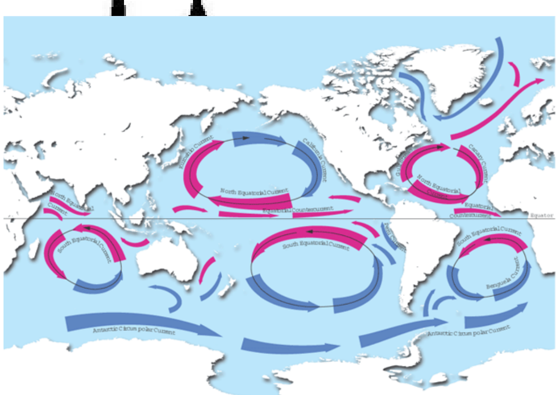
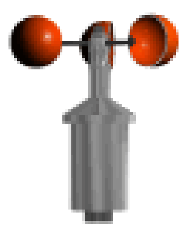
Earth Science 106

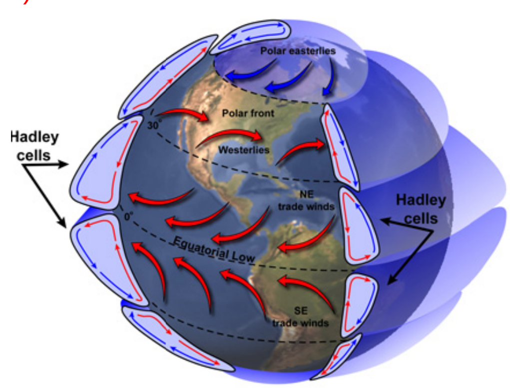
Laboratory Manual

2015-2016

(Updated February 2016)







Earth Science 106

Earth System Science III

2015-2016

(Updated February 2016)

Laboratory Manual

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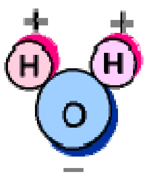
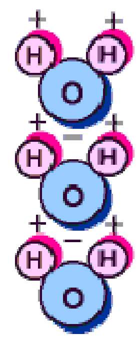
ES 106 Laboratory # 1
PROPERTIES OF WATER

Introduction

What are the physical and chemical properties of water that make it so unique and necessary for living things? When you look at water, taste and smell it – well, what could be more boring? Pure water is virtually colorless and has no taste or smell. But the hidden qualities of water make it a most interesting subject. In today's lab, you will explore some of the properties of water. You will also be introduced to the concept of density as a property of matter.

The Water Molecule's Properties





You probably know water's chemical formula is H_2O. As the diagram to the left shows, that is one atom of oxygen attached to two atoms of hydrogen. The hydrogen atoms are bonded to one side of the oxygen atom, resulting in a water molecule having a positive charge on the side where the hydrogen atoms are and a negative charge on the other side, where the oxygen atom is. Molecules with charge differences such as this are called polar molecules.

Since opposite electrical charges attract, water molecules are attracted to one another, making water kind of "sticky." As the right-side diagram shows, the side with the hydrogen atoms (positive charge) attracts the oxygen side (negative charge) of a different water molecule.

All these water molecules attracting each other mean they tend to clump together. This is why water drops are drops! If it wasn't for Earth's gravity, a drop of water would be ball shaped – a perfect sphere.

Water's Physical Properties

Here's a quick rundown of some of water's properties:

- Water is unique in that it is the only natural substance that is found in all three states – liquid, solid (ice), and gas (steam) – at the temperatures normally found on Earth. Earth's water is constantly interacting, changing, and in movement.
- Water is unusual in that the solid form, ice, it is less dense than the liquid form, which is why ice floats. Notice the density of water at various temperatures in the chart on the following page

Density of Water	Solid (ice)	Liquid
0° C (32° F)	0.917 g/cm^3	0.9998 g/cm^3
4° C (39.2° F)		1.0000 g/cm^3
100° C (212° F)		0. 95865 g/cm^3

- Water has a very high surface tension. It tends to clump together in drops rather than spread out in a thin film. The surface can support small objects that have greater density than water. Surface tension is also responsible for capillary action, which allows water (and its dissolved substances) to move through the roots of plants and through the tiny blood vessels in our bodies.
- The freezing and boiling points of pure water at sea-level pressure are the baseline with which Celsius temperature is measured:

Phase change temperature of pure water at various pressure	▪ Solid-liquid (freezing)	▪ Liquid-vapor (boiling)
Sea level	▪ 0° C (32° F)	▪ 100° C (212° F)
4265 m (14,000 ft) above sea level	▪ 0° C (32° F)	▪ 85.8° C (186.4° F)

- Pure water has a pH of 7, which is neutral, neither acidic nor basic.
- Water is called the "universal solvent" because it dissolves more substances than any other liquid. This means that wherever water goes, either through the ground or through our bodies, it takes along valuable chemicals, minerals and nutrients.
- Water has a high specific heat. This means that water can absorb a lot of heat energy before it gets hot. Water is valuable to industries and in your car's radiator as a coolant because of this property. The high specific heat of water also helps regulate the rate at which air changes temperature, which is why the temperature change between seasons is gradual rather than sudden, especially near the oceans.

Goals and Objectives

- Be able to define specific heat, surface tension, and polar molecule.
- Be able to define and calculate density.
- Observe the effects of the polar nature of water on its properties.
- Apply the scientific method to identify materials based on their properties.

Useful Websites

- http://www.uni.edu/~iowawet/H_2OProperties.html
- http://www.simetric.co.uk/si_water.htm
- http://www.physicalgeography.net/fundamentals/8a.html

Name____________________________

Lab Day_____ Time_________________

Pre-lab Questions – Complete these questions before coming to lab.

1. Define the following terms.
   A. Density

   B. Polar molecule

   C. Surface tension

   D. Specific heat

2. Calculate the following temperature conversions: Note: $F^0 = \frac{9}{5}C^0 + 32$
   A. 32ºF to ºC

   B. 100ºC to ºF

   C. 46ºF to ºC

   D. 25ºC to ºF

Part A – Exploring Some Properties of Water

For this part of the lab you will explore the surface tension of water.

Activity 1:
Predict the number of drops of water you can fit on a penny. ____________
Use the dropper to place water, one drop at a time on the penny until it spills off the penny. How many drops did it hold? ____________________

Activity 2:
Place a piece of wax paper over a piece of newspaper. Place a few drops of water on the wax paper. Look at the newsprint. What happens to the appearance of the newsprint? Note your observations.

Activity 3:
Carefully place a dry pin on water in a watch glass so the water supports its weight (**Hint**: fill watch glass until the water bulges over the top and gently insert pin from side). While the pin is on the water, gently add a drop of detergent near the pin. What happened to the pin? Note your observations.

Does a pin "float" on water in the same way as a block of wood floats? Describe:

Activity 4:
Tie a piece of thread in a loop (> 1" in diameter) and float it on water in the watch glass. Add a drop of detergent inside the loop. What happened to the thread loop? Note your observations.

Thoroughly clean the watch glass to remove all traces of detergent. Float another loop of thread as before. Predict what will happen if you add a drop of detergent outside the loop.

Try it. Note your observations.

Part B – Which Clear Liquid Is Water? Using properties to identify it.

You are on the Planet WOU and are in need of water. The residents of Planet WOU – the WOLFIANS – do not speak any Earth languages, but you are trying to communicate with them. All that the Wolfians are able to understand is that you need a clear liquid. They do not understand the various properties and characteristics of water that you are trying to explain to them. They bring your group samples of 4 clear liquids that they have located on Planet WOU. You are now faced with a serious predicament. If you drink the wrong liquid, you could become violently ill or die. On the other hand, if you don't get any more water, you will also die. Hence, the conundrum: Which of these liquids is water?

Activity:
Your spacecraft has many testing materials onboard, including a known sample of water, which you can use to explore all the liquids. You check the spacecraft manual for situations of this nature, and identify a series of experiments, tests, or procedures that should enable you to distinguish water from the other liquids with a great degree certainty. In order to be extra sure of your identification of water (after all, your life is on the line), you must also design one other experiment, test, or procedure to confirm the other tests. Your group can use the data table on the following page to summarize your observations. Remember, there is no taste testing, smelling, or touching of the liquids allowed.

Do NOT put any other materials into the large test tubes labeled 1-5. The samples that you receive in the numbered test tubes are all that you get to use. If you contaminate them or run out, you won't be able to continue your investigations. So read and follow the instructions below.

Carry out your experiments on the liquids in small test tubes, watch glasses, and beakers using as little of the unknown liquids as possible for each test.

After you have completed your experiments be sure to clean up completely, so the equipment is ready for another lab group to use.

Do NOT put any other materials into the large test tubes labeled 1-5.

TABLE 3: Liquid Investigation Data

Question asked:		**Known Water sample**	**Unknown Liquid 1**	**Unknown Liquid 2**	**Unknown Liquid 3**	**Unknown Liquid 4**
What is the pH of the liquid?						
Which materials float on the liquid (check: ice, toothpick, ~~oil,~~ and salt)						
Which materials dissolve in the liquid? Use small amount of solid! (check salt, sugar, and baking soda) Note any reactions.	Salt					
	Sugar					
	Soda					
How long does it take for 2.5 mL to evaporate? (Use a small beaker for this test and be very careful!) Is there a residue?						
Student designed test: (describe test in this space, and put results to the right)						

Questions

1. Based on your tests, which sample is most likely water?

2. Indicate which ones you know are not water, and why you know this.

3. How confident are you in your determinations? Briefly explain.

4. Briefly outline the procedure that you followed to solve this problem.

5. Which test was the most effective in addressing the needs of the problem? Explain why you think it was so effective.

6. Which test was the least effective in addressing the needs of the problem? Explain why you think it was so ineffective.

Name____________________________

Lab Day_____ Time__________________

POST-LAB ASSESSMENT

1. Suppose that you are doing dishes after a greasy meal. You take a greasy pan and fill it with water. A thin film of grease completely covers the surface of the water in the pan. You place a drop of Dawn dishwashing liquid in the middle of the pan and the grease shoots away from the drop towards the sides of the pan. "Wow!" you exclaim to yourself "Dawn really does take grease out of the way, just like in the commercial." Using what you observed in today's lab, what actually happened? Do you think this behavior would only happen with Dawn, or would other dishwashing liquid produce this effect as well? (If you have never seen the Dawn commercial on TV, try this experiment at home with a greasy pan.)

2. Imagine that you have a 2 inch long, ½ inch diameter rod made of a clear material. Your goal is to determine what material makes up the rod. Your first guesses as to the composition of the rod are glass and ice. To test these hypotheses, you place the rod in a beaker of water and it sinks to the bottom.

a. Could the rod be made of ice?

b. Could the rod be made of glass?

c. After this experiment, have you uniquely determined the composition of the rod, or is there another clear material in addition to glass that would sink to the bottom of a beaker of water? What else could it be?

d. Can you think of a test to distinguish between this material and glass?

ES 106 Laboratory # 2
HEAT AND TEMPERATURE

Introduction

Heat transfer is the movement of heat energy from one place to another. Heat energy can be transferred by three different mechanisms: *convection*, *conduction,* and *radiation*.

Matter can change from one phase to another with the addition or removal of heat. These changes are called *phase changes*. Phases can change through *melting, freezing, evaporation,* or *condensation* of matter.

Goals and Objectives

- Be able to *define* heat, temperature, internal energy, heat transfer, phase change, absolute zero, radiation, conduction, convection, and thermal expansion
- *List* the mechanisms of heat transfer and types of phase changes
- *Identify* good conductors of thermal energy.

Useful Websites

- http://lamar.colostate.edu/~hillger/temps.htm
- http://www.metric-conversions.org/
- http://www.school-for-champions.com/science/heat_transfer.htm
- http://hyperphysics.phy-astr.gsu.edu/hbase/heacon.html

Name___________________________

Lab Day_____ Time________________

Pre-lab Questions – Complete these questions before coming to lab.

1. Define the following terms:
   A. Temperature:

   B. Heat:

   C. Internal Energy (also sometimes referred to as Thermal Energy):

   D. Conduction:

   E. Convection:

   F. Radiation:

2. Convert the following temperatures: (Note: $C^o + 273 = K$)
   A. 0^oC to K

   B. 180 K to ^oC

   C. 50^oF to K

3. Give three examples of phase changes that you encounter in your daily life. These phase change examples could be occurring in materials other than water.

4. **Complete Part A, on the following pages, before coming to lab.**

Part A – Temperature, internal energy, and molecular motion

To get started, you will draw three pictures to gain a better understanding of temperature. Start in column 1 of Table 1. In box 1, draw a thermometer. The thermometer's mercury *hasn't* risen at all. In box 2, draw 3 dots. In box 3, write a small capitol "E = 0".

Begin column 2 of the table. In box 4, draw another thermometer. This thermometer's mercury has risen some. In box 5, draw the same three dots. Coming out from each dot, draw a small arrow. Have each arrow point a different direction. In box 6, write a capitol "E" that is mid-sized and bigger than the one before.

Begin your final column of pictures. In box 7, draw a thermometer with the mercury at a very high level. In box 8, draw the three dots with arrows pointing in the same directions as before. Make the arrows much longer than in the previous drawing. In box 9, write a capitol "E" that is much bigger than the other two "E"s.

Table 1:

Column 1	Column 2	Column 3
Box 1	Box 4	Box 7
Box 2	Box 5	Box 8
Box 3	Box 6	Box 9

You have just drawn a depiction of temperature. Thermometers measure the changes in the thermal energy of atoms and molecules that occur as temperature changes. Suppose the first thermometer measures a temperature of about 0 Kelvin (i.e., absolute zero), the second measures 70 Kelvin (about —200ºC), and the third measures about 700 Kelvin (about 425ºC).

The dots represent molecules. In the first column, the molecules were not moving, so there were no arrows. In the second column, the molecules were moving slowly, so there were small arrows. In the third column, the molecules were moving fast and the arrows were big. The "E" represents energy. The first had a small "E", meaning that its thermal energy level was low. The second had more thermal energy, so it had a bigger "E". The final had a big "E" because it had the most thermal energy.

Questions:

1. What is the relationship between temperature, heat, and internal energy? Be sure to compare and contrast these three terms/concepts.

2. *Absolute zero*, which occurs at 0 kelvins, is the lowest temperature that a material can reach. Assume that you have a substance at absolute zero. For this substance, describe what do you know about:
    a. the motion of its molecules

    b. its internal energy level

3. On the Kelvin temperature scale, room temperature is about 300 K. For the substance at room temperature. Refer to your diagram on pg. 2.3.:
    a. What can you say about the motion of its molecules?

    b. What can you say about its internal energy level?

Part B – Heat Transfer

Station 1: Heat Transfer by Radiation
This station consists of two sets of papers, each including a shiny piece, a dull black piece, and white piece. A light shines on one group, while a heating pad warms the second group.

First we will consider the group upon which the light shines. Place your hand on the black piece of paper. Note what you feel. Next, place your hand on the shiny piece. Ask yourself, "Do you feel anything different from the black piece?" Do the same for the white piece of paper, and compare what you feel to the previous two.

Now we will consider the group warmed by the heating pad. Touch each piece of paper. Ask yourself: "Does each give off a different amount of warmth, or are they all constant"?

You just investigated radiation. Radiation occurs when energy is transferred in the form of infrared waves. These waves can either be absorbed or emitted. If a material absorbs these waves, the temperature of the material rises.

Questions

1. Consider the pieces under the light. List these pieces, from the warmest (first) to the coolest.

2. Given this result, which is the best absorber? Which is the worst absorber?

3. Would you rather wear black or white on a hot summer day? Explain your answer.

4. Imagine that you are a lemur and you warm yourself from your surroundings. On cool mornings, would you rather have dark or light fur? Explain your reasoning.

Station 2: Heat Transfer by Conduction

This station has 3 spoons placed in a bowl of hot water. There is a plastic, metal, and wooden spoon. Touch each spoon one by one.

Materials that are hot have fast moving molecules, while things that are cool have slow moving molecules. The water in the bowl, therefore, has fast moving molecules. These molecules are moving around and bump into the slow moving molecules of the spoon. Because they are running into other molecules, the fast molecules lose some of their speed and slow down. The smaller molecules of the spoon pick up this speed. This mechanism of heat transfer is called *conduction.*

All materials conduct heat with different abilities. A material that conducts heat well is a "good thermal conductor". In our spoons-in-hot-water example, given each spoon is in the hot water for the same amount of time, the temperature of a good thermal conductor will be higher than that of a poor one.

Questions

1. Can you tell a difference in their temperatures? ___________________

2. Which feels the hottest? _______________________________________

3. Which feels the coolest? _______________________________________

4. List the spoons in the order from best conductor to worst.

5. Now you've seen that some materials conduct heat better than others. If you were frying yourself an omelet for breakfast, would you rather use a skillet with a metal or a plastic handle? Why?

6. You are building a new house and are given the choice of building the walls out of plywood or sheet metal. Which material should you use if your goal is to lose heat from the house as slowly as possible? Explain your reasoning. (Hint: think about the spoons.)

Station 3: Heat Transfer by Convection

Convection occurs when heat is carried from one place to another through the bulk movement of fluid. When part of a fluid warms, the volume of it expands, and it becomes less dense. The cooler and denser fluid surrounding it pushes the warm fluid upward. As the warm fluid rises, the cooler fluid takes it place. This cooler fluid is then warmed and pushed upward, creating a current. In order for convection to occur, matter must be present and free to move so that it can carry heat.

Activity:
Observe the movement of the fluid in the convection demonstration. In the space below, draw a sketch of the demonstration setup. Label the temperatures of the two heat reservoirs. Use arrows to show movement of fluid and label hot currents with H and cold currents with C.

Questions

1. Write a paragraph detailing your observations and how they help you to visualize a convection process.

2. Let's imagine you are preparing to make macaroni and cheese at home, so you are boiling water in a pan on the stove. Your roommate comes in and tells you that you must stir the water if you want it to get warm. Otherwise the water near the burner will stay hot and the water near the top will stay cold. Explain to your roommate why you do not need to stir the water.

3. Baseboard heaters work by distributing heat throughout the room using convection currents. Explain why the heaters are installed near the floor rather than near the ceiling. Draw a diagram of this situation showing the flow of air in the room.

Part C – Determination of Density by Water Displacement

Density is defined as mass per unit volume (density = mass/volume). The units of density are commonly expressed as grams/cubic centimeter (g/cm^3). As noted in the lab introduction, the density of pure water is 1 g/cm^3; also note that 1 cm^3 = 1 milliliter (1 mL).

Activity:
You will be determining the density of two cylinders composed of unknown metals. Mass will be measured using the balances provided, and volume will be measured by water displacement. Once the densities of the metals are calculated, you will compare your calculated value to a list of standard values to determine the metal that composes your cylinders.

Procedure

1. Select two metal cylinders. Make sure they are different metals (i.e., with different masses).
   Weigh the two metal cylinders and record their masses in Table 1, below.

2. Determine the volume of the cylinders by following these steps:
   a. Place approximately 15 mL of water in a small graduated cylinder. Record this as your initial volume in the table below.
   b. Carefully place the metal cylinder into the graduated cylinder so that it is totally immersed. Record this as you final volume in Table 1. Now determine the volume of the each cylinder by subtraction.

Table 1: Metal Cylinder Data

	Metal Cylinder #1	**Metal Cylinder #2**
Mass		
Final Volume		
Initial Volume		
Volume of cylinder		

3. Calculate the density of each of the two metal cylinders. Be sure to show your work, including units, in the space below.

Density #1 = _____________ **Density #2=** ____________

4. Based on you your calculated densities, determine which metal composes the cylinders. Refer to Table 2: Standard Densities of Some Metals.

Metal Cylinder #1 _______________________________________

Metal Cylinder #2 _______________________________________

Table 2: Standard Densities of Some Metals (g/cm³).

