Oceanography Handout

The oceans cover 71% of the earth's surface and are home to our fisheries, and perhaps more importantly are essential in the maintenance of our climate. This document is a brief review of key facets of oceanography.

One of the most important aspects of the oceans is that they moderate our climate through (1) the heat required (or evolved) when water evaporates, precipitates, freezes or melts, and (2) ocean currents which transport warm water to high latitudes (see below). When we write the simple reaction that describes the evaporation of water, a very large heat effect is involved

$H_2O^{liq} = H_2O^{vap}$ heat is absorbed when reaction goes to the right (~150 j/gm)

And when heat input to the atmosphere increases, much of that heat is used to evaporate water rather than cause a temperature rise in the atmosphere.

A second important aspect of the oceans is that they are salty. However they contain not only sodium, Na+, but a whole slew of cations and anions. Some of the more common ones are as follows:

Species	Concentration In seawater (mg/kg)	Concentration in avg. river water (mg/kg)	Mean Residence time (million years)
Chloride, Cl^-	19350	5.75	120
Sodium, Na^+	10760	5.15	75
Sulfate, SO^{4-}	2712	8.25	12
Magnesium, Mg^{2+}	1294	3.35	14
Calcium, Ca^{2+}	412	13.4	1.1
Potassium, K^+	399	1.3	11
Bicarbonate, HCO_3^-	145	52	0.10
Bromide Br^-	67	0.02	100
Boron B^{3+}	4.6	0.01	10
Strontium, Sr^{2+}	7.9	0.03	12
Fluoride, F^-	4.6	0.10	0.5
Total	35150	89	

Source: Schlesinger (1991) Biogeochemistry

Note that the final column gives mean residence time – the time that an average cation or anion will remain in solution. This implies that not only is there input from rivers but there must also be sinks where cations and anions are sequestered. Two of the more important sinks are shells and coral skeletons made of in $CaCO_3$ (the minerals calcite and aragonite) and SiO_2 (amorphous silica) – a given organism will make its shell of one of these minerals. Consequently, these animals extract Ca^{2+}, Mg (which substitutes for Ca), Si, and CO_3^{-2} from seawater to make their shells. Similarly many cations and anions become adsorbed onto sedimentary particles and are buried in deep sea sediments.

A very important influence on seawater chemistry is the hydrothermal systems that characterize the mid ocean ridges. These are systems of circulating seawater that flow through hot, new ocean crust at the mid-ocean ridges and there are innumerable reactions that occur as the seawater flows through the basaltic crust. As we discussed earlier in class, these reactions are hydration reactions whereby water becomes bound in minerals as the OH^- anion, e.g., serpentine, $Mg_6Si_4O_{10}(OH)_8$. Scientists estimate that the total volume of the oceans circulates through these systems once every 8 million years. Much of the Mg^{2+} and Ca^{2+} in seawater is derived from the reactions involving seawater and basaltic crust at the ocean ridges. Another important source of cations and anions is volcanism which releases gas and dust into the atmosphere, and directly into the oceans in the case of mid-ocean ridge volcanism.

Temperature variation in the oceans is complicated. Surface temperatures range from 28^{o}C in the tropical areas of the Indian and Pacific Oceans to near 0^{o}C near Antarctica. However, this temperature only characterizes the upper 100-500 m (where the water is warm). Below this depth the temperature decreases rapidly in a zone called the thermocline to a temperature of less than 5^{o}C, and the deep ocean is a very cold place regardless of latitude. The deep ocean is also slightly more saline than typical surface waters (35000 mg/kg versus 33000 mg/kg) and together, the lower temperature and increased salinity of the deep water makes it denser than the surface waters.

Particularly important characteristics of the oceans are the ocean currents. There are surface currents (see powerpoint) which are driven by prevailing winds, and a global, ***thermohaline*** circulation that is particularly important in moderating our climate. Temperature and salinity contrasts drive these currents (hence "thermohaline"). These currents tend to form large circular current systems called ***gyres***. You will note that in the northern hemisphere the sense of rotation in these gyres is clockwise, and in the southern hemisphere the sense of rotation is counterclockwise. This consistent sense of rotation is due to the ***Coriolis*** effect. Consider a small volume element (say 1 cm^3) of water located on the equator. The angular velocity of this volume element due to the earth's rotation is much greater than the angular velocity of a volume element at 45^{o}N because the rotational orbit of this latter element is much smaller than that of a volume element at the equator. Consequently when water moves north from the equator it retains its excessive angular velocity and will be deflected to the right. In the northern hemisphere, water moving south from high latitudes has a small rotational velocity and will be deflected to the west (left) as it moves towards the equator. The reverse is true in the southern hemisphere.

The global, ***thermohaline*** (driven by temperature and salinity differences) circulation is extremely important in moderating the climate of the earth. The circulation (see powerpoint) begins in the North Atlantic where warm, salty water transported from the equator cools. This water becomes denser as it cools and sinks to form North Atlantic Deep Water (NADW) which is transported south along the ocean floor. Warm surface waters are driven north to replace this sinking cold water, and this arm of the circulation forms the famous Gulf Stream which moderates the climate of northern Europe (just note for comparison the latitude of London and Hudson's Bay).. The NADW travels south to near Antarctica and then to the east where it ultimately mixes with surface water in the Pacific and is warmed. This warm water returns to the Atlantic and flows north to the Arctic where it cools and the cycle is repeated. The total time for water to make the cycle is about 1000 years. One of the most important aspects of the circulation is that warm water transported along the surface to high latitudes will warm the atmosphere and can make locations at high latitudes habitable.