GEOL1551 Seawater Properties **Name: ___________________________________**

Readings: *Lab 5 document and textbook chapter on Seawater Properties*

Objectives: to introduce you to methods of collecting seawater properties data (e.g., salinity, temperature, pH), and how those data may be displayed and interpreted to understand oceanographic processes.

Temperature:

As energy enters the ocean from the sun, the radiation is absorbed and is stored in the mass of the ocean water as heat. The energy also evaporates sea-water and thus increases its salinity, but for the purposes of this exercise we will focus our attention on the portion of incoming radiation that heats the water. Heating a substance leads to expansion and therefore a decrease in the **density** (mass per unit volume). Conversely, cooling a substance increases its density, and in the case of seawater changes in density brought about by seasonal heating and cooling constitute one of the processes that generate ocean currents. A simple model of oceanic circulation in surface waters in a single region can be constructed on the basis of **temperature** alone.

Understanding oceanic circulation is important because the water motion influences the distribution of energy and materials on the earth, defines marine biological environments, and has a major impact on climate. Coastal currents strongly influence local climates and produce the differences in temperature and humidity on a given summer day between, for example, San Diego, California, and Savannah, Georgia, two points that, although on different coasts, are at about the same latitude and would therefore be expected to have similar climates. The major factor is the temperature of the surface water in each area because it controls or regulates local air temperatures and humidities.

The permanent **thermocline** (**Fig. 1**), the water layer within which temperature decreases rapidly with depth, acts as a density barrier to vertical circulation; that is, we may view this thermocline as the floor of the low-density warm surface, or mixed, layer and the ceiling for the cold dense bottom waters. Large-scale vertical movements of the water between bottom and surface, are inhibited by the strong contrast in density between the two layers. However, in the polar regions, surface waters are much colder and therefore denser, so that little temperature variation exists between surface waters and deeper waters in these areas. Here vertical circulation takes place as surface waters sink to replenish deep waters in the major oceans.

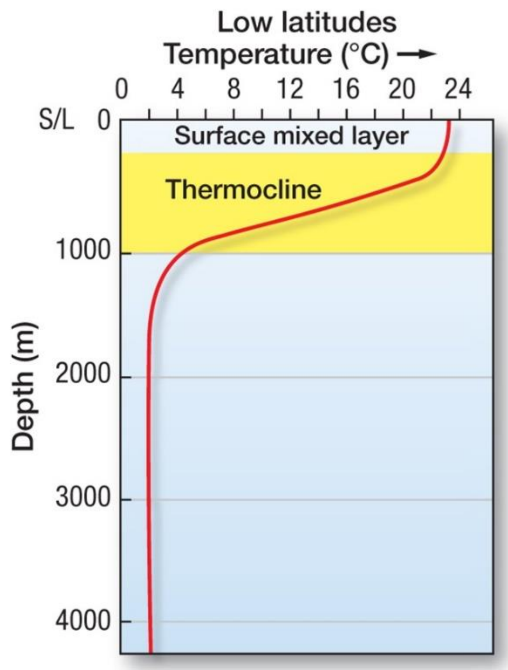


Fig. 1. Illustration of the thermocline at low latitudes (near the equator) in the world's oceans

The distribution of **surface temperatures** in the major oceans is shown in **Figure 2**. Note that the isotherms tend to warp toward the equator on the east sides of the oceans, and poleward on the west sides. This is due to the <u>major circulation pattern</u> by which warm water is carried from the equator toward the poles on the west sides, and cooler water from the subarctic regions moves toward the equator on the east sides.

