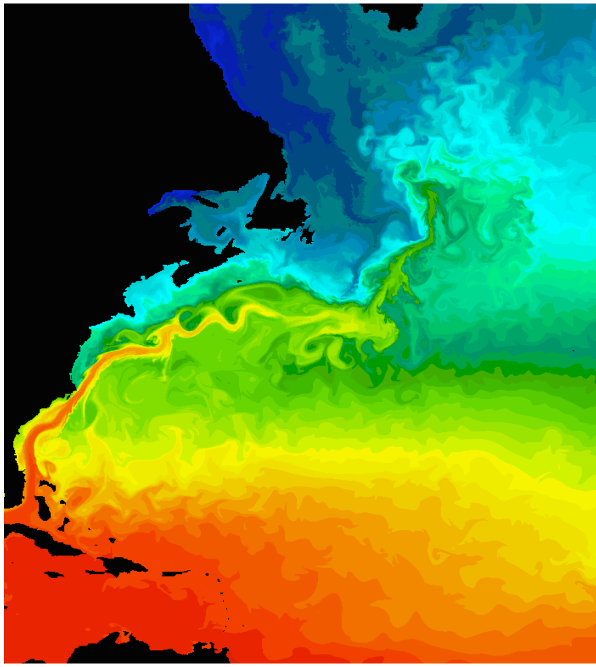
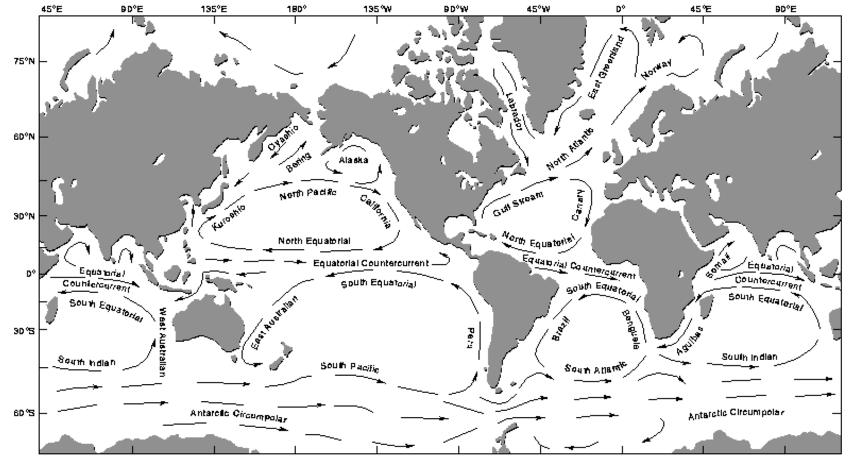


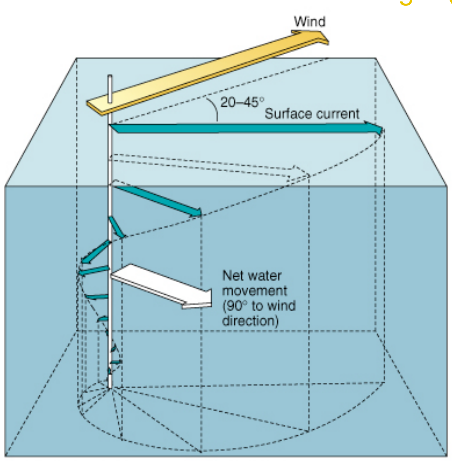
lecture 7

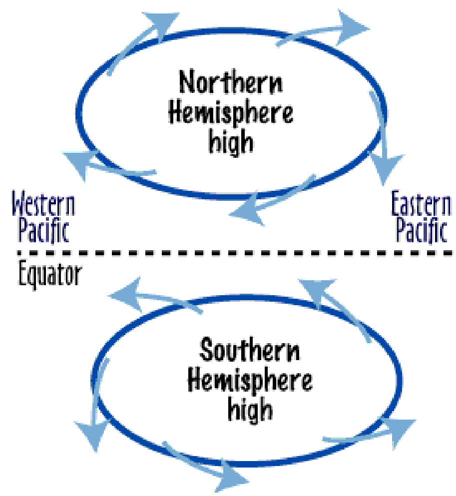
Ocean circulation and climate



Recall that the surface ocean circulation is organized into gyres, which rotate clockwise in the northern hemisphere, and counterclockwise in the southern hemisphere. Recall also the concept of Ekman drift:

