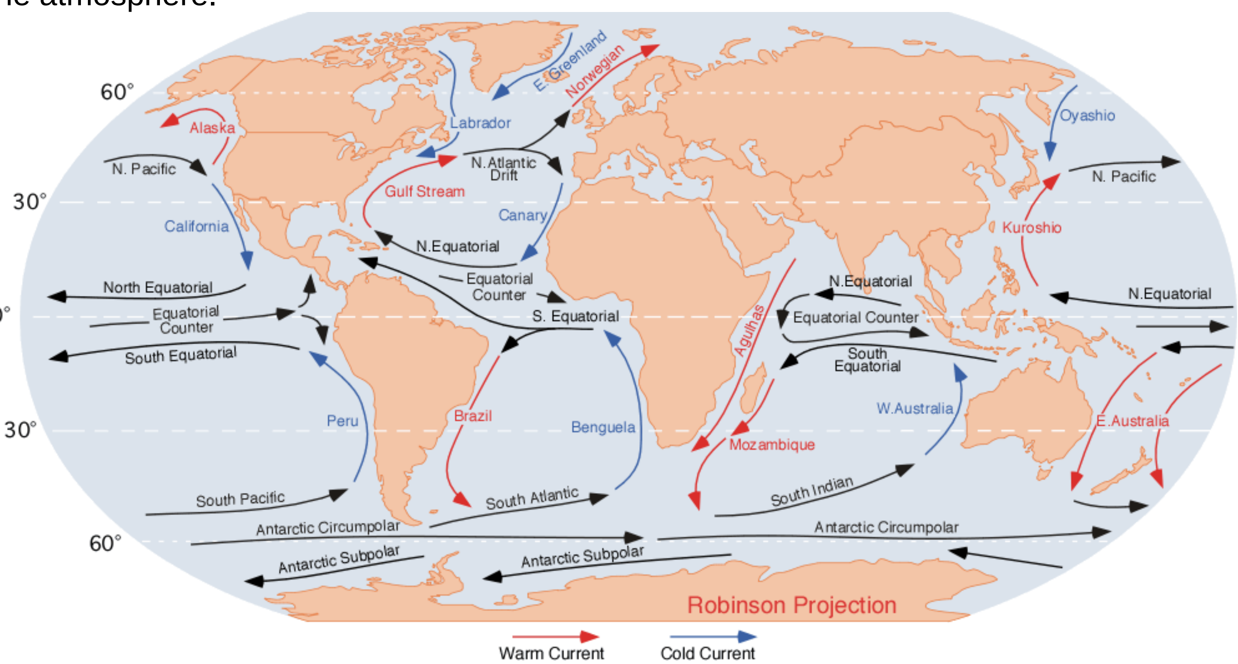
Ocean water is constantly in motion, powered by many different forces. Winds, for example, generate surface currents, which influence coastal climate. Winds also produce waves like the ones shown in Figure 1. Some waves carry energy from powerful storms to distant shores, where their impact erodes the land. In some areas, density differences create deep-ocean circulation. This circulation is important for ocean mixing and recycling nutrients.

Surface Circulation

Ocean currents are masses of ocean water that flow from one place to another. The amount of water can be large or small. Ocean currents can be at the surface or deep below. The creation of these currents can be simple or complex. In all cases, however, the currents that are generated involve water masses in motion.

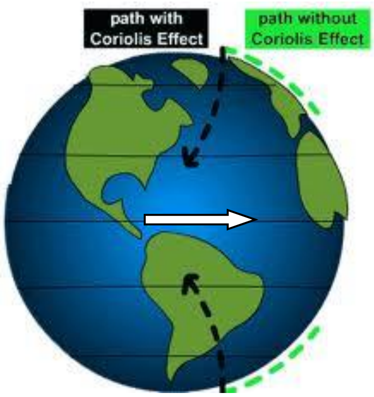
Surface Currents

Surface currents are movements of water that flow horizontally in the upper part of the ocean's surface. **Surface currents develop from friction between the ocean and the wind that blows across its surface.** Some of these currents do not last long, and they affect only small areas. Such water movements are responses to local or seasonal influences. Other surface currents are more permanent and extend over large portions of the oceans. These major horizontal movements of surface waters are closely related to the general circulation pattern of the atmosphere.



