Surface Circulation

The westerlies and the trade winds are two of the winds that drive the ocean's surface currents.

Key Ideas

- Ocean water circulates in currents.
- Surface currents are caused mainly by wind, and affect the uppermost 10% of the ocean.
- Circulation of the other 90% of the ocean is driven by gravity, as dense water sinks and less dense water rises.
- Upwelling and downwelling describe the vertical movement of water masses.
- The Coriolis effect modifies the course of ocean currents.
Ocean Currents

- Transfer heat from tropical to polar regions
- Influence weather and climate
- Distribute nutrients and scatter organisms

Surface Currents

Surface currents are driven by wind

Most of Earth’s surface wind energy is concentrated in the easterlies and westerlies.

Due to the forces of gravity, the Coriolis effect, and winds, water often moves in a circular pattern called a gyre.
Surface Currents

Water moves clockwise in the Northern Hemisphere gyres and counterclockwise in the Southern Hemisphere gyres.

Flow Within a Gyre

Gyres can be further subdivided into distinct currents. The four interconnected currents in the North Atlantic Gyre have different flow characteristics and temperatures.
The motion of the water at the surface is driven by the wind. Each subsequent layer below is driven by the movement of the water above, and slowed down by friction. This is termed the Ekman spiral, although the water itself does not spiral.
Flow Within a Gyre

The effect of Ekman spiraling and the Coriolis effect cause the water within a gyre to move in a circular pattern.
Flow Within a Gyre

The surface of the North Atlantic is raised through wind motion and Ekman transport to form a low hill. Why is the center of the hill offset to the west?
Geostrophic Gyres

Geostrophic gyres - a balance between the pressure gradient and the Coriolis effect. Of the six great current systems in the ocean, five are geostrophic gyres.

Currents Within Gyres

Western boundary currents - narrow, deep, fast currents on the western sides of ocean basins; their edges are sharp.

- Gulf Stream
- Japan Current
- Brazil Current
- Agulhas Current
- Eastern Australian Current
Currents Within Gyres

Eastern boundary currents – cold, shallow, broad and slow currents on the eastern sides of ocean basins; their boundaries are not well defined.

- Canary Current
- Benguela Current
- California Current
- West Australian Current
- Peru Current

Water flow in the Gulf Stream and the Canary Current, parts of the North Atlantic gyre.
Currents Within Gyres

Table 5.1 Boundary Currents in the Northern Hemisphere

<table>
<thead>
<tr>
<th>Type of Current (example)</th>
<th>General Features</th>
<th>Speed</th>
<th>Transport (millions of cubic meters per second)</th>
<th>Special Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western Boundary Currents</td>
<td>Warm</td>
<td>Swift</td>
<td>Large, usually 50 km or greater.</td>
<td>Sharp boundary with coastal circulation system: little or no coastal upwelling; waters tend to be depleted in nutrients, unproductive; waters derived from trade wind belts.</td>
</tr>
<tr>
<td>Gulf Stream, Kuroshio (Katsushika) Current</td>
<td>Warm</td>
<td>Swift, hundreds of kilometers per day.</td>
<td>Large, usually 50 km or greater.</td>
<td>Sharp boundary with coastal circulation system: little or no coastal upwelling; waters tend to be depleted in nutrients, unproductive; waters derived from trade wind belts.</td>
</tr>
<tr>
<td>California Current, Canary Current</td>
<td>Cold</td>
<td>Slow, tens of kilometers per day.</td>
<td>Small, typically 10-15 km.</td>
<td>Diffuse boundaries separating from coastal currents; coastal upwelling conjures waters derived from mid-latitudes.</td>
</tr>
</tbody>
</table>


Countercurrents return water to the opposite sides of ocean basins

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Countercurrents flow on the surface in the opposite direction from the main currents.

Undercurrents are countercurrents that flow beneath the surface current.

Cold and warm water eddies
A  Coastal upwelling

Wind blows parallel to coast

Warm surface layer blown offshore

Cool water upwells from below

B  Equatorial upwelling

Northern trade winds

Warm surface water

Equator

Southern trade winds

Warm surface water

Cool water upwells from below
Wind induced vertical circulation - vertical movement induced by wind-driven horizontal movement of water.

Upwelling is the upward motion of water. This motion brings cold, nutrient-rich water to the surface.

Downwelling is downward motion of water. It supplies the deeper ocean with dissolved gases.
Figure 8.14

(a) Summer

(b) Winter

W = wind  T = net water transport  MSL = mean sea level
Surface currents distribute tropical heat. The warm ocean currents are shown in red and cold currents in blue.

**Effects of Surface Currents on Climate**

**Studying Currents**

**Float methods** depend on the movement of a free-floating object.

**Flow methods** measure the current as it flows past a fixed object.
Ocean water, circulating in currents, distributes heat from the equator to the poles. Currents have a profound effect on Earth’s weather and climates.