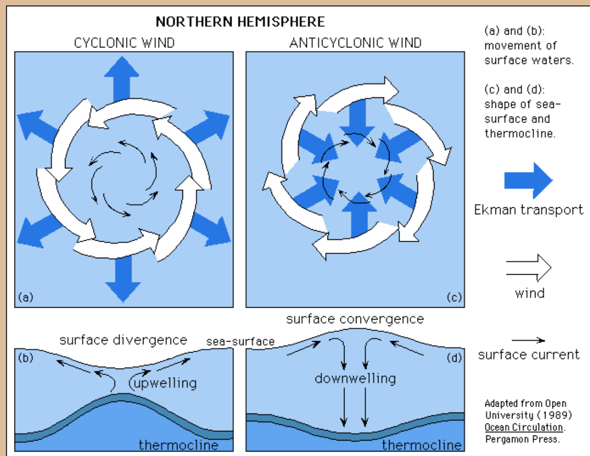
Ekman drift refers to the mechanical response of the ocean to wind blowing across its surface. The surface water is dragged along with the wind. However, due to the Coriolis force, it is deflected somewhat to the right (in the NH). The surface water drags along the water immediately beneath it but at a somewhat slower speed, and this layer is also deflected to the right under the influence of the Coriolis force. The result is a spiraling pattern in the current direction with ever decreasing current speeds with depth. **The net transport of water is to the right of the wind.**

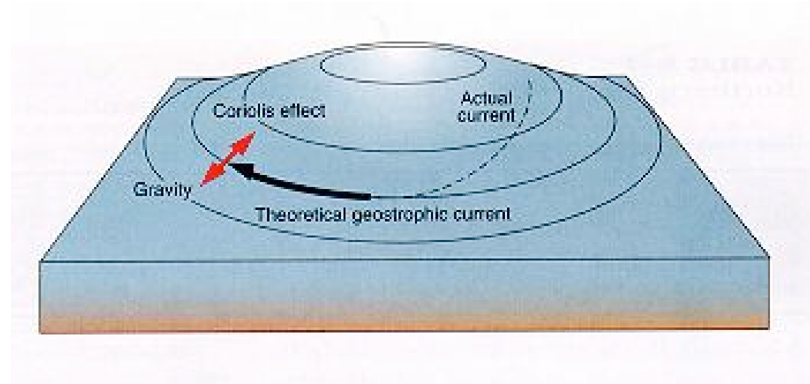




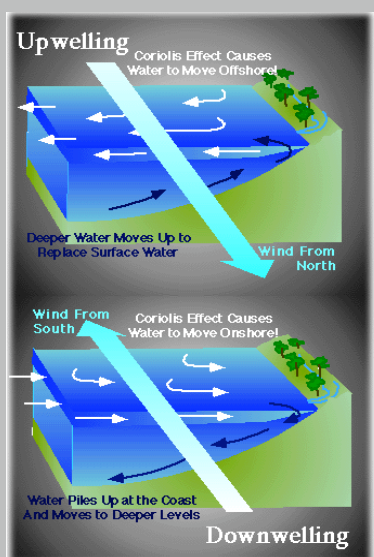
Because the ocean is typically cooler than land in the subtropics, the air over the subtropical ocean is denser than over land. This means that pressure is high over the subtropical ocean. Because of the Coriolis effect, high pressure means that in the subtropics, air is circulating clockwise over northern hemisphere ocean basins, and counterclockwise over southern hemisphere ocean basins.

Through the Ekman mechanism, the clockwise atmospheric flow (in the northern hemisphere) creates a pile-up of water in the middle of the ocean basin. One effects of this pile-up or convergence of water is **downwelling** (downward movement of water) in the middle of the subtropical oceans.





Another effect is that seawater tries to flow down the “hill” of water in the middle of the basin. As it does, the Coriolis force deflects it to the right. This is what generates the clockwise circulation or gyre.