Gyres

Huge circular-moving current systems dominate the surfaces of the oceans. These large whirls of water within an ocean basin are called **gyres** (*gyros* = a circle). There are five main ocean gyres: the North Pacific Gyre, the South Pacific Gyre, the North Atlantic Gyre, the South Atlantic Gyre, and the Indian Ocean Gyre. Find these gyres the figure above (note: thePacific on right side of the globe wraps around and connects with the other half of the Pacific on left)

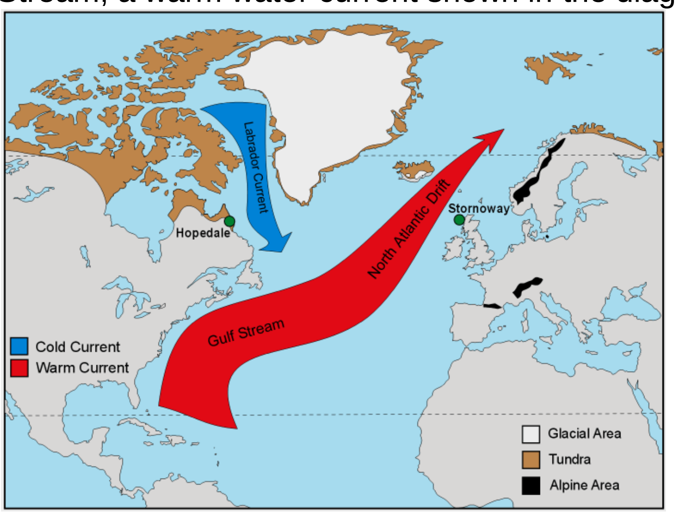


Although wind is the force that generates surface currents, other factors also influence the movement of ocean waters. The most significant of these is the Coriolis effect. The **Coriolis effect** is the deflection of currents away from their original course as a result of Earth's rotation. **Because of Earth's rotation, currents are deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.** As a consequence, gyres flow in opposite directions in the two different hemispheres.

Four main currents generally exist within each gyre. For example, the North Pacific Gyre consists of the North Equatorial Current, the Kuroshio Current, the North Pacific Current, and the California Current. The tracking of floating objects that are released into the ocean reveals that it takes about six years for the objects to go all the way around the loop.

Ocean Currents and Climate

Ocean currents have an important effect on climates. **When currents from low-latitude regions move into higher latitudes, they transfer heat from warmer to cooler areas on Earth.** The Gulf Stream, a warm water current shown in the diagram, is an excellent example of this phenomenon. The Gulf Stream brings warm water from the equator up to the North Atlantic Current, which is an extension of the Gulf Stream. This current allows Great Britain and much of northwestern Europe to be warmer during the winter than one would expect for their latitudes, which are similar to the latitudes of Alaska and Newfoundland. The prevailing westerly winds carry this warming effect far inland. For example, Berlin, Germany (52 degrees north latitude), has an average January temperature similar to that experienced at New York City, which lies 12 degrees latitude farther south.

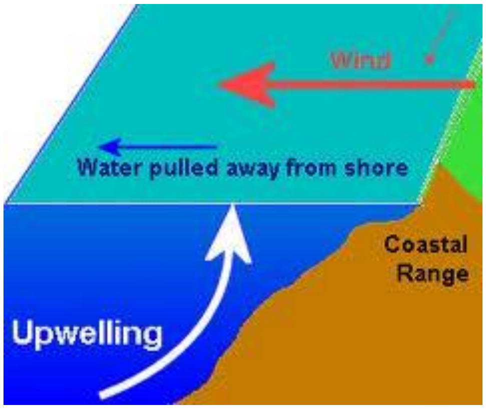


The effects of these warm ocean currents are felt mostly in the middle latitudes in winter. In contrast, the influence of cold currents is most felt in the tropics or during summer months in the middle latitudes. Cold currents begin in cold high-latitude regions. **As cold water currents travel toward the equator, they help moderate the warm temperatures of adjacent land areas.** Such is the case for the Benguela Current along western Africa, the Peru Current along the west coast of South America, and the California Current.

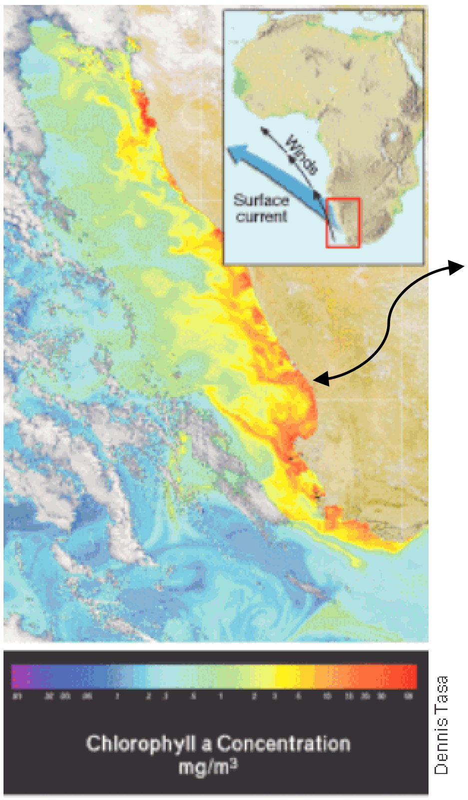
Ocean currents also play a major role in maintaining Earth's heat balance. They do this by transferring heat from the tropics, where there is an excess of heat, to the polar regions, where less heat exists. Ocean water movement accounts for about a quarter of this heat transport. Winds transport the remaining three-quarters.

