then select **Color by: LAT > Color Scheme.** The different colors applied to the buoy positions and the Get Information Tool will help you find these points. Measure the net distance (start to finish) traveled by Buoy 41630. Measure the actual distance traveled by clicking the points in the path of the buoy. Determine the net and average actual speed of the buoy. *How does the SST change along the path of the buoy?* Repeat the above for Buoy 41631.

You can search for data close to where you live at the National Data Buoy Center: http://www.ndbc.noaa.gov/. Download current or archived data for a buoy, create a table containing the data, and analyze it.

Additional Resources

- National Geographic Education's encyclopedia entries on remote sensing and more: http://education.nationalgeographic.com/education/reference-and-news/
- NOAA Drifter Data Assembly Center's information about drifting buoys: http://www.aoml.noaa.gov/phod/dac/dacdata.html and at the NDBC (http://www.ndbc.noaa.gov/drift.shtml)
- POET's additional SST data for different regions, different time periods, and at different scales: http://poet.jpl.nasa.gov
- Historic information about the HMS Challenger's 19th century study of the world's oceans: http://aquarium.ucsd.edu/Education/Learning_Resources/Challenger/
- NOAA's Ocean Explorer "Mountains in the Sea" website, featuring different data collection techniques: http://oceanexplorer.noaa.gov/explorations/03mountains/background/challenger/challenger.html

Data Dictionary

Additional information about each of the layers used in this project.

- U.S. States—Polygon layer with U.S. state borders and demographic data, from ESRI.
- Countries—Polygon layer with country boundaries, from ESRI.
- North American Currents—Lines indicating three important ocean currents in North America.
- North Atlantic Gyre—Layer showing the North Atlantic Gyre.
- Sea Surface Temperatures 2007—Monthly MODIS data on SST for January 2007 to November 2007 from http://poet.jpl.nasa.gov/. Data obtained as ARC GRID ASCII files for the area 60° N to 5° N (latitude) and 144° W to 44° W (longitude).

How Warm Is the Ocean?

Currents and Sea Surface Temperature

By Steven Moore, Jennifer Vuturo-Brady, and Hedley Bond

How do ocean currents impact seasonal sea surface temperatures?

In this activity, you will use satellite imagery to learn more about ocean circulation and the major currents impacting the East and West Coasts of the United States. This investigation will help you build an understanding of circulation patterns within the ocean and the significance of those patterns. You will observe seasonal changes in Sea Surface Temperatures (SSTs) throughout the year, identifying months with the warmest and coldest coastal SSTs.

