Section 1
Currents

Key Concept The circulation of ocean water distributes water, heat, dissolved gases, and dissolved solids around Earth's surface.

What You Will Learn
- The sun is the major source of energy that drives wind and ocean currents.
- Surface currents and deep currents form convection currents that move ocean water.

Why It Matters
Earth's ocean plays an important role in the transfer of both matter and energy around Earth's surface.

Imagine that you are stranded on a desert island. You put a message asking for help into a bottle and throw the bottle into the ocean. Is there a way to predict where your bottle will end up? Actually, there is a way to predict where the bottle will end up. The oceans contain streamlike movements of water called *ocean currents.* Currents are influenced by a number of factors, including wind, Earth's rotation, and the position of the continents. With knowledge of ocean currents, people are able to predict where objects in the open ocean will be carried.

Surface Currents
Horizontal, streamlike movements of water that occur at or near the surface of the ocean are called **surface currents.** Surface currents can reach depths of several hundred meters. These currents also reach lengths of several thousand kilo meters and can travel across oceans. The Gulf Stream, shown in **Figure 1,** is one of the strongest surface currents on Earth. The Gulf Stream transports at least 25 times more water each year than is transported by all of the rivers in the world combined.

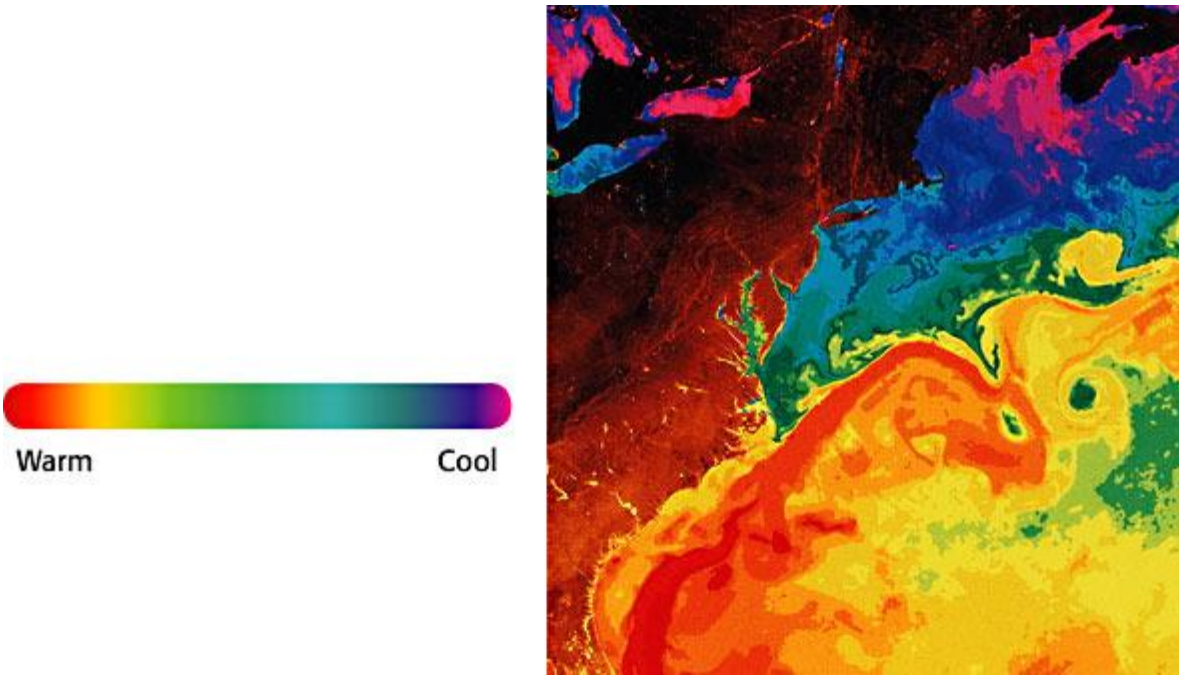


Figure 1 This false-color image taken from an infrared satellite shows the Gulf Stream moving warm water northward along the east coast of the United States.
Surface currents are controlled by three factors: global winds, the Coriolis effect, and continental deflections. These three factors keep surface currents flowing in distinct patterns around Earth.

Global Winds

Have you ever blown gently on a cup of hot chocolate? You may have noticed that your breath pushes the hot chocolate across the surface of the liquid in your cup. In much the same way, winds that blow across the surface of Earth's oceans push water across Earth's surface. This process causes surface currents in the ocean.

