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 waves, 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 are 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:

$$\text{Density} = \text{Mass (g)} / \text{Volume (cm}^3\text{)}$$

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 so that weak chemical (hydrogen) bonds between the water molecules become 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 called salinity, expressed in parts per thousand, otherwise known as parts 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

Figure 1 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; 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. The deep zone is actually present at the earth’s surface at the high latitudes.

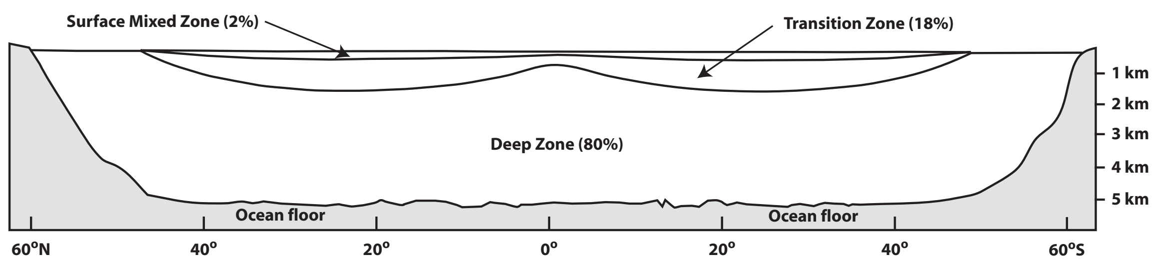


Figure 1. Layered structure of the oceans.

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

Depth (meters)	Low Latitude Density (g/cm^3)	High Latitude Density (g/cm^3)
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.

Note: 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.

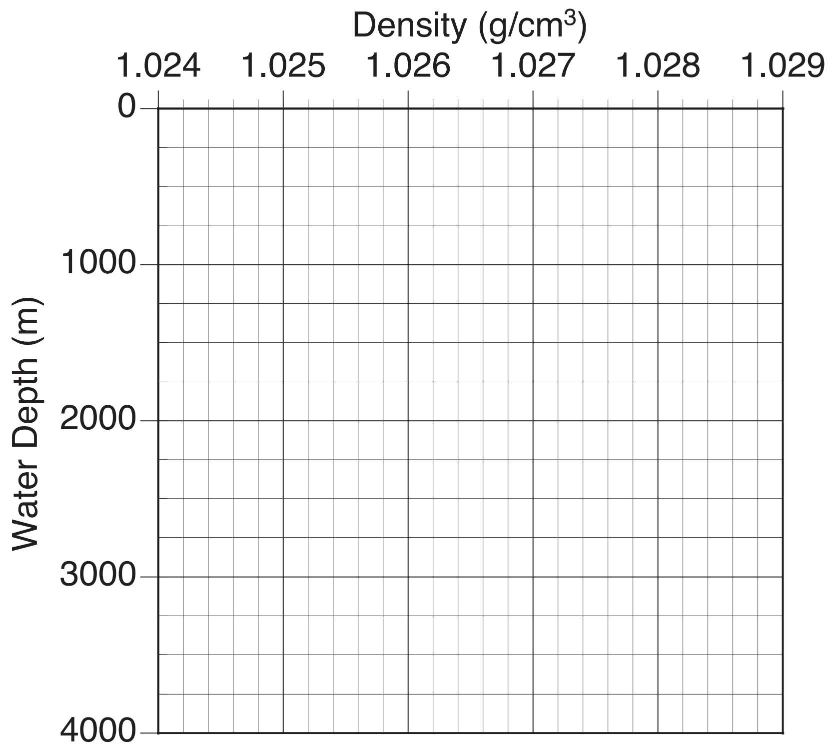


Figure 2. Density versus depth graph.

Questions:

1. Use the data in Table 1 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. Label the three ocean layers on Figure 2. Draw two horizontal lines to seperate these layers.

3. Describe the density of the three ocean layers.

	(g / cm^3)	Relative (Low, Medium, High)
Lowest	____________________	____________________
Medium	____________________	____________________
Highest	____________________	____________________

4. Based on your answers to questions 1 to 3 comment on the validity of the following statement. “In nature objects with lower densities will always sink below objects with higher densities.”