Upwelling

In addition to producing surface currents, winds can also cause vertical water movements. **Upwelling** is the rising of cold water from deeper layers to replace warmer surface water. Upwelling is a common wind-induced vertical movement. One type of upwelling, called coastal upwelling, is most characteristic along the west coasts of continents, most notably along California, western South America, and West Africa.



Coastal upwelling occurs in these areas when winds blow toward the equator and parallel to the coast. Coastal winds combined with the Coriolis effect cause surface water to move away from shore. As the surface layer moves away from the coast, it is replaced by water that "upwells" from below the surface. This slow upward movement of water from depths of 50 to 300 meters brings water that is cooler than the original surface water and results in lower surface water temperatures near the shore.



Upwelling brings greater concentrations of dissolved nutrients, such as nitrates and phosphates, to the ocean surface. These nutrient-enriched waters from below promote the growth of microscopic plankton, which in turn support extensive populations of fish and other marine organisms. The figure at the left shows an increase in photosynthetic phytoplankton due to increased food from an upwelling.

Figure 4 Effects of Upwelling This image from the SeaStar satellite shows chlorophyll concentration along the southwest coast of Africa. High chlorophyll concentrations, in red, indicate high amounts of photosynthesis, which is linked to upwelling nutrients

Deep-Ocean Circulation

In contrast to the largely horizontal movements of surface currents, deep-ocean circulation has a significant vertical component. It accounts for the thorough mixing of deep-water masses.

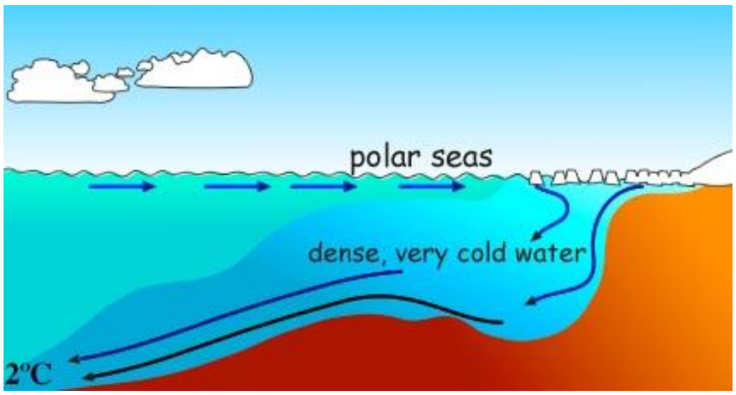
Density Currents

Density currents are vertical currents of ocean water that result from density differences among water masses. Denser water sinks and slowly spreads out beneath the surface. **An increase in seawater density can be caused by a decrease in temperature or an increase in salinity.** Processes that increase the salinity of water include evaporation and the formation of sea ice. Processes that decrease the salinity of water include precipitation, runoff from land, icebergs melting, and sea ice melting. Density changes due to salinity variations are important in very high latitudes, where water temperature remains low and relatively constant.

High Latitudes

Most water involved in deep-ocean density currents begins in high latitudes at the surface. In these regions, surface water becomes cold, and its salinity increases as sea ice forms. When this water becomes dense enough, it sinks, initiating deep-ocean density currents. Once this water sinks, it is removed from the physical processes that increased its density in the first place. Its temperature and salinity remain largely unchanged during the time it is in the deep ocean. Because of this, oceanographers can track the movements of density currents in the deep ocean. By knowing the temperature, salinity, and density of a water mass, scientists are able to map the slow circulation of the water mass through the ocean. **Figure 5**

