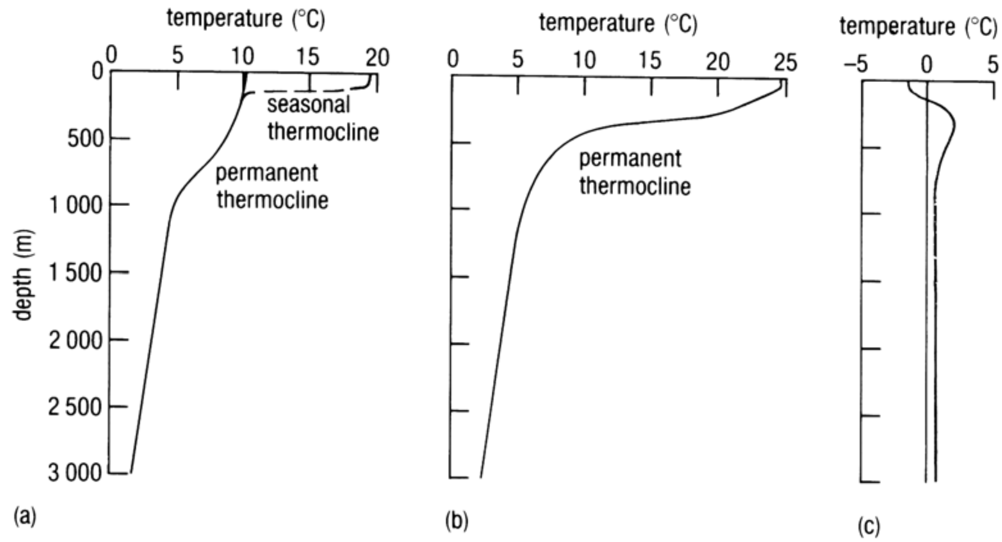
Lecture 3 questions Temperature, Salinity, Density and Circulation

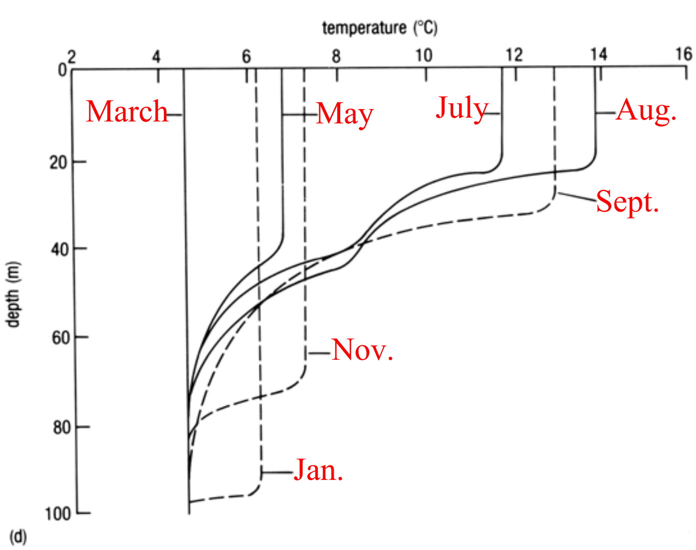
(1) These are profiles of mean ocean temperature with depth at various locations in the ocean which in the following (a, b, c) figures corresponds to high, low and mid latitudes? Why?



(a) mid latitudes (b) low latitudes (c) high latitudes. Warm surface water at low latitudes and cold surface water at high latitudes. Mid latitudes have a seasonal thermocline.

The next figure is a succession of temperature profiles in the upper 100 meters of the ocean at one station in different months of the year (Northern Hemisphere). Label the profiles with the appropriate month starting January, every other month was sampled.

Given that changes of temperature resulting directly from seasonal variations of incident radiation can no longer be detected below about 200 m, how would the curve look for the section between 100 and 200 m?



Solid lines represent seasonal thermocline growth and dashed lines seasonal thermocline decay. Starting in the Spring (March) the seasonal thermocline starts to develop and in August it is at the maximum. Then with cooling and increased wind in the Fall the thermocline deteriorates.
Between 100-200 m we would see the permanent thermocline, steep gradient and about 10-8 degrees C.

(2) What is the principal of constant proportions? Does it apply to all constituents of seawater? Why/Why not? What is the ratio of potassium concentration to total salinity. What would potassium conc. be for salinity of 40? of 32? What will the K/Cl ratio be in these cases?