Another influence on surface temperatures, in the coastal waters on the eastern sides of ocean basins, is **upwelling**, or the rise of cooler waters from lower depths. First, the **Coriolis effect** causes water that has been set in motion by winds or other forces to be deflected to the right in the Northern Hemisphere, and to the left in the Southern Hemisphere. However, owing to friction, the surface layer drifts at an angle of 45 degrees to the wind direction. As a consequence of the Ekman spiral, the net transport of water is 90 degrees to the right of the wind direction in the Northern Hemisphere (and 90 degrees to the left of it in the Southern Hemisphere). This means that-in the waters off the coast of Florida, for example-winds blowing from the south along the Atlantic coast drive surface waters to the right, or offshore, and this water is replaced by cooler nutrient-rich water from depths of 200-300 meters. Although upwelling occurs at many places along both coasts of the United States, it is particularly important along the coasts of

California, Oregon, and Florida. It may be detected by temperature measurements, because it produces colder water inshore, and the isotherms warp upward toward the shore. Types of upwelling are illustrated in **Figure 3.**

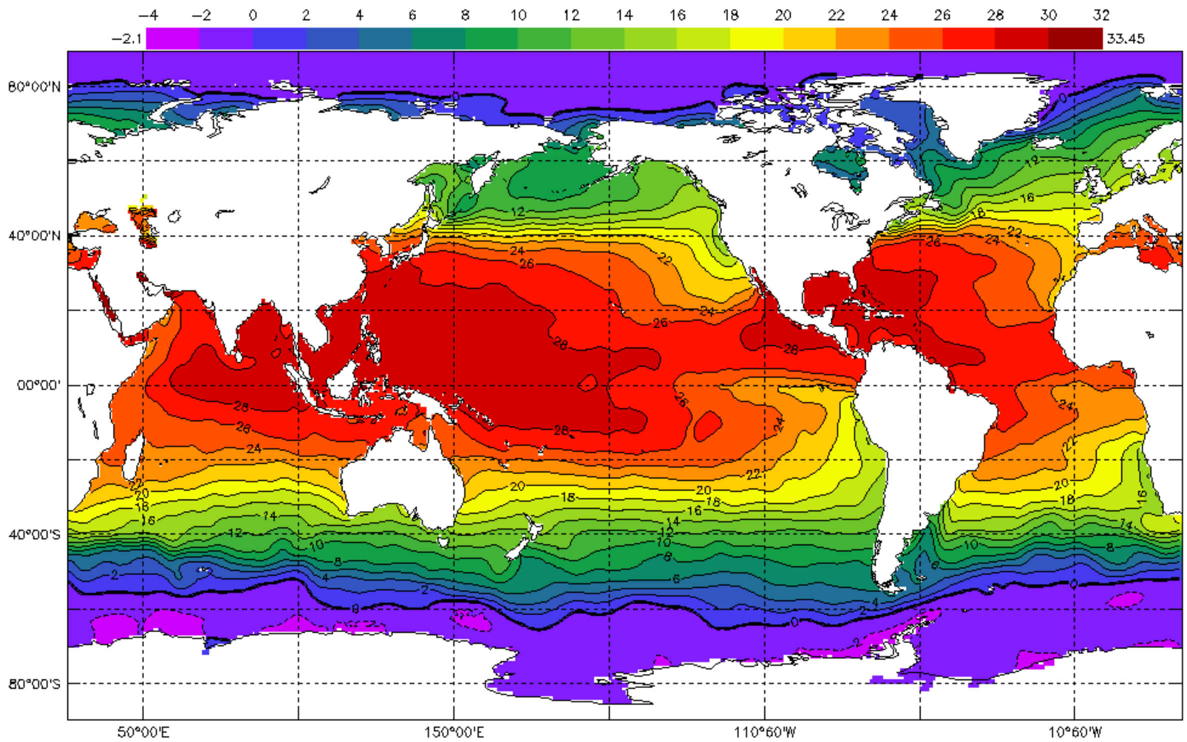


Fig. 2. Map of monthly mean August sea surface temperatures

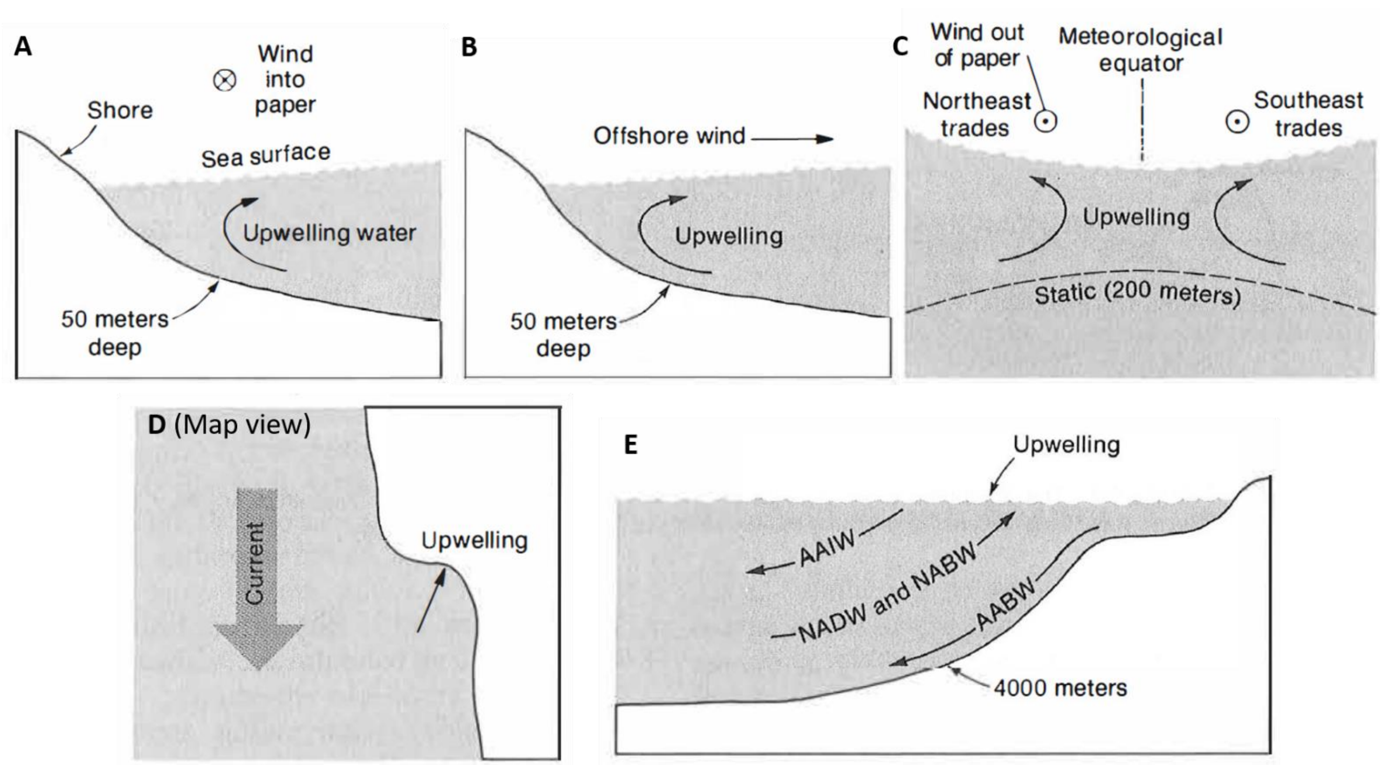
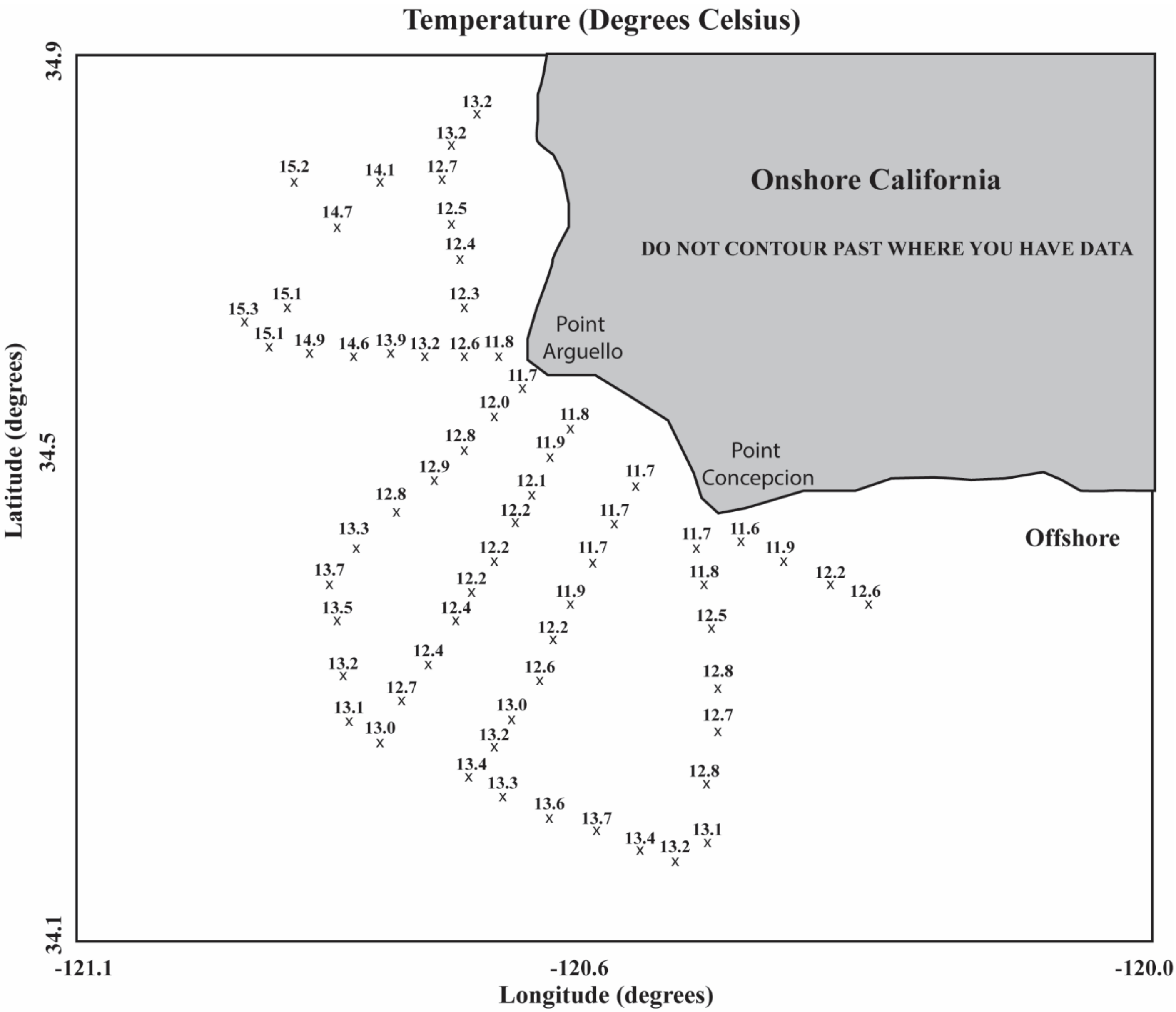


