9.5: Currents, Upwelling and Downwelling

The movement of surface currents also plays a role in the vertical movements of deeper water, mixing the upper water column. **Upwelling** is the process that brings deeper water to the surface, and its major significance is that it brings nutrient-rich deep water to the nutrient-deprived surface, stimulating primary production (see section 7.3). **Downwelling** is where surface water is forced downwards, where it may deliver oxygen to deeper water. Downwelling leads to reduced productivity, as it extends the depth of the nutrient-limited layer.

Upwelling occurs where surface currents are diverging, or moving away from each other. As the surface waters diverge, deeper water must be brought to the surface to replace it, creating upwelling zones. The upwelled water is cold and rich in nutrients, leading to high productivity. Many of the most productive regions on Earth are found in upwelling zones. In the equatorial Pacific, the trade winds blow the North and South Equatorial Currents towards the west, while Ekman transport causes the upper layers to move to the north and south in their respective hemispheres. This creates a divergence zone, and a region of upwelling and high productivity (Figure 1).
A similar process occurs near the Antarctic continent, creating one of the most productive regions on Earth, the Antarctic divergence. In this case, the West Wind Drift (Antarctic Circumpolar Current) is flowing parallel to, but in the opposite direction of the East Wind Drift. With both currents occurring in the Southern Hemisphere, Ekman transport will be to the left, so the eastward-flowing West Wind Drift water will be transported to the north, and the westward-flowing East Wind Drift water will be transported to the south, creating a highly productive divergence zone (Figure \(\PageIndex{2}\)).

![Figure \(\PageIndex{2}\)](https://example.com/image2.png)

Downwelling occurs where surface currents converge. The converging water has nowhere to go but down, so the surface water sinks. Since surface water is usually low in nutrients, downwelling leads to low productivity zones. An example of a downwelling region is off of the Labrador coast in Canada, where the Gulf Stream, Labrador, and East Greenland Currents converge.

### Coastal Upwelling

Upwelling and downwelling also occur along coasts, when winds move water towards or away from the coastline. Surface water moving away from land leads to upwelling, while downwelling occurs when surface water moves towards the land. Historically, some of the most productive commercial fishing grounds have been associated with coastal upwelling. Along the coast of California, the local prevailing winds blow towards the south. Ekman transport moves the surface layer 90° to the right of the wind, meaning the net Ekman transport is in an offshore direction. The water displaced near the coast is replaced by cold, nutrient-rich deeper water that is brought to the surface through upwelling, leading to high productivity (Figure \(\PageIndex{3}\)).
As wind blows along a coastline, Ekman transport moves the surface layer in a direction $90^\circ$ to the wind. In this figure, it is to the right of the wind, indicating a Northern Hemisphere location. As surface water moves offshore, it is replaced by upwelled deeper water (By Lichtspiel [Public domain], via Wikimedia Commons).

The same process happens off the coast of Peru, which for a long time had the world’s largest commercial fishery. Winds along the Peruvian coast blow towards the north, and since Peru is in the Southern Hemisphere, the Ekman transport is $90^\circ$ to the left of the wind, which causes the surface water to move offshore and leads to upwelling and productivity. In any coastal upwelling location, if the winds reverse, surface water moves towards the shore and downwelling is the result.

Upwelling can also occur due to geological features of the ocean floor. For example, as deep water currents encounter seamounts or other raised features, the water is forced upwards, bringing nutrient-rich water to the surface. This helps explain why productivity is often high in the water over seamounts.