Different winds cause currents to flow in different directions. The pattern of global winds that blow near the ocean surface is shown in **Figure 2.** Near the equator, the winds blow mostly east to west. Between 30° south latitude and 60° south latitude, winds blow mostly west to east.

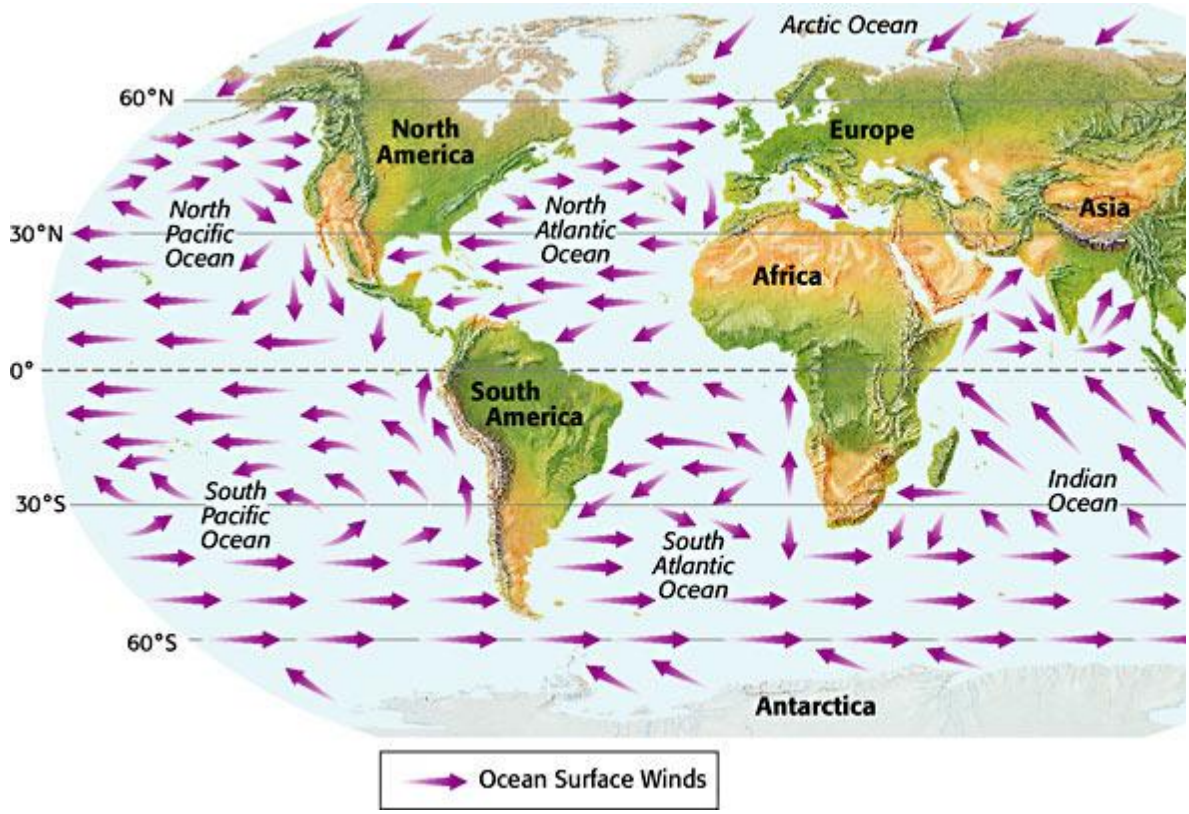


Figure 2 This map shows the pattern of winds that blow near the surface of Earth's oceans.

How the Sun Powers Ocean Currents

The sun heats air near the equator more than it heats air at other latitudes. Pressure differences form because of these differences in heating. For example, the air that is heated near the equator is warmer and less dense than surrounding air. Warm, less dense air rises and creates an area of low pressure near the equator. Pressure differences in the atmosphere cause the wind to blow. So, the sun causes winds to blow, and winds cause surface currents to form. Therefore, the major source of the energy that powers surface currents is the sun.

Standards Check What is the major source of the energy that powers surface currents in the ocean?

The Coriolis Effect

Earth's rotation causes some wind and ocean currents to be deflected from the paths they would take if Earth did not rotate. This deflection of moving objects from a straight path due to Earth's rotation is called the **Coriolis effect.** Because Earth rotates, points on Earth near the equator travel faster than points closer to the poles. This difference in speed of rotation causes the Coriolis effect. For example, water or wind traveling south from the North Pole actually goes toward the southwest instead of straight south. Wind and water deflect to the right because the water and wind move east slower than Earth rotates beneath them. **Figure 3** shows that in the Northern Hemisphere, currents are deflected to the right. In the Southern Hemisphere, currents are deflected to the left.