Fig. 3. Diagrams of various kinds of upwelling. A: Coriolis-effect upwelling. B: Wind-driven upwelling. C: Open-ocean Coriolis effect equatorial upwelling. D. Obstruction upwelling. E. Density-Driven upwelling (deep water). AABW = Antarctic bottom water. AAIW = Antarctic intermediate water. NADW = North Atlantic deep water. NABW = North Atlantic bottom water.

Part 1:

1. **Figure 4** below represents a group of sea surface temperatures taken as part of a program known as Organization of Persistent Upwelling Structures (OPUS). The data are from a region near Point Conception and Point Arguello, California. **Surface temperatures** were recorded at a depth of 2 meters by lowering an instrument from a Scripps Institution of Oceanography ship.



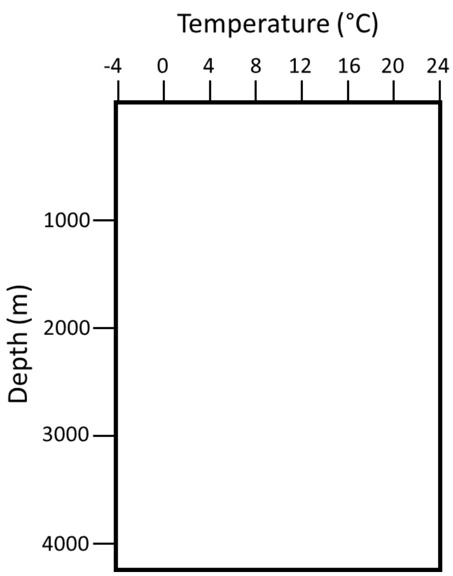
(a) **Contour the surface temperatures at a 0.5 Celsius-degree contour interval. It is suggested that you contour <u>whole</u> degrees to start, then fill in half-degree intervals by interpolation.** You should have isotherm contours from 12ºC-15ºC. An ***<u>isotherm</u>*** is a line connecting points of equal temperature.

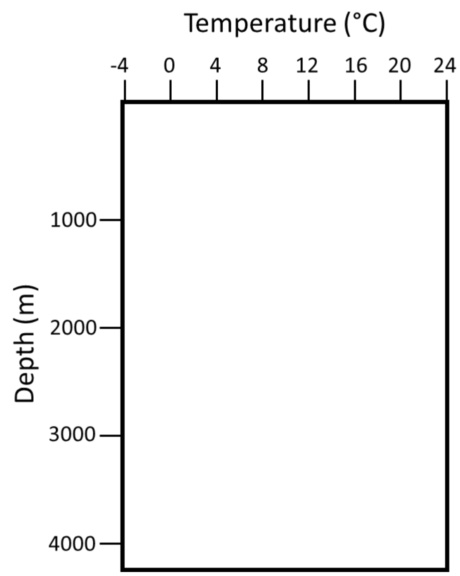
(b) Is upwelling occurring here? If so, which type? <u>Hint</u>: The dominant wind direction along the coast of California is from north to south.

2. Refer to the information given in this lab, your textbook and Figures 1 & 2 to answer the following questions:

(a) Where is water of the greatest density formed? **Why?**

(b) **Draw** a **depth** vs. **temperature** curve for the Arctic (left) and one for the equatorial region (right). In the middle, **explain** the difference between them. In which of these regions will surface and deep water vertically mix?





(c) Why is water so much cooler along the coast of North America than at equivalent latitudes on the opposite side of the Pacific Ocean?

Salinity

The density, or mass per unit volume, of sea-water depends upon two properties: temperature and salt content, or salinity. As water cools, its density increases. As its salt content increases, its density also increases. Because water of high density tends to sink, and that of low density tends to rise above or settle below water that is at the average density of the oceans, the change in density is one process whereby water motion is generated. Therefore, we are interested in the distribution of both salinity and temperature of water, since these are the two factors that determine the circulation that is caused by density changes.

The oceans get their salt from the weathering and dissolution of minerals on land and from volcanic emanations. The mobile constituents of minerals are carried in solution by streams to the sea where they accumulate and are recycled by various processes. Salinity is a "conservative" property; that is, one that remains constant for the ocean as a whole for long periods of time, even though the local salinity varies within limits over the surface of the oceans. The average salinity for the oceans as a whole is 34.73 parts salt per 1000 parts water (34.73‰) or 34.73 grams dissolved substance per kilogram of water. Concentrations between 33.0‰ and 37.0‰ have been measured in the open ocean. High salinity, or dilution, is found only in coastal waters or in partially enclosed seas. Such extremes are due largely to excessive runoff from the land, or to high evaporation rates and little mixing with other waters, as in the Red Sea and the Mediterranean Sea. **Note: ‰ is parts per thousand – this is not the same as percent (%) which is parts per hundred.**

General variations in **<u>salinity</u>** are zoned from the equator to the poles (**Figure 5**). Values are low at the equator, highest in subtropical regions and at mid-latitudes, and lowest in the polar regions. The major processes responsible for this distribution are evaporation, precipitation, and mixing. **Where evaporation exceeds precipitation, salinity values are high, and in areas of high rainfall, they are lower**.