Metal	**Density** (g/cm³)
Aluminum	2.70
Brass	8.56
Copper	8.80
Lead	11.00
Steel	7.83

5. Percent error is determined to see how close a measurement is to a standard value. Use the equation below to calculate error:

$$\left|\frac{\text{Expected value - Observed value}}{\text{Expected value}}\right| \times 100 = \text{Percent Error}$$

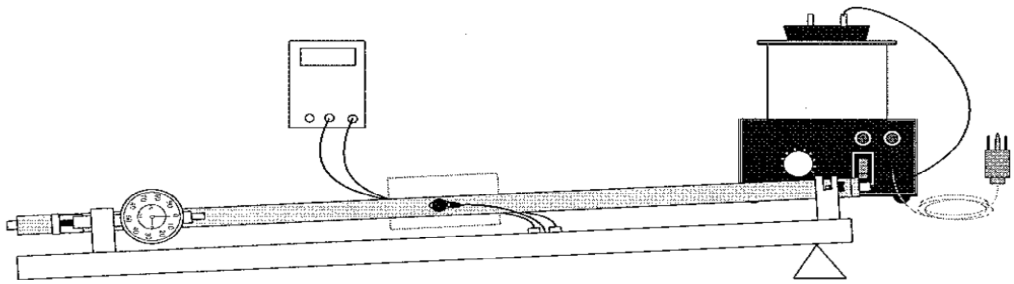
Show your work below for the percent error in your measurements.

<u>**Metal Cylinder #1**</u>

<u>**Metal Cylinder #2**</u>

List and briefly discuss two factors that contributed to the error you just calculated. (Do not cite "human error"! Specify the source of that human-caused error.)

Part D – Thermal Expansion



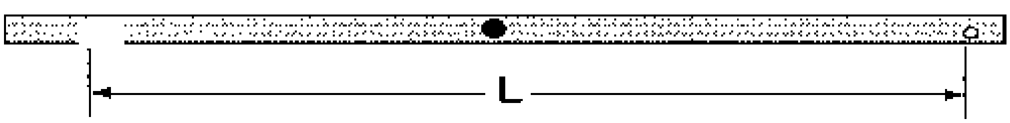
This apparatus consists of copper, steel and aluminum rods connected to a steam generator. One end of the rod is fixed in place. The dial gauge can be used to measure expansion as steam passes through the rod. Before you begin, make sure the rod is at room temperature.

Activity:

1. Turn on the steam generator.

   CAUTION: The steel tank gets **HOT** when the unit is on.

2. Measure the length of the rod at room temperature. Measure from the inner edge of the stainless steel pin on one end, to the inner edge of the angle bracket at the other end. Record your results in Table 3.



3. Turn the outer casing of the dial gauge to align the zero point on the scale with the long indicator needle. As the rod expands, the indicator needle will move in a counter clockwise direction.

4. When steam starts to flow from the steam generator attach the generator tube to the end of the metal rod.

5. As steam begins to flow through the rod, watch the dial gauge. Record the expansion of the rod length as indicated by the displacement of the needle on the dial gauge in Table 3. (Each increment on the dial gauge is equivalent to 0.01 mm of tube expansion.

6. Record the change in length for the steel, copper and aluminum rods.

Table 3	Length at Room Temp. (mm)	Change in Length due to heating (mm)	Length when rod is hot (mm)
Copper			
Steel			
Aluminum			

Hopefully you noticed that the three metals expanded in different amounts. Different materials expand and contract different amounts as temperature changes. This depends on the "thermal coefficient of expansion." Those materials with small coefficients expand or contract the least, while those with large coefficients change volume the most.

7. The rods in this experiment are made from aluminum, steel and copper.

   Based on your observations, which of these has the smallest thermal coefficient of expansion?

   Which has the largest?

8. Does there seem to be a relationship of the density of the material and its thermal coefficient of expansion? If so, what is this relationship?

9. If you were building a small model railroad, would you use aluminum or steel to avoid buckling? (Explain your reasoning).

10. On the way to your friend's apartment, you pass some railroad track. Last summer, the tracks buckled so badly that the trains couldn't use them. Write a short paragraph describing why this happened, and how the builders could have built the rails to keep this from happening.

Part E – Phase Changes

There are (for the purpose of this lab) 3 phases of matter: gas, liquid, and solid. Matter can change from one phase to another depending on the amount of heat added or lost. This change from one form of matter to another is called a *phase change*. A solid can *melt* into a liquid if heat is added. A liquid can *freeze* into a solid if heat is taken away. A liquid can *evaporate* into a gas if heat is supplied, while a gas can *condense* into a liquid if heat is removed. If matter melts, freezes, evaporates, or condenses, it is undergoing a phase change.

This is a group activity using the computer, so your instructor will explain it. A diagram of the set up appears in Figure 1.

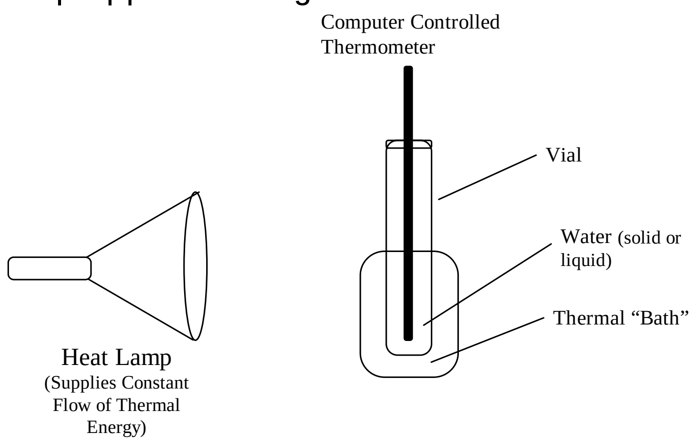


Figure 1: Experimental set up

When heat is added to ice, the temperature increases (see Figure 2). Once the temperature reaches the melting point of 0 degrees Celsius, the ice begins to change phase into a liquid. Even though you are adding heat, the water stays at 0^oC until all of the ice is melted. Once all the ice melts, the added heat allows the water's temperature to increase above 0^oC. When the temperature reaches the boiling point of water, 100^oC, then the water changes from a liquid to a gas. Again, even though you add heat, the temperature remains at 100^oC until all the liquid has turned into a gas. Once it has all evaporated, the temperature begins to rise above 100^oC.

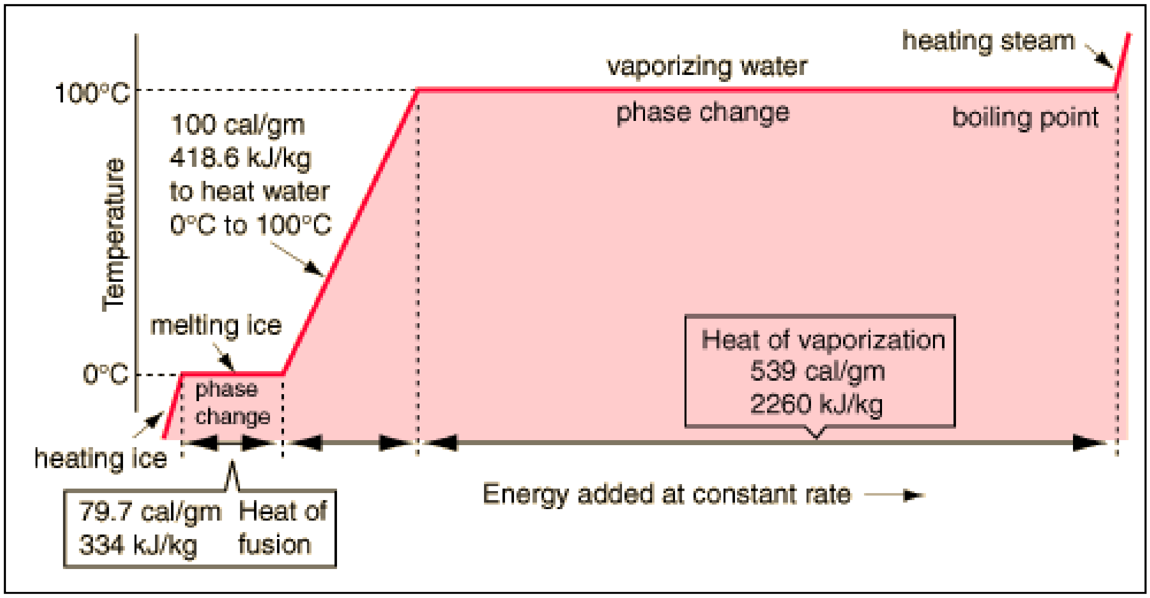


Figure 2: Theoretical graph of the change in temperature of water as heat is added.

1. Label the line segments in Figure 2 where ice is present, where water and ice are present (i.e. melting is taking place), where just water is present, where water and water vapor are present (i.e. boiling is taking place), and where just water vapor is present.

2. Print out a copy of the temperature vs. time graph from the experiment. Identify and label the regions on the graph when the water is solid, is changing from solid to liquid, and is all liquid.

3. Notice that the slope of the curve in Figure 2 changes abruptly when a phase change is reached. The slope of the curve on your experimental graph printout, however, shows a gradual change in slope when the melting phase change is reached. Why do the two graphs have such different shapes?

4. In your experiment, there was always transfer of thermal energy into the water. Why are there regions in which the temperature is not changing? Explain in detail what is happening.

Name________________________

Lab Day/Time_________________

POST-LAB ASSESSMENT

1. What heat transfer mechanism(s) is/are used when infrared energy is transferred from a red giant star to Earth? Consider all the possibilities, and explain each. (What heat transfer mechanism(s) can transfer energy through the vacuum of space?)

2. What heat transfer mechanism(s) is/are used when heat energy from the core of Earth is transferred to the crust? Consider all the possibilities, and explain each.

3. Fire safety guidelines say that if you must escape from a burning building, touch metal doors before you open them. Through what mechanism would heat be transferred from the hot side to the cool side of the door?

4. Describe what happens to the temperature and the thermal energy of water when it boils.

5. The rate of thermal energy transfer of water in an ice cube tray depends on the differences in temperature between the water and the air in the freezer. The closer the objects are in temperature, the slower the thermal energy is transferred. Knowing this, dispel the myth that hot water freezes faster than cold water. (Consider the thermal energy in hot versus cold water placed in the ice cube tray).

6. Imagine that you have a piece of granite with of density 2.65 g/cm^3. If the mass of the piece of granite is 120 g, what is the rock sample's volume? (show your calculations)

ES 106 Laboratory # 3
INTRODUCTION TO OCEANOGRAPHY

Introduction

The global ocean covers nearly 75% of Earth's surface and plays a vital role in the physical environment of Earth. For these reasons, oceanography is an important part of the Earth sciences. Oceanographers apply the concepts from the sciences of chemistry, physics, geology, and biology to understand this critical component of Earth system.

This lab investigates some of the physical characteristics of the oceans. To establish a point of reference, the extent, depths and distribution of the world oceans are examined. The two of the most important variables of seawater, salinity and temperature, are studied to determine how they influence the density of water, and in turn deep ocean circulation.

Goals and Objectives

- Locate and name the major water bodies on Earth
- Study the distribution of land and water in each hemisphere
- Explore the influence that salinity and temperature of seawater have on the density of seawater
- Describe how the salinity and temperature of seawater vary with latitude and depth in the oceans

Useful Websites

- http://www.earthcare.ca/balloon/curriculum_facts.html
- http://www.grida.no/climate/vital/32.htm
- http://visibleearth.nasa.gov/view_set.php?categoryID=817
- http://atlas.mapquest.com/atlas/

Name________________________

Lab Day/Time_________________

Pre-lab Questions – Complete these questions before coming to lab.

1. Define the following terms:
   A. Salinity

   B. Thermohaline circulation

   C. Latitude

   D. Longitude

2. In what units is ocean water salinity expressed? How is salinity calculated?

3. Suppose that you take a sample of 500 g of ocean water and let the water evaporate. The mass of the remaining salts is 17 g. What was the salinity of the ocean water?

4. If the salinity of ocean water is 37 parts per thousand, what is the mass of salts dissolved in 2 kg of ocean water?

Part A – Extent, Distribution, and Area of the Oceans

Activity 1: Geography of the world oceans
For this activity, study the available resources, including maps and globes around the lab room, and maps in your textbook, to become familiar with the oceans and major water bodies of Earth. **Locate and label each** of the following oceans and major water bodies **with the name** on the world map provided on the next page.

Oceans:	**Major Water Bodies:**		North Sea
Pacific	Arabian Sea	Caribbean Sea	Persian Gulf
Atlantic	Baltic Sea	Caspian Sea	Red Sea
Indian	Bay of Bengal	Coral Sea	Sea of Japan
Arctic	Bering Sea	Gulf of Mexico	Sea of Okhotsk
	Black Sea	Mediterranean Sea	Weddell Sea

Activity 2: Area of the Oceans and Distribution of Land and Water
The surface area of Earth is about 510 million square kilometers (197 million square miles). Of this, oceans and seas cover approximately 360 million square kilometers (140 million square miles). Use this information to answer the following questions. (Show calculations with units.)

1. What percentage of Earth's surface do oceans and seas cover? ______%

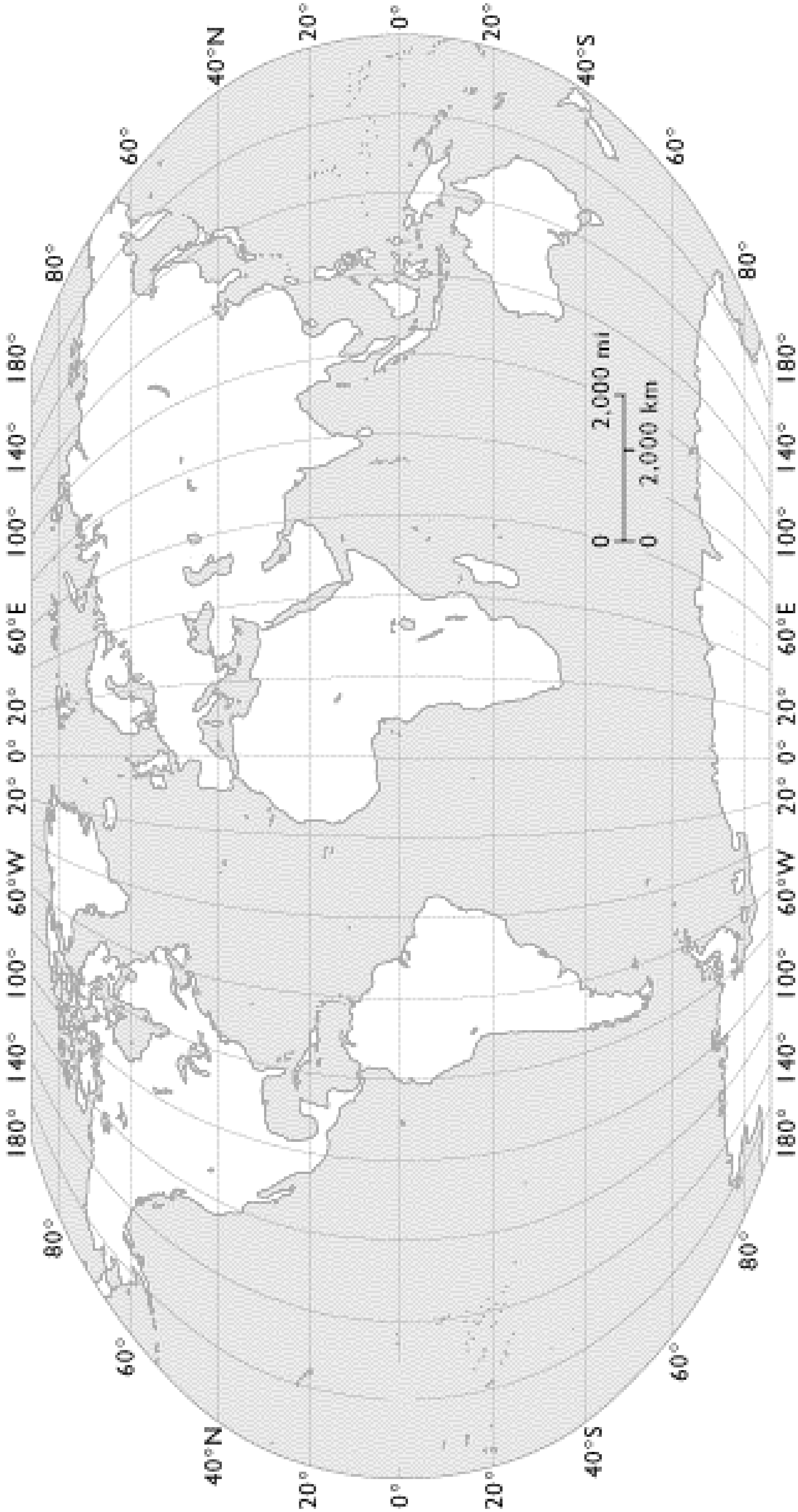
2. What percentage of Earth's surface is land? _______________________%

Study the world ocean maps provided and Figure 1 to answer the following questions (refer to Figures 13.1 and 13.2, p. 410-411, in *Earth Science 14th ed*. textbook by Tarbuck, et al.).

3. Which hemisphere, Northern or Southern, could be called the "water" hemisphere and which the "land" hemisphere?

   Water hemisphere ____

   Land hemisphere ____



180°
140°
100°
60°W
20°
0°
20°
60°E
100°
140°
180°
40°N
20°
0°
20°
40°S
60°
80°
0
2,000 mi
0
2,000 km

Using Figure 1, determine the percentage of Earth's surface that is ocean at the latitudes listed below. (Show calculations in box.) % is part/whole. The whole refers to the total amount of Earth at THAT latitude. It changes with distance from the equator.

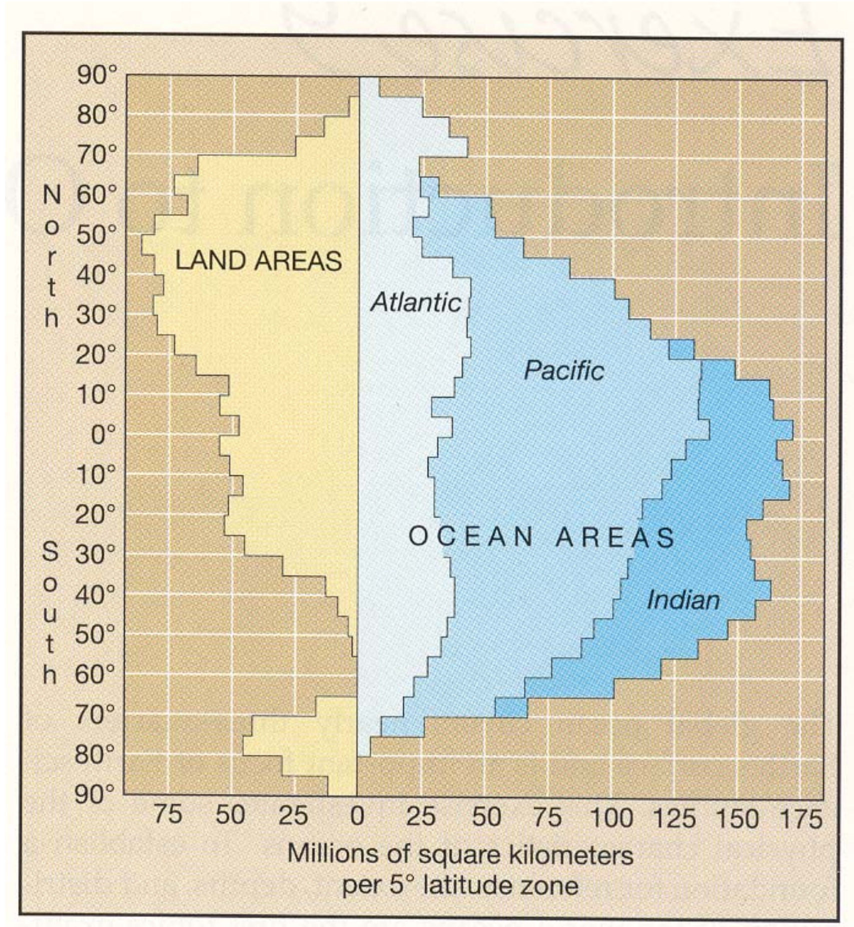
<table>
<tr><td>60-65º N: ___% ocean</td><td rowspan="4">

Figure 1: Distribution of land water in each 5º latitude belt. (Figure 13.2A in *Earth Science 14th ed.*, Tarbuck, et al., p. 411)</td></tr>
<tr><td>40-45º N: ___% ocean</td></tr>
<tr><td>40-45º S: ___% ocean</td></tr>
<tr><td>60-65º S: ___% ocean</td></tr>
</table>

4. In the Northern Hemisphere, how does the width of the oceans change as you go from the equator to the pole?

5. In the Southern Hemisphere, how does the width of the oceans change from the equator to the pole?

6. Which ocean covers the greatest area?

Part B – Characteristics of Ocean Water

The average density of surface ocean water is 1.025 g/mL, but this varies from place to place, and with seasons. Variations in *salinity* and *temperature* are the two most important factors in creating the density differences that create deep-ocean circulation, which will be studied in greater detail below.