The **major ions** (>1mg/kg seawater) at S = 35.000 (from Pilson)

Ion	Formula	g/Kg	mmol/Kg
Sodium	Na^{+}	10.781	468.96
Magnesium	Mg^{2+}	1.284	52.83
Calcium	Ca^{2+}	0.4119	10.28
Potassium	K^{+}	0.399	10.21
Strontium	Sr^{2+}	0.00794	0.0906
Chloride	Cl^{-}	19.353	545.88
Sulfate	SO_4^{2-}	2.712	28.23
Bicarbonate	HCO_3^{-}	0.126	2.06
Bromide	Br^{-}	0.067	0.844
Borate	$H_3BO_4^{-}$	0.0257	0.416
Fluoride	F^{-}	0.00130	0.068
Totals	11	35.169	1119.87

The principal of constant proportions states that the ratio of the major conservative ions in seawater is constant. This applies only to conservative elements, other ions can change significantly in space and time independent of salinity changes.
K/35.169 = 0.011; for S = 40, K = 40x 0.011 = 0.440 and for S = 32, K = 0.352.
Salinity will increase by extensive evaporation relative to precipitation and sea ice formation, it will decrease as a result of increased precipitation, river input and ice melt.

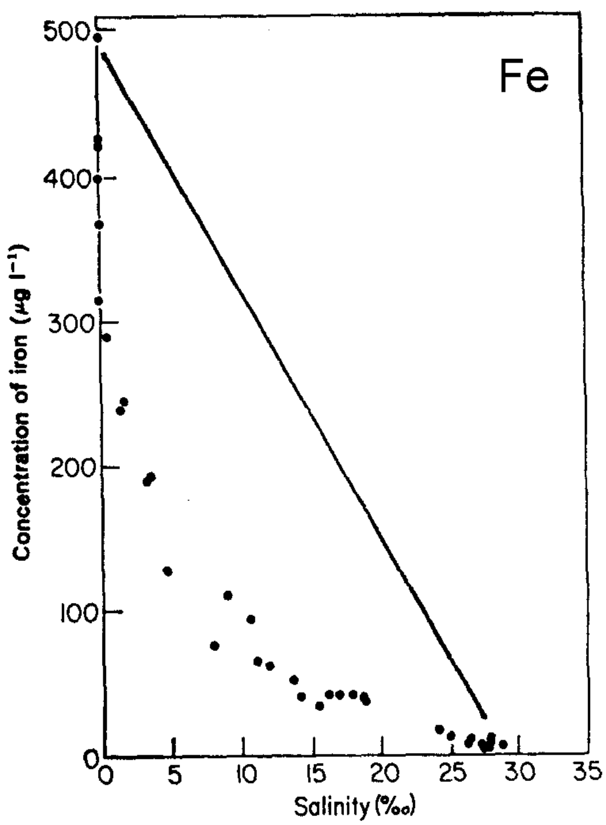
(3) When seawater undergoes evaporation: Which is true?

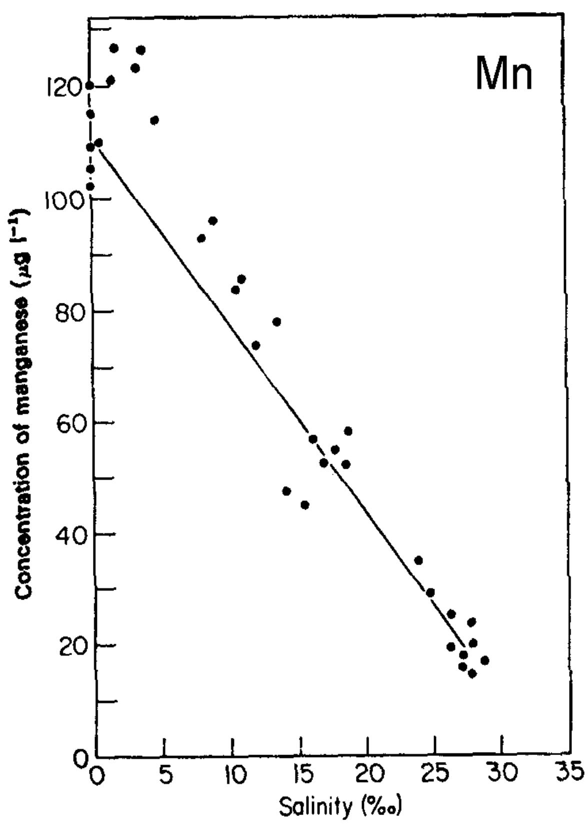
A. The remaining water becomes more saline
B. The proportions of Na and other ions change
C. The proportion of the major ions remain the same
D. The proportion of K to other ions remain constant
E. A and B
F. A and C
G. A, C and D

Element	River water (ug/L)	Seawater (ug/L)
Cl	0	16.6
Mn	120	2
Fe	500	3
Cl	Fe	Mn
13.8	10	20
11.1	30	40
15	50	60
8.3	100	85
2.8	200	110
1.1	300	130

(4) Plot a mixing curve between seawater and river water using the data above. Plot the concentration of Fe, and Mn on this mixing curve. Explain the curves.