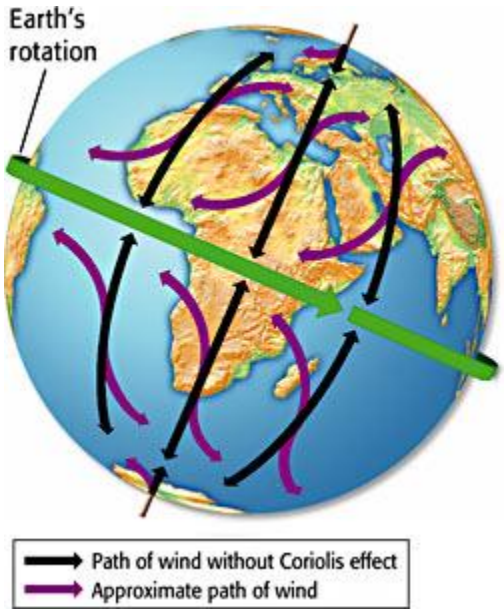


Figure 3 The Coriolis effect in the Northern Hemisphere causes winds and water traveling north or south to appear to be deflected to the right.

The Coriolis effect is most noticeable for objects that travel very fast or that travel over long distances. Over short distances, the difference in Earth's rotational speed from one point to another point is not great enough to cause deflection.

Standards Check How are air and ocean currents deflected by the rotation of Earth?

Continental Deflections

If Earth's surface were covered only with water, surface currents would travel freely across the globe in a very uniform pattern. However, water does not cover the entire surface of Earth. Continents rise above sea level over about one-third of Earth's surface. When surface currents meet continents, the currents are deflected and change direction. Notice in **Figure 4** how the South Equatorial Current turns southward as it meets the coast of South America. The southward-flowing current is called the Brazil Current.

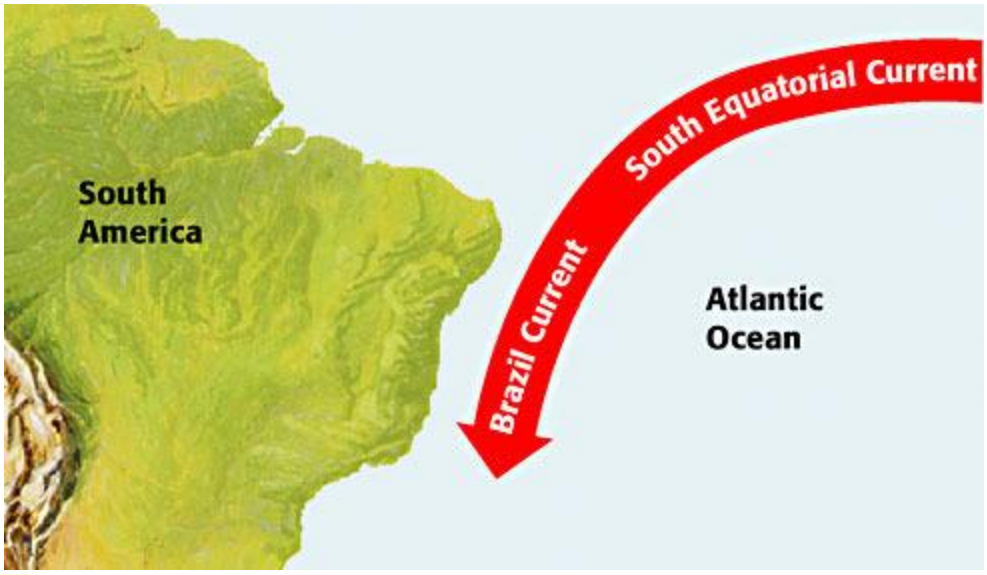


Figure 4 If South America were not in the way, the South Equatorial Current would probably flow farther west.

How Surface Currents Distribute Heat

The flow of surface currents transfers, or distributes, heat energy from one part of Earth to another. The transfer of energy as a result of the movement of matter is called *convection*. So, surface currents transfer heat energy by convection. As **Figure 5** shows, both warm-water and cold-water currents travel from one ocean to another. Water near the equator absorbs heat energy from the sun. Then, warm-water currents carry the energy from the equator to other parts of the ocean. The heat energy from

the warm water is transferred to colder water or to the atmosphere. Cold-water currents absorb heat energy from the atmosphere and from other ocean currents.