Salinity is the amount of dissolved material in water. It is typically expressed as parts per thousand (‰), called 'per mil'. Per mil means 'per 1000 parts', in contrast to 'percent', which is 'per 100 parts' (%). This concentration is a weight ratio: typical sea water has a salinity of about 35 ‰ , meaning one kilogram (1000 grams) of sea water contains about 35 grams of dissolved salts. Although there are many dissolved salts in seawater, sodium chloride ($NaCl$) is the most abundant.

Variations in the salinity of seawater are influenced primarily by changes in the water content of the seawater. In regions where evaporation rates are high, removing the water and leaving behind the salts increases the concentration of dissolved material in seawater. Alternatively, in areas of high precipitation and high runoff from rivers and streams, the additional water dilutes the seawater and lowers the salinity. Because the factors that influence the concentration of salts in seawater vary, the salinity of seawater also varies with latitude and depth.

Seawater *temperature* is the most extensively determined variable of the oceans because it is easily measured and has an important influence on marine life. Like salinity, ocean water temperatures vary from equator to pole and vary with depth. Temperature, like salinity, also affects the density of seawater, but density of seawater is more sensitive to temperature fluctuations than salinity. Cool surface water, which has a greater density than warm water, forms in the Polar Regions, sinks and flows towards the tropics.

To study the effects of temperature and salinity on the density of water, locate the following lab equipment: graduated cylinder, small beaker, dye/food coloring and small test tubes. Follow the directions outlined below for each of the two activities.

Activity 1: Temperature-Density Experiment

Procedure:

1. Fill the graduated cylinder with cold tap water to the 100 mL mark.
2. Put 2-3 drops of dye in a small test tube and fill it ½ full with hot water.
3. Pour the contents of the test tube slowly into the cylinder and record your observations here:

4. Empty the cylinder and refill it with hot water to the 100 mL mark.
5. Add a test tube full of cold water and 2-3 drops of dye to some ice in a beaker. Stir the solution for a few seconds. Fill the test tube ¾ full with some liquid (leaving ice behind) from your beaker. Pour this cold liquid slowly into the cylinder and record your observations here:

6. Thoroughly clean and rinse all glassware before starting Activity 2.

Questions:

1. Given equal salinities, which temperature of water has the greater density? _____________
2. Write a brief summary of your temperature-density experiment.

Activity 2: Salinity-Density Experiment

Procedure:

1. Place a rubber band at the 75 mL line of the graduated cylinder and fill the cylinder with cool tap water to the 100 mL line.
2. Place several drops of food coloring into a small test tube and fill the test tube about ½ full of Solution A. Slowly pour the solution in to cylinder and observe what happens. Briefly describe your observations here:

3. Repeat these steps two more times but now measure the time required for the front edge of the saltwater to travel from the rubber band at 75 mL line to the bottom of the cylinder. Record the times for each test in Table 1, below. Be sure to drain the cylinder after each trial and refill it with fresh water and use the same amount of solution with each trial.
4. Determine the travel time two times for Solution B exactly as you did with Solution A and enter your measurements in the data table.
5. Thoroughly clean all of the glassware and return it to the bin.

Table 1: Experimental Data for Density of Saline Solutions

Solution	**Timed Trial #1**	**Timed Trial #2**	**Average of trials**
A			
B			

Questions:

1. Which solution has the greater density? ____________________________
2. Which solution has the greatest salinity? ____________________________
3. Write 2-3 sentences summarizing the results of the salinity-density experiment.

For Further Thought:
Table 2 lists the approximate surface water salinity values at various latitudes in the Atlantic and Pacific Oceans. Using the data, construct a salinity curve for each ocean on the graph (Figure 2) provided on the next page. Use a *different colored pencil for each ocean*. Answer the questions on page 3.11 using the graph and your textbook for reference.

Table 2: Surface water salinity in the Atlantic and Pacific Oceans.

Latitude	Atlantic Ocean	Pacific Ocean
60ºN	33.0 ‰	31.0 ‰
50ºN	33.7 ‰	32.5 ‰
40ºN	34.8 ‰	33.2 ‰
30ºN	36.7 ‰	34.2 ‰
20ºN	36.8 ‰	34.2 ‰
10ºN	36.0 ‰	34.4 ‰
0º	35.0 ‰	34.3 ‰
10ºS	35.9 ‰	35.2 ‰
20ºS	36.7 ‰	35.6 ‰
30ºS	36.2 ‰	35.7 ‰
40ºS	35.3 ‰	35.0 ‰
50ºS	34.3 ‰	34.4 ‰
60ºS	33.9 ‰	34.0 ‰

Using the data in Table 3, construct a graph showing both temperature and density of sea water. Use Figure 3, on the next page, and plot a colored line for temperature, and a separate differently-colored line for density on the same graph. Answer the questions on page 3.12 using the graph and your textbook for reference.

Table 3: Average surface water temperature and density of seawater at various latitudes.

Latitude	Surface Temperature	Surface Density
60ºN	5	1.0258
40ºN	13	1.0259
20ºN	24	1.0237
0º	27	1.0238
20ºS	24	1.0241
40ºS	15	1.0261
60ºS	2	1.0272

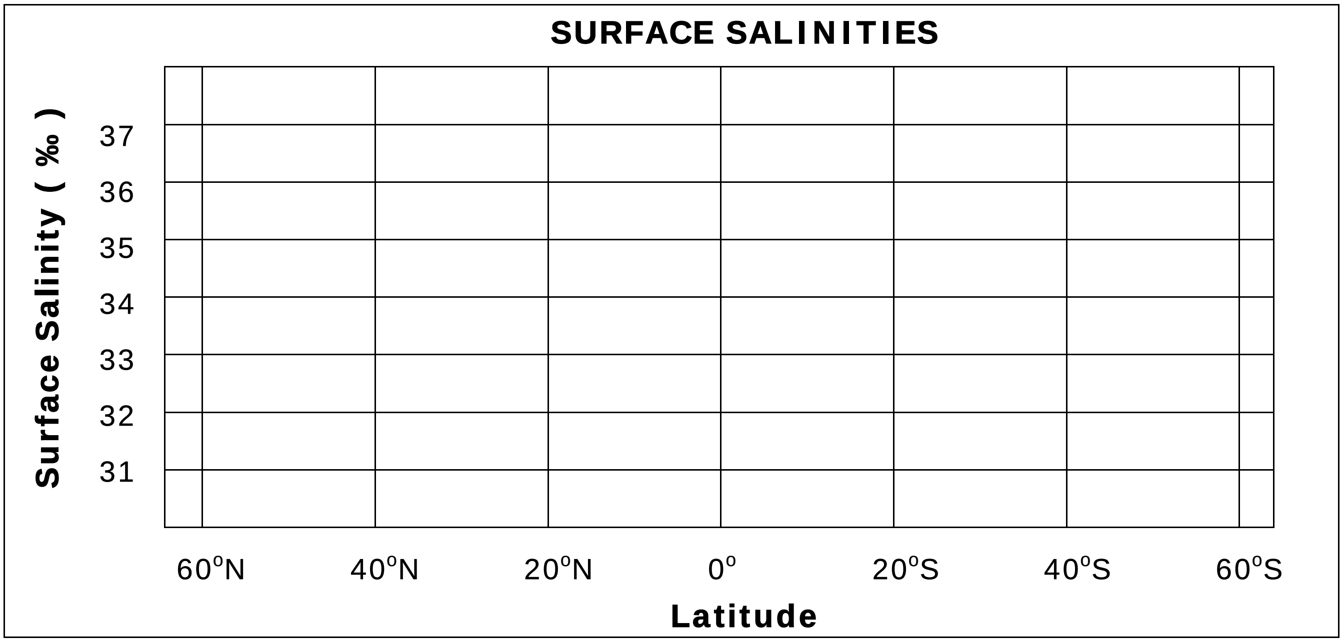


Figure 2: graph of surface salinity of world oceans by latitude

Use data in Table 2 to plot the salinity at various latitudes

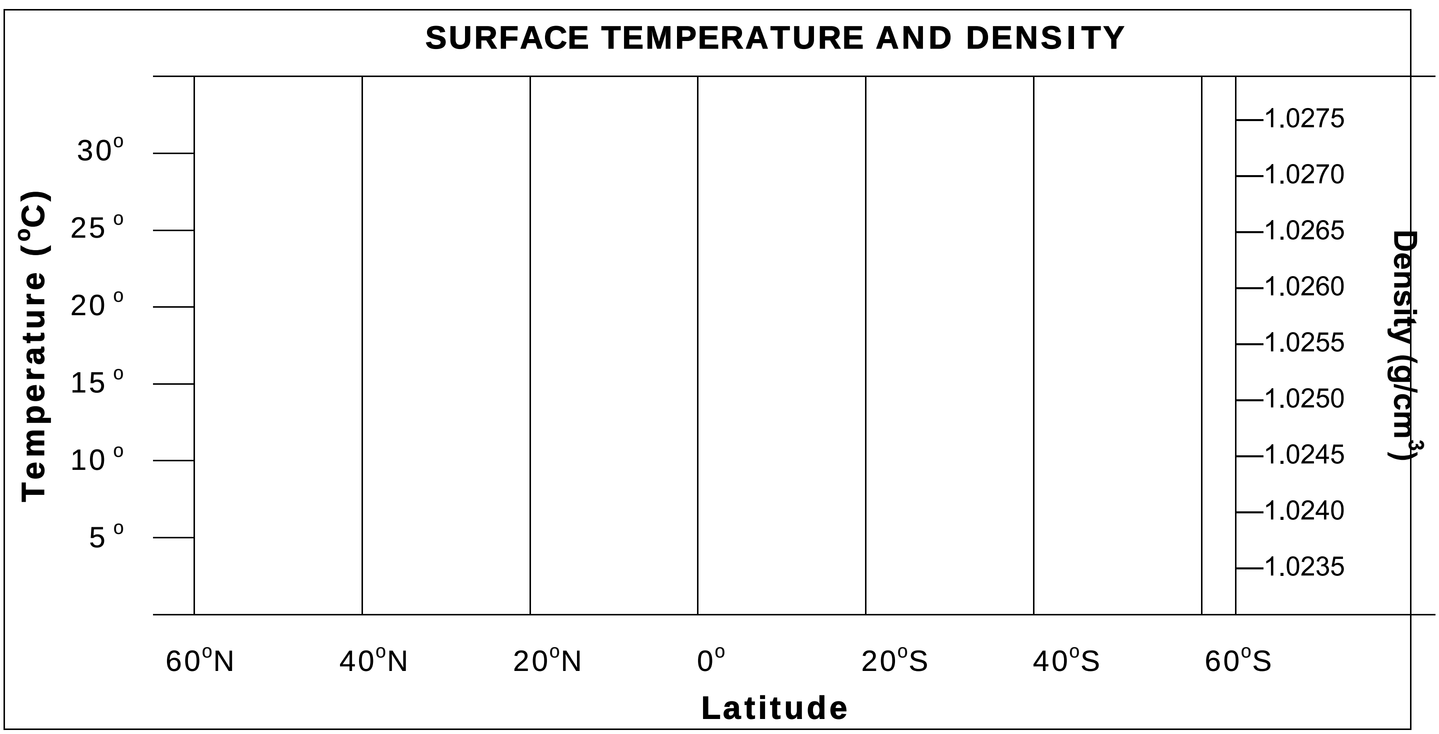


Figure 3: Graph of surface water temperature and density of world oceans by latitude

Use data in Table 3 to plot the temperature and density at various latitudes

Questions about the graph you plotted in Figure 2:

1. At which latitudes are the highest surface salinities located?

2. What are the two factors that control the concentration of salts in seawater?

3. What is the reason for the difference in surface water salinity between equatorial (0°) and subtropical regions (20-30°) in the Atlantic Ocean? (HINT: Refer to Fig. 14.2, p. 435, in *Earth Science 14th ed*. by Tarbuck, et al.).

4. Which ocean, the Atlantic or the Pacific, has higher average surface salinities?

5. Suggest a reason for the difference in average surface salinities between the oceans.

Questions about the graph you plotted in Figure 3:

6. Briefly describe the overall relationship between temperature and density.

7. Describe the surface temperature and surface density of ocean waters in equatorial regions.

8. Describe the surface temperature and surface density at high latitudes.

9. What is the reason for the fact that higher average surface densities are found in Southern Hemisphere?

10. Refer to the density curve in Figure 3. What evidence supports the fact that temperature more than salinity is the controlling factor of density of seawater? (Hint: see useful websites)

Part C – Salinity-driven Ocean Currents

Salinity differences within the oceans help drive global ocean circulation. To understand how salinity differences can set up currents that overturn much of the oceans' volume, your instructor will perform a demonstration. In the demonstration, two horizontal tubes connect two vertical columns of water, one containing fresh water and the other saline water. Dye is added to the water in both columns increase the visibility of the currents. Initially, the valves close the horizontal tubes.

Questions

1. Before your instructor opens the valves, try to predict what will happen once the valves are open.

2. How did the results compare with your predictions?

3. Write a short paragraph describing how the results in the demonstration relate to the global ocean conveyor belt (see Fig. 15.7, p 457-458, in *Earth Science 14th ed.,* by Tarbuck, et al.).

4. How did the rate of water circulation in this salinity demonstration today compare to the rate of circulation due to convection in last week's lab? Which demonstration seemed to produce more rapid circulation, temperature differences or salinity differences?

5. Is the relative influence of salinity and temperature differences on circulation in the oceans the same as it was in the demonstrations you looked at in lab? Why?

Name_________________________

Lab Day/Time_________________

POST-LAB ASSESSMENT

1. Which solution in the salinity-density experiment you conducted (Part B, Activity 2) had the greater density? ______
2. Give the approximate latitude and longitude of the following water bodies. (Choose a point more or less at the center of the sea).
   a. Mediterranean Sea: _____________________________________
   b. Sea of Japan: _____________________________________
   c. Indian Ocean: _____________________________________
3. Write a brief statement comparing the distribution of water and land in the Northern Hemisphere to the distribution in the Southern Hemisphere.
4. Circle the word in parentheses that is most appropriate response with respect to sea water.
   A. The higher the salinity of seawater, the (**lower , higher**) density.
   B. The lower the temperature of seawater, the (**lower , higher**) the density.
   C. Surface salinity is least in (**polar , subtropical , equatorial**) regions.
   D. (**Temperature , Salinity**) has a greater influence on the density of seawater.
   E. (**Warm , Cold**) seawater with (**high , low**) salinity would have the greatest density.
   F. Vertical movements of ocean water are most likely to begin in (**equatorial , subtropical , polar**) regions, because the surface water there is (**most , least**) dense.
5. Why is the surface salinity of an ocean higher in the subtropics than in the equatorial regions?

ES 106 Laboratory # 4
THE DYNAMIC OCEAN FLOOR
Sea Floor Topography and Paleomagnetism

Introduction

One of the most significant scientific revelations of the 20th Century is the fact that the ocean basins are geologically young, ephemeral features. Based upon this discovery, a revolutionary theory called plate tectonics has been developed that helps to explain and interrelate earthquakes, mountain building, and other geologic events and processes.

The theory of plate tectonics is the foundation used by Earth scientists to help explain the origin of mountains and continents, the occurrence of earthquakes, the evolution and distribution of plants and animals, as well as many other geologic processes. Using information from the ocean basins, including topography, age, and mechanisms of their evolution, Earth scientists have developed the exciting theory called plate tectonics. Plate tectonics states that Earth's surface is broken in to rigid slabs of lithosphere called plates. The plates are separating at mid-ocean ridges, where new ocean crust is forming. Along the plate margins, earthquakes are generated as plates slide past each other, collide to form mountains, or override each other causing deep-ocean trenches. This laboratory examines some of the lines of evidence that have been used to verify this comprehensive model of the way Earth scientists view our dynamic Earth.

Goals and Objectives

- Locate and describe the general features of the ocean basins with an emphasis on locating and describing the mid-ocean ridge system and deep-ocean trenches
- Determine the rate of sea-floor spreading that occurs along a mid-ocean ridge by using paleomagnetic evidence and determine age of ocean basin

Useful Websites

- http://www.pmel.noaa.gov/vents/nemo/explorer/concepts/pillows.html
- http://earthsci.org/education/teacher/basicgeol/platec/platec.html
- http://www.platetectonics.com/oceanfloors/index.asp
- http://visibleearth.nasa.gov/view_set.php?categoryID=871
- http://www.intute.ac.uk/sciences/worldguide/worldmapbig/385.html
- http://www.metric-conversions.org/

Name________________________
Lab Day/Time__________________

Pre-lab Questions – Complete these questions before coming to lab.

1. Describe each of the following ocean floor features:
   A. Mid-ocean ridge

   B. Deep-ocean trench

   C. Continental shelf

   D. Continental slope

   E. Abyssal plain

   F. Seamount

2. Suppose that the ratio scale on a map is 1:50,000. This means that 1" on the map represents 50,000" on Earth's surface. If you measure the following distances on the map using a ruler, you can convert the map distances to the real world distances with the ratio scale, and change units with conversion factors. Do this for the distances indicated below. Remember to show the formulas with units that you used to convert these values. Conversion factors can be found in the appendix of your textbook.

   A. 3 inches = _________ miles

   B. 2 cm = _________ km

   C. 10 cm = _________ miles

Part A – Ocean Basin Topography

Understanding the topography of the ocean basins has been critical to developing the theory of plate tectonics. In the mid-20th century oceanographic research vessels mapped the sea floor and by the 1960s research concerning rock magnetism, the cause and distribution of earthquakes, and the age of ocean sediments lead to the development of the theory of plate tectonics.

Various features are located along the continental margins and ocean basin floor. Study the *World Ocean Floor* maps of the *Pacific Ocean* and the *Atlantic Ocean*, and *The World: Physical* map to answer the following questions. (Refer to your textbook as needed.)

1. From the *Atlantic Ocean* map, what is the approximate average ocean depth along the continental shelves bordering North America?

2. Approximately how high above the adjacent ocean floor does the Mid-Atlantic Ridge rise? (Hint: You have to subtract to get this answer.)

3. Give an average depth for a sampling of trenches from the *Pacific Ocean* map, to approximate how deep most of the deep-ocean trenches are.

4. Write a brief statement comparing the width of the continental shelf along the east coast, west coast, and gulf coast of North America, as viewed on *The World: Physical* map, or comparing the *Atlantic Ocean* map and the *Pacific Ocean* map.

5. How would you describe the general topography of the abyssal plains? What do you suppose is the composition of the abyssal plains?