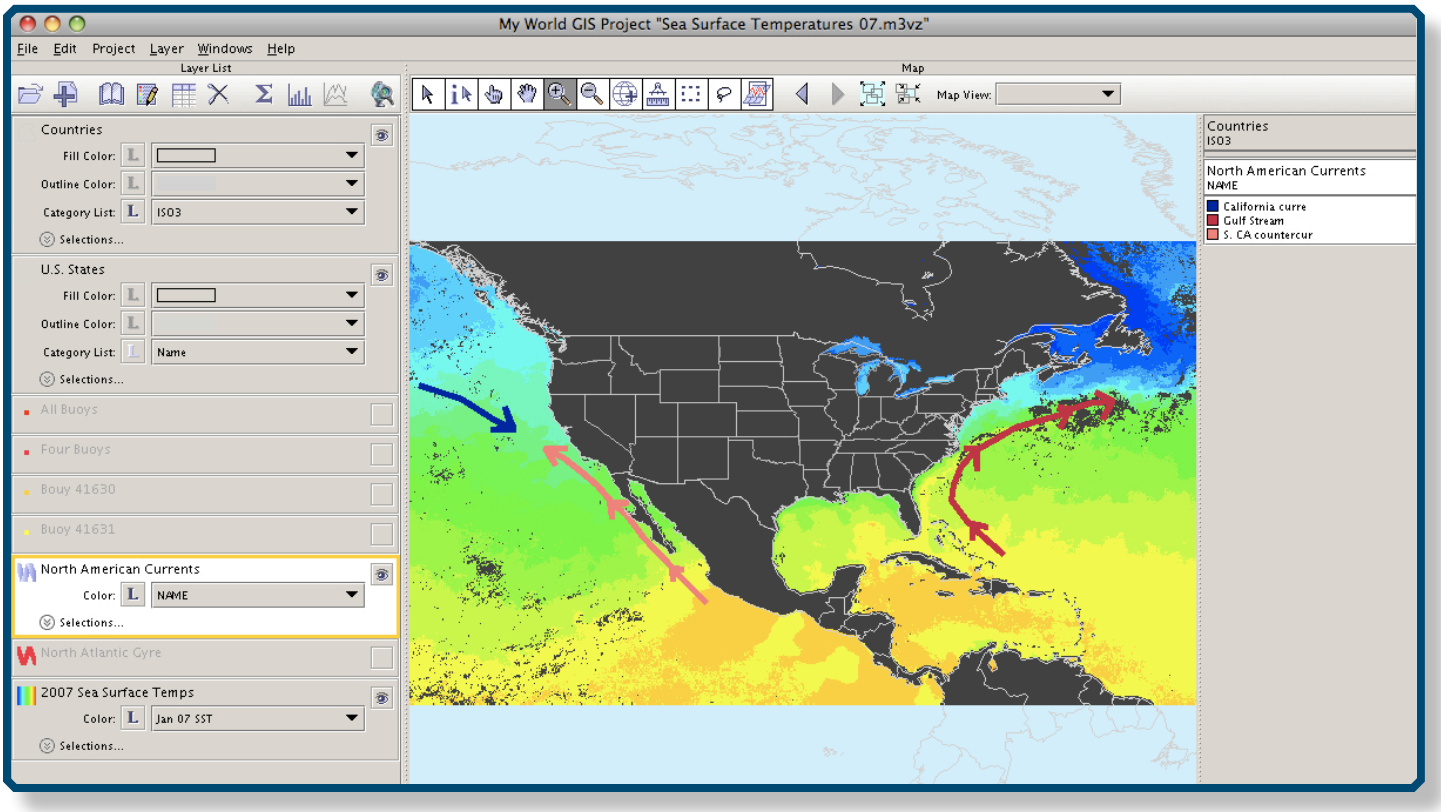
Use the student answer sheet to record answers for each of question below.

Part I: Exploring Sea Surface Temperature

GETTING STARTED

1. Launch My World GIS by double-clicking its icon on the Dock (Mac) or Start List (PC).

2. Navigate to the file, **Sea Surface Temperatures 07.m3vz,** and choose **Open > Project.** You can also double-click the project name to open the project.



The view in the map window includes North America, Central America, and a satellite image showing the average SST in degrees Celsius (°C) for January 2007. Scientists constructed the images used in this section with data obtained from a Moderate Resolution Imaging Spectroradiometer (MODIS) sensor mounted on the Terra satellite, operated by the National Aeronautics and Space Administration (NASA.) The MODIS sensor measures the amount of thermal infrared radiation given off by the surface of the ocean. The image displayed on the map was constructed from data obtained at night to avoid misleading values due to the effects of sunlight. Researchers then calculated the sea surface temperatures from the infrared data to produce a *false-color* image. The image is called *false-color* because the colors you see are a representation of wavelengths that are not visible to the human eye. Any gray spots scattered over the image represent missing data, mostly from clouds. A spectrum of colors is used in the image to represent different sea surface temperatures.

3. Notice that only three layers from the **Layer List** are visible in the **Map** window: Countries, U.S. States, and 2007 Sea Surface Temps.

QUESTION 1: Refer to the SST legend below the image.

a. Which colors represent the warmest waters?

b. Which colors represent the coldest waters?

