Laboratory Exercise #6 - Introduction to Oceanography

A. Introduction

Oceanography is obviously the study of the oceans. However, there are many different branches within the science of oceanography that draw knowledge and expertise from every major scientific discipline. For example, marine biologists study the organisms and the ecology of the oceans. Conversely, physical oceanographers are interested in the physics of the ocean; examining the nature of wave, tides, and ocean currents. Chemical oceanographers examine how the chemistry of the oceans changes with location and time. Finally, geologic oceanographers are mainly interested in how the bedrock and sediments of the ocean crust formed. This lab will focus mainly on the physical and chemical aspects of seawater and will address the fundamental structure of the world's oceans.

B. Some Definitions

Oceanography to a large extent is greatly influenced by the following three measurable parameters.

Density – Is simply defined as a mass per volume. In oceanography the units are typically expressed as:

Density = Mass (g) / Volume (cm^3)

Note that one cm^3 equals one milliliter. Pure water at 4^o C has a density that is exactly 1.0000 g / cm^3.

IMPORTANT SIDE NOTE - Significant Digits – Note that there are four digits after the decimal place. THIS IS IMPORTANT. Scientists refer the number of digits written for a given observation as significant digits. The number of significant digits is a measure of the precision of your data. Basically, what 1.0000 g / cm^3 indicates is that in the lab you can measure the weight of water to the nearest 0.0001 g / cm^3, which is to the nearest 0.1 mg; requiring a high precision analytical balance. Bottom-line – the ten digit number generated by your calculator is almost always not the correct number and you need to learn how to round off your numbers to reflect your ability to measure that number.

Temperature – From a strictly physics prospective, temperature is a measure of the average kinetic energy that water molecules possess. The warmer the water the more movement will be exhibited by individual water molecules. Lower temperatures will decrease water molecular movement. In pure water at 0^o C the movement of water molecules is decreased significantly that weak chemical (hydrogen) bonds between the water molecules becomes stronger than the kinetic movement of the water molecules. At this point the water freezes and becomes a solid (ice).

Salinity – Seawater is obviously salty, unlike freshwater, and the measure of the degree of saltiness of seawater is salinity, expressed in parts per thousand, otherwise known as per mil (‰). Average seawater has a salinity of 35 ‰, which means:

965 parts	Water
35 parts	Dissolved Solids “Salt”
1000 parts	Total

Today, typical seawater varies in its salinity between 31 to 40 ‰.

Salinity is directly correlated with density; the more salty the seawater the greater the density. In terms of temperature there is an inverse relationship with higher temperatures causing thermal expansion and lower densities.

C. Introduction to Physical Oceanography

Examine Figure 1 that illustrates the three basic layers of the oceans. The top layer of the ocean is the surface mixed zone. This zone is warmed from absorption of solar radiation and is mixed by wave and tidal action. This warm layer does not extend more than 300 meters below the surface and therefore by volume accounts for only 2% of the world's oceans. Additionally, note that there is only a surface zone present at the lower and middle latitudes. Below the surface zone is the transitional zone which is present to a depth of 1000 m; note the transitional zone occupies about 18% of the world's oceans by volume and is present only below the surface mixed zone, which is present again in the low to middle latitudes. Most of the ocean by volume (80%) consists of the deep zone. Note that the deep zone is actually present at the earth's surface at the high latitudes.

