

# Surface Currents – Tutorial Script

The **Ekman Spiral** is the term we use to describe the motion that occurs when wind blows on the surface of the oceans. That energy forms waves and currents. In waves, the water oscillates in a circular orbit as energy passes through it, each molecule or floating object returning to its original position after each oscillation. No net movement of water as a wave passes through. We'll talk more about waves in the next chapter. Currents, on the other hand, are moving water, a small amount of forward velocity that IS transferred to the water due to the drag of the wind on the water. In this process, the wind transfers about 1/100<sup>th</sup> of its energy. This water is pushed forward – not in exactly the same direction the wind is blowing, but 45 degrees to the right in the northern hemisphere and to the left in the southern. Why not straight ahead? The coriolis effect. Notice that in the Ekman spiral, surface water drags on the water beneath it and makes that water also move – even slower – but generally in the same direction, except 45 degrees to the right of the water above it. This dragging on the water happens as we continue deeper and deeper into the surface waters until we reach about 100 meters depth. During that time, you can imagine each 10 meters of water dragging on the 10 meters of water underneath it, and we get a spiraling motion of currents – each progressively slower and progressively more rotated. Plankton on the surface will be carried by currents moving much more strongly than currents a few meters below. And plankton on the surface can move in the opposite direction of the currents a few meters below. When we sum up all these current layers we find the net motion, called **Ekman Transport**, is 90 degrees to the right of the wind direction in the northern hemisphere.

Ekman Transport and the Ekman Spiral can be seen clearly by comparing net transport of water to 100 m depth with the observed transport of surface floating objects, such as ships and icebergs. The surface objects move at a 45 degree angle to the wind. But the entire 100-m-packet of water moves, net, 90 degrees.

Ekman transport causes water blown by the westerlies and trade winds to move 90 degrees to the right in the northern hemisphere and left in the southern. That causes water to pile up in domes in the center. This image shows one such dome from the top and the sides, with the two major wind systems overlain. The coriolis effect is pushing the water inward to the center of the dome. Gravity is trying to pull it back out and flatten it. The rotation of the Earth is causing it to be off center, much like what happens when you're in a car that's turning around a corner. Finally, the continents act as barriers to continual motion in a line and trap this motion in a basin. Net result: the water in the northern hemisphere, within the belts of the Westerlies and Trade Winds, moves in a clockwise circle around a center. We call this circle a **gyre**. In the southern hemisphere, it moves the opposite way, counterclockwise, creating two gyres for the Atlantic Ocean, two for the Pacific, and one for the Indian.

Global ocean maps that display sea surface heights let us see where the highest centers are for each of these domes.

Looking more closely at how water moves around these gyres, we call the current that moves poleward along the western boundary of the ocean a **western boundary current**. The one that runs equatorward along the eastern boundary is called an **eastern boundary current**. The one that runs westward along the equator is called an **equatorial current**. The one that runs eastward along the top is called a **transverse current**.

Close inspection of the shape of the domes shows that the width through which the currents move is much tighter on the west than on the east. On the western boundary, water is shoved through a narrow space and thus will have increased speed, force, and depth – much like what happens when you put your thumb over the end of a hose: the water comes out much faster and stronger. The eastern boundary currents, on the other hand, are wider, slower and shallower.

This map of the major surface currents in the world's oceans shows the different boundary currents for all the oceans. Notice the eastern boundary current of the North Pacific gyre runs along California and is called the **California Current**. It is moving away from the poles, where it has lost much of the heat that the gyre originally picked up at the equator. Because the California Current is so shallow it can extend up onto the continental shelf. In the Atlantic Ocean, the western boundary current runs north along the east coast of the United States. This current is called the **Gulf Stream**. It contains warm water from the equator and is transferring it poleward, quickly. It is too deep and narrow to extend up onto the continental shelf, so it sits as far as 300 miles offshore of

the Eastern seaboard of the United States. It is used by ships to speed up the journey to Europe, and the warm waters keep the objects stored in the hold quite warm as well. The Gulf Stream is the fastest moving current in the world's oceans. It travels anywhere from 3 to 10 km/hr and carries 100 million cubic meters of water per second.

Equatorial counter currents run along the equator eastward between the two normal equatorial currents of the main gyres. Equatorial counter currents are usually small trickles that form because of the build up of water on the western edge of the equatorial oceans. Both equatorial currents, from the northern and southern gyres, carry a lot of water westward. A large pile of water forms there, and while most moves poleward along the coasts via western boundary currents, some slides backwards along the equator – through both a surface current and a slightly deeper undercurrent.

The largest volume surface current in the world's oceans is the West Wind Drift (or Antarctic Circumpolar Current). It moves 130 million cubic meters of water per second. That's 130 times the amount of water flowing through all the world's rivers combined. The West Wind Drift is caused by the westerly winds that move from the west towards the east across the 30°S to 60°S latitudes. Around Antarctica, these winds are not impeded by land obstacles, so they are able to get quite strong and move a large amount of water.

The northern Atlantic Ocean also has some important currents that mix the surface waters of the North Atlantic with those of the Arctic. This simplified generalized map of world's surface currents combines all the major surface currents discussed in this tutorial: the five main gyres, the equatorial counter currents, and the polar currents – those in the North Atlantic, and those around Antarctica.

Pause now.

For more information and more detail, continue on to the next video in the series.

[End credits]

### **Ocean Circulation Series:**

- Part 1: Thermohaline Currents
- Part 2: Surface Currents
- Part 3: Ocean Mixing and Pollution
- Part 4: ENSO

### **Surface Currents**

Geoscience Video Tutorial  
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