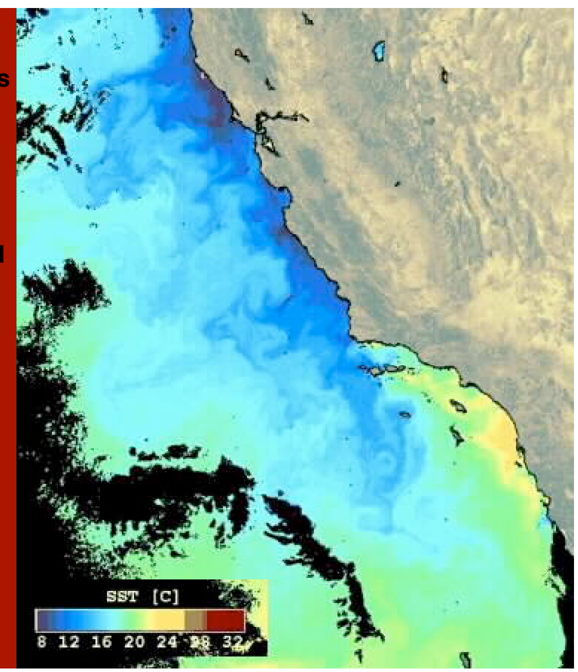


The Ekman mechanism is also responsible for **coastal upwelling and downwelling**. In the northern hemisphere, if one is moving with the wind and the coast is on the left, water will be transported away from the coast by the Ekman mechanism. Deep water will be pulled up to compensate for the lost surface water at the coast (upwelling).

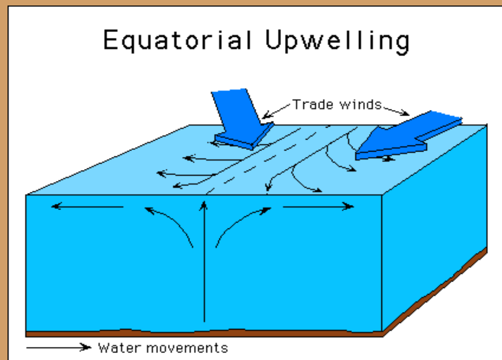
If one is moving with the wind and the coast is on the right, water is transported toward the coast and the surface waters are driven downward (downwelling).

One can often see evidence of upwelling and downwelling by examining sea surface temperatures.

One area where upwelling often occurs is off the coast of California. This satellite image shows cold temperatures all along the California coast, indicating that deep cold water is being pulled to the surface. In what direction are the winds blowing?



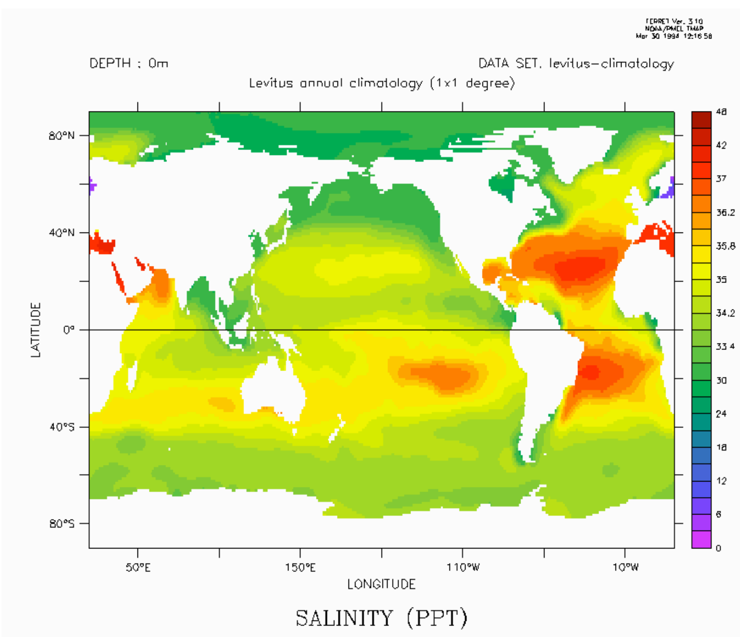
The Ekman mechanism also drives **Equatorial Upwelling**. Recall that near the equator, trade winds blow toward the west. These winds transport water poleward in both hemispheres, forcing cold deeper waters to the surface at the equator. It turns out that deep waters are very rich in nutrients. For this reason, zones of upwelling can be very clearly seen from satellite images of chlorophyll, the chemical that makes plants green.