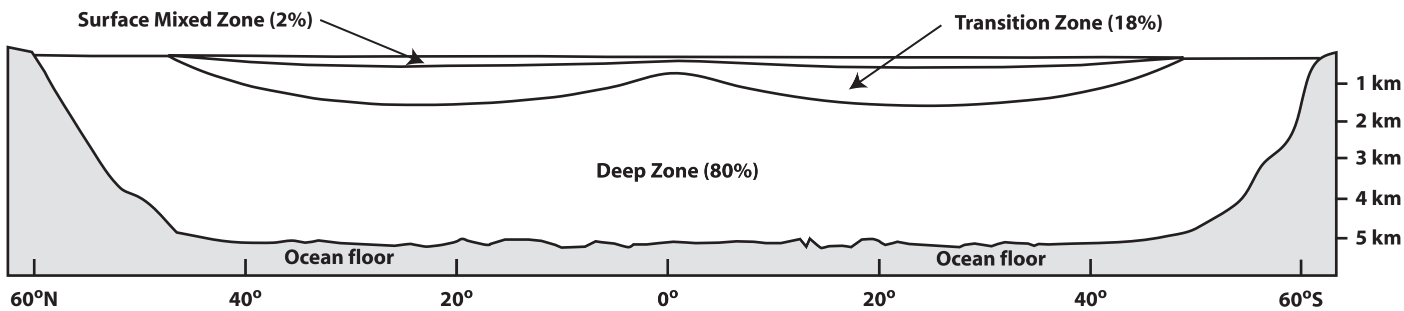


Figure 1. Layer structure of the oceans.

The structure of the ocean is caused by a density difference between these three layers.

Depth (meters)	**Low Latitude Density (g/cm³)**	**High Latitude Density (g/cm³)**
0	1.0250	1.0279
250	1.0254	1.0279
500	1.0265	1.0279
750	1.0275	1.0279
1000	1.0279	1.0279
2000	1.0279	1.0279
3000	1.0279	1.0279
4000	1.0279	1.0279

Table 1 provides data on how density varies with depth for both a low and high latitude location. (make)

Note: that the difference between the surface mixed and deep zone in the low latitudes is 0.003 g / cm^3. This slight difference in density is significant enough to cause the development of these three layers.

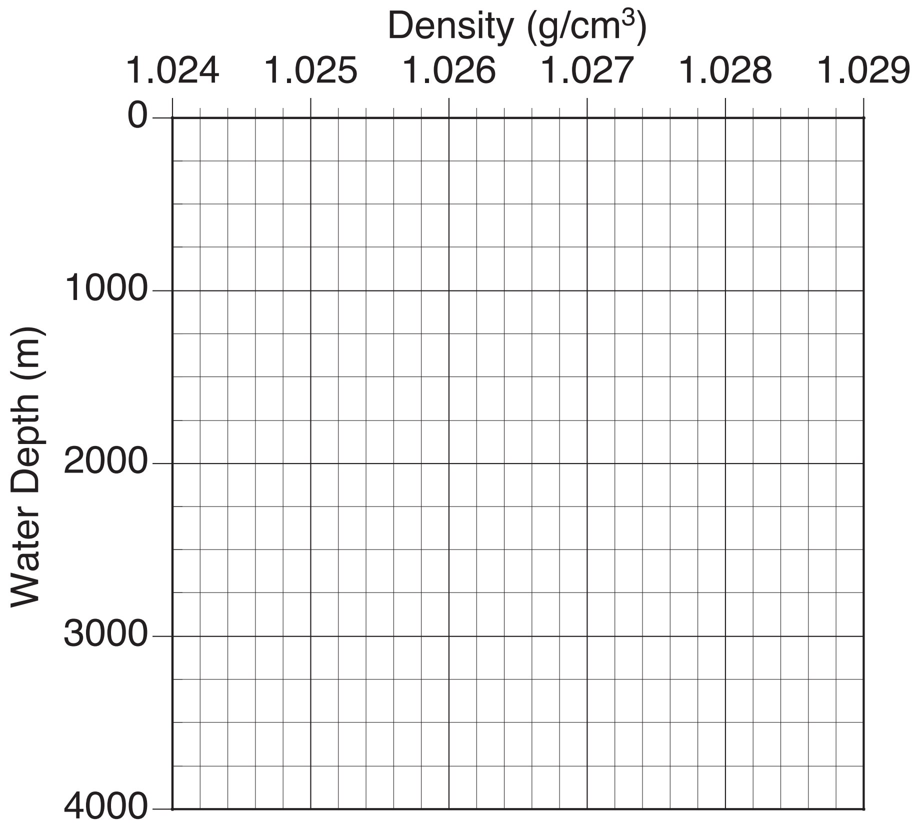


Figure 2. Density versus depth graph.

Questions:

1. Use this data to construct high and low latitude density profiles on Figure 2. Make sure you label your high and low latitude profiles with a distinct line type.

2. Describe the density (in g / cm^3) of the three ocean layers.

Surface ______________________________________

Transitional ______________________________________

Deep ______________________________________

3. Based on your answers to questions 1 and 2 is the following statement true or false. “In nature objects with lower densities will always rise above objects with higher densities.” Defend your answer.