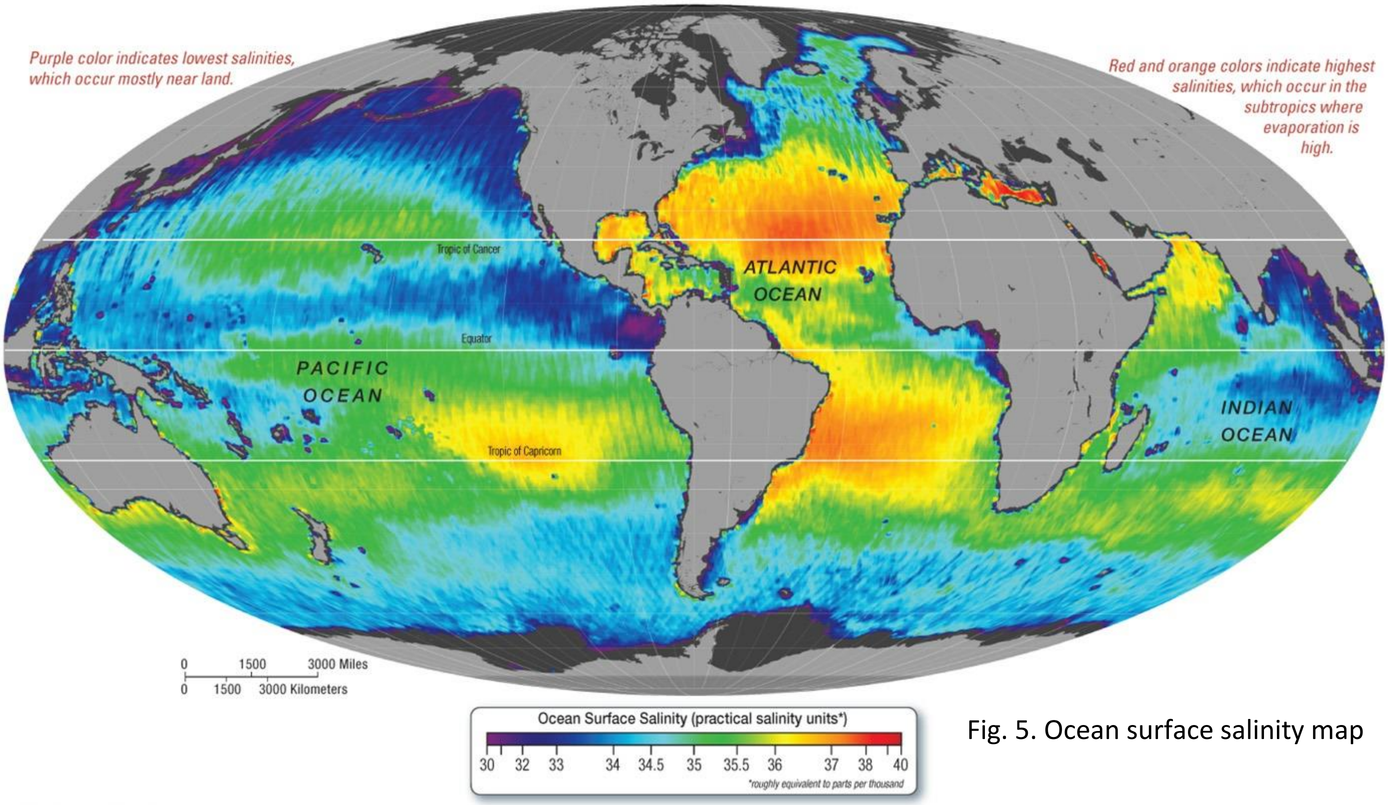


Fig. 5. Ocean surface salinity map

3. Give the concentration of seawater with a salinity of 3.69 percent (%) in the following units:

(a) ______________ Parts per thousand (‰)