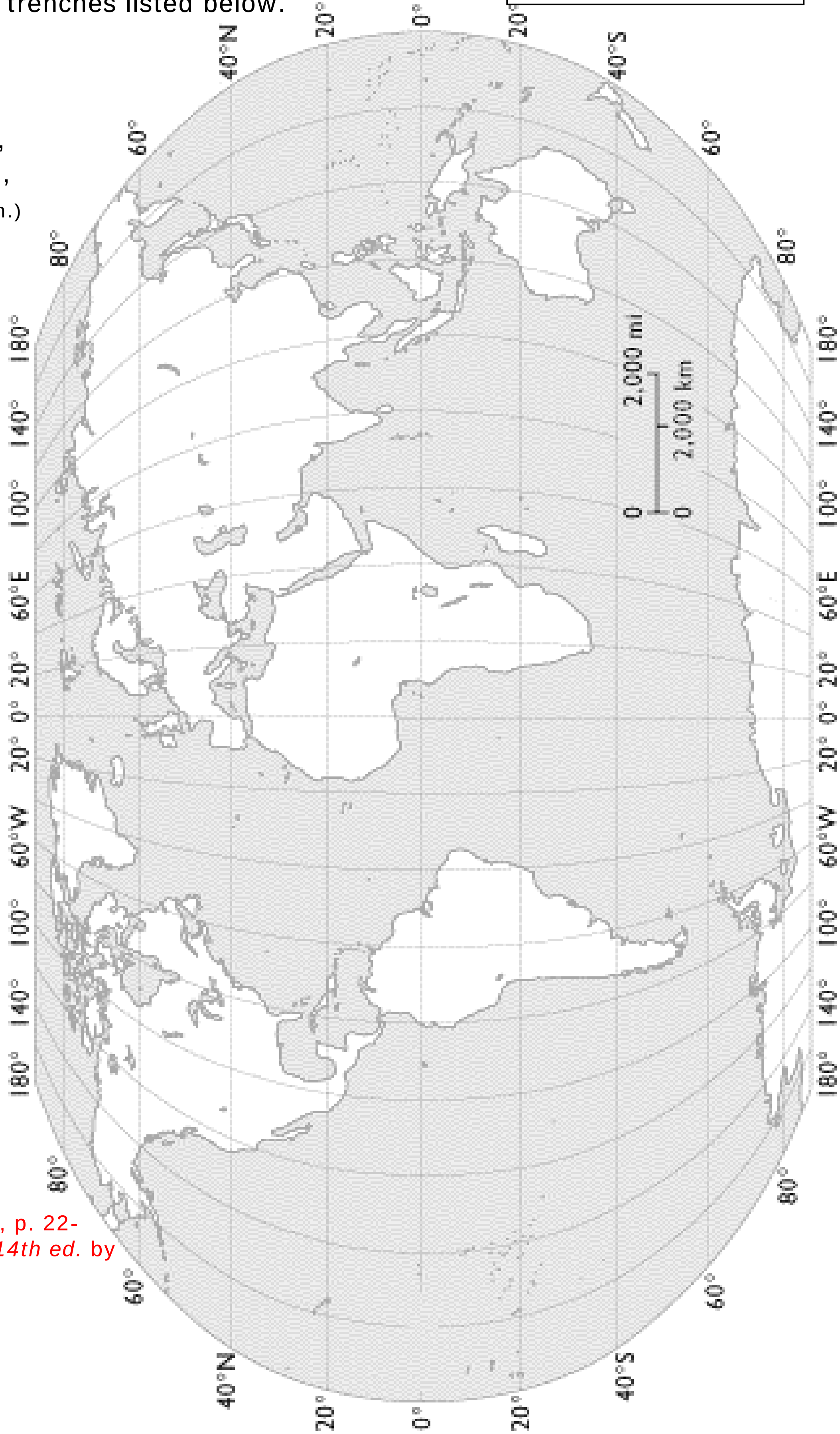
6. What do seamounts represent? What is the generally accepted explanation for the numerous seamounts that dot the Pacific Ocean deep-ocean basin floor?

On the world map below, **draw the global ocean ridge system in <u>red</u>**.

Label each trench with its <u>name</u>.

Locate on the map and **draw a <u>blue</u> line** to represent the trenches listed below.

Puerto Rico,
South Sandwich,
Middle American,
(same as Central Am.)
Peru-Chile,
Aleutian,
Kuril,
Japan,
Mariana,
Tonga,
Kermadec,
Java
Ryukyu



(Hint: see Fig. 1.20, p. 22-23, *Earth Science, 14th ed.* by Tarbuck, et al.)

Part B – Paleomagnetism and Sea Floor Spreading

The critical evidence for sea-floor spreading is based on studies of changes in Earth's magnetic field through time. Some minerals in igneous rocks (e.g. magnetite) become aligned with Earth's magnetic field at the time of their formation. From detailed paleomagnetic and geochronological studies, geologists have discovered that the polarity of Earth's magnetic field has periodically reversed, meaning that the north magnetic pole becomes the south magnetic pole and vice versa. The sequence of reversals occurring in the past several million years has been dated with the use of radiometric techniques, represented in Figure 1.

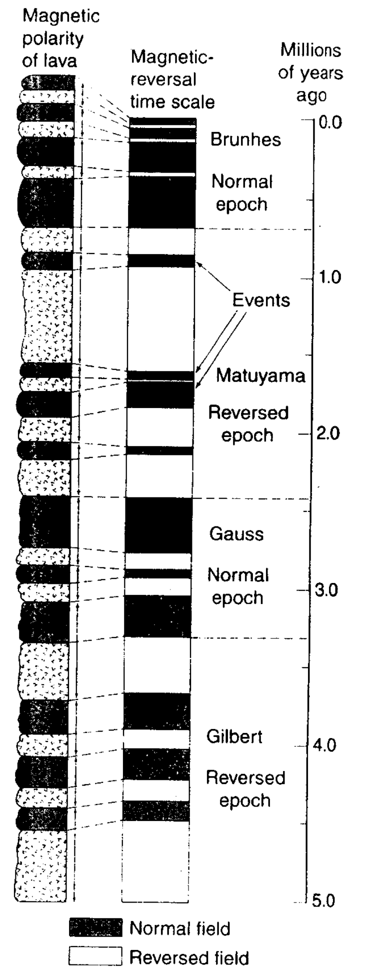


Figure 1: Schematic illustration of magnetic polarities of lava flows used to construct a time scale of magnetic reversals over the past 5 million years.

Study Figure 1 and answer the following questions.

1. How many times has the magnetic field of Earth reversed (changed orientation) in the past 5 million years? ____________________ times (total number of changes).
2. Approximately how long ago did the current normal epoch (Brunhes Normal epoch) begin? _______________________________ years ago.
3. Two million years ago, what direction would a compass needle have pointed – north or south? _______________________________________
4. Based on the pattern, does it appear as though Earth is due for another magnetic polarity reversal in the near future? Briefly explain your reasoning.

Activity: Calculate rate of spreading and age of ocean basins.

As tectonic plates separate along a mid-ocean ridge, magma from the mantle rises to the surface and creates new ocean floor. As the magma cools, the minerals assume a magnetic orientation equal to the prevailing magnetic field. The plates continue to separate and if Earth's magnetic field reverses polarity, new material forming at the ridge is magnetized in the opposite direction. This process results in magnetic striping of the ocean crust running parallel to the mid-ocean ridge.

Earth scientists can measure the magnetic striping by towing a device called a magnetometer behind a ship. The magnetometer records the strength of the magnetic field in a given location. Figure 2 shows magnetic records for the South Atlantic Ocean basin and the North Pacific Ocean basin. Where the rocks have the same magnetic polarity as the present-day field, we find stronger than average magnetic field (represented as a peak called a positive anomaly); where the rocks preserve reverse polarity, we measure weaker than average magnetic field (represented as a trough called a "negative anomaly").

Using the known time scale of magnetic reversals, we can determine the age of a magnetic anomaly. By dividing the distance from the ridge crest to the magnetic anomaly by the age of the magnetic anomaly, we can determine the spreading rate at the ridge.

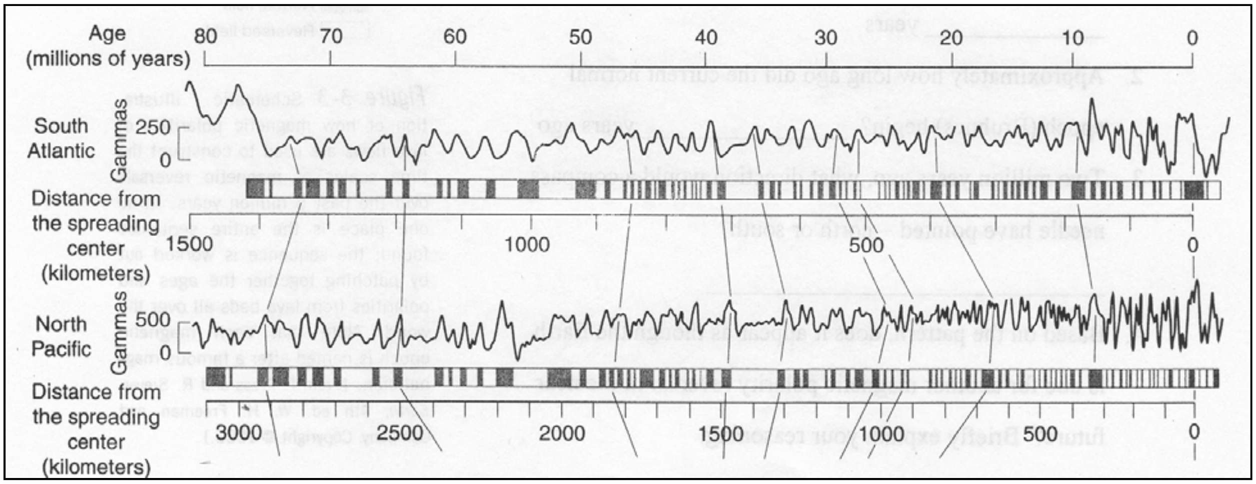
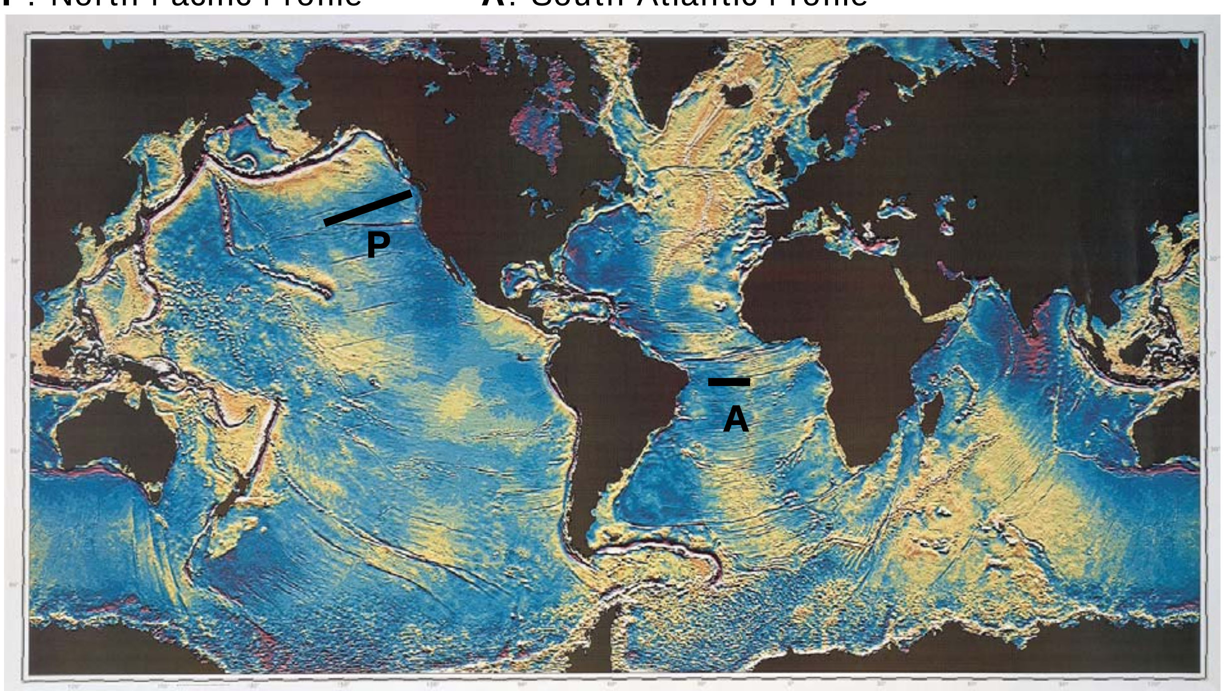


Figure 2: Magnetic anomalies (the peaked curves) recorded perpendicular to spreading centers (ocean ridges) in the major ocean basins reveal a similar sequence of magnetized rocks. **Note**: this figure shows only the ocean floor basins from the ridge toward the western side of the ocean basin to the "0" representing the location of the spreading center (oceanic ridge).

Figure 3: Image of ocean floor with the location of the magnetic anomaly profiles shown.

P: North Pacific Profile **A**: South Atlantic Profile



http://www.britannica.com/EBchecked/topic-art/175962/394/Gravity-map-of-the-worlds-ocean-basins-compiled-from-Seasat

Use Figure 2 to answer the following questions:
Start by drawing a line on Figure 2 at 50 million years, across the anomalies

1. Using the distance scale in Figure 2 which ocean basin has undergone the greatest amount of spreading in the last 50 million years, the Pacific or the Atlantic?

   ____

2. How far in kilometers are the 50 million year-old rocks on the left side of the South Atlantic Ocean basin from the oceanic ridge?

   ______________________________ km

3. How far in kilometers the 50 million year-old rocks on the left side of the North Pacific Ocean basin from the oceanic ridge?

   ______________________________ km

The distances in the questions above are for only one side of the ocean basin (in this case to the left of the ridge). Assuming that the ridge spreads equally on both sides, the actual distance each ocean basin has opened would be twice this amount. With this in mind, answering the following:

4. How far in **total** has each ocean basin opened in the past 50 million years? (Multiply by 2…then convert to cm by multiplying by 100,000.)
   a. South Atlantic Ocean basin - _________km= ___________________cm
   b. North Pacific Ocean basin - __________km= ___________________cm

By knowing both the distance that each ocean basin has opened and the time it took to open that distance, the rate of sea-floor spreading can be calculated. Divide the total distance opened (in centimeters) by the number of years. (Useful conversion factors: 1 km = 1000 meters, 1 m = 100 cm)

5. Determine the spreading rate in centimeters per year for the two areas shown in Figure 2. (Show formulas for calculations, with units.)
   a. **South Atlantic**

   b. **North Pacific**

What rate did you calculate for the **South Atlantic Ocean**? ________.
Use it to calculate an estimate of how many millions of years ago the North Atlantic and South Atlantic Ocean basins began to form by following the instructions below.

6. On *The World: Physical* map, find the ratio scale 1:_________________

South Atlantic Basin Information	**North Atlantic Basin Information**
7. Record the map distance (in centimeters) between the seaward edge of the continental shelf along eastern South America off of Brazil directly eastward to Africa.	8. Record the map distance (in centimeters) from the eastern edge of the continental shelf near North Carolina on North America to the seaward edge of the continental shelf along at Mauritania (20°N latitude) on northwestern Africa.

Multiply the centimeter distance by the map ratio scale. This gives the distance in centimeters across the Atlantic Ocean in the real world. (Show formulas for calculations, with units, below for each location.)

9. South Atlantic Basin width	10. North Atlantic Basin width

To determine the age of the ocean basin, **divide the distance** in cm (#9, 10) between the continental shelves **by the rate** of **Atlantic** sea-floor spreading in cm/yr (recorded above). (Show formulas/units, in the box.)

11. South Atlantic Basin age	12. North Atlantic Basin age

13. Jurassic rocks (basalt dikes and lava flows) occur in New Jersey. These are interpreted as rocks that formed when North America and Africa rifted apart. Why would you expect to find volcanic rocks associated with the onset of rifting? (See Fig. 9.33 B & F, pages 308-309, Tarbuck, et al., *Earth Science* 14^{th} ed).

14. Is your calculated age consistent with this geologic data? Refer to the geologic time scale on the last page of this lab manual. Explain your answer.

Part C – Pillow Lavas

Watch the brief video snippet of pillow lavas erupting near Hawaii on the computer, see the 'useful website':
http://www.pmel.noaa.gov/vents/nemo/explorer/concepts/pillow_lava.html

1. Study the sample of pillow lava in the classroom. In the space below, sketch and describe the sample, making particular note of the texture (grain size) of the margins compared to the center of the rock.

2. Interpret how the pillow lava formed.

3. Pillow lavas can be observed at several locations in the Coast Range of western Oregon, including on Mary's Peak west of Corvallis and in Depoe Bay. What does the presence of pillow lavas on peaks in the Coast Range tell us about the geologic history of the Coast Range? (Did the sea used to be that deep, or is there a piece of sea floor uplifted by convergent tectonic processes?)

Name________________________

Lab Day/Time_________________

POST-LAB ASSESSMENT

1. In the space here, sketch a general profile of an ocean floor between two continents illustrating a mid-ocean ridge and a deep-ocean trench. Label each and show relative plate motions with arrows.

(Hint: see Fig. 9.33, p. 308-309, Tarbuck and Lutgens, Earth Science, 14th Edition)

2. Imagine that you were to take a deep diving submersible to a mid-ocean ridge. What would be the chemical composition of the lava rocks that you would find (basalt, andesite, or rhyolite)? What shapes would the lava have?

3. A geologist claims to have found a sequence of rocks that was formerly a piece of ocean crust up in a mountain range. What types of rocks would you expect to find in the sequence? (What types of rocks would be on the bottom of the sequence? What types of rocks would sit on the top of the sequence?)

4. If an ocean is opening at a rate of 5 cm/yr, how wide will the ocean be in 125 million years? Give your answer in kilometers. (Show formulas for calculations, with units)

ES 106 Laboratory # 5
EARTH-SUN RELATIONS AND ATMOSPHERIC HEATING

Introduction

Weather is the state of the atmosphere at a particular place for a short period of time. The condition of the atmosphere at any place and time is described by measuring the four basic elements of weather: temperature, humidity, air pressure, and wind. Of all the controls that are responsible for causing global variations in the weather elements, the amount of solar radiation received at any location is certainly one of the most important. Investigating the journey of solar radiation and how it is influenced and modified by air, land, and water will provide a better understanding of one of the most basic weather elements, atmospheric temperature.

Temperature is an important element of weather and climate because it greatly influences air pressure, wind, and the amount of moisture in the air. The single greatest cause of temperature variations over the surface of Earth is differences in the amount of solar radiation received. Secondary factors, such as ocean currents, altitude and differential heating of land and water, can also affect local temperatures. The unequal heating that takes place over the surface of Earth is what sets the atmosphere in motion, and the movement of air is what brings changes in our weather.

For life on this planet, the relations between Earth and Sun are perhaps the most important of all of the astronomical phenomena. The amount of solar energy (radiation) striking Earth is not constant throughout the year at any particular place but varies with the seasons. However, the total amount of radiation that the planet intercepts from Sun equals the total radiation that it loses back into space. It is this balance between incoming and outgoing radiation that keeps Earth from becoming continuously hotter or colder.

Goals and Objectives

- Examine what happens to solar radiation as it enters and interacts with the Earth system.
- Explore the effect that sun angle has on the intensity and duration of solar radiation that any particular location receives throughout the year.
- Diagram the relationship between Earth and Sun on the dates of the solstices and equinoxes.
- Compare how the heating of a surface is related to its albedo and contrast the differences in the heating and cooling of land and water.

Useful Websites

- http://www.physicalgeography.net/fundamentals/6i.html
- http://hyperphysics.phy-astr.gsu.edu/hbase/phyopt/albedo.html
- http://zebu.uoregon.edu/disted/ph162/l4.html
- http://home.iprimus.com.au/nielsens/solrad.html
- http://solardat.uoregon.edu/SolarRadiationBasics.html

Name________________________

Lab Day/Time__________________

Pre-lab Questions – Complete these questions before coming to lab.

1. Define the following terms:
   A. Equinox

   B. Solstice

   C. Infrared radiation

   D. Albedo

2. The amount of solar energy per unit area hitting the outside of Earth's atmosphere is greater than the amount that actually reaches Earth's surface. Give at least three factors that contribute to the decrease in the amount of energy reaching Earth's surface and explain each.

