Ocean Circulation in the North Atlantic

The Fluid Ocean

If you’ve been to the beach, or a rocky coast, you have probably seen the ebb and flow of tides and the power of waves as they crash along the shore. The vast waters of the world’s ocean are in perpetual motion and play a critical role in redistributing energy and maintaining Earth’s climate. Covering over 70 percent of the planet and with an average depth of 12,100 feet (3,688 meters), the reach of this fluid medium is truly wide and deep.

Global ocean circulation is very complex and involves many interconnected components at various scales. One key component is the meridional overturning circulation (MOC), which describes the movement of ocean waters at different latitudes and depths averaged over long periods of time. (Meridional means along a longitude line, or along the north–south axis.)

Power of the Ocean


Have you ever been to the beach? How about a large river, or a small river that has flooded after a rainstorm?

What was it like? Describe your experience watching the waves or currents, and their effect on the beach or banks of the river/stream.
Earth’s Unequal Heating and Winds

Because of the tilt of Earth on its axis, Earth’s surface and atmosphere are unevenly heated by the Sun. This creates a difference in the amount of thermal energy received at the tropics and the poles. Convection currents form in the atmosphere as warmer air rises and cooler air sinks. This movement of air produces a circulation pattern—or wind—that redistributes heat in the atmosphere.

Warm air near the equator rises, moves toward the poles, sinks around 30°N/S latitude, and then flows back toward the equator. This strong circulation cell of overturning air, combined with the effect of Earth’s rotation, results in wind patterns that are predictable by latitude. The winds at each latitudinal band flow toward the east or the west depending on the differences in temperature and pressure, altitude, and factors such as swirling storm systems. For example, in the mid-latitudes (roughly 30° to 60°N/S), surface winds flow from west to east and are called westerlies.
Patterns of Surface Winds


What patterns do you see in the winds?

Where are some places that the winds move in a northward direction?

What is the relationship between unequal heating of Earth’s surface and surface winds?

Surface Winds and Surface Currents

What do winds have to do with ocean currents? Ocean currents are the movement of water from one location to another. Surface currents occur in the upper 100 meters (about 300 feet) of the ocean. Winds near Earth’s surface play an important role in driving these ocean surface currents.
Surface Winds


Ocean Currents

https://d43fweuh3sg51.cloudfront.net/media/media_files/eea6060d-976b-4536-bcac-cf184717f38b/2abd6f6c-0413-4c97-9bea-8c967578cd2c.mp4
What general patterns or relationships do you see between the wind patterns and water currents? Provide evidence to support your observations.

**Sea Surface Temperature**

Just as winds result from unequal heating of Earth by the Sun, the unequal heating of the ocean also contributes to the movement of ocean currents. This map shows the long-term average global sea surface temperature, which is the temperature of the water found in the top few centimeters of the ocean. In this map, yellows and reds (bands of light or dark in the middle of the map) represent warmer water temperatures while blues (bands at the top and bottom) represent cooler water temperatures.

*Sea Surface Temperature*

https://ilp-media.wgbh.org/filer_public_thumbnails/filer_public/b7/b0/b7b0bcff-a96f-4878-a4eb-714a838db472/ssstempmap_17-6-20.png_1778x1000_q85_subsampling-2_upscale.png

Describe the overall pattern of sea surface temperature across the globe. How do you think sea surface temperatures are connected to the unequal heating of Earth by the Sun?
Surface Currents and Temperature

Sea Surface Temperatures along Currents

https://pbslm-contrib.s3.amazonaws.com/WGBH/buac17/buac17-vid-currents-highres.mp4
These images show computer simulations of the flow of the ocean surface water for one year. The colors show the temperatures of the water. Observe the global pattern of the ocean surface circulation. Look for circular currents of water, called eddies.

Use the following table to take notes on the general patterns you observe.

<table>
<thead>
<tr>
<th>Question</th>
<th>Notes</th>
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<tbody>
<tr>
<td>1. Describe the general temperature of currents near the equator.</td>
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<td>2. Describe the general temperature of currents near poles.</td>
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<td>3. What is the general pattern of current flow and temperature within the Atlantic basin?</td>
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<td>4. What inferences can you make about how heat travels in terms of surface currents?</td>
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<td>5. How are ocean eddies involved in the transfer of heat in the ocean?</td>
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**Sea Surface Salinity**

The amount of salt in ocean water has an influence on how the ocean moves and how it transports heat. Several processes contribute to ocean salinity, or its concentration of dissolved salts. As precipitation falls on land, rocks undergo weathering and erosion, which results in the release of dissolved salts and other minerals. The dissolved salts ultimately enter the ocean over time. Hydrothermal vents and volcanoes on the seafloor are also sources of dissolved salts.