Depth (meters)	Low Latitude Temperature (^oC)	High Latitude Temperature (^oC)
0	25	2
250	24	2
500	22	2
750	13	2
1000	4.5	2
2000	2	2
3000	2	2
4000	2	2

Table 2 provides data on how temperature varies with depth for both a low and high latitude location.

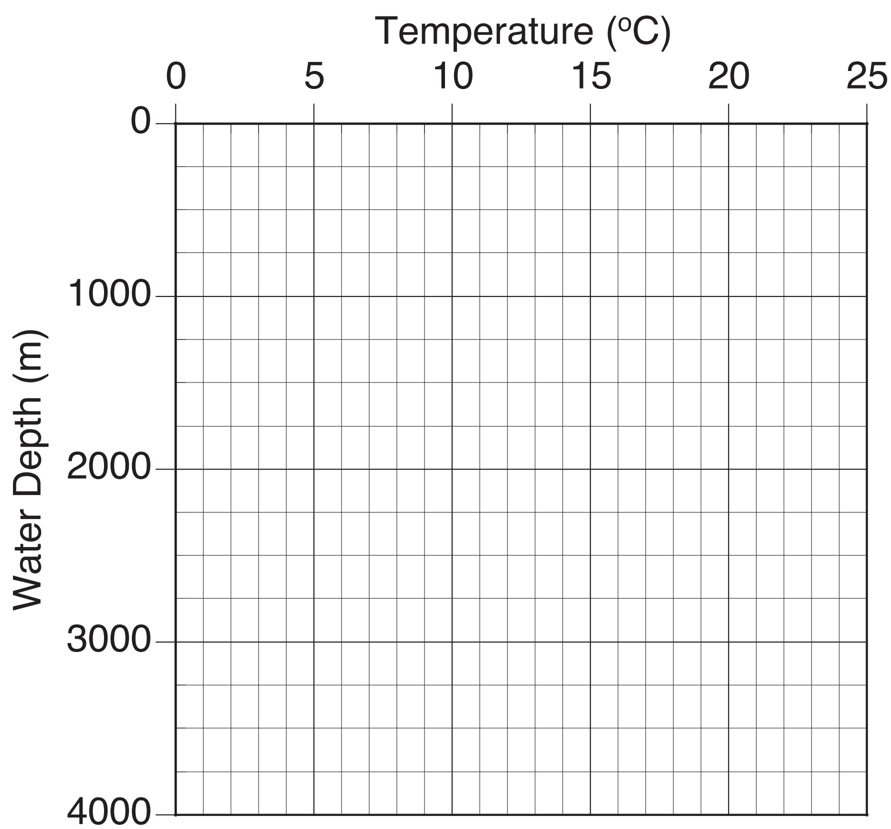


Figure 3. Temperature versus depth graph.

Questions:

4. Use this data to construct high and low latitude temperature profiles on Figure 3. Make sure you label your high and low latitude profiles with a distinct line type.

5. Describe the temperature (in ^{O}C) of the three ocean layers.

Surface ______________________________________

Transitional ______________________________________

Deep ______________________________________

6. Based on your answers to questions 4 and 5 is the following statement true or false? “The higher the temperature the greater the density of seawater.” Defend your answer.

The transition zone in the lower and middle latitudes defines an area where both density increases and temperature decreases rapidly. In the transition zone, the rapid change in density is referred to as the pycnocline and the rapid change in temperature is called the thermocline.

Question:

7. Contrast the nature of the pycnocline and thermocline present in the transition zone as indicated on Figures 2 and 3.

Ocean currents are bodies of seawater that travel large distances through the ocean. There are both surface and deep currents. We will focus on the surface currents of which there are two basic types, warm and cold. Within each ocean basin currents circulate in a circular movement, which is referred to as a gyre.