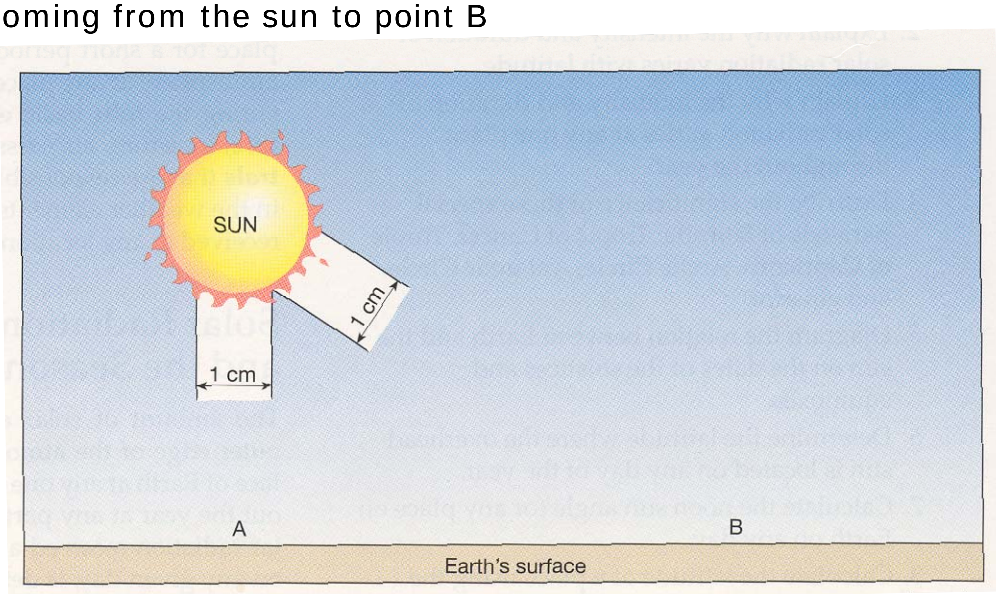
3. With a ruler, draw a line across the bottom of the page. Divide it into centimeters. Divide one of those centimeters into millimeters. Don't guess! Use the ruler to measure. Label them.

Part A – Solar Radiation and the Seasons

The amount of solar energy (radiation) striking the outer edge of the atmosphere is not uniform over the face of Earth at any one time, nor is it constant throughout the year at any particular place. The intensity and duration of sunlight determine the amount of solar radiation received at any particular place on Earth on any given day. *Intensity* is the amount of solar energy per unit area per unit time that hits a given surface and is determined by the angle at which the rays of sunlight strike the surface. *Duration* refers to the length of daylight. The typical unit of solar radiation is watts per square meter. The average intensity of solar radiation falling on a surface perpendicular to the solar beam in the upper reaches of the atmosphere is about 350 watts per square meter. As the radiation passes through the atmosphere, it undergoes absorption, reflection, and scattering. Therefore, at any one location, less radiation reaches Earth's surface than was originally intercepted at the upper atmosphere.

Activity 1: Sun Angle Solar Radiation and Latitude
The amount of radiation striking a square meter at the outer edge of the atmosphere, and eventually Earth's surface, varies with latitude because of different **sun angles** at different latitudes. **On Figure 1, extend the 1 cm wide beam of sunlight from the Sun vertically to point A on the surface. Extend the second 1 cm wide beam, beginning at the sun, to the surface at point B.** Notice that the sun is directly overhead (vertical) at point A and the beam of sunlight strikes the surface at a 90º angle above the horizon. Using a protractor, measure the angle between the surface and the beam of sunlight coming from the sun to point B

Figure 1
Vertical and oblique sun beams.



Refer to Figure 1 to fill in this table

	POINT A	**POINT B**
Angle of beam to surface	90°	
Width of beam in mm		

1. Of the two beams, which is more spread out at the surface and covers a larger area. ___________
2. Which surface would receive more watts per square meter? ___________

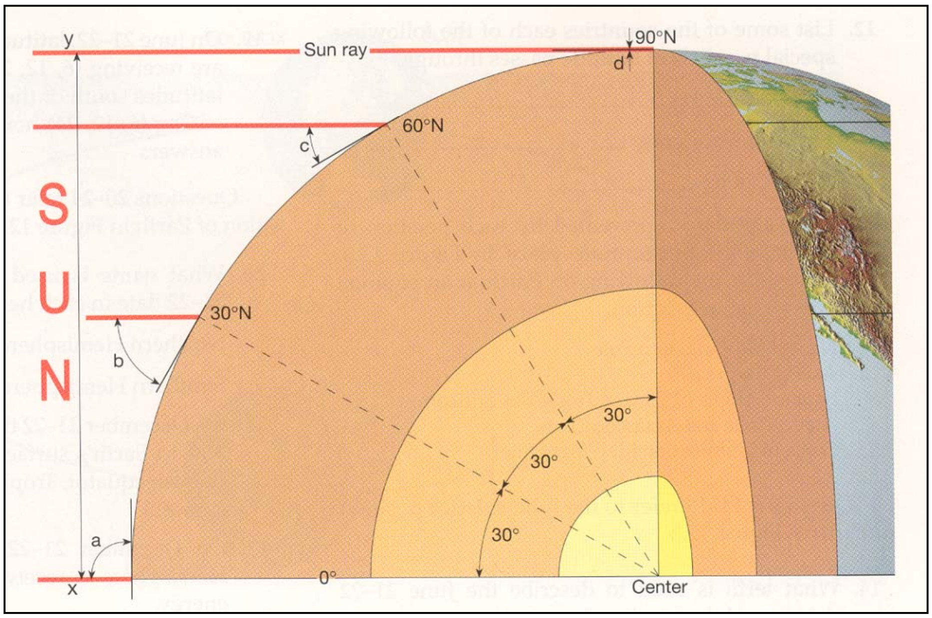


Figure 2
Distribution of solar radiation per 30° segment of latitude on Earth's surface.

Use Figure 2 to answer questions concerning the total amount of solar radiation intercepted by each 30° segment of latitude on Earth.

3. With a metric ruler, measure the total width of incoming rays from point *x* to point *y* in Figure 2.
   The total width is :→ _______ cm = ________ mm.
4. Assume the total width of the incoming rays (from point *x* to point *y*) equals 100% of the solar radiation that is intercepted by Earth.
   Each millimeter would equal:→ __________%.
5. What percentage of the total incoming radiation is concentrated in each of the following zones? (Hint: Multiply the total distance in mm by %/mm, from above.)

Latitude range	mm	%
0° - 30°		
30° -60°		
60° - 90°		

6. Use a protractor to measure the angle between the surface and sunray at each of the following locations in Figure 2. (Round off to the nearest 5 degrees.) Angle B is already done as an example.

Angle a:	
Angle b:	**60º**
Angle c:	
Angle d:	

7. What is the general relationship between the amount of radiation received in each 30º segment and the angle of the sun's rays?

8. Briefly explain in your own words what fact about Earth creates the unequal distribution of solar energy, even though each zone represents an equal 30º segment of latitude.

Figure 3
Earth-Sun relations

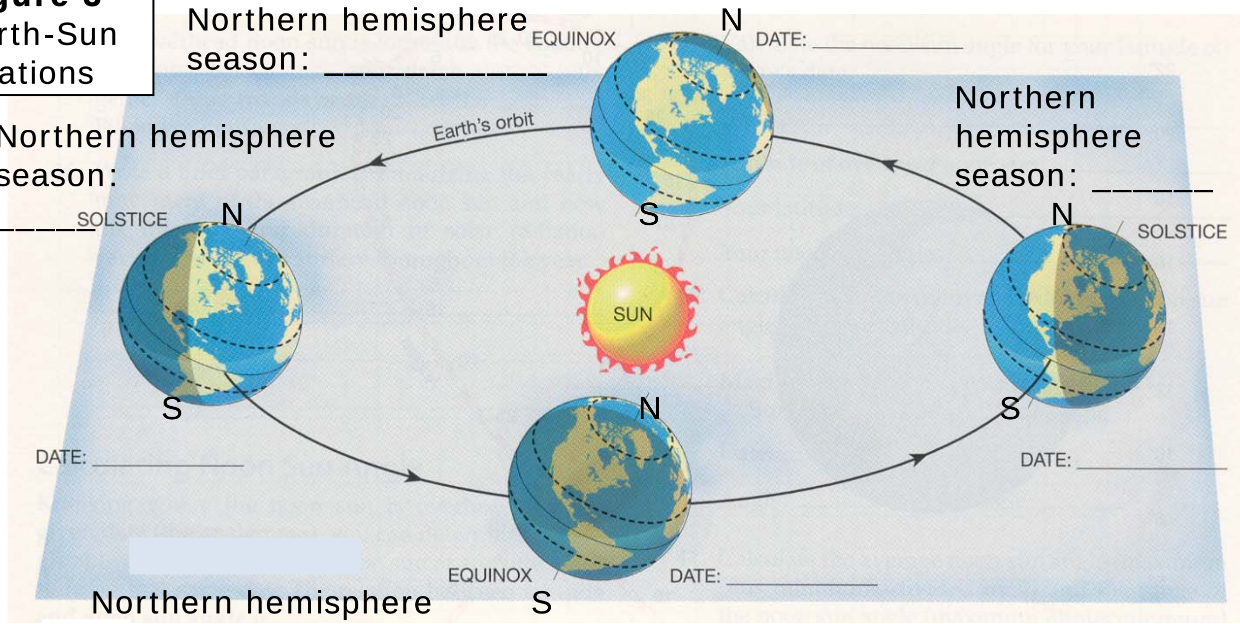
Fill in the proper names and dates on Figure 3

Northern hemisphere season: ___________

Northern hemisphere season: _____

Northern hemisphere season: ______

Northern hemisphere season: ___________



Activity 2: Yearly Variation in Solar Energy

The amount of solar radiation received at a particular place would remain constant throughout the year if it were not for these facts:

- Earth rotates on its axis and revolves around (orbits) Sun.
- Earth's axis is inclined 23 ½^o from perpendicular to its plane of orbit.
- Throughout the year, Earth's axis points to the same place in the sky. This causes the noon Sun to appear directly overhead at the equator twice a year, as it migrates from directly over the Tropic of Cancer (23 ½^o N latitude), to directly over the Tropic of Capricorn (23 ½^o S latitude), and back, from one June solstice to the next.

As a consequence, there are variations in the intensity of solar radiation and changes in the length of daylight and darkness at every place on Earth. The seasons are the result of this changing intensity and duration of solar energy, and subsequent heating of the atmosphere.

Table 1, below, lists the hours of daylight on the solstices and equinoxes at each 10^o of latitude on Earth's surface. Use this table and Figure 3 to answer the questions on the following page.

Latitude (degrees)	Summer Solstice	Winter Solstice	Equinoxes
0	12 h	12 h	12 h
10	12 h 35 min	11 h 25 min	12
20	13 12	10 48	12
30	13 56	10 04	12
40	14 52	9 08	12
50	16 18	7 42	12
60	18 27	5 33	12
70	24 h (for 2 mo)	0 00	12
80	24 h (for 4 mo)	0 00	12
90	24 h (for 6 mo)	0 00	12

Table 1: Hours of daylight.

Use Table 1 and Figure 3 to answer the question on the next page.

1. What term is used to describe June 20-21 in each hemisphere?	Northern Hemisphere:
	Southern Hemisphere:
2. What latitude is receiving the most intense solar energy on June 20-21?	Latitude:
3. What name is used to describe Dec. 21-22 in each hemisphere?	Northern Hemisphere:
	Southern Hemisphere:
4. For the Northern Hemisphere, what terms are used to describe these dates?	March 20-21:
	September 22-23:
5. For the Southern Hemisphere, what terms are used to describe these dates?	March 20-21:
	September 22-23:

6. (Circle responses) On June 20-21, latitudes north of the Arctic Circle are receiving (**0 / 6 / 12 / 24**) hours of daylight, while latitudes south of the Antarctic Circle are experiencing (**0 / 6 / 12 / 24**) hours of darkness.
7. (Circle response) On December 21-22, the (**Northern / Southern**) Hemisphere is receiving the most intense solar energy.

8. What latitude is receiving the most intense solar energy on:	March 21?
	September 22?

9. Describe the length of daylight everywhere on Earth on March 20-21 and September 22-23:

10. Use the Table 1 to find how many hours of daylight there would be at each of the following latitudes on December 21-22.

90 degrees N: ______________ hrs ______________ min

40 degrees N: ______________ hrs ______________ min

0 degrees: ______________ hrs ______________ min

40 degrees S: ______________ hrs ______________ min

90 degrees S: ______________ hrs ______________ min

Part B – The Nature of Earth's Surface and Atmospheric Heating

The various materials that comprise Earth's surface play an important role in determining atmospheric heating. Two significant factors are the albedo of the surface and the different abilities of land and water to absorb and reradiate radiation. *Albedo* is the reflectivity of a substance, usually expressed as the percentage of radiation that is reflected from the surface. Since surfaces that have high albedo are not efficient absorbers of radiation, they cannot return much long-wave radiation to the atmosphere for heating. Most light-colored surfaces have high albedo, causing light-colored surfaces (and the air above them) to be typically cooler than dark surfaces.

Activity 1: Albedo Experiment
To better understand the effect of albedo on atmospheric heating, conduct the experiment below using the provided apparatus and answer the questions. Before getting started, predict which will have the higher albedo – the black can or the silver can.

Procedure:

Step 1: Place the black and metallic containers (with lids and thermometers) about 6 inches away from the light source.

- **Make certain** that both containers are equal distance from the light and are not touching one another.
- Have the light is **shining on the sides** of the cans, not on the white foam lids.
- **Use cans that have cooled** since another group did the activity.
- Be sure thermometers are **not touching the sides** of the cans.

Step 2: Start recording the temperature of both containers with the computer by pressing 'start', or fill out Table 2 "Albedo Experiment Data" by reading the thermometer.

Step 3: Turn on the light and allow the computer to continue to record the temperature of both containers **for 5 minutes**, or read it from the thermometers and record on the data table at about 30-second intervals **for 5 minutes**.

Step 4: Print the graph, or plot the temperatures from the data table on Figure 4, the albedo experiment graph. Be sure to label which line represents the black can and the metallic can.

Do not fill out if you used the computer.

Use the printout instead of the table and graph**.**

Table 2: Albedo Experiment Data	**Starting Temperature**	**30 sec**	**1 min**	**1.5 min**	**2 min**	**2.5 min**	**3 min**	**3.5 min**	**4 min**	**4.5 min**	**5 min**
Black Container											
Silver Container											

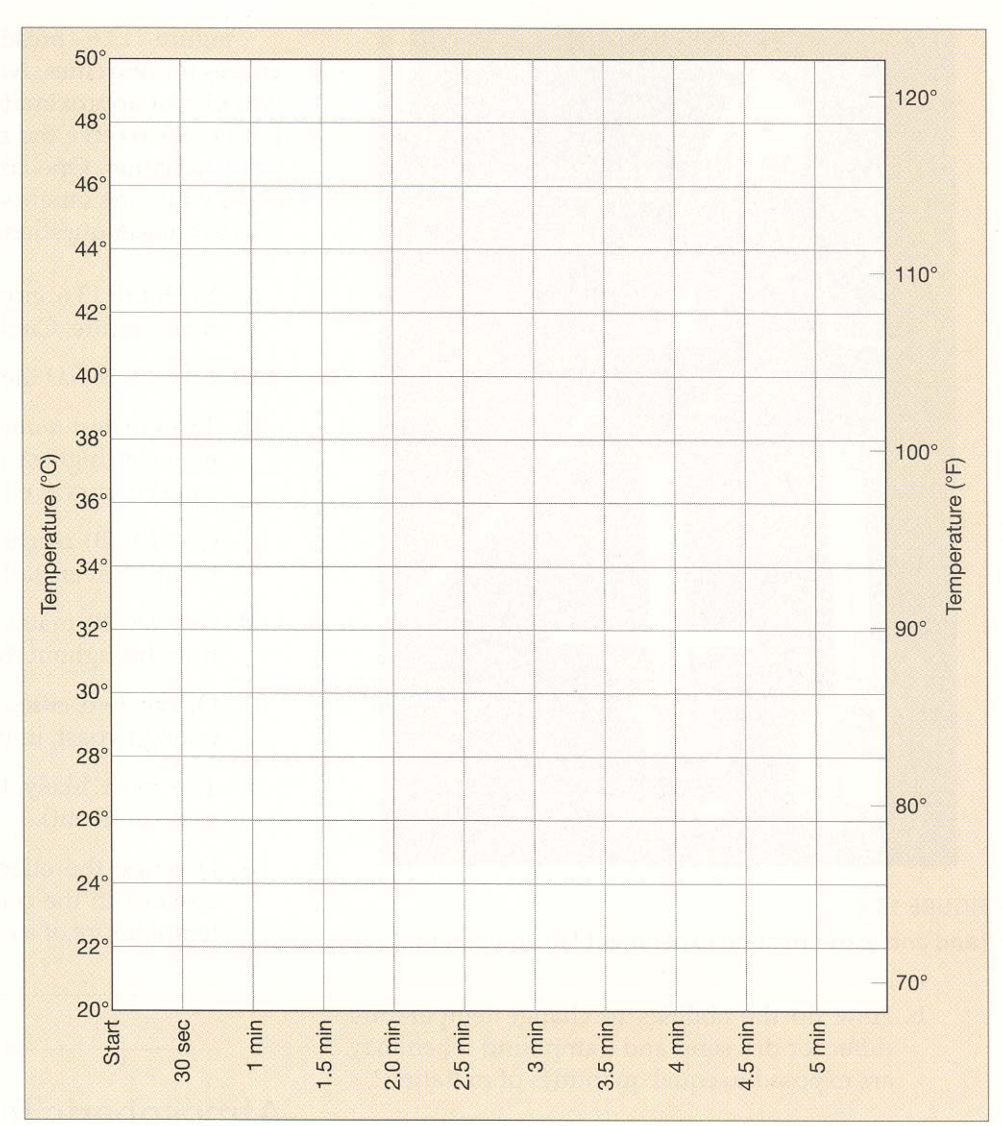


Figure 4: Graph of data from the albedo experiment.

Questions:

1. Which container has the higher albedo? ___________________________

2. Does this result match your prediction?

3. Write a brief summary of the results of the albedo experiment.

4. List two examples of natural Earth surfaces or materials that have high albedo.

5. List two examples of natural Earth surfaces or materials that have low albedo.

6. Given equal amounts of radiation reaching the surface, the air over a snow-covered surface will be (**colder** / **warmer**) than air above a dark-colored, barren field. Explain your choice fully in terms of what you have learned about albedo.

7. Why is it wise to wear light-colored clothes on a sunny, hot day?

8. If you lived in an area with long cold winters, a (**light** / **dark**) –colored roof would be the best choice.

Activity 2: Land and Water Heating Experiment

Land and water influence the air temperatures above them differently because they do not absorb and reradiate energy equally. In this activity, you will investigate the differential heating of land and water. Use the equipment provided, follow the lab procedure given below, and answer the questions.

Procedure:

Step 1: Hang a light from a stand so it is equally about 5 inches above the top of the two beakers – one containing dry sand and the other containing water at room temperature.

Step 2: Put temperature probes with plastic sleeves on them in the beakers of sand and water. Place them so that **the tips are just below** the surfaces of the sand and water. Use the plastic sleeves to support them in this position. Or use thermometers in similar positions.

Step 3: Start recording the temperatures for both the dry sand and water by pressing 'start' on the computer, or record in Table 3 "Land and Water Heating Data", if you are using the thermometers.

Step 4: Turn on the light and have the computer record the temperatures for **10 minutes**. Press stop at the end of 10 minutes. Or record the data in table at about one-minute intervals for 10 minutes if you are using the thermometers.

Step 5: Print the graph, or plot the temperatures for the water and dry sand from the data table on Figure 5. Be sure each line is labeled

Note: the tips of the temperature probes are only just below the surface of the sand and water.

Do not fill out if you used the computer.