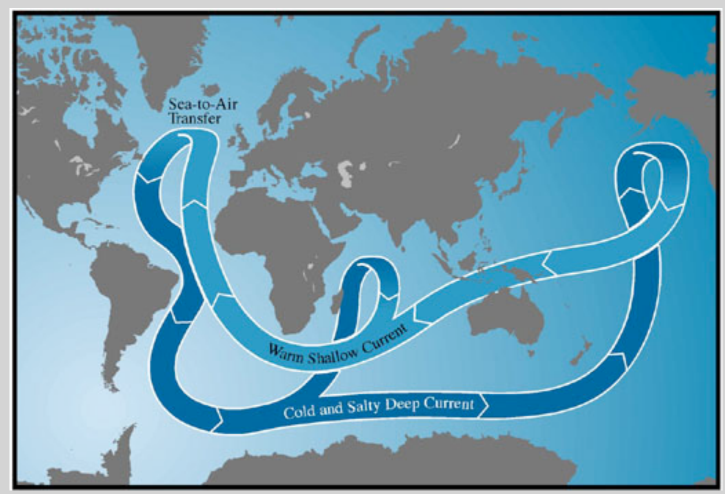


Adapted from Thurman, Harold V. (1997) **Introductory Oceanography, 8/E.** Prentice-Hall, Inc., New Jersey.

On much longer time scales, vertical motion can also occur in the ocean through deep convection, rather than shallow wind-driven overturning. This almost always takes place at high latitudes during the wintertime, when the cold atmosphere extracts huge quantities of heat from the surface ocean. If this process extracts enough heat, the water can become dense enough to sink to the depths of the ocean. Once it sinks, this water spreads throughout the global ocean. Eventually it returns to the surface.

This overturning circulation is known as the **thermohaline circulation**. It typically takes about 1000 years for a chunk of water to sink, flow through the deep ocean, and then return to the surface. This is an indication of how sluggish the deep ocean circulation is.





Because of its high salinity, North Atlantic water is more susceptible to sinking than other waters with the same temperature. This is therefore a major sinking region of the global thermohaline circulation. The Southern Ocean is also a site of deep convection. All of the deep water of the entire ocean originates in one of these two regions.

So how can the ocean influence climate?

Short time scales (less than a few years)

The contrast in the heat capacity of the land and ocean has a profound effect on our climate's seasonality and its response to increasing greenhouse gases.

The ocean plays a critical role in the El Niño phenomenon, a periodic climate oscillation centered in the equatorial Pacific, and a topic we will come to later on in the course.

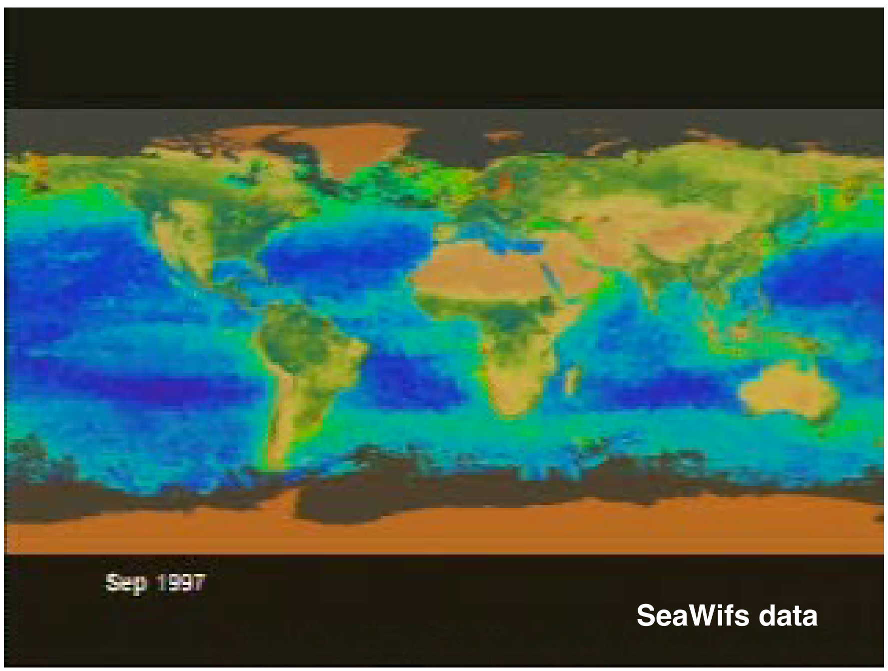
Long time scales (greater than a few years)