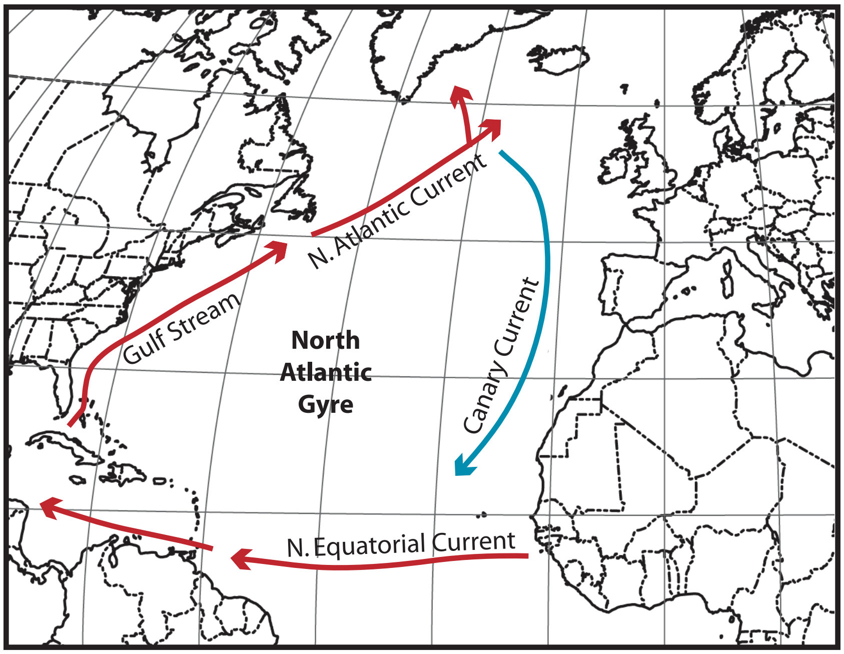


Figure 4. Ocean surface currents with warm currents indicated by red and cold currents by blue. (Modified from Tarbuck ; focus on the north Atlantic Basin)

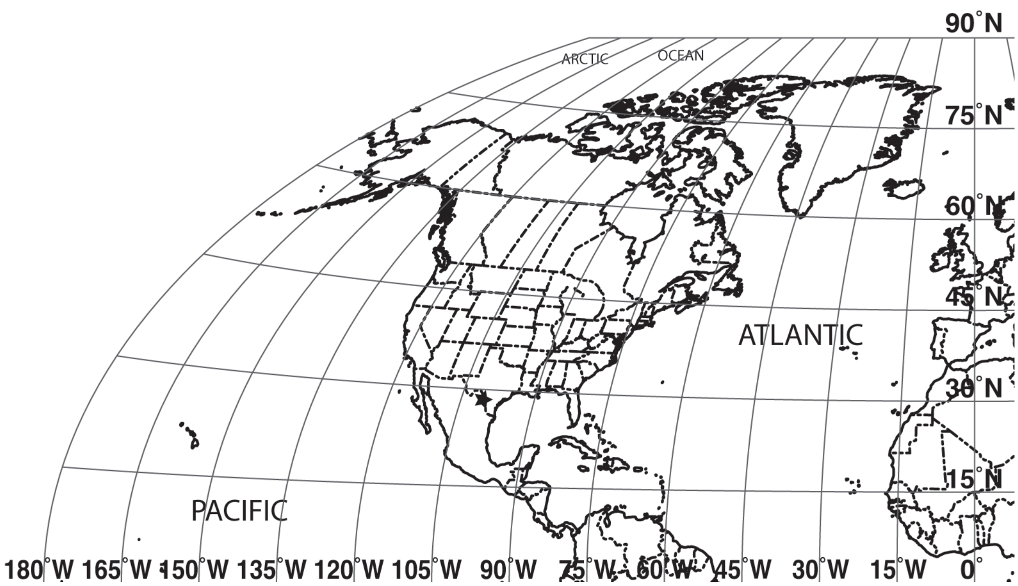


Figure 5. Northern Atlantic and Pacific Oceans.

Question:

8. On the map (Figure 5) in the Pacific Ocean indicate the locations in the oceans where warm currents are present.

9. On the map (Figure 5) in the Pacific Ocean indicate the locations in the oceans where cold currents are present.

10. In general from what latitudes do the warm and cold ocean surface currents come from?

11. Describe the movement of ocean circulation throughout the both the northern Atlantic and Pacific basins.

12. Describe how surface ocean currents can affect the climate of a coastal region.

D. Introduction to Chemical Oceanography

Seawater has a remarkable uniform chemistry. The same portions of “chemicals” are present nearly everyplace in the oceans. The chemicals that are present in seawater are dissolved solids. Everyone has experience with dissolved solids in some form; for example, the sugar dissolved in ones soda or coffee. A dissolved solid is a material that is dispersed at the atomic level within a solution such as water. When solids are broken down in a solution of water to individual atoms or molecules (collection of atoms) these particles commonly become electrical charged. An ion is an electrically charged atom or molecule. There are two types of ions:

Positive ions = cations

Negative ions = anions

Therefore seawater has dissolved cations and anions. The dominant cation is Na^+ (sodium) and the dominant anion is Cl^+ (chlorine). However, there are other cations and anions present in seawater (Table 3).

