

Name:

Date:

## TEACHER VERSION: Suggested Student Responses Included

### Ocean Boundary Currents

**Guiding Question:** How do western boundary currents influence climate and ocean productivity?

#### Introduction

The circulation of water in the oceans plays an important role in the overall biogeochemistry of the ocean and in the heat balance of the Earth. Surface currents are governed by winds and the rotation of the Earth. Atmospheric trade winds lead to the formation of surface currents, which are driven from east to west along the equator. When these currents encounter land, they divide to the north and south along the eastern borders of continents, or the *western boundaries* of the oceans. As the currents move towards the poles, they are deflected by the rotation of the Earth known as the *Coriolis force*. These currents return towards the equator on the eastern side of the oceans and form a cyclic pattern called a *gyre*.

Western boundary currents are among the largest and strongest ocean currents and typically move 40 to 120 km (25 and 75 miles) per day. These currents also extend much deeper than most other surface currents, down to a depth of 1000 m (3300 feet) or more. Thus, the strong western boundary currents are so deep that they are deflected by the continental margins, which prevent these currents from flowing onto the shallow continental shelves.

#### Effects on Biology

The different characteristics of boundary currents on either side of ocean basins play a large role in controlling their areas' biological productivity. The longer water has been at the surface of the ocean, the longer the phytoplankton (microscopic ocean plants) have had to use up the available nutrients. "Old" surface water piles up along the western boundaries of the ocean basins and is usually not well mixed with the deeper, nutrient-rich water below it. This nutrient-poor water causes the area to be relatively unproductive. Regions dominated by eastern boundary currents are different. These areas have prevailing winds that blow offshore, pushing away surface water and allowing deeper, nutrient-rich water to come to the surface to replace it. This process is called upwelling. Upwelling causes parts of the coastal ocean along eastern basin margins to be extremely productive. Scientists use chlorophyll concentrations as a way to measure phytoplankton growth, or productivity.

#### Effects on climate

As the western boundary currents move towards the poles, they transport large amounts of heat. About half of the heat that is moved from the tropics to the polar regions is transported by these currents (the other half is moved by the atmosphere).

Since western boundary currents transport a lot of heat from the tropics to the poles, they modify climate on the surface of the planet. For example, without the Gulf Stream (the



western boundary current in the North Atlantic Ocean) parts of Europe would be much colder.

This is the reason why London is so much warmer than Chicago (the average temperature in London is 10 degrees warmer than Chicago), even though London is located further north (latitude 51N) than Chicago (latitude 41N). It also influences the climate of the east coast of Florida, keeping temperatures warmer in the winter and cooler than the other southeastern states in the summer.

## The Kuroshio Current

The **Kuroshio Current** (also known as the Japan Current) is a northward flowing branch of the North Equatorial Current in the Pacific Ocean. The Kuroshio Current moves northeast past Japan and then turns eastward from Japan into the North Pacific Ocean. It is unique, because it terminates essentially in the center of the North Pacific Ocean. Sea surface temperature images provide an excellent demonstration of the variability of the flow of the Kuroshio as it marks the boundary of the North Pacific Gyre. Similar to the Gulf Stream, the Kuroshio marks the boundary of warm low-productivity water and colder, higher-productivity water as seen in satellite chlorophyll images.

### *Part 1: Reading questions*

1. What factors are important in setting up western boundary currents?

*Atmospheric trade winds cause surface currents to blow East to West. When they hit land, the current is divided North and South, creating the western boundary current.*

2. How do western boundary currents influence climate?

*Western boundary currents bring large amounts of warm water from the equator to the poles, moving heat up to the northern regions.*

3. What are some properties of ocean biology of western boundary currents?

*Western boundary currents are generally nutrient poor. Phytoplankton have used up most nutrients in the surface waters because the water is not well mixed with deeper, nutrient-rich waters.*



## Part 2: Temperature patterns

1. From the Student Climate Data website (<http://studentclimatedata.unh.edu>), click on the 'Ocean Data' tab at the top of the page.
2. Under 'Tools and Data' in the left panel, click 'DICCE Portal' to bring you out to the NASA DICCE data portal.
3. In the **Area of Interest** section (below the map), type in the coordinates as shown below for the Kuroshio Ocean Current off the coast of Japan. Click 'Update Map.'

Area of Interest: West:	125	North:	50	South:	18	East:	-155	Update Map
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4. Under the '**Physical Ocean**' parameter section, click the box next to 'Sea Surface Temperature.'

Ocean	
<input type="checkbox"/>	The Physical Ocean(2002/07/01 - 2012/03/31)
Parameter	
<input type="checkbox"/>	Euphotic depth
<input checked="" type="checkbox"/>	Sea Surface Temperature (11 micron day)

5. In the '**Temporal**' section, set the Begin Date to January 2004 and the End Date to December 2004.

Begin Date	Year	2004	Month	Jan
End Date	Year	2004	Month	Dec

6. Using the '**Select Visualization**' drop-down menu, select 'Animation.'
7. Click [Edit Preferences](#) and under the **Color Bar** section click 'Custom.' Set the **Min value** to 12 and the **Max value** to 22.
8. Click [Generate Visualization](#)
9. It may take a few minutes for DICCE to create the animation. Once the map loads, *but before* you move through the animation, observe the patterns in sea surface temperature for January (the first image). Using a map or online tool label Japan, Hawaii, China, and the Philippines on the blank map below. Next, draw in the Kuroshio Ocean Current in January and label the average temperature *above* and *below* the current.