Use the printout instead of the table and graph**.**

Table 3: Land and Water Heating Data. If you used the computer, do not record the data here. Use the printout instead of the table and graph

	0 min	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min
Water											
Dry Sand											

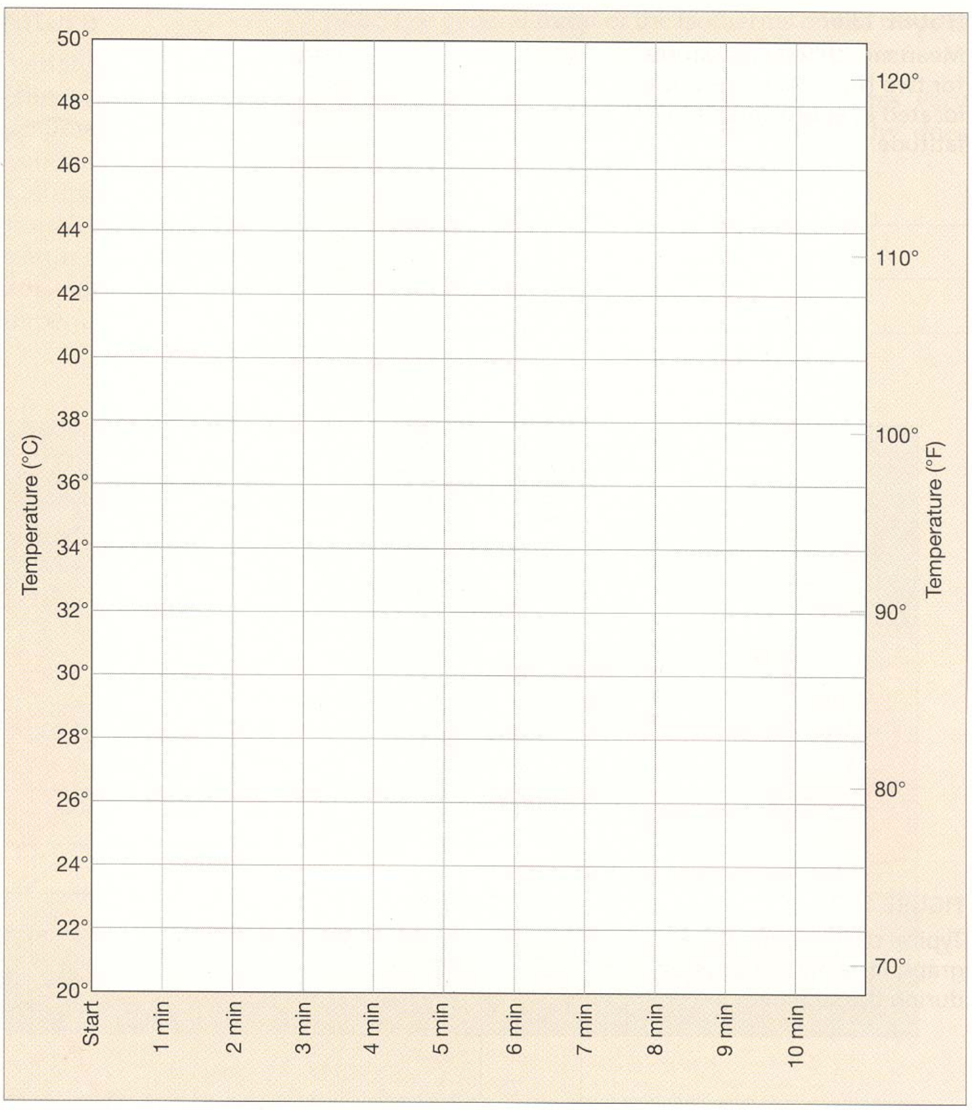


Figure 5: Graph for land and water heating experiment.
Do not use this if you have the computer print-out of your data.

Questions about the Land—Water heating activity:

1. How do the abilities to change temperatures differ for dry sand and water when they are exposed to equal amounts of radiation?

2. List and thoroughly describe *two* reasons for the differential heating of land and water.

Activity 3: Temperature Relationships to Land-Water and Cloudy-Clear

Figure 6 (top of next page) presents the annual temperature data for two cities, City A and City B, located in North America at approximately 37º-north latitude. On any given date, both cities receive the same intensity and duration of solar radiation. One city is in the center of the continent, while the other is on the west coast (say San Francisco, CA and Wichita, KS). You may want to refer to Fig. 16.18, p. 498-499, *Earth Science, 14th ed.*, by Tarbuck, et al. to help you understand these questions

Circle the answer for following questions using Figure 6.

1. City (A / B) has the highest average monthly temperature.
2. City (A /B) has the lowest average monthly temperature.
3. The greatest annual temperature range (difference between highest and lowest monthly temperatures) occurs at City (A / B).
4. City (A / B) reaches is maximum average monthly temperature at an earlier date.
5. City (A / B) maintains a more uniform temperature throughout the year.
6. Of the two cities, City A is the most likely to be located (along a coast / in the center of a continent).

7. The most likely location for City B is (coastal / mid-continent).

8. Describe the effect that the location of each city has on the temperature variations of that city throughout the year.

Figure 6
Mean monthly temperatures for two North American cities located at approximately 37°N latitude.

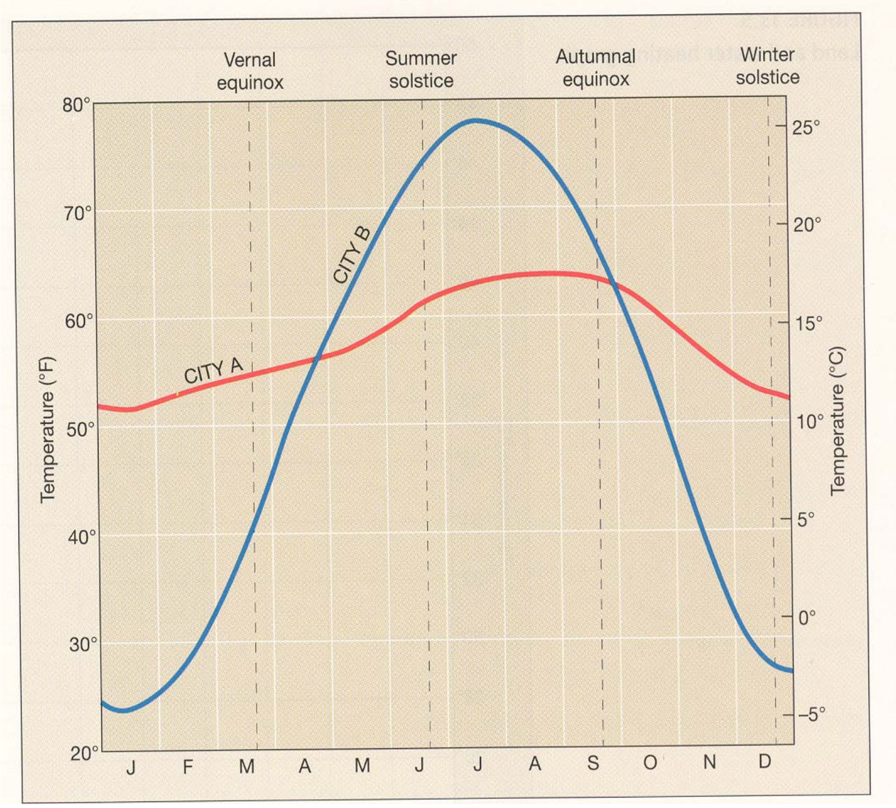
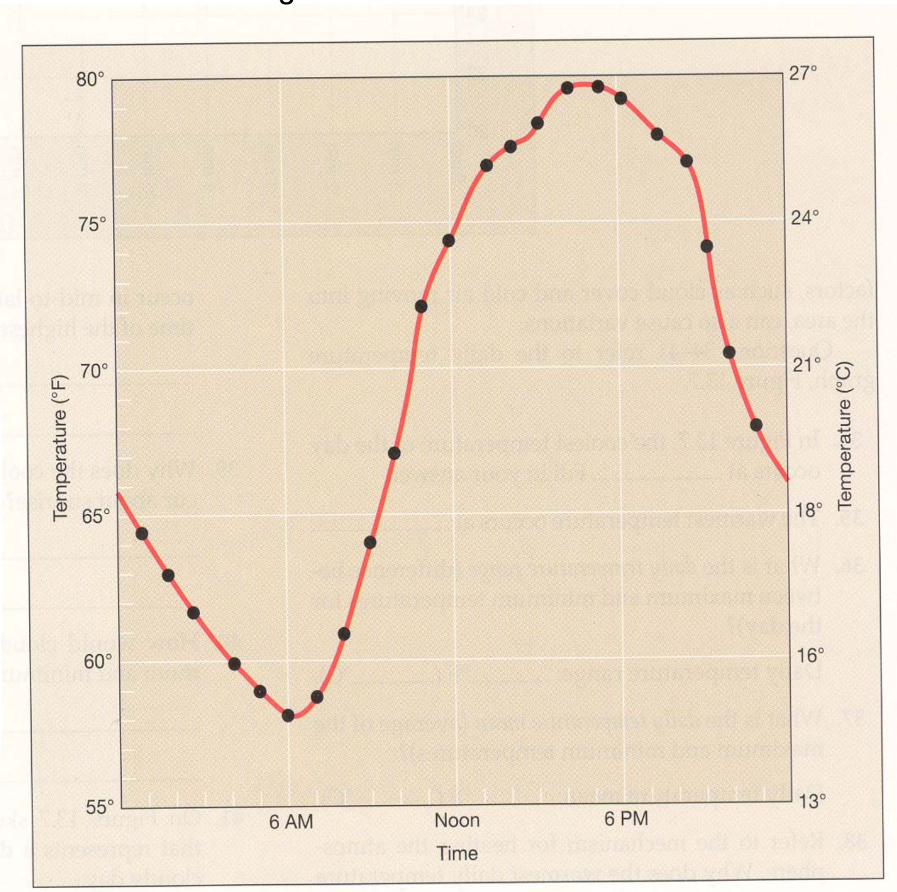


Figure 7 shows how daily temperature varies for a typical mid-latitude city. In general, the daily temperatures that occur at any particular place are the result of long-wave radiation being released at Earth's surface. However, secondary factors, such as cloud cover and cold air moving into the area, can also cause variations.

Figure 7
Typical daily temperature graph for a mid-latitude city during the summer.



Use Figure 7 to answer these questions:

3. The coolest temperature of the day occurs at ____________________,

   and the warmest temperature occurs at ________________________.
   (time of day)

4. What is the daily temperature range (difference between maximum and minimum temperatures for the day), in degrees Celsius?

5. What is the daily mean temperature (average of maximum and minimum temperatures) in degrees Celsius?

6. Considering how the atmosphere is heated, why does the warmest daily temperature not occur at the time of the highest sun angle, but rather in mid to late afternoon?

7. Why does the coolest temperature of the day occur about sunrise?

8. How would cloud cover influence daily maximum and minimum temperatures?

9. **On Figure 7**, sketch and label a line that would represent a daily temperature graph for a cloudy 24 hour period.

Name________________________

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POST-LAB ASSESSMENT

Imagine that you are designing a house that gets its heat and electricity from solar energy. The house is located in Oregon.

1. How would you want to angle the solar collector panels to receive the most energy from the Sun? Would the collectors face north, south, east or west? Would the collectors lie horizontally (flat on the ground), vertically (like a billboard), or at an angle? Justify your answers.

2. Would the optimal orientation for the panels change during the day? How and why, or why not?

3. Would the optimum orientation change through out the year? How and why, or why not?

4. Using what you have learned in lab today, explain why deserts often have very cold nighttime temperatures.

5. Using what you have learned in lab today, explain why an expansion of ice sheets would lead to an overall cooling of Earth's atmosphere. Be sure to consider what happens to incoming visible solar radiation when it hits a snowy or icy surface.

ES 106 Laboratory # 6
MOISTURE IN THE ATMOSPHERE

Introduction

The first part of this laboratory examines the changes of state of water, how the water vapor content of the air is measured, and the sequence of events necessary to cause cloud formation. Water vapor, which is an odorless, colorless gas produced by the evaporation of water, comprises only a small percentage of the lower atmosphere (generally less than 4% by volume). However, it is an important atmospheric gas because it is the source of all precipitation, aids in the heating of the atmosphere by absorbing radiation, and is the source of latent heat (hidden or stored heat). No analysis of the atmosphere is complete without an investigation of water vapor in atmosphere, because it strongly influences humidity and precipitation. By observing, recording, and analyzing weather conditions, meteorologists attempt to define the principles that control the complex interactions that occur in the atmosphere.

The second part of this laboratory focuses on making weather observations. Weather plays an important role in our daily lives. We want to know what the weather will be, so that we can plan to bring umbrellas, put on sunscreen, drive cautiously, dress a certain way, or know when it will be nice for outdoor activities. People talk about weather. The weather is newsworthy. It can become headlines in local, regional, national, and international news reports. Weather forecasts are found in newspapers, on TV, on the radio, and a growing variety of websites on the internet. Weather forecasts provide short-term (hours, days or weeks) predictions of the state of our atmosphere.

Objectives

- Explain the adiabatic process and its role in cooling and warming the air.
- Calculate the temperature and relative humidity changes that take place in air as the result of adiabatic cooling.
- Make measurements of relative humidity and dewpoint temperature.
- Appreciate the role technology plays in helping make weather observations.

Useful Websites

- http://www.nws.noaa.gov
- http://www.eoearth.org/article/Atmospheric_humidity
- http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/atmospheric_moisture/humidity.html
- http://nova.stanford.edu/projects/mod-x/id-moist.html
- http://www.temperatures.com/dewpoint.html

Name_________________________

Lab Day/Time__________________

Pre-lab Questions – Complete these questions before coming to lab.

1. Define the following terms:
   A. Relative Humidity

   B. Dew-point temperature

   C. Adiabatic temperature change

   D. Condensation

2. What is the difference between dry adiabatic lapse rate and wet adiabatic lapse rate? Which is greater? Why are they different?

3. If a beaker can hold 600 mL of liquid and it is 40% full, calculate the volume of liquid in the beaker. (Show formula for calculation, with units.)

4. If a beaker can hold 800 mL of liquid and it has 150 mL, calculate the percentage of the beaker that is filled. (Show formula, with units.)

Part A – Water Vapor Capacity of Air, Relative Humidity, and Dew-Point Temperature

Activity 1: Water Vapor Capacity of Air
The water vapor capacity of air is directly related to, and limited by, its temperature. The table below presents the water vapor capacity of a kilogram of air at various temperatures. Use the table to answer the following questions.

Table 1: Water vapor capacity of a kilogram of air at average sea level pressure.

Temperature (°F)	Temperature (°C)	Grams of water vapor per kg of air (g/kg)
- 40	- 40	0.1
- 22	- 30	0.3
-4	- 20	0.75
14	- 10	2
32	0	3.5
41	5	5
50	10	7
59	15	10
68	20	14
77	25	20
86	30	26.5
95	35	35
104	40	47

1. To demonstrate the relation between air temperature and water vapor capacity, prepare a graph by **plotting data from Table 1 in Figure 1**.

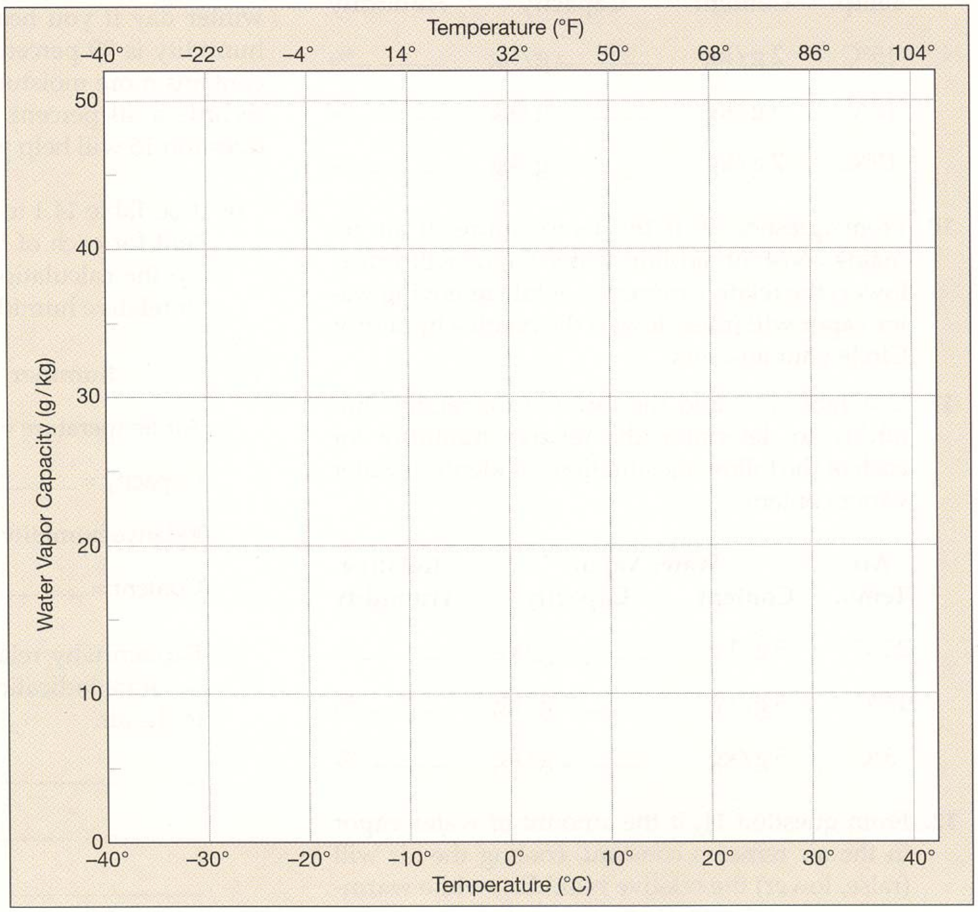


Figure 1: Graph of water vapor capacity of a kilogram of air versus temperature. Refer to Table 1 for values.

2. Read your graph to determine the water vapor capacity of a kilogram of air at each of the following temperatures	40º C: __________ grams/kilogram 68º F: __________ grams/kilogram 0º C: __________ grams/kilogram -20º C: __________ grams/kilogram

3. Read your graph to determine the effects described below. Write your answers in the areas to the right.	Change in water vapor capacity (increase/decrease)	Amount of change of the water vapor capacity in grams of a kilogram of air
Raising the air temperature from 10 to 15 ^{o}C		
Raising the air temperature from 35 to 40 ^{o}C		

4. Using your graph and the table, write a brief statement that relates the water vapor capacity of air to the temperature of air.

Activity 2: Relative Humidity and Dew Point Temperature

Relative humidity is the most common measurement used to describe water vapor in the air. In general, it expresses how close the air is to reaching its water vapor capacity. Relative humidity is the ratio of the air's water vapor content (amount actually in the air) to its water vapor capacity at a given temperature, expressed as a percent. The general formula is:

$$\text{Relative Humidity } (\%) = \left(\frac{\text{water vapor content}}{\text{water vapor capacity}}\right) \text{ x } 100\%$$

For example, the water vapor capacity of a kilogram of air at 25ºC would be 20 grams per kilogram. If the actual amount of water vapor in the air was 5 grams per kilogram (the water vapor content), the relative humidity would be calculated as follows:

$$\text{Relative humidity } (\%) = \left(\frac{5g/kg}{20g/kg}\right) \times 100 = 25\%$$

5. Use the Table 1 or Figure 1, and the general formula for relative humidity to determine the relative humidity for various water vapor contents of air at identical temperatures. Fill out Table 2, below

Table 2: Change in relative humidity with no change in temperature

Air Temp (°C)	Water Vapor Content	Water Vapor Capacity	Relative Humidity
15ºC	2 g/kg	g/kg	%
15ºC	5 g/kg	g/kg	%
15ºC	7 g/kg	g/kg	%

6. From Table 3, if the temperature of air remains constant, how does adding water vapor affect the relative humidity?

7. What effect will removing water vapor have on the relative humidity?

8. Use Table 1 and the general formula for relative humidity to determine the relative humidity for air at various temperatures with identical water vapor content. Fill out Table 3 below.

Table 3: Change in relative humidity with no change in water content

Air Temp (°C)	Water Vapor Content	Water Vapor Capacity	Relative Humidity
25ºC	5 g/kg	g/kg	%
15ºC	5 g/kg	g/kg	%
5ºC	5 g/kg	g/kg	%

9. So, if the amount of water vapor in the air remains constant, what effect will cooling or warming the air have on the relative humidity?

10. In the winter, air from outside is heated as it is brought into our homes. What effect does heating the air have on the relative humidity inside the home? What can be done to lessen this effect, while still being comfortable? (Hint: see Table 2 or 3)

11. Explain why a cool basement is humid (damp) in the summer. (Hint: see Table 3)

12. Write brief statements describing each of the two ways that the relative humidity of air can be changed. (Hint: see Table 2 and Table 3)

13. Use Table 1 to determine the water vapor content for each of the following situations. As you do the calculations, keep in mind the definition of relative humidity. Show calculations at right.