CATIONS	Weight Percent of Dissolved Salts	ANIONS	Weight Percent of Dissolved Salts
Na^+	30.6 %	Cl^-	55.0 %
Mg^{2+}	3.7 %	SO_4^{-2}	7.7 %
Ca^{2+}	1.2 %	Carbonate ions	< 1 %
K^+	1.1 %		

Table 3. Relative proportions of cations and anions present in seawater.

A remarkable fact in the relative proportions of ions in seawater is constant throughout the world’s oceans. The salinity (total amount of ions) can change significantly but the proportion of ions is fixed. Basically, seawater is always dominated both Na^+ and Cl^+ despite whether the salinity is 31 or 40‰.

Questions:

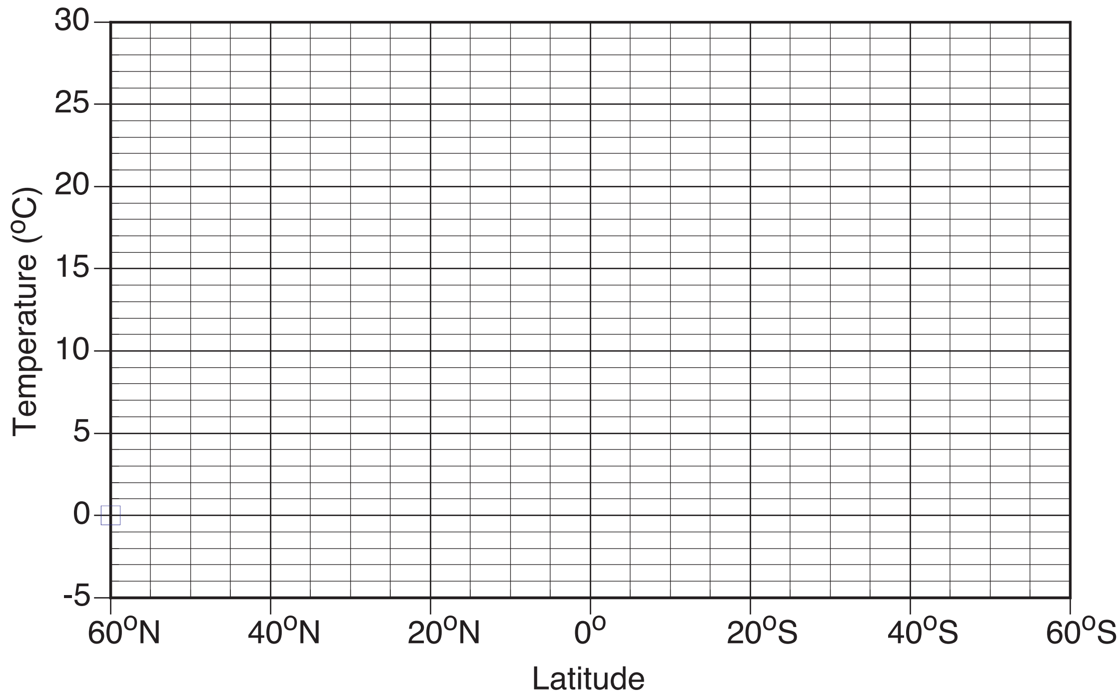
13. List the cations and anions dissolved in seawater? Circle the dominant cation and anion in seawater!

14. Does the proportion of cations and anions in seawater change? Comment in detail.

Latitude	**Temperature (^oC)**	**Salinity (‰)**
60^{o}N	0	33
50^{o}N	5	33.7
40^{o}N	10	34.8
30^{o}N	15	36.7
20^{o}N	23	36.8
10^{o}N	26	36
0^o	27	35
10^{o}S	27	35.9
20^{o}S	26	36.7
30^{o}S	23	36.2
40^{o}S	15	35.3
50^{o}S	8	34.3
60^{o}S	-1	33.9

Table 4. Ocean surface water salinity and temperatures for the Atlantic basin.