The average salinity of seawater is 35 parts per thousand. That's 35 grams of salt per 1,000 grams of seawater, or 3.5 percent. Salinity variations throughout the ocean are influenced by differences in precipitation and evaporation. Increased precipitation decreases salinity by adding freshwater; increased evaporation increases salinity by concentrating the salt.
Sea Surface Density

The density of seawater is affected by both its temperature and its salinity. Water with a higher salt concentration is denser than water with a lower salt concentration, and colder seawater is denser than warmer seawater. Density determines whether something—be it a solid object or a flowing fluid—will float or sink. High-density waters will sink and become the deep bottom waters of the ocean.

Here is a map showing the average global sea surface density over a long period of time. Focus on the Atlantic basin. Based on the density data in this map, in which regions or areas of the Atlantic do you think the water will sink?
You can also use the Interactive Map:


Explain why you circled the specific areas you did. Provide evidence from the density map, sea surface temperature map, or other sources to support your explanation.

Global Ocean Circulation and the North Atlantic

The interaction of unequal temperatures, surface winds, and density differences in the ocean influence the flow of water through Earth’s ocean basins. Global ocean circulation involves a complex system of meridional overturning circulation (MOC) cells, wind-driven gyres, and eddies, which combine to transport heat from the equator toward the poles. MOC describes the movement of water over latitude (north/south) and depth (surface/deep) averaged over long periods of time. Gyres are giant circular currents that fill entire basins. Eddies are smaller, temporary swirling flows.

The North Atlantic plays a dominant role in the transport of heat northward. The Atlantic Ocean basin is relatively small and salty due to less input of freshwater, compared to the Pacific. Thus, the convection of very salty, extremely dense water masses occurs predominantly in the North Atlantic.
A map of the northern Atlantic Ocean shows a prominent current that flows northeast, from the southern tip of Florida, along the coast of North America, and then toward Europe and North Africa.


In the North Atlantic, the overturning circulation spans the northern and southern hemispheres. The warm surface waters make up the upper portion of the overturning circulation. As warm surface waters move northward from equatorial regions to the high northern latitudes, they cool and increase in salinity and density. There, in the Nordic and Labrador Seas (near Iceland and Greenland), the cooled, dense waters sink. This dense, deep water mass remains quite cold as it spreads southward, forming the bottom portion of the overturning circulation at depths of approximately 1,500 meters (almost 5,000 feet) and greater. In the Southern Ocean, the deep, dense waters rise and return to the surface.

The Role of Eddies

It is important to keep in mind that the large-scale sinking and rising of water of an overturning circulation cell is a very complex, three-dimensional phenomenon. The movement of water does not follow a single, simple path along the surface or at depth, nor is it driven by winds or density differences alone. With recent advances in ocean observation and measurement techniques, oceanographers have found that the overturning circulation results from a complex interplay between variables, including winds; tides; density; temperature; topography; and the effects of eddies, at differing scales of time and space.
Tens of kilometers wide, eddies can extend to great depths and travel for long distances before their energy becomes depleted over weeks or months. As they churn along, evolving as they go, these swirling currents transport with them heat, salt, and nutrients. Eddies have been found to have a large influence on the spreading of waters at depth. For example, researchers have discovered that there are multiple pathways for dense, deep waters in the North Atlantic to travel southward, with eddies driving some of the flow toward the interior of the ocean basin.
How do eddy patterns change throughout the year as shown? What evidence do the images provide about the role eddies play in transporting heat?

Eddies—Winter, Spring, Summer, Fall

Visualizing Surface and Deep Current Flows

You have learned how the unequal heating of Earth and its resulting winds and differences in sea surface temperature, salinity, and density contribute to overturning in the ocean.

The following data visualizations show ocean current flows at the surface and at 2,000 meters (about 6,500 feet) below the surface. The visualizations were produced using a computer model that accounts for observational data, including data from remote-sensing satellites and direct ocean measurements, representing the best estimate of ocean flow at different depths.
Note the overall northward movement of surface currents along the western boundary of the North Atlantic basin (along the east coast of North America). At depth, while the general southward flow is visible in many places along the western Atlantic boundary, the flow is not
continuous or limited to one pathway; many pathways are present for the circulation of deep waters, with eddies playing an important role.

Summarize Your Understanding

In this lesson, you have explored how Earth’s vast fluid ocean is affected by unequal heating and winds. Data visualizations and maps provided evidence for the roles that sea surface temperature, sea surface salinity, and sea surface density play in global ocean circulation. You have also seen how eddies affect the transport of heat. All of these factors contribute to the interconnected and dynamic Earth systems that redistribute the Sun's energy throughout our planet. Based on what you have learned, answer this closing question:

How does the ocean redistribute the Sun’s energy through the Earth system?