TABLE 4	**Relative humidity**	**Water Vapor Capacity**	**Water Vapor Content (g/kg)**
SUMMER Air temperature = 86º	20%	g/kg	
WINTER Air temperature = 50ºF	76%	g/kg	

14. One misconception concerning relative humidity is that it alone gives an accurate indication of the amount of water vapor in the air. For example, on a winter day if you hear on the car radio that the relative humidity is 90%, can you conclude that the air contains more moisture than a summer day that records a 40% relative humidity? Using the information in Table 4, explain why relative humidity does not give an accurate indication of the amount of water vapor in the air.

Refer to Table 1 for these questions

15. What is the dew-point temperature of a kilogram of air that contains 7 grams of water vapor?

Dew-point temperature = ________________________ ^oC

16. What is the dew-point temperature of a kilogram air that contains 10 grams of water vapor?

Dew-point temperature = ________________________ ^oC

17. What is the relative humidity of the air with 10 grams of water if its temperature is 25^oC?

Relative humidity = ________________________ %

Activity 3: Measuring humidity using a psychrometer

Air is *saturated* when it has reached its water vapor capacity and contains all the water vapor that it can hold at a particular temperature. **In saturated air, the water vapor content equals its capacity**. The temperature at which air is saturated is called the *dew-point temperature*. Put another way, the dew point is the temperature at which the relative humidity of the air is 100%. Previously, you determined that a kilogram of air at 25^oC, containing 5 grams of water vapor, had a relative humidity of 25%: not saturated. However, when the temperature was lowered to 5^oC, the air had a relative humidity of 100% and was saturated. Therefore, 5^oC is the dew-point temperature of the air in that example. Answer questions 15 and 16 at the top of the next page.

A psychrometer measures humidity by measuring the drop in temperature created by evaporation of water—the drier the air, the more evaporative cooling will occur. A thermometer with a dry bulb and a thermometer with its bulb inside a wet cloth are slung through the air. Air rushing over the wet cloth causes water to evaporate, and this cools the wet-bulb thermometer. Table 6 is used to convert the temperature difference between the wet and dry bulbs into relative humidity and Table 7 can determine dew-point temperatures from temperature measurements. Refer to Tarbuck and Lutgens, Earth Science 14th ed., p. 523-524, Fig. 17.9 for illustration of sling psychrometer; instructions for use are on the next page.

To operate the sling psychrometer:

- Wet the cotton cover on one thermometer with distilled water
- Sling it to allow evaporation to lower the temperature.
- After one minute, read the temperature on the wet bulb.
- Sling it for another minute and read the temperature again. If it is the same as the first reading, record that as the 'wet bulb temperature' in Table 5.
- If it is less than before, sling it for another minute, and read the temperature again.
- Continue doing this until the wet-bulb temperature reading is the same from one minute to the next.
- Determine the relative humidity and the dew-point temperature using Tables 6 and 7, on the following page.

TABLE 5: Sling Psychrometer Data	
Dry-bulb temperature (°C)	
Wet-bulb temperature (°C)	
Difference between dry- and wet-bulb temperatures (°C) (subtract)	
Relative humidity (from Table 6)	
Dew-point temperature (from Table 7)	

Explain the principle that governs the operation of a psychrometer for determining relative humidity.

Table 6: Relative Humidity determined by Wet Bulb Temp. Depression

Relative humidity (percent).

Dry-Bulb (Air) Temperature; Depression of Wet-Bulb Temperature (Dry-Bulb Temperature Minus Wet Bulb Temperature = Depression of the Wet Bulb); Relative Humidity Values

Dry bulb (°C)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
−20	28																					
−18	40																					
−16	48	0																				
−14	55	11																				
−12	61	23																				
−10	66	33	0																			
−8	71	41	13																			
−6	73	48	20	0																		
−4	77	54	32	11																		
−2	79	58	37	20	1																	
0	81	63	45	28	11																	
2	83	67	51	36	20	6																
4	85	70	56	42	27	14																
6	86	72	59	46	35	22	10	0														
8	87	74	62	51	39	28	17	6														
10	88	76	65	54	43	38	24	13	4													
12	88	78	67	57	48	38	28	19	10	2												
14	89	79	69	60	50	41	33	25	16	8	1											
16	90	80	77	62	54	45	37	29	21	14	7	1										
18	91	81	72	64	56	48	40	33	26	19	12	6	0									
20	91	82	74	66	58	51	44	36	30	23	17	11	5									
22	92	83	75	68	60	53	46	40	33	27	21	15	10	4	0							
24	92	84	76	69	62	55	49	42	36	30	25	20	14	9	4	0						
26	92	85	77	70	64	57	51	45	39	34	28	23	18	13	9	5						
28	93	86	78	71	65	59	53	45	42	36	31	26	21	17	12	8	4					
30	93	86	79	72	66	61	55	49	44	39	34	29	25	20	16	12	8	4				
32	93	86	80	73	68	62	56	51	46	41	36	32	27	22	19	14	11	8	4			
34	93	86	81	74	69	63	58	52	48	43	38	34	30	26	22	18	14	11	8	5		
36	94	87	81	75	69	64	59	54	50	44	40	36	32	28	24	21	17	13	10	7	4	
38	94	87	82	76	70	66	60	55	51	46	42	38	34	30	26	23	20	16	13	10	7	5
40	94	89	82	76	71	67	61	57	52	48	44	40	36	33	29	25	22	19	16	13	10	7

* To determine the relative humidity, find the air (dry-bulb) temperature on the vertical axis (far left) and the depression of the wet bulb on the horizontal axis (top). Where the two meet, the relative humidity is found. For example, when the dry-bulb temperature is 20°C and a wet-bulb temperature is 14°C, then the depression of the wet bulb is 6°C (20°C − 14°C). From Table C-1, the relative humidity is 51 percent and from Table C-2, the dew point is 10°C.

Table 7: Dew-point temperature (C°)

Dew-point temperature (°C)

Dry-Bulb (Air) Temperature; (Dry-Bulb Temperature Minus Wet-Bulb Temperature = Depression of the Wet Bulb); Dew-Point Values

Dry bulb (°C)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
−20	−33																					
−18	−28																					
−16	−24																					
−14	−21	−36																				
−12	−18	−28																				
−10	−14	−22																				
−8	−12	−18	−29																			
−6	−10	−14	−22																			
−4	−7	−12	−17	−29																		
−2	−5	−8	−13	−20																		
0	−3	−6	−9	−15	−24																	
2	−1	−3	−6	−11	−17																	
4	1	−1	−4	−7	−11	−19																
6	4	1	−1	−4	−7	−13	−21															
8	6	3	1	2	−5	−9	−14															
10	8	6	4	1	−2	−5	−9	−14	−18													
12	10	8	6	4	1	−2	−5	−9	−16													
14	12	11	9	6	4	1	−2	−5	−10	−17												
16	14	13	11	9	7	4	1	−1	−6	−10	−17											
18	16	15	13	11	9	7	4	2	−2	5	10	−19										
20	19	17	15	14	12	10	7	4	2	−2	−5	−10	−19									
22	21	19	17	16	14	12	10	8	5	3	−1	−5	−10	−19								
24	23	21	20	18	16	14	12	10	8	6	2	−1	−5	−10	−18							
26	25	23	22	20	18	17	15	13	11	9	6	3	0	−4	−9	−18						
28	27	25	24	22	27	19	17	16	14	11	9	7	4	1	−3	−9	16					
30	29	27	26	24	23	21	19	18	16	14	12	10	8	5	1	−2	−8	−15				
32	31	29	28	27	25	24	22	21	19	17	15	13	11	8	5	2	−2	−7	−14			
34	33	31	30	29	27	26	24	23	21	20	18	16	14	12	9	6	3	−1	−5	−12	−29	
36	35	33	32	31	29	28	27	25	24	22	20	19	17	15	13	10	7	4	0	−4	−10	
38	37	35	34	33	32	30	29	28	26	25	23	21	19	17	15	13	11	8	5	1	−3	9
40	39	37	36	35	34	32	31	30	28	27	25	24	22	20	18	16	14	12	9	6	2	−2

Activity 4 – Measuring dew-point temperature by condensation

Another way to determine the dew-point temperature is to cool a vessel until condensation begins to form on the outside of it. When you do this, it is very important that you change the temperature in small increments, and carefully monitor for the appearance of condensation. To get a feel for this activity, put about 100 mL of water into a 250 mL beaker. Dry the outside of the beaker. Measure the temperature with a digital thermometer. Put about 50 mL of ice into the water. Stir gently with the thermometer. Notice the drop in temperature. Touch the outside of the beaker to find out if there has been condensation. Now you realize how much the temperature drops with addition of ice, and how to feel condensation on the beaker.

Instructions to determine relative humidity by cooling air to the dew-point: Begin the measurement of the dew-point temperature by starting with a dry beaker at room temperature. Put about 150 mL of tap water into it. Add ice in 5 to 10 mL amounts, allowing it to completely melt before noting temperature and checking for condensation. You should add only enough ice each time to bring the temperature down about 1^{o} C. Continue until you notice condensation on the beaker. The temperature is your dew-point temperature. Record it below:

Dew-point temperature (°C) __________

Questions

18. Compare your measured dew-point temperature above with the value you determined using the psychrometer in Activity 3?

19. If the values are different, what factors might explain those differences?

Use Table 1 or Figure 1 to determine the values in questions 21 and 22.

20. What is the water vapor capacity of 50°F air? _________________

21. What is the water vapor capacity of 41°F air? _________________

22. If saturated air at 50°F is cooled to 41°F, how much water vapor will condense out of the air?

Part B – Adiabatic Processes

As you have seen in Part A, the key to causing water vapor to condense is to cool the air to its dew-point temperature. This is necessary before precipitation can occur. In nature, when air rises, it encounters less pressure, so it expands, and it cools. The reverse is also true. Air that descends encounters higher pressures, is compressed, and will warm. Temperature changes brought about solely by expansion or compression are called *adiabatic* temperature changes.

Air with a temperature above its dew point (unsaturated air) cools by expansion at a rate of **1 °C per 100 meters of changing altitude.** This is the **dry adiabatic lapse rate**. After the dew point temperature is reached, continued cooling cause condensation to occur. Latent heat that has been stored in the water vapor will be released. The heat being released by the condensing water slows down the rate of cooling of the air. Rising saturated air will continue to cool by expansion, but at a lesser rate of about **0.5 °C per 100 meters of changing altitude** – the **wet adiabatic lapse rate**. Descending air will always warm at the dry adiabatic lapse rate. This is because, as it warms, its water vapor capacity increases, and it is no longer saturated. (See Table 3 for demonstration of this effect.)

Figure 2 shows the movement of a parcel of air, starting at sea level with a temperature of 25ºC and a relative humidity of 50%. The air is forced to rise over a 5,000 meter mountain and descend to a plateau 2,000 meters above sea level on the opposite (leeward) side. Answer the questions on the following page. While doing so, think about the parallels between this problem and the orographic effect in western Oregon.

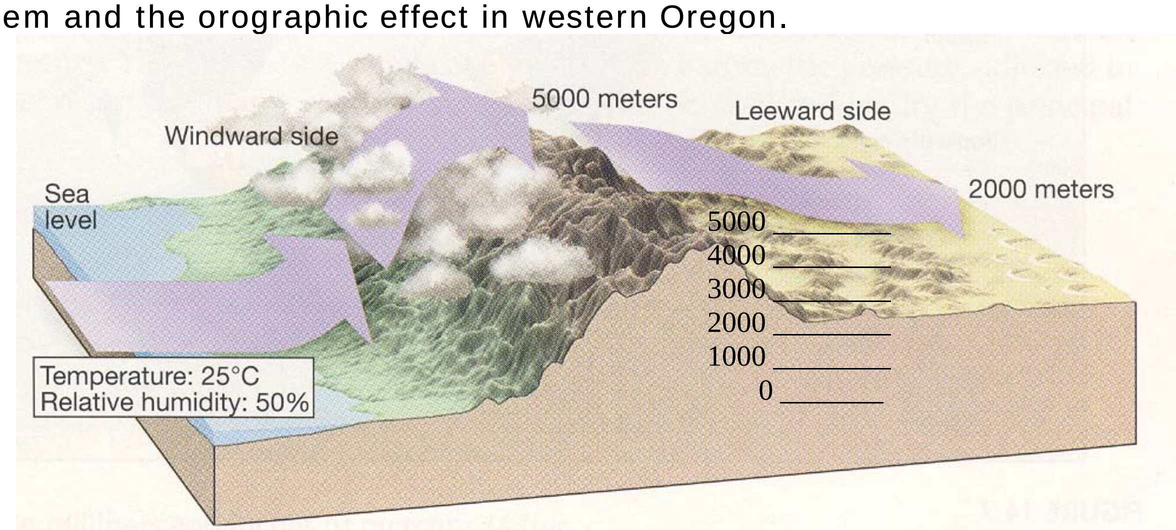


Figure 2: Adiabatic processes result in condensation associated with a mountain barrier.

In questions where you have to choose between more than response, CIRCLE YOUR ANSWER. Pay attention to your previous answers in later responses. You can write on the drawing on pg. 6.11 to keep track of the information. **See Table 1, 6 and 7** for specific values at certain temperatures.

Questions:

1. What is the water vapor capacity, content, and dew point temperature of the air at sea level? Capacity = ______________ g/kg of air

   Content = ______________ g/kg of air

   Dew-point temperature = ____________ ºC
2. The air at sea level is (**SATURATED** / **UNSATURATED**).
3. The air will initially (**WARM** / **COOL**) as it rises over the windward side of the mountain. It changes temperature at the (**WET** / **DRY**) adiabatic lapse rate, which is ______________ ºC per 100 meters.
4. What will be the air's temperature at 500 meters? __________________
5. Condensations (**WILL** / **WILL NOT**) take place at 500 meters. (See #1.)
6. The rising air will reach its dew point temperature at ________________ meters and water vapor will begin to (**CONDENSE** / **EVAPORATE**).
7. From the altitude where condensation begins to occur, to the summit of the mountain, the rising air will continue to expand and will (**WARM** / **COOL**) at the (**WET** / **DRY**) adiabatic lapse rate of about ______________ ºC per 100 meters.
8. The temperature of the rising air at the summit of the mountain (elevation 5000 meters) will be ______________ ºC.
9. What is the water vapor capacity when the air is at 5000 meters? ______
10. When the air begins to descend on the leeward side of the mountain, it will be compressed and its temperature will (**INCREASE** / **DECREASE**).
11. Assume that the relative humidity of the air is **below 100%** during its entire descent to the plateau. The air will be (**SATURATED** / **UNSATURATED**) and will warm at the (**WET** / **DRY**) adiabatic lapse rate of about ______________ ºC per 100 meters.
12. As the air descends and warms on the leeward side of the mountain, its relative humidity will (**INCREASE** / **DECREASE**).
13. The air's temperature when it reaches the plateau at 2,000 meters will be _____________ ºC.

Name_________________________

Lab Day/Time__________________

POST-LAB ASSESSMENT

1. Explain why mountains might cause dry conditions on their leeward sides. (Recall page 6.12 to help you explain this phenomenon.)

Answer the following by circling the correct response.

2. Liquid water changes to water vapor by the process called (condensation, deposition, evaporation, sublimation).

3. (Warm, Cold) air has the greatest water vapor capacity.

4. Lowering the air temperature will (increase, decrease) the relative humidity.

5. At the dew-point temperature, the relative humidity is

6. (25%, 50%, 75%, 100%).

7. When condensation occurs, heat is (absorbed, released) by water vapor.

8. Rising air (warms, cools) by (expansion, compression).

9. In the early morning hours when the daily air temperature is often coolest, relative humidity is generally at its (lowest, highest).

10. Using the concepts that you have learned in today's lab, explain why when it is raining in the Willamette Valley, the weather is often sunny in Bend.

11. What is the dew-point temperature of a kilogram of air when a psychrometer measures an 8°C dry-bulb temperature and a 6°C wet-bulb reading?

ES 106 Laboratory # 7
WEATHER – OREGON CLIMATE

Introduction

Climate is the measure and description of average weather conditions for a place on Earth's surface over time. Earth's climate system is very complex. The atmosphere, hydrosphere (mostly oceans), lithosphere, cryosphere (ice), and biosphere all contribute to Earth's climate.

Understanding how all of these subsystems work is what helps scientists determine how subsystems respond to change. Oregon is a diverse place with regards to climate. The purpose of this lab is study the climate of Oregon and to focus on the major influences on Oregon's varied climate.

Goals and Objectives

- Interpret climatic data from maps, tables, and graphs
- Describe Oregon's climate based on climatic data
- Develop an understanding of the major factors influencing Oregon's climate

Useful Websites

- http://weather.noaa.gov/weather/OR_cc_us.html
- http://www.wrcc.dri.edu/CLIMATEDATA.html
- http://www.oregonphotos.com/pagetwentyone-Q.html
- http://www.worldbook.com/wb/Students?content_spotlight/climates/north_american_climate_oregon
- http://www.musc.edu/cando/geocam/atacama/atacama.html
- http://www.esa.int/esaEO/SEM3PIWJD1E_index_0.html
- **http://www.wou.edu/las/physci/taylor/gs106/OregonRoadTrip.htm**

Name_________________________

Lab Day/Time__________________

Pre-lab Questions – Complete these questions before coming to lab.

1. Define the following terms:

   A. Orographic lifting

   B. Rain shadow

   C. Jet Stream

2. What is the effect of proximity to a major body of water (like the Pacific Ocean) on climate? How does this relate to the amount of heat that water must absorb to change its temperature?

3. What happens to the temperature of an air mass as it rises? Why?

4. What happens to the relative humidity of an air mass as it rises? Why?

See "Jump Start Activity" on next page to get a jump start on your work.

Laboratory Jump Start Activity

Work in groups to complete the table below by filling in the blanks. Imagine, in your mind's eye, a road trip from Newport, OR to Corvallis, OR to Sweet Home, OR to Santiam Pass, OR to Bend, OR to Burns, OR to Boise, ID. Describe what type of weather and vegetation you would experience on your drive **during the winter months**, for example over Christmas Break. For weather descriptions, your options are: "rainy", "snowy", "sunny and clear", and temperatures can be "above freezing", or "below freezing". For vegetation descriptions, your options are Spruce-Douglas Fir, Ponderosa Pine, agricultural fields (e.g. grass seed, wheat, etc.), Juniper-sagebrush, and sagebrush.

See http://www.wou.edu/las/physci/taylor/gs106/OregonRoadTrip.htm in 'useful websites' if you are unfamiliar with Oregon. Look at the graphs of climate data to fill in the weather and temperature.

Location (as you drive from west to east)	**Weather and temperature**	**Vegetation**
Newport		
Corvallis		
Sweet Home		
Santiam Pass		
Bend		
Burns		
Boise		

In the space below, write a brief paragraph discussing what you think the controlling factors are on the weather and vegetation observations that you've made on your road trip. (Describe what makes the weather like it is in the various places.)