4. Use the Get Information tool  to obtain SST and *latitude* values for selected locations on the Atlantic and Pacific coasts in order to compare temperatures.

   To use the Get Information tool, make the SST layer active by clicking it. (Note that the active layers have a yellow border.) Select the Get Information tool, and then click a location along the coast. A window, **Information for layer "2007 Sea Surface Temps,"** will appear with area, latitude, longitude, and temperature for all eleven months of the SST data set. If you click the **Keep Records in Table** check box, all the data records from subsequent queries with the tool on that layer will appear as a list in the table. Close the Information window when you are finished.

   Latitude tells you how far north or south of the equator you are, while **longitude** provides the distance east or west of the prime meridian (0° longitude.) The prime meridian runs through Greenwich, England.

QUESTION 2: How do water temperatures in the Pacific Ocean compare with those found in the Atlantic Ocean during 2007?

QUESTION 3: The waters surrounding the island of Newfoundland, which lies off the eastern coast of Canada at a latitude of 50° N and a longitude of 55° W, appear deep blue in the SST images for the first few months of 2007. What does this mean? (Hint: Check the temperature with the Get Information tool. A temperature of 99° indicates that you've selected a point with missing data for that month.)

5. Examine the seasonal changes in SSTs along the Atlantic coast of the United States during 2007 to see when the warmest and coldest temperatures occur. The temperatures for all eleven months at a selected location will be shown in the Information window. You can view the different temperature images by selecting different months in the pull-down menu on the **2007 Sea Surface Temps** layer. Each month and year is represented by a three-letter month code followed by a two number year. For example, **Apr07 SST** shows the average SST data for April 2007.

QUESTION 4:

a. In which month are the coastal waters the warmest along the East Coast?

b. In which month are the coastal waters the coldest along the East Coast?

6. Flip back and forth between the images for the coldest and warmest months by selecting each in the pull-down menu. Notice how far north the warm water moves on the East Coast.

7. Determine the geographic extent of the warm coastal waters (greater than or equal to 24° C) by moving your cursor over the northernmost location reached by warm water along the East Coast. The latitude and longitude of the cursor's location is displayed below the legend. In My World, longitude is listed first, then latitude. It is conventional to record latitude first, and then longitude, and you should list them that way on your data sheet.

8. Activate the U.S. States layer, and use the Get Information Tool to find the name of the state that warm water reaches at its northern most extent.

QUESTION 5:

a. How far north did warm coastal waters (above 24° C) extend along the East Coast during the month of warmest waters in 2007? Give both the latitude and state name.

b. How far north did warm coastal waters extend along the East Coast during the coldest month of 2007? Give both the latitude and the state name.

9. Click and drag the Zoom In Tool to draw a rectangle of interest to include the East Coast of the United States. Click at one corner of where you want your rectangle to start on the map and drag out to create the rectangle area. Measure the shift in warm (above 24°C) coastal waters between the warmest and coldest months. First, click the Measurement Tool. Then click the northernmost extent of warm water. Then move your cursor in a southerly direction to draw a line to where the warm waters extend during the coldest month. Double-click to end the measurement line. The length of the line in kilometers will appear at the bottom of the My World window. (Note: You can change the measurement unit by selecting from the menu, **Edit > Preferences...**)

QUESTION 6:

a. How many kilometers do the warm coastal waters shift along the East Coast between warmest and coldest months?

b. How many miles is this? (1 kilometer = 0.62 miles)

10. Next, study seasonal changes in water temperature along the West Coast. Use the Move Map Tool, to move the view to the West Coast. Using the same approach as you did for Question 4, examine each month's image to determine the months of warmest and coldest waters along the West Coast.

QUESTION 7:

a. In which month are coastal waters the warmest along the Pacific Coast?

b. In which month are coastal waters coldest along this coast?

Flip between the images for these two months, and notice how far south the cold water moves; it may help to zoom in to the boundary a little to see this better.