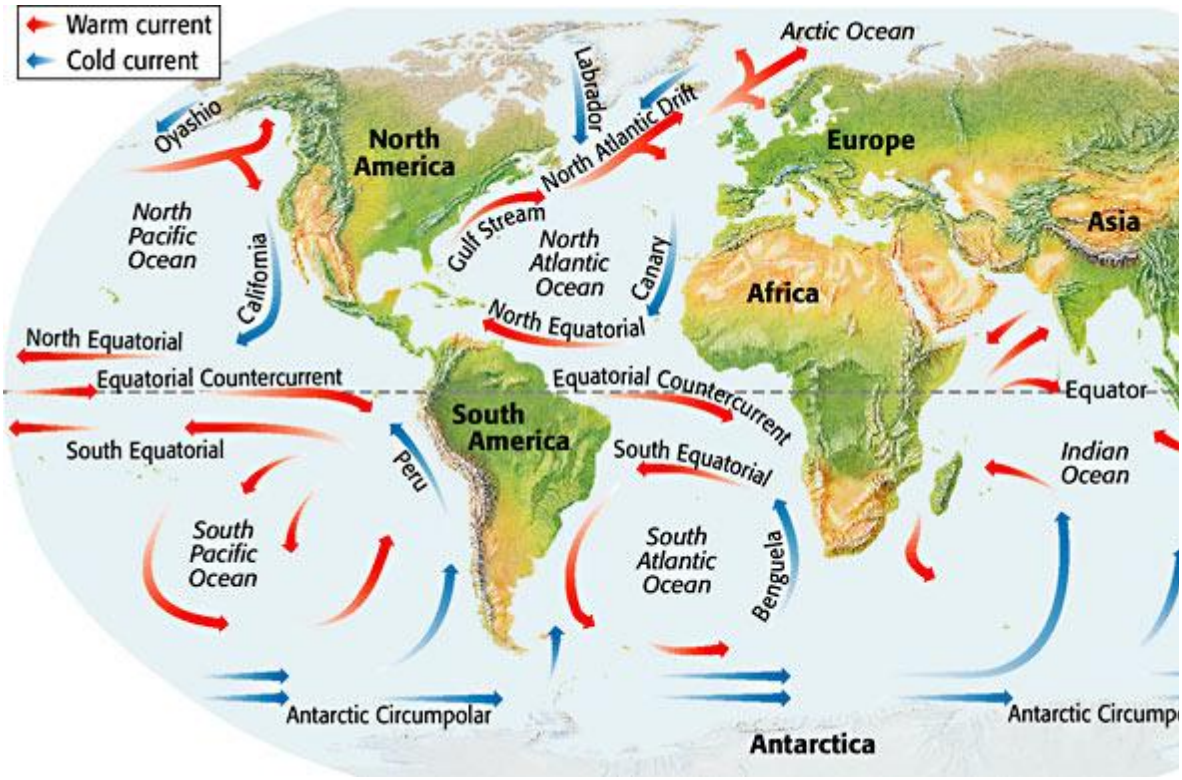


Figure 5 This map shows Earth's major surface currents.

Standards Check How do surface currents distribute heat in the oceans?

Deep Currents

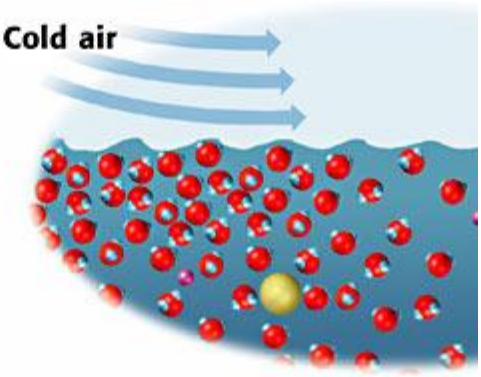
Movements of ocean water far below the surface are called **deep currents.** Unlike surface currents, deep currents are not controlled by wind. Instead, the movement of deep currents is caused by differences in water density. Water that flows deep in the ocean is denser than water at the ocean surface. *Density* is the amount of matter in a given space or volume. The density of ocean water is affected by salinity and temperature. *Salinity* is a measure of the amount of dissolved salts or solids in a liquid. Water with high salinity is denser than water with low salinity. And cold water is denser than warm water.

