Class 6.1: Introduction to Ocean Physics

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Main role of the ocean-atmosphere is to redistribute heat on Earth
The side of Earth facing the Sun (the daytime side) receives a tremendous dose of intense solar energy. This energy drives the global ocean atmosphere engine, creating pressure and density differences that stir currents and waves in both the atmosphere and the ocean. (Fasulto and Trenberth, 2008)

The atmosphere transfers heat and water vapor from place to place on Earth. Within the atmosphere, complex relationships exist among air composition, temperature, density, water vapor content, and pressure.

Ocean currents are masses of ocean water that flow from one place to another. These currents transfer heat from warmer to cooler areas on Earth, just as the major wind belts of the world do. Wind belts transfer about two-thirds of the total amount of heat from the tropics to the poles; ocean surface currents transfer the other third.

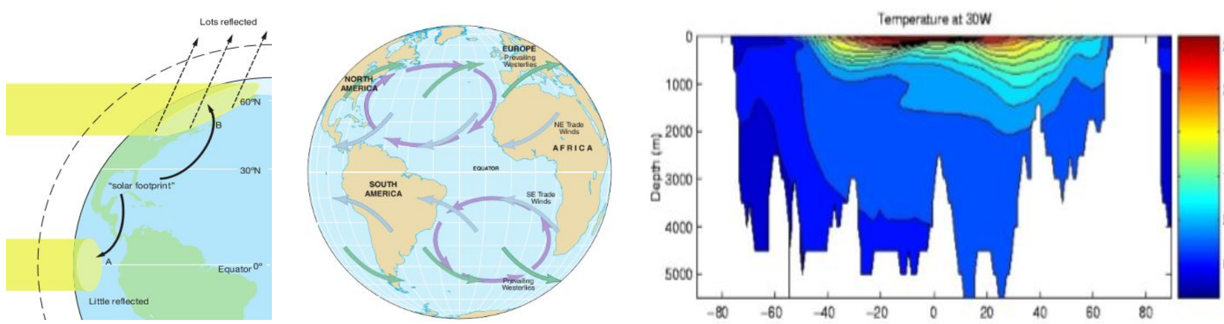

Figure 1. (1) Solar radiation received on Earth. (2) Atlantic Ocean surface circulation pattern. (3) Temperature through Atlantic Ocean.

Water's high heat capacity, climate modulation at long time scales.
Water's thermal properties influence the world's heat budget and are in part responsible for the development of tropical cyclones, worldwide wind belts and ocean surface currents. The heat removed from the tropical ocean (evaporation latitudes) is carried toward the poles and is released at higher latitudes through precipitation (precipitation latitudes), thus moderating Earth's climate. (Douglas and Knox, 2009)

Surface currents can be measured directly or indirectly. The great depth at which deep currents exist makes them even more difficult to measure than surface currents. Most often, they are *mapped using underwater floats that are carried within deep currents. One such unique oceanographic program that began in 2000 is called Argo, which is a global array of free-drifting profiling floats that move vertically and measure the temperature, salinity, and other water characteristics of the upper 2000 meters (6600 feet) of the ocean. (For more information on Argos,* www.argo.ucsd.edu)

Salinity is the total amount of solid material dissolved in water including dissolved gases but excluding dissolved organic substances. The most abundant components in a kilogram of 3.5 $\%_o$ (parts per thousand) salinity seawater are Na, Cl, Mg, K, Ca and SO_4. The processes which affect seawater salinity are precipitation, runoff (stream discharge), melting icebergs, and melting sea ice because decrease seawater salinity by adding more freshwater to the ocean. At high latitudes, abundant precipitation and runoff and the melting of freshwater icebergs all decrease salinity. In addition, cool temperatures limit the amount of evaporation that takes place (which would increase salinity).The formation and melting of sea ice balance each other out in the course of a year and are not a factor in changes in salinity. .Seawater contains various dissolved substances that increase its density. In the open ocean, seawater density averages between 1.022 and 1.03 g/ml (depending on its salinity). The ocean, like Earth's interior, is layered according to density. Low-density water exists near the surface and higher density water occurs below.

As temperature increases seawater density decreases (due to thermal expansion). As salinity increases seawater density increases (due to the addition of more dissolved material). As pressure increases seawater density increases (due to the compressive effects of pressure).

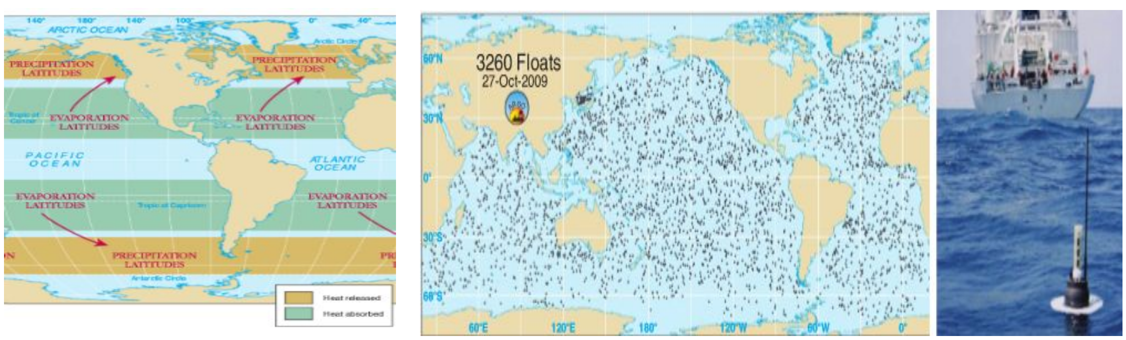

Figure 2. (L) Atmospheric transport of surplus heat from low latitudes into heat-deficient high latitudes. (R)The Argo system of free-drifting submersible floats.

Vertical Circulation and mixing drive the upward nutrient fluxes required to support phytoplankton growth.

Photosynthetic organisms such as phytoplankton use the green pigment chlorophyll to capture energy from the Sun and perform photosynthesis. In the ocean, the two main factors that limit the amount of photosynthetic primary productivity are the availability of nutrients and the availability of solar radiation. Upwelling is a flow of deep water toward the surface that brings *water from depths below the euphotic zone. This deep water is rich in nutrients and dissolved gases because there are no phytoplankton at these depths to consume these compounds. Although tropical regions receive adequate sunlight year round, a permanent thermocline prevents the mixing of surface and deep water. As phytoplankton consume nutrients in the surface layer, productivity is limited because the thermocline prevents replenishment of nutrients from deeper water. There are many physical features that affect nutrient levels in the euphotic zone and thereby greatly modify the general pattern. These include fronts, which are relatively narrow regions characterized by large horizontal gradients in variables such as temperature, salinity, and density, and eddy-formations such as rings and large-scale gyres, which have characteristic rotational patterns of circulation. The general latitudinal patterns of primary productivity are altered by a number of different physical processes that lead to nutrients being redistributed in the water column in discrete areas. These processes occur on scales varying from very large (e.g. gyres and continental upwelling), to smaller (e.g. tidal fronts and rings), to the very small scales which only the top few meters of the water column are mixed. The vertical profile of phytoplankton production changes with season and with latitude. High surface productivities generally occur in temperate latitudes in spring and autumn, whereas chlorophyll and productivity maxima occur considerably deeper in tropical waters.*