The mixing point end members are seawater and river water with their respective salinity and Fe and Mn concentrations. From the following curves we see that Fe is depleted from solution upon mixing and Mn is added at very low salinities and then behaves conservatively.





(5) Indicate 2-3 areas in the ocean where you might expect upwelling to occur. How might this effect he sea surface temperature in these areas.

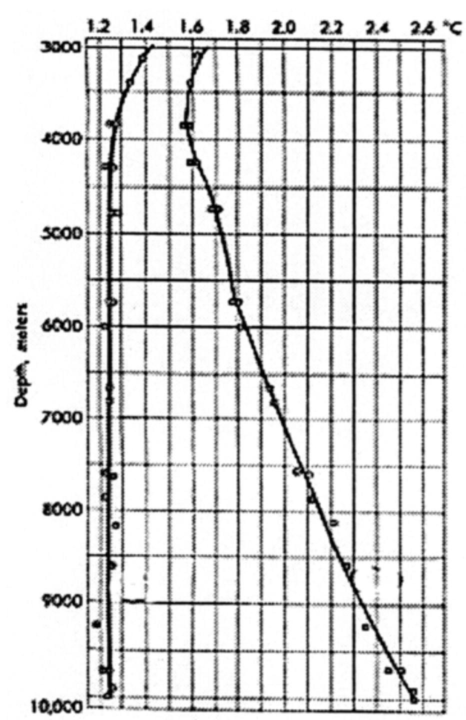
Upwelling would be expected at divergence zones (Equatorial and high latitude) and along the coasts at the western boundaries of continents. The sea surface temperature will be reduced due to mixing with cold sub thermocline waters.

(6) Mediterranean Intermediate Water (MIW) is a water mass, which is situated at mid depth in the North Atlantic. The temperature of this water mass is about 10º C and the water masses above and below have temperatures of 2 to 3º C these water masses have salinities of about 34.9‰. What would you expect the salinity of the MIW water mass to be (qualitatively) and can you suggest how it is produced?

Salinity of MIW would be higher to maintain the appropriate density.
Incoming surface water from the North Atlantic, which is cool and has normal ocean salinity, is heated by the intense Mediterranean sun. More importantly the high evaporation rates of this area (relative to ppt) increases the salinity to more than 36.5‰. This very dense but warm water sinks to the bottom of the Mediterranean Sea until it spills over the shallow sill of the Straits of Gibraltar and moves west in the mid depth of the North Atlantic as an elongated tongue of warm, salty water

(7) Define σt. What is the main use of this value? Could σt be used for indication of water column stability (density stratification)?

A value corresponding to water density at atmospheric pressure as determined from its *in-situ* temperature and salinity (ρ-1000; units are kg/m^3). It is used to identify water masses (constant sigma t). It gives only a rough indication of stability, as it is uncorrected for adiabatic effects and so it gives spurious information about density (and hence stability), especially in the deep water. A more reliable measure of stability will be σθ (potential density; water density at atmospheric pressure as determined from its *potential* temperature).