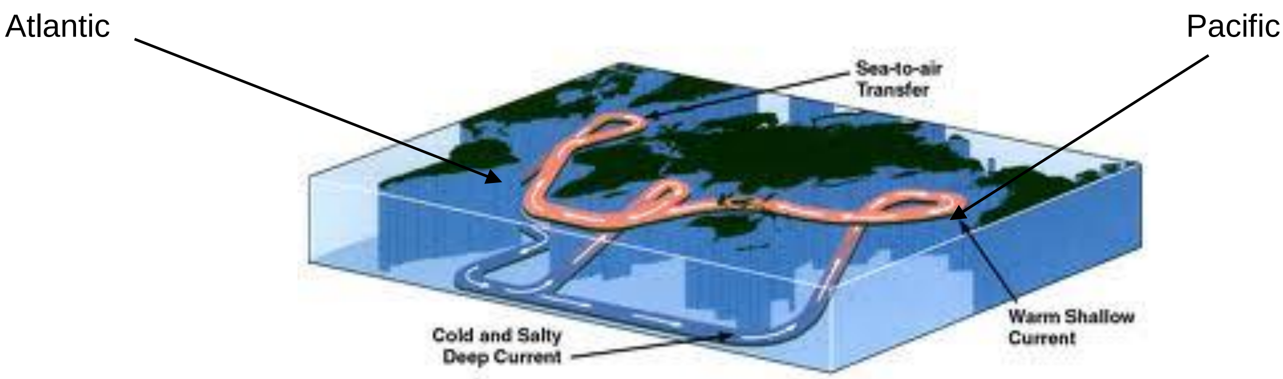
Sea Ice in the Arctic Ocean When seawater freezes, sea salts do not become part of the ice, **leading to an increase in the salinity of the surrounding water**.



Near Antarctica, surface conditions create the highest density water in the world. This cold, salty water slowly sinks to the sea floor, where it moves throughout the ocean basins in slow currents. After sinking from the surface of the ocean, deep waters will not reappear at the surface for an average of 500 to 2000 years.

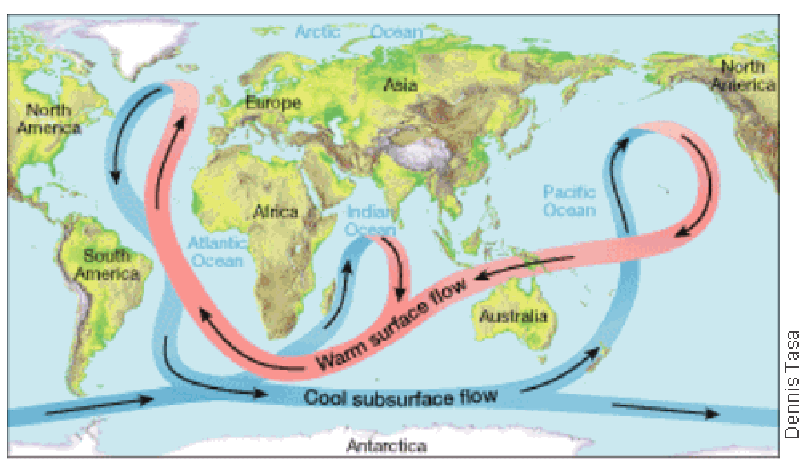
Evaporation

Density currents can also result from increased salinity of ocean water due to evaporation. In the Mediterranean Sea conditions exist that lead to the formation of a dense water mass at the surface that sinks and eventually flows into the Atlantic Ocean. Climate conditions in the eastern Mediterranean include a dry northwest wind and sunny days. These conditions lead to an annual excess of evaporation compared to the amount of precipitation. When seawater evaporates, salt is left behind, and the salinity of the remaining water increases. The surface waters of the eastern Mediterranean Sea have a salinity of about 38‰ (parts per thousand). In the winter months, this water flows out of the Mediterranean Sea into the Atlantic Ocean. At 38‰, this water is more dense than the Atlantic Ocean surface water at 35‰, so it sinks. This Mediterranean water mass can be tracked as far south as Antarctica. The figure below shows how cold salty water sinks in the Atlantic, flows along the bottom and then some rises to the surface on the other side of Africa while other continues around to the Pacific where it rises and curves back on the surface in a loop.



A Conveyor Belt

This simplified model of ocean circulation is similar to a conveyor belt that travels from the Atlantic Ocean through the Indian and Pacific oceans and back again. The diagram below shows this conveyor belt model. This world ocean current is called the **Thermohaline Conveyor**. In this model, warm water in the ocean's upper layers flows toward the poles. When the water reaches the poles, its temperature drops and salinity increases, making it more dense. Because the water is dense, it sinks and moves toward the equator. It returns to the equator as cold, deep water that eventually upwells to complete the circuit. As this "conveyor belt" moves around the globe, it influences global climate by converting warm water to cold water and releasing heat to the atmosphere.



This "conveyor belt" model of ocean circulation shows a warm surface current with an underlying cool current.