How Deep Currents Form

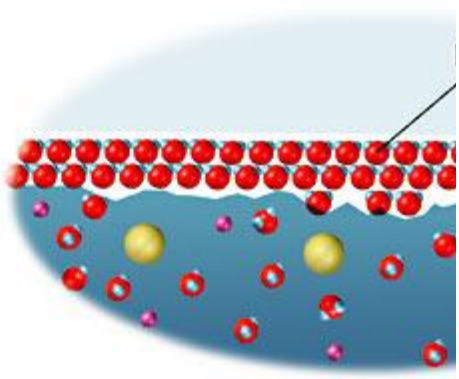
The density of ocean water can be increased in three ways, as **Figure 6** shows. In these ways, ocean water at the surface can become denser than water below it. The denser water sinks. This downward movement takes water from the surface to the deep ocean. Deep currents flow below the surface. These currents are made up of dense water that sinks and then flows along the ocean floor or along the top of a layer of denser water.

Figure 6 How Ocean Water Becomes More Dense

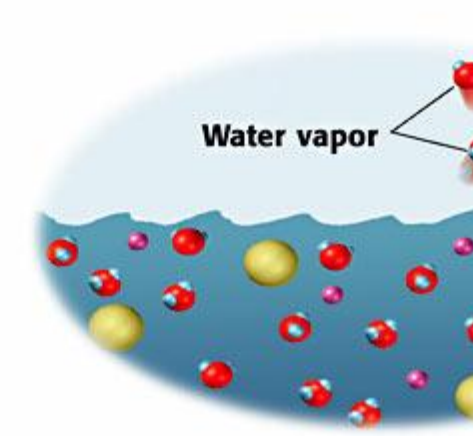
Decreasing Temperature In Earth's polar regions, cold air chills the water molecules at the ocean's surface. This decrease in temperature causes the molecules to slow down and move closer together. Thus, the water's volume decreases, which makes the water denser.



Increasing Salinity Through Freezing In some places, ocean water freezes at the surface. Ice floats on top of the water because ice is less dense than liquid water. The dissolved solids in the ocean water do not become part of the ice and remain in the water that has not frozen. This process increases the salinity of the water, and the water becomes denser.



Increasing Salinity Through Evaporation Salinity also increases through evaporation of surface water. Evaporation is especially common in warm climates. It removes water but leaves solids behind. As a result, salinity increases and the water becomes denser.



Because the ocean is so deep, there are several layers of water at any location in the ocean. The deepest and densest water in the ocean is Antarctic Bottom Water, which forms near Antarctica. North Atlantic Deep Water is less dense and forms in the North Atlantic Ocean. Less-dense water always stays on top of denser water. So, the North Atlantic Deep Water flows on top of the Antarctic Bottom Water when the two meet.

Convection Currents

Surface currents and deep currents are linked in the ocean. Together they are called **convection currents** because their movement results partly from differences in water density. Convection currents transfer energy as they flow, as shown in **Figure 7.** Warm water at the ocean surface absorbs energy from the sun. Surface currents carry this energy to colder regions. The warm water loses energy to its surroundings and becomes cooler. As the water cools, it becomes denser and sinks. The cold water travels along the ocean bottom. Then, the deep water rises to the surface as surface water moves away. The cold water warms as it absorbs energy from the sun, and the cycle continues.

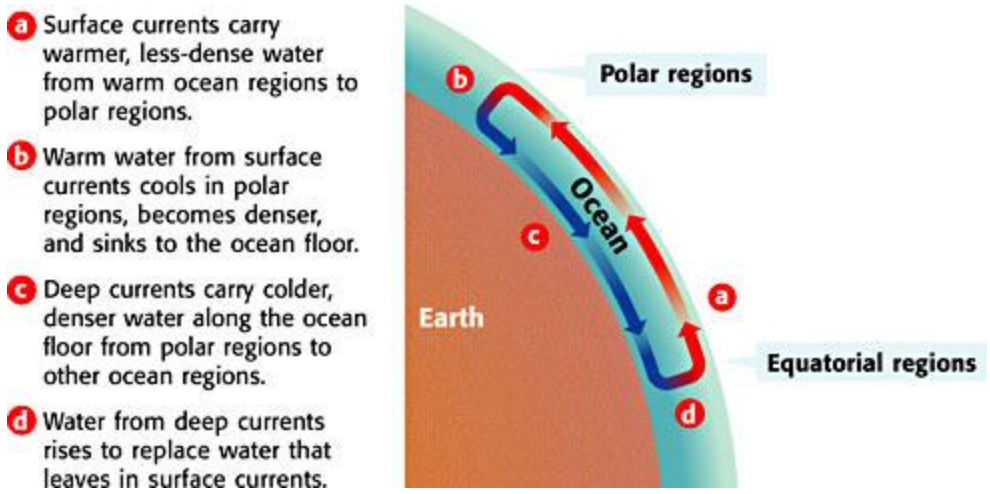


Figure 7 The warmer, less-dense water in surface currents cools and sinks. This water then becomes the colder, denser water in deep currents.

