Surface Ocean Circulation

What Goes Around Comes Around

Wind-driven ocean circulation

- circulation of the upper water masses is set in motion by the energy of the prevailing winds
- as wind blows across ocean surface, air molecules collide with water molecules
  - inefficiently transfers energy from air to water
  - water moves at only about 3-4% of the wind speed

- gyres are large, circular, horizontal current systems
  - caused by west-moving ocean currents in the trade winds, east-moving ocean currents in the westerlies and deflection of ocean currents by the continents
  - the subtropical gyres transport warm waters poleward along the western edges of the ocean basins, and cool waters equatorward along the eastern sides

Global ocean surface circulation

- Notice how the currents roughly correspond to the wind directions, especially in the regions of the subtropical gyres.
Ekman theory

- The prevailing winds create a drag (wind stress) on the ocean surface.
- The momentum gained at the surface is transferred deeper but energy is lost with increasing depth.
- The Coriolis effect deflects the moving water to the right.
- A decrease in current speed coupled with continuous deflection with increasing depth creates a theoretical spiral of moving water called the Ekman Spiral.
- Adding all the vectors (magnitude and direction) of the Ekman Spiral yields a net current direction that is $\sim 90^\circ$ to the prevailing wind.
- This composite current is called Ekman Transport.

Ekman transport

- The surface current is $\sim 45^\circ$ to the prevailing wind, due to Coriolis deflection.
- Flow velocity decreases exponentially with depth, all the while being deflected by Coriolis.
  - The depth where the direction of flow is opposite to that of the surface, and the velocity is only about 5% of the surface flow, is called the "Ekman depth."
  - Ekman transport affects a surface ocean layer with a typical depth between 50-150 m.
  - Ekman transport controls the motion of the surface ocean.
    - divergence: upwelling
    - convergence: downwelling

Ekman transport on Earth

- Polar Easterlies
- Westerlies
- Trade Winds
- Polar Easterlies
- Trade Winds
- Westerlies
- Polar Easterlies

Ekman convergence & divergence

- Pressure gradients develop in the ocean because the sea surface is warped into broad mounds and depressions with a relief of about one meter.
- Mounds on the ocean’s surface are caused by converging currents, places where water sinks (or downwells).
- Depressions on the ocean’s surface are caused by diverging currents, places from where water rises (or upwells).
Phytoplankton pigment divergence of water masses results in upwelling and high productivity in subpolar waters. Convergence of water masses causes near-surface waters to pile-up in the subtropics. Divergence of water masses results in upwelling and high productivity at the equator.