(b) ______________ Parts per million

(c) ______________ Grams (salt) per kilogram (water)

The salinity of seawater is not a difficult property to determine. One reason is that regardless of the absolute concentration of salts in solution, the major dissolved constituents exist in virtually a constant ratio to one another. In theory, if you determine the concentration of a major dissolved ion in a sample, you should be able to calculate the concentration of the other major constituents. Because chloride is the most common dissolved ion and one of the easiest to determine precisely, its concentration is determined, and from that measurement the salinity is calculated:

Salinity (‰) = 1.80655 X chlorinity (‰)

4. What is the salinity of seawater with a chlorinity of 20.3‰? Show work.

5. Using Figure 5 answer these questions:

(a) Give a **latitude** **<u>range</u>** for where salinity values are ***high***. Give a **latitude** **<u>range</u>** for where salinity values are ***low***.

(b) Which of the two oceans (Atlantic or Pacific) is saltier? By what amount (approximately)?

(c) **<u>Why</u>** do you think that ocean would be saltier, given what you know about drivers of salinity from the lab text?

Part 2:

Use interactive data found at the specific URLs below to address the associated questions:

Visit: <u>http://explorations.visualocean.net/chemistry/activity1.php?level=application</u>

Look at the <u>background information</u> to answer the following questions.

1. What is a mooring in **<u>this</u>** context?

2. What is a CTD? What data does it **<u>acquire</u>**, and what data can be **<u>calculated</u>** from it?

Choose "Coastal Atlantic vs. Coastal Pacific" dataset. Look at the <u>data graph</u> to answer the following questions.

3. Where are these data from? Be specific.

4. What is the **<u>range</u>** of variation of salinity through the year for the **Pacific** versus the **Atlantic** mooring? Which is higher? Does this match your observation of the static map averages in Part 1 Question 5b?

Visit: **https://datalab.marine.rutgers.edu/explorations/chemistry/activity2.php?level=exploration**

Explore toggling on the different parameters that may affect ocean salinity (Air Temperature, Sea Surface Temperature, and Rain Rate) while comparing to salinity measured off the Oregon coast in the Pacific Ocean. Notice that the left Y-axis shows salinity values, and the right Y-axis shows your chosen second parameter. You can change the time period from the full year to only certain months by using the bar below the graph.

5. Toggle on **rain rate** – What effect does a high rain rate have on salinity measurements? What about a low rain rate?

6. How do your detailed observations of these paired datasets support (or not) your answer to Part 1 Question 5a? Question 5c?

Assessing the pH of seawater

Visit: http://explorations.visualocean.net/chemistry/activity3.php?level=exploration

Using Background Information

7. These data were acquired from which mooring site and what water depths?

8. What does pH **actually** measure within the ocean water?

Data Graph

9. As you descend through the water column does it become more acidic, or more basic?

Visit: https://datalab.marine.rutgers.edu/explorations/chemistry/activity4.php?level=exploration

Using Background Information

10. **Where** were these data acquired? What mooring site **and** what water depths?

11. What data are we looking at in each of these graphs? What is the time frame of this dataset?

Using the data graph – click and drag a box in the upper right graph to select different time frames of interest.

12. Select a box size of ~1 month in length and scroll it through time to observe how the scatterplot changes through over the course of the year. During which months (or seasons) is there little "scatter" in the data? (When is the data on the left restricted to a small range of pH and pCO2 values?) During which months is there wide variability in the data?

13. Look at the data from August to September. Describe the relationship you see between pH and pCO2 that month. In other words, when pH levels are high in August/September, are the pCO2 readings in the water high or low?

14. Why do you think there is more variability in this data during certain parts of the year, and less variability in others? (Consider what contributes CO2 to the water column!)