Depth (meters)	Low Latitude Temperature (^{o}C)	High Latitude Temperature (^{o}C)
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.

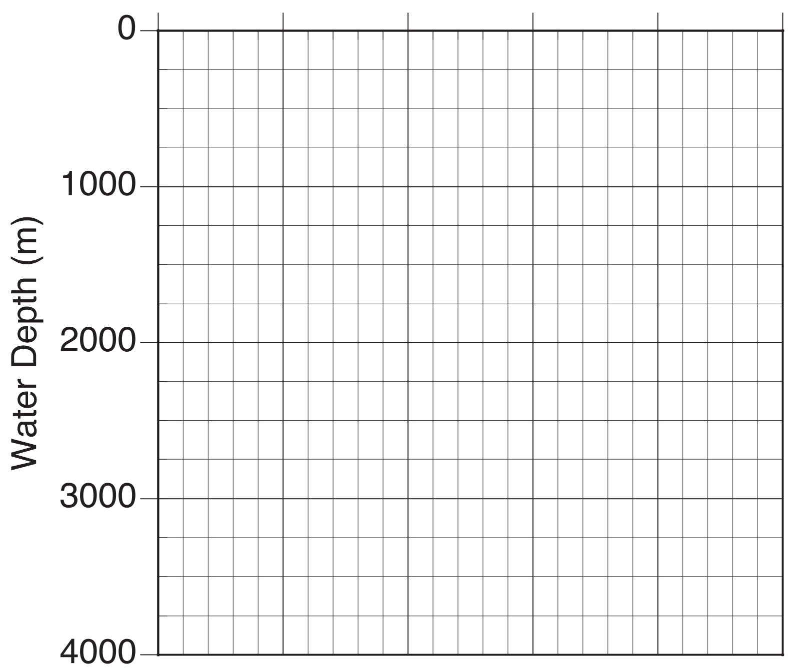


Figure 3. Temperature versus depth graph.

Questions:

5. Use the data in Table 2 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.

6. Label the three ocean layers on Figure 3. Draw two horizontal lines to seperate these layers.

7. Describe the temperature of the three ocean layers.

	(Temperature ^{o}C)	Relative (Low, Medium, High)
Lowest	____________________	____________________
Medium	____________________	____________________
Highest	____________________	____________________

8. Based on your answers to questions 5 to 7comment on the validity following statement. “The higher the temperature, the greater the density.”

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:

9. Compare and contrast the shapes of the pycnocline and thermocline present in the transition zone as indicated on Figures 2 and 3. Do they trend in the same direction or are they opposite.

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

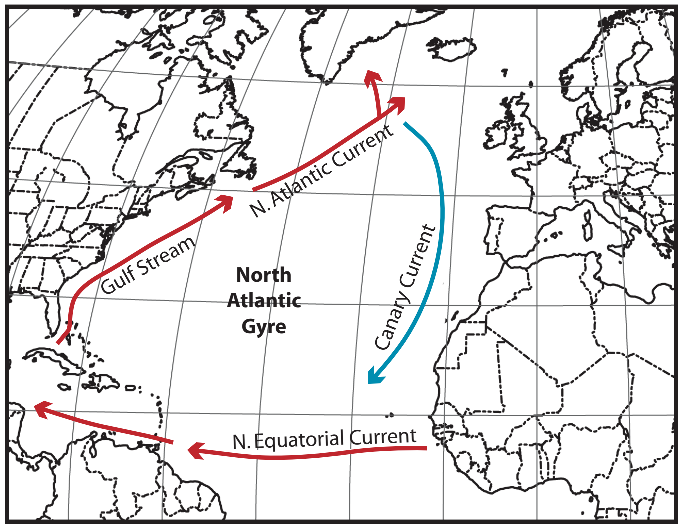


Figure 4. Ocean surface currents with warm currents indicated by red and cold currents by blue in the northern Atlatnic Basin.

Question:

10. On the map below (Figure 5), in the North Pacific Ocean, indicate with shading where the warm currents of the surface zone are present. Note that you have only one half of the Pacific Basin and gyre in Figure 5.

11. On the map below (Figure 5), in the North Pacific Ocean, indicate with shading where the cold currents of the surface zone are present. Note that you have only one half of the Pacific Basin and gyre in Figure 5.