A.



B.

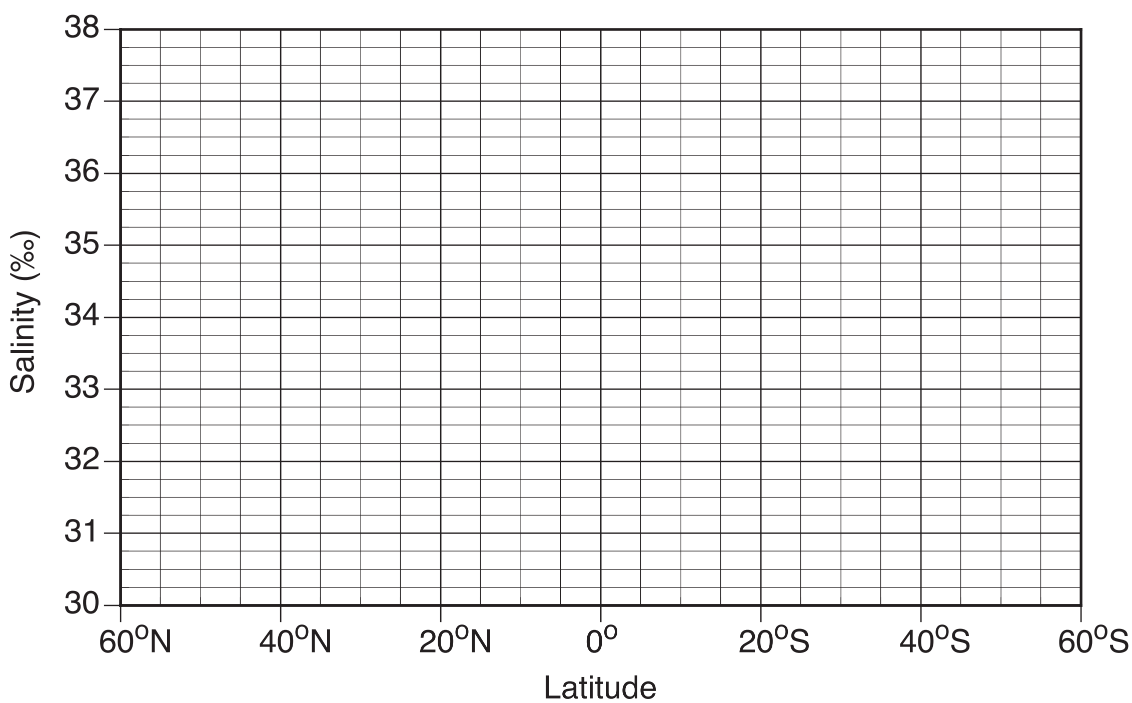


Figure 6. Graphs for plotting salinity (6A) and temperatures (6B).

<u>Questions:</u>

15. Use the data from Table 4 to construct a plot of salinity and temperatures temperature varies with latitude on Figure 6. Make sure you label your plots of salinity and temperature with a distinct line type. Note that the scale for temperature is on the left and salinity on the right side of the graph.

16. Calculate the average salinity of seawater from Table 4.

17. Describe the salinity, relative to average (above or below), for the following latitudes

0^o ______________________

30^o ______________________

60^o ______________________

Salinity is influence by a number of physical processes associated with the hydrologic cycle. For example, excessive precipitation (or runoff from rivers) can dilute seawater resulting in decreased salinity. Conversely, excessive evaporation can concentrate dissolved solid content, after all it is only the water that evaporates and not the dissolved solids. At higher latitudes where sea ice exists the formation of ice, which consists of pure water, again excludes dissolved solids resulting in increased salinity. However, melting sea ice has the opposite affect diluting seawater and decreasing salinity.

<u>Questions:</u>

18. What physical processes control the salinity of surface seawater near the equator?

19. What physical processes control the salinity of surface seawater near 30^o relatively high?

20. What physical processes control the salinity of surface seawater near 60^{o} relatively low? Specifically, what process dominates at this latitude the formation or melting of ice based on the data you plotted?