Standards Check What is a convection current?

Global Circulation

Ocean water circulates through all of Earth's ocean basins. The paths shown in **Figure 8** are like the main highway on which much ocean water flows. If you could follow a water molecule on this path, you would find that the molecule takes more than 1,000 years to come back to its starting point!

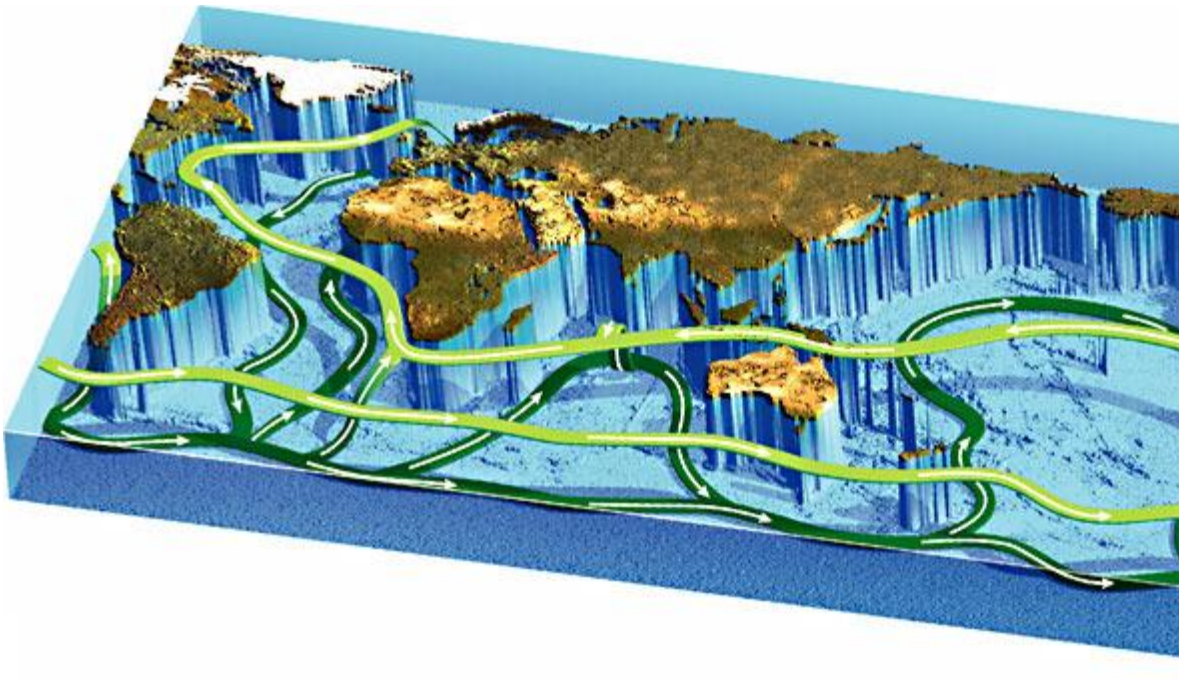


Figure 8 This map shows the main paths of global ocean circulation. Antarctica is not shown on this map, but the currents at the bottom of the map circulate around Antarctica. These currents are called circumpolar currents.

Material Transport by Global Circulation

Global ocean circulation moves more than just water— materials in the water are moved as well. Two of the most important materials transported this way are oxygen and nutrients. Oxygen is taken from the surface to the deep ocean by deep currents. Nutrients are brought to the surface as deep water rises to the surface.

Heat Transport by Global Circulation

Global ocean circulation is also very important in the distribution of heat. About half of the heat that is transported around Earth's surface is carried by convection currents in the ocean. Thus, ocean circulation is important in global climate regulation.

Standards Check What are three of the things that are transported by global ocean circulation?

Section Summary

- Surface currents form as wind transfers energy to ocean water.
- Surface currents are controlled by three factors: global winds, the Coriolis effect, and continental deflections.
- Deep currents form where the density of ocean water increases. Water density depends on temperature and salinity.
- Surface currents and deep currents combine to form convection currents that transfer energy.
- Earth's global circulation moves water through all oceans and distributes materials and heat.