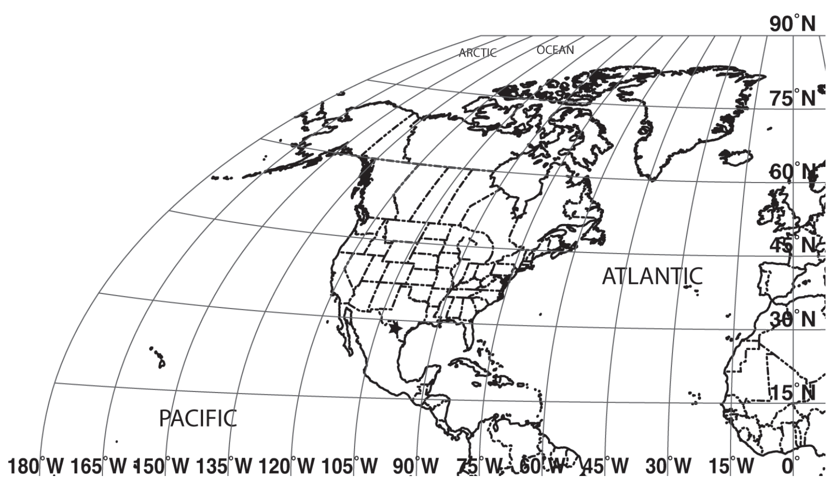


Figure 5. Northern Pacific and Atlantic ocean basins.

12. In general from what latitudes (high vs. low) do the warm and cold ocean surface currents come from?

Warm Currents ____________________ Cold Currents _____________________

13. Describe the general direction of movement of ocean currents throughout the North Atlantic basin as indicated in Figure 5.

14. Describe how surface ocean currents can affect the climate of a coastal region. Specifically, compare the climates of Great Britian and Labrador which are at the same latitude

D. Introduction to Chemical Oceanography

Seawater has a remarkable uniform chemistry. The same portions of "chemicals" are present nearly every place in the oceans. The chemicals that are present in seawater are dissolved solids. Everyone has had 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 electrically charged. An ion is an electrically charged atom or molecule. There are two types of ions:

Positive ions = cations
Negative ions = anions

Therefore, seawater contains 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 that they are 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 by both Na^{+} and Cl^{-} whether the salinity is 31 or 40‰.

<u>Questions:</u>

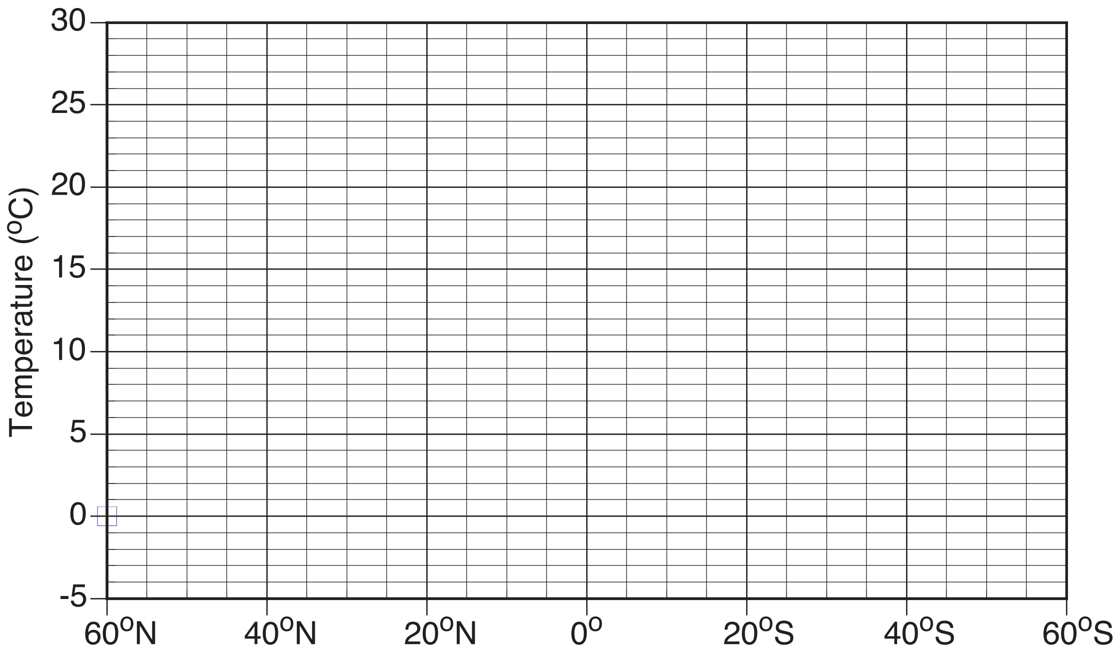
15. List the cations and anions dissolved in seawater. Circle the dominant cation and anion in seawater.