Ocean waters are continuously in motion. Waves and currents exchange and mix seawater, redistributing heat, nutrients, sediments, organisms, and pollutants across large and small distances. Near the ocean surface, currents are affected by wind, Earth's rotation, and, in shallow areas, ocean floor *bathymetry,* or shape. *Bathymetry* is the study of the underwater depth of ocean and lake floors—the underwater equivalent of topography.

Deeper in the ocean, water circulation is driven by differences in water density caused by temperature or salinity. These differences create invisible boundaries that separate a water mass—and its inhabitants—from another. A *surface current* is water moving within the upper 400 meters of the ocean. Surface currents make up about 10 percent of all the water motion in the ocean. The remaining 90 percent is made up of deep-water currents, which sink into the deep ocean basins at high latitudes where temperatures are low enough to cause the water's density to increase.

11. Zoom out, using either **Zoom to Previous Extents,** or **Zoom to Active Layer,** so that you can see the waters off both coasts of the United States.

Part II: Exploring Currents

IDENTIFYING THE WARM AND COLD CURRENTS

1. Select the **North American Currents** layer by clicking the box to the right of this layer in the Layer List and activate it by clicking its name. Three currents appear as colored lines in your window. Find the names of the three surface currents shown in this layer by choosing the **Get Information** tool and clicking each current's line. The name of the current will appear in an information window. The California Current and the Gulf Stream are both boundary currents that flow along the edge of a continent. Boundary currents separate coastal waters from oceanic waters. The Gulf Stream is one of the strongest surface currents on Earth. It is warm, deep, fast, and relatively salty. Compared to the Gulf Stream, the California Current is cool, broad, slow, and shallow.

QUESTION 8: Compare the California Current and the Gulf Stream in terms of (a) their location, (b) direction of flow, and (c) water temperature. (Hint: Which current, if any, moves warm waters northward, and which, if any, moves cold waters southward?)

The uneven heating of Earth's surface by the sun combined with the planet's own rotation results in warm surface water being transported in a westward direction, first along and then away from the equator. The surface currents, bounded by the continents, follow a clockwise rotation pattern in the Northern Hemisphere and a counterclockwise rotation pattern in the Southern Hemisphere. These large, circular rotation patterns are called gyres.

2. Turn on and activate the **North Atlantic Gyre** layer. To see all of this gyre, use **Zoom to Active Layer.** The My World Data Library includes data showing all the surface currents. To view this layer select **File > Import Add Data to Map,** or click the button for **Add Data to Map.** Navigate through the data library for the **Surface Currents** layer and add it to your project. On this layer you can observe world surface currents: cool currents as blue, warm currents as red. You can see the approximate length of each current and, for some, the name by using the **Get Information** tool.

Name _____ Date_____

How Warm Is the Ocean?

Use the Student Instructions pages to launch My World GIS and complete the activity. Fill in your answers on these pages.

Part I: Exploring Sea Surface Temperature

1. Refer to the SST legend below the image.

a. Which colors represent the warmest waters? _____

_____

b. Which colors represent the coldest waters? _____

_____

2. How do water temperatures in the Pacific Ocean compare with those found in the Atlantic Ocean during 2007? _____

_____

_____

_____

3. The waters surrounding the island of Newfoundland, which lies off the eastern coast of Canada at a latitude of 50° N and a longitude of 55° W, appear deep blue in the SST images for the first few months of 2007. What does this mean? (Hint: Check the temperature with the Get Information tool. A temperature of 99° indicates that you've selected a point with missing data for that month.)