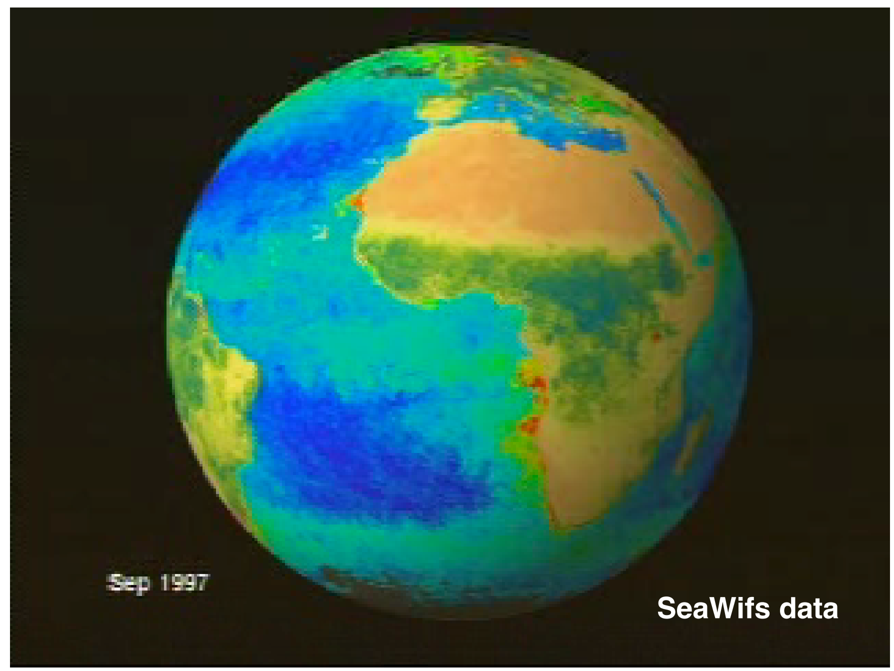
Changes in the global thermohaline circulation, which warms the North Atlantic, can affect temperatures in that region.

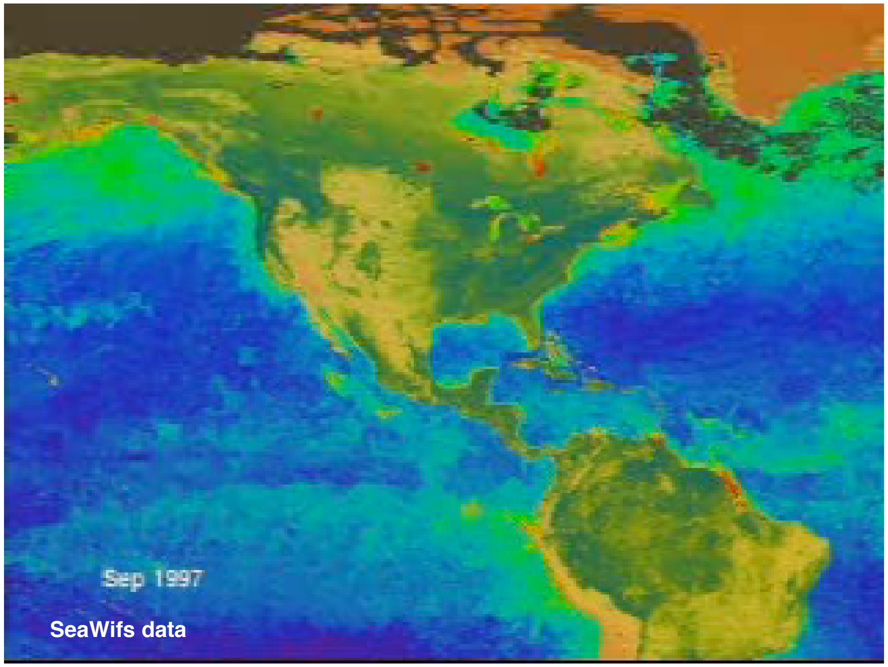
Long-term changes in sea ice coverage can affect the planet's energy balance.

Changes in ocean ecosystems because of ocean circulation changes probably have a large influence on climate on time scales of hundreds to thousands of years. Ocean ecosystems help regulate CO_2 concentrations in the atmosphere, and hence the greenhouse effect.

We can get a gross measure of biological activity from space by measuring photons that indicate the presence of chlorophyll, the chemical plants use for photosynthesis. This is done with the SeaWifs satellite instrument. Let's use these images to relate our understanding of atmosphere and ocean circulation to the distribution of life on earth.



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SeaWifs data