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

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

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

A.



B.

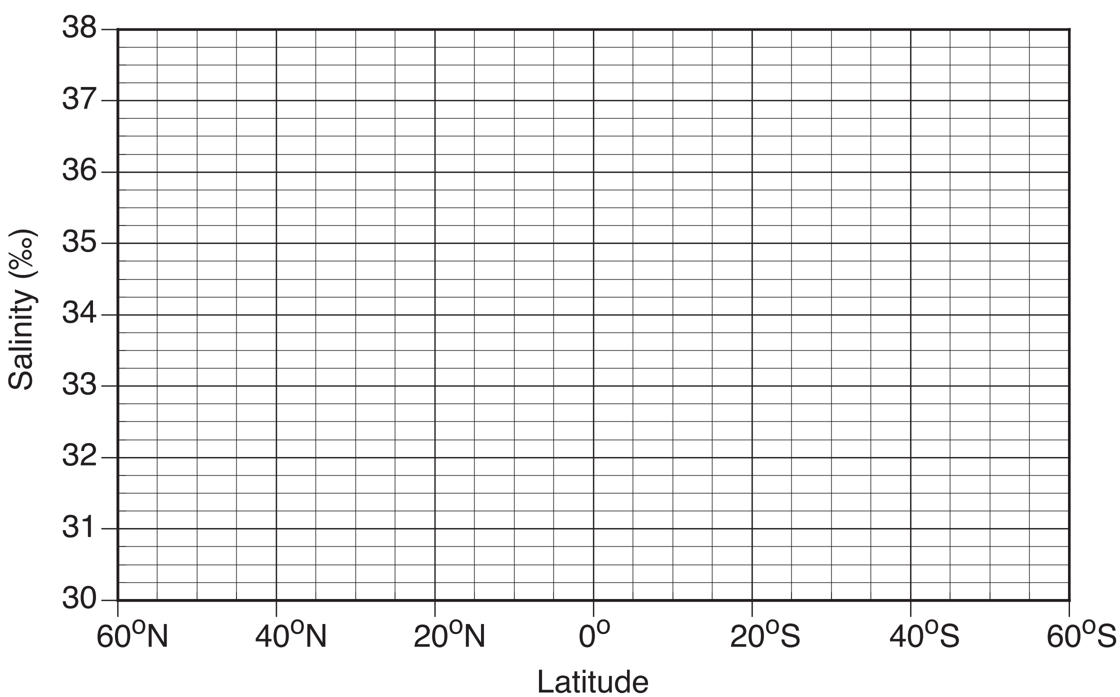


Figure 6. Graphs for plotting temperature (6A) and salinity (6B).

Questions:

17. Use the data in Table 4 to construct a plot of salinity and temperature variations with latitude on Figure 6.

18. Calculate the average salinity from Table 4.

19. Describe the salinity (below average, near average, or above average) at the following latitudes

0^o ____________________

30^o ____________________

60^o ____________________

20. Describe how surface temperature varies with increasing latitude.

Salinity is influenced 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, 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 excludes dissolved solids resulting in increased salinity. However, melting sea ice has the opposite affect diluting seawater and decreasing salinity.

21. The salinity at the eqautor is near average. This is because there is a balance between the fluxes that add and remove water from the ocean. Write an equation that expresses this balance.

22. What physical processes control the salanity of surface seawater near 30 degrees latitude. Clue: is there much ice in places at this latitude like the Gulf of Mexico???

23. What physical processes control the salinity of seawater near 60 degrees latitude? At this latitude there is significant ice so think about whether the formation or melting of ice dominates based on the data in Figure 6b.