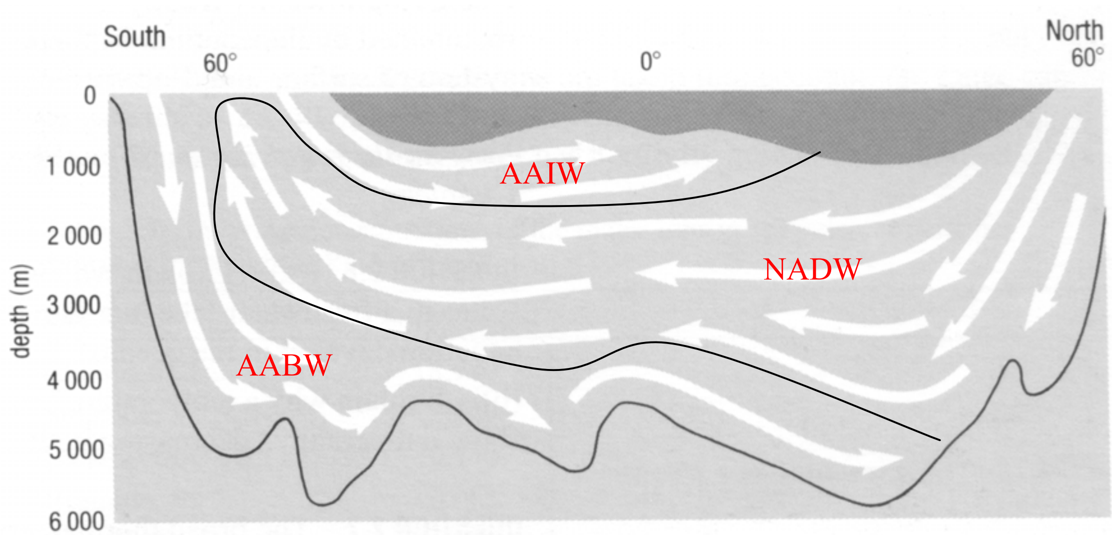
(8) Define potential temperature. Would you expect the potential temperature of seawater at a depth of 5km to be greater or less than the *in situ* temperature. Explain.

The difference between *in situ* and potential temperature can best be seen in the bottom deep trenches. Which is potential and which is in situ on this graph?

Potential temperature is the temperature of a water parcel that is raised adiabatically (without heat gain or loss) to the sea surface. The temperature would always cool as the water is brought up because water decompresses (less molecules per unit volume) and temperature decreases.

Seawater would be subject to reduced pressure in the adiabatic change from a depth of 5km up to sea level. It would become less compressed so its potential temperature will be lower than its *in-situ* temperature. The potential temperature in the figure is uniform with depth while the *in situ* temperature slowly increases.

(9) Sketch the boundaries between the 3 water masses below the 10 degrees isotherm. What are theses water masses?



Diagrammatic section to illustrate the general form of the deep circulation in the Atlantic Ocean, driven by cold dense water sinking in high latitudes

(10) Paleo-botanical data suggests that during the Eocene (~40 million years ago) tropical trees were abundant at everywhere on earth and $\delta^{18}O$ records in marine carbonates are –2 permil for rocks all over. What would this imply about the temperature distribution on Earth? Where would you expect that the deep-water masses formed at that time? What was the deep oceans temperature relative to the present day?

Temperatures are more evenly distributed. Deep water masses would have most likely formed in areas of high evaporation thus high salinity in mid latitudes. This is where the densest water formed thus circulation patterns could have been very different and deep waters were warmer.

(11) Thick salt deposits found beneath the floor in the Mediterranean Sea have an age of 4.5 million years. They cover an area of 2 x 10^{11} m^2 and have an average thickness of 1000m. They consist of about half $CaSO_4$ (136 g/mol) and half NaCl (48.45 g/mol). By how much would the deposition of this salt have changes the ocean's salinity? By how much would it have changed the Ca (40 g/mol) content?

Ocean salt content now is = 35 g/l
Ocean volume = 1.37 x 10^{21} liters
Salt content = 1.37 x 10^{21} liters x 35 g/l = 4.8 x 10^{22} grams

Mediterranean salt deposits are: 2 x 10^{15} cm^2 x 10^5 cm x 2.5 g/cm^3 = 5 x 10^{20}g
Thus, 1% reduction in salinity.

Ca in the ocean: 1 x 10^{-2} mol/l x 1.37 x 10^{21} liters x 40 g/mol = 5.5 x 10^{20} g Ca
Ca in Mediterranean salts: ½ x 5 x 10^{20}g x 40/136 = 0.74 x 10^{20} g Ca
Hence 0.74/5.5 x 100 is ~ 13% reduction in Ca content!!!

(12) Climate records contained in Greenland ice reveal that during the last 60,000 years conditions switched back and forth between millennial duration intervals of intense cold and moderate cold. Each interval of intense cold was matched by an ice-rafting event in the northern Atlantic and by a greatly increased influx of dust onto the ice cap as well as changes in the atmospheric methane concentration. It has been suggested that these large climate shifts are associated with changes in ocean circulation specifically the shut down of the "conveyer belt". Can you think of ways that the conveyer belt would shut down? Can you think of any evidence that would support this theory?

Reduced surface density due to ice melt and input of fresh water. We could check for paleo salinity of surface dwelling organisms ($\delta^{18}O$, or organisms that live in low salinity water).