_____

_____

4. Examine the seasonal changes in SSTs along the Atlantic coast of the United States during 2007 to see when the warmest and coldest temperatures occur.

a. In which month are the coastal waters the warmest along the East Coast? _____

_____

_____

Name _____ Date_____

How Warm Is the Ocean?

b. In which month are the coastal waters the coldest along the East Coast? _____

_____

5a. How far north did warm coastal waters (above 24°C) extend along the East Coast during the month of warmest waters in 2007? Give both the latitude and state name._____

_____

b. How far north did warm coastal waters extend along the East Coast during the coldest month of 2007? Give both the latitude and the state name._____

_____

_____

6a. How many kilometers do the warm coastal waters shift along the East Coast between warmest and coldest months? _____

_____

b. How many miles is this? _____

7. Study seasonal changes in water temperature along the West Coast.

a. In which month are coastal waters the warmest along the Pacific Coast? _____

_____

b. In which month are coastal waters coldest along this coast? _____

_____

Part II: Exploring Currents

8. Compare the California Current and the Gulf Stream in terms of (a) their location, (b) direction of flow, and (c) water temperature. (Hint: Which current, if any, moves warm waters northward, and which, if any, moves cold waters southward?)_____

_____

_____

Name _____ Date_____

How Warm Is the Ocean? Answer Key

Use the Student Instructions pages to launch My World GIS and complete the activity. Fill in your answers on these pages.

Part I: Exploring Sea Surface Temperature

1. Refer to the SST legend below the image.

a. Which colors represent the warmest waters? Reds represent the warmest water temperatures.

b. Which colors represent the coldest waters? Deep blues represent the coldest water temperatures However, the warmest waters seen in 2007 are colored orange.

2. How do water temperatures in the Pacific Ocean compare with those found in the Atlantic Ocean during 2007? In June 2007, most of the Atlantic Ocean seen in the SST layer was warm or orange (temperatures greater than 24°C), while water temperatures in the Pacific Ocean were in the colder blue to green range (between 14 and 22°C). That is, the Pacific Ocean was colder than the Atlantic Ocean.

3. The waters surrounding the island of Newfoundland, which lies off the eastern coast of Canada at a latitude of 50° N and a longitude of 55° W, appear deep blue in the SST images for the first few months of 2007. What does this mean? (Hint: Check the temperature with the Get Information tool. A temperature of 99° indicates that you've selected a point with missing data for that month.)

The deep blue color of the waters surrounding Newfoundland in winter 2007 means that ice was present on the surface there, as temperatures were below 0° C.

4. Examine the seasonal changes in SSTs along the Atlantic coast of the United States during 2007 to see when the warmest and coldest temperatures occur.

a. In which month are the coastal waters the warmest along the East Coast? In August coastal waters were warmest along the East Coat in most locations; September waters were warmer in some locations.

Name _____ Date _____

How Warm Is the Ocean? Answer Key

b. In which month are the coastal waters the coldest along the East Coast? In March coastal waters were coldest along the East Coat in most locations; February waters were colder in some locations.

5a. How far north did warm coastal waters (above 24°C) extend along the East Coast during the month of warmest waters in 2007? Give both the latitude and state name. During 2007, warm coastal waters reached New Jersey beaches at a latitude of approximately 39° N.

b. How far north did warm coastal waters extend along the East Coast during the coldest month of 2007? Give both the latitude and the state name. During the coldest month of 2007, warm coastal waters extended to the central Florida coastline at a latitude of approximately 28° N.

6a. How many kilometers do the warm coastal waters shift along the East Coast between warmest and coldest months? The warm coastal waters shift approximately 1,350 km along the East Coast between the warmest and the coldest months.

b. How many miles is this? (1 kilometer = 0.62 miles) 840 miles

7. Study seasonal changes in water temperature along the West Coast.

a. In which month are coastal waters the warmest along the Pacific Coast? Coastal waters along the West Coast are warmest during August or September.

b. In which month are coastal waters coldest along this coast? Coastal waters along the West Coast are coldest during March or April.

Part II: Exploring Currents

8. Compare the California Current and the Gulf Stream in terms of (a) their location, (b) direction of flow, and (c) water temperature. (Hint: Which current, if any, moves warm waters northward, and which, if any, moves cold waters southward?) The California Current runs south along the West Coast, bringing cold water down from the north. The Gulf Stream runs north along the East Coast, bringing warm water up from the equator.