10. Now take some time to observe the patterns in sea surface temperature over the entire year by pressing the play button or using the forward and back buttons to move through the animation.

- Describe some of your initial observations. Does the current generally stay in one place or does it shift? What are some similarities and differences in the sea surface temperature patterns between the different months?

*The current shifts northward in the summer, reaching its highest point in August, and then returning south in the winter. Below the current always remains greater than 22°C, above is always less than 12°C.*

### Part 3: Chlorophyll patterns

- Return to the data portal page by clicking the [Home](#) tab on the top-left of the page.
- Click *off* the Sea Surface Temperature box, and click *on* the box next to ‘Chlorophyll a concentration’ under the ‘Ocean Biosphere’ section.

<input type="checkbox"/> Ocean Biosphere(1997/09/01 - 2014/12/31)		
Parameter	Data Product Info	
<input checked="" type="checkbox"/> Chlorophyll a concentration	SWFMO_CHLO.CR	SeaWiFS
<input type="checkbox"/> Chlorophyll a concentration	MAMO_CHLO_9km.CR	MODIS-Aqua

- Keep the Visualization as an Animation, and click [Edit Preferences](#). Under the **Color Bar** section make sure ‘Custom’ is selected, and set the **Min value** to 0.05 and the **Max value** to 1.5.
- Click [Generate Visualization](#)
- Again, once the map loads, take some time to observe the patterns in chlorophyll concentration over the year.
- Where on the map are chlorophyll concentrations the lowest? The highest?

*Chlorophyll concentrations are lowest in lower latitudes (around the Philippines), and highest off the coasts of China, Japan and at higher latitudes (above the Kuroshio Current).*

- In what months do you observe the highest chlorophyll concentrations? Why do you think this is?

*The highest chlorophyll concentrations are in June. This probably is because this is when phytoplankton are photosynthesizing and increasing in population due to warmer weather and favorable sunlight conditions.*

- Compare the patterns in chlorophyll concentrations with the patterns in sea surface temperature, either by using your answer above in Part 2, or clicking on [Result #1](#) at the top of the page to view the sea surface animation again.

9. What effect does the Kuroshio Current have on patterns of chlorophyll and temperature?

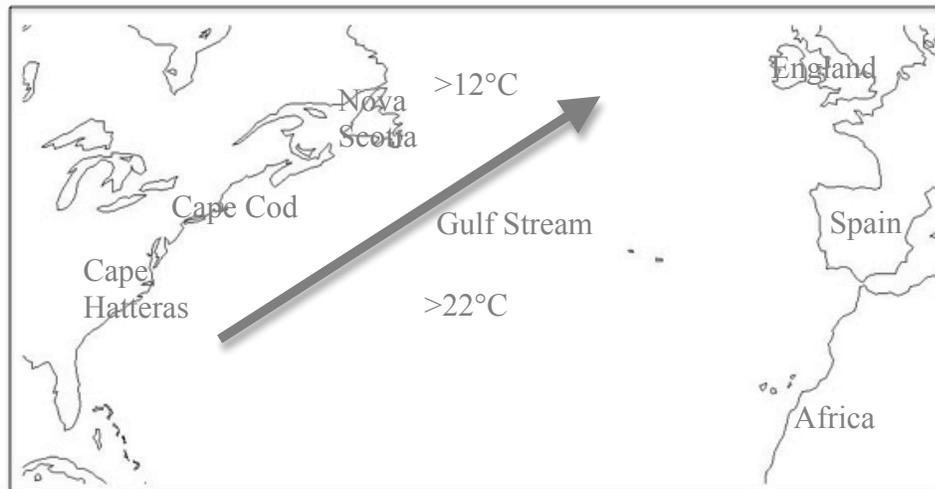
*The Kuroshio Current creates a boundary between very different temperature and biotic conditions. Lower temperature and higher chlorophyll concentrations are found above the current.*

#### **Part 4. The Gulf Stream**

10. Repeat parts 2 and 3 for the Gulf Stream by redefining your area box to these coordinates:

Area of Interest: West:  North:  South:  East:

11. Once the map loads, *but before* you move through the animation, observe the patterns in sea surface temperature for January (the first image). On the blank map below, first label Cape Hatteras, Cape Cod, Nova Scotia, England, Spain, and Africa. Next, draw in the Gulf Stream current in January and label the average temperature *above* and *below* the current.



12. After examining the patterns of chlorophyll and temperature for the Gulf Stream, what characteristics do the Kuroshio and the Gulf Stream share? Try to name at least five.

*Some example answers:*

- 1. Both create a horizontal boundary across the ocean*
- 2. Temperature above both is less than 12°C*
- 3. Temperature below both is less than 22°C*
- 4. Chlorophyll concentrations are highest in the summer, above the current*
- 5. Both begin at a land mass and move northward before moving eastward*