Activity 1: Physiographic Provinces of Oregon

Provinces
Basin and Range
Blue Mountains
Cascade Range
Coast Range
Columbia Basin
High Plains
Klamath Mountains
Steens Mountains
Wallowa Mountains
Willamette Valley

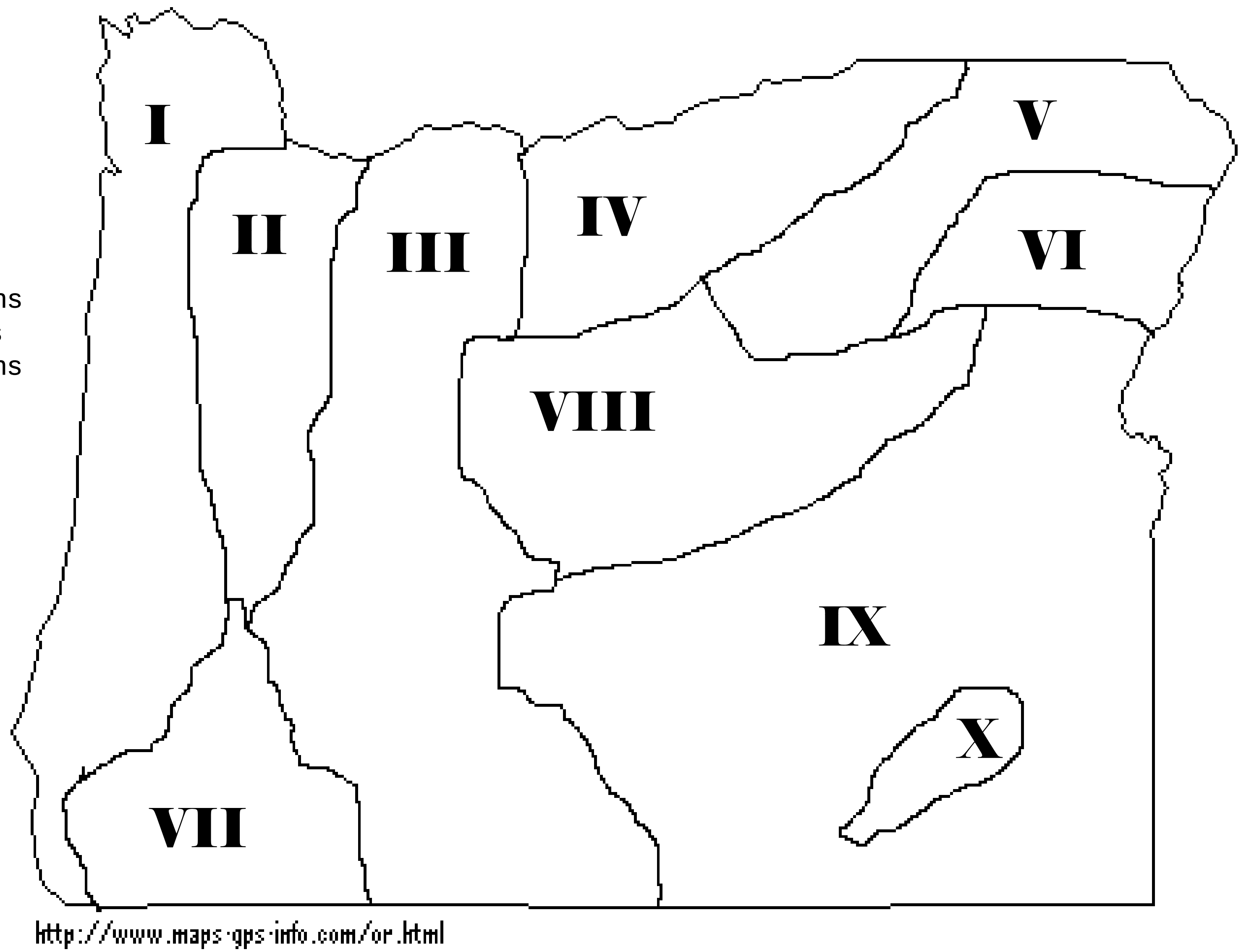


Figure 1: Physiographic provinces of Oregon

Part A – Physiography and Precipitation Maps of Oregon

Activity 1: Physiographic Provinces of Oregon

Oregon is divided into several physiographic zones (I through VIII, with subzones) based on topography (landscape configuration), bedrock geology, and climate. These physiographic zones are listed (in alphabetic order) on page 7.4, with the map labeled Activity 1: Physiographic Provinces of Oregon. Using the map and the list, fill in the table below by matching the geography to the listed province. Work in groups.

Province Map Number	**Province Name (from list on map)**
I	
II	
III	
IV	
V	
VI	
VII	
VIII	
IX	
X	

Activity 2: Classified Precipitation Map of Oregon

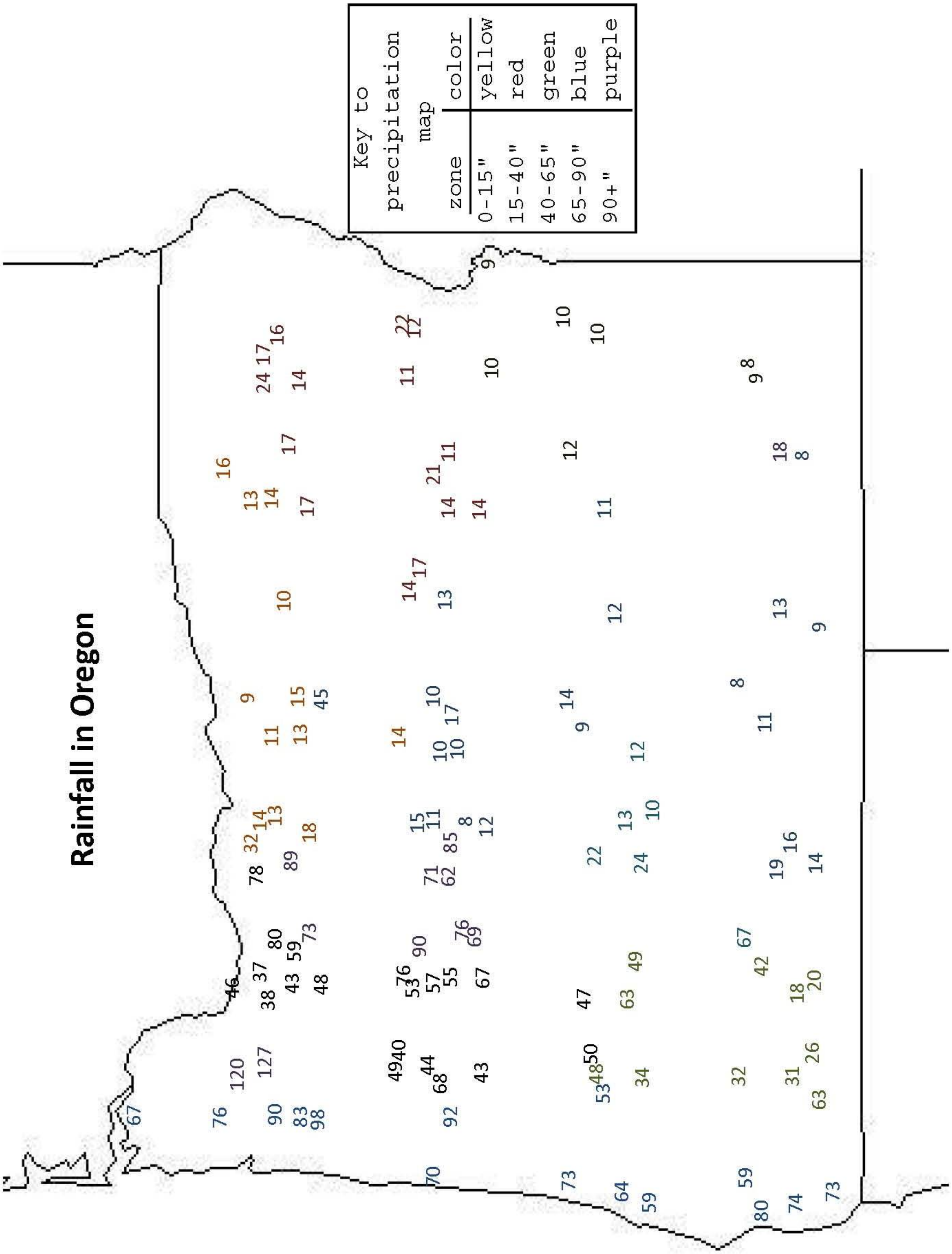
The map labeled "Rainfall in Oregon" shows annual rainfall (in inches/year) for stations in Oregon. Your task is to create a classified precipitation map for Oregon by drawing lines for the precipitation zones noted on the map. Color-code the data into the following annual precipitation zones:

Precipitation Zone	Map Color
<15 in/yr	Yellow
15-40 in/yr	Red
40-65 in/yr	Green
65-90 in/yr	Blue
>90 in/yr	Purple

Here's how you do it:

- At each station, read the annual precipitation and color-code each value by using a colored pencil and the zone colors listed above. Do not color the entire map at this time, only color-code the station.
- Now you have the stations color-coded. **Use a regular <u>pencil</u>** to draw map boundary lines between each color-coded interval, separating the stations by color. *NOTE: make sure you interpolate between data points and **draw a boundary line for each precipitation zone.*** <u>Don't leave out intervening zones</u> that may not have data points. In other words, have the rainbow of colors between the data points that are not in adjacent zones. Like a staircase, all the steps need to be between higher zones and lower ones. See 'useful websites' for some guidance.
- Color in the entire map, filling in the appropriate color for your boundary lines. Do this quickly, but neatly (don't spend the rest of the period coloring…just get on with it).

Figure 2: Rainfall zones in Oregon



Answer the following questions in the space provided:

1. Compare the Physiographic Map (Part A) to the Precipitation Map (Part B). What inferences can you make with regards to landforms and precipitation in Oregon?

2. Which REGIONS of the state are driest?

3. Which REGIONS of the state are the wettest?

4. Which direction do weather systems come from in Oregon: northerly, southerly, easterly, westerly?

5. How do these weather patterns relate to the precipitation-landscape relationships that you observed above?

6. What does the term "rain shadow" mean?

7. How does it form in Oregon?

8. Which parts of Oregon are in a "rain shadow"?

Part B - Plotting Climate Data on Graphs

Activity 1: Temperature Transect

Table 1 (page 7.10) is a summary of average annual climate data for locations in Oregon. The weather station locations are arranged by region in the state. Station name abbreviations are shown in parentheses (e.g. Corvallis station = CVO). The station locations are shown on below.

Plot a bar graph of temperature across Oregon, using data in Table 1. Use the average July High Temperature (degrees F) for the following stations: Newport (ONP), Corvallis (CVO), Santiam Pass (SP), Redmond (RDM), Burns (BNO), and Ontario, (ONO). Use the graph paper on Figure 4: Graph of Temperature Transect Across Oregon (page 7.11). Plot a vertical bar to the temperature shown on the Y-axis at the appropriate position marked on the X-axis. **Do not have the bars touch one another**; they should be narrow bands of equal width.

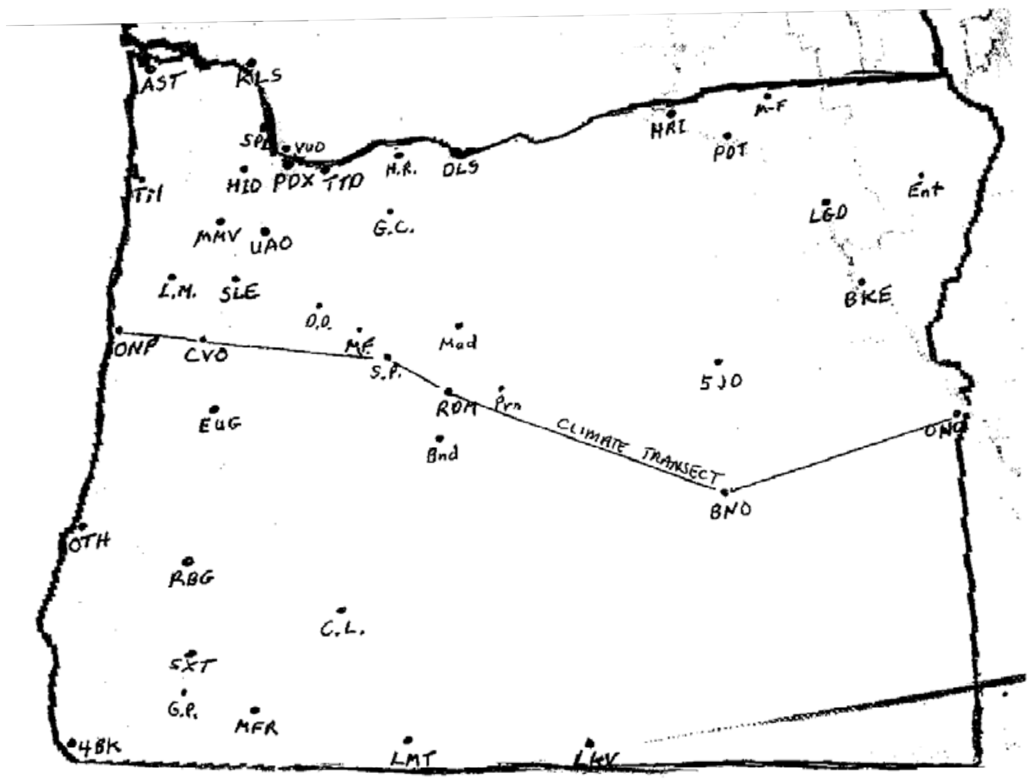


Figure 3: Weather Station Location map for Oregon

OREGON CLIMATE				Mean Annual					
	elev.	Jul Hi	Jan Lo	Temp	Precip	Snow	% Precip		
Location	*feet*	*deg F*	*deg F*	*deg F*	*in.*	*in.*	*Nov-Apr*	*Koeppen's Climate Classification*	
Coast									
Astoria (AST)	10	68	36	51	66	5	75%	Csb	*1st Letter*
Tillamook	10	67	36	50	89	3	75%	Cfb	A: Humid tropical
Newport (ONP)	140	65	37	50	72	2	76%	Csb	B: Dry
North Bend (OTH)	10	66	39	53	63	2	81%	Csb	C: Moist with mild winters
Brookings (4BK)	50	68	41	54	75	-	79%	Csb	D: Moist with cold winters
Coast Range									E: Polar climates
Laurel Mountain	3590	64	30	44	112	110	75%	Csb	
Willamette Valley									*2nd Letter*
Portland (PDX)	30	80	34	54	36	5	73%	Csb	S: Semi-arid
Hillsboro (HIO)	160	80	33	52	38	5	76%	Csb	W: Arid
McMinnville (MMV)	150	82	34	52	42	5	78%	Csb	w: dry winters
Salem (SLE)	200	82	33	52	39	6	77%	Csb	s: dry summers
Corvallis (CVO)	190	80	33	52	43	6	78%	Csb	f: Wet all seasons
Eugene (EUG)	360	82	34	53	49	6	79%	Csb	
Southwestern Valleys									*3rd Letter*
Roseburg (RBG)	510	84	35	54	32	4	78%	Csb	h: Hot and dry
Grants Pass	920	90	33	55	31	5	81%	Csa	k: Cool and dry
Medford (MFR)	1300	91	30	54	19	8	75%	Csa	a: Summers long and hot
Klamath Mountains									b: Summers long and cool
Sexton Summit (SXT)	3840	75	31	48	37	97	76%	Csb	c: summers short and cool
Cascades									
Government Camp	3980	68	24	42	86	278	76%	Dsb	
Detroit Dam	1220	77	33	51	87	18	76%	Csb	
Marion Forks	2480	80	26	46	68	112	77%	Csb	
Santiam Pass (SP)	4750	73	21	40	87	437	77%	Dsc	
Crater Lake	6470	68	18	38	66	495	78%	Dsc	
North Central									
Hood River	500	80	28	51	31	36	80%	Csb	
The Dalles (DLS)	100	88	30	55	14	12	79%	Csa	
Hermiston (HRI)	620	88	26	53	9	8	69%	BSk	
Pendleton (PDT)	1480	88	27	52	12	17	67%	BSk	
Milton-Freewater	970	89	28	54	14	12	64%	BSk	
South Central									
Madras	2230	87	23	49	11	12	62%	BSk	
Redmond (RDM)	3060	85	22	47	9	20	60%	BSk	
Prineville	2840	87	22	48	10	12	62%	BSk	
Bend	3660	82	22	46	12	35	67%	BSk	
Klamath Falls (LMT)	4090	85	20	48	13	35	70%	Dsb	
Burns (BNO)	4140	84	13	43	13	42	57%	Dfb	
Lakeview (LKV)	4780	84	19	46	16	65	66%	Dsb	
Northeast									
LaGrande (LGD)	2750	86	24	49	17	30	58%	Dsb	
Enterprise	3880	78	12	41	16	53	50%	Dfb	
John Day (5JO)	3060	88	21	49	13	24	54%	Dfb	
Baker City (BKE)	3370	85	17	46	11	25	57%	Dfb	
Southeast									
Ontario (ONO)	2140	96	19	52	10	18	67%	BSk	

South-Central Oregon data

Table 1: Mean Annual Climate Summary for Oregon

Questions:

1. What do you observe about the July temperature patterns when comparing Newport to Burns and Ontario, Oregon? What physical mechanisms in the atmosphere may account for this relationship?

2. What do you observe about the July temperature patterns when comparing Santiam Pass to Burns and Ontario, Oregon? What physical mechanisms in the atmosphere may account for this relationship?

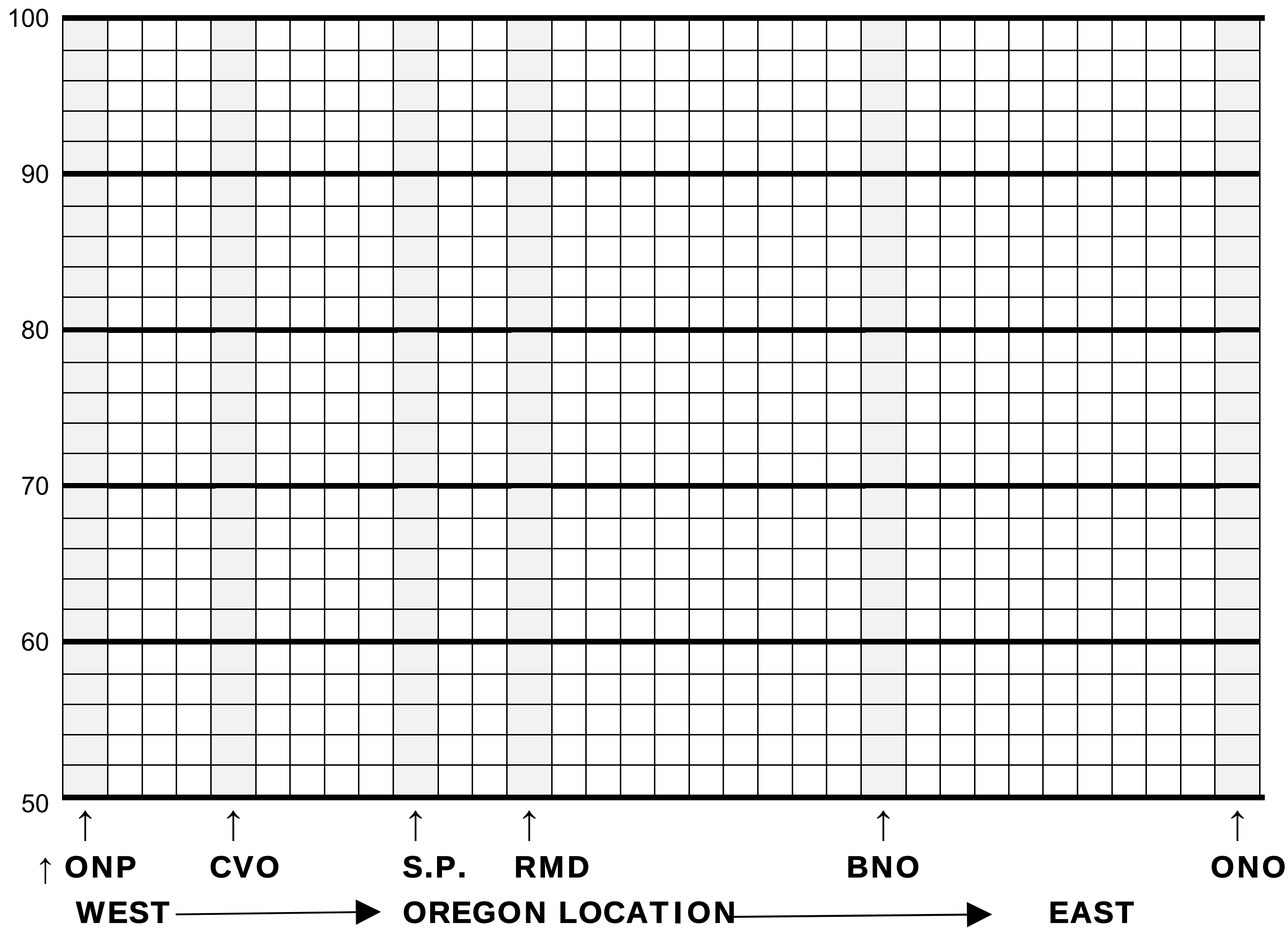


Figure 4: Bar Graph of Temperature Transect Across Oregon

Based on your precipitation data (Part A) and temperature data (Part B), *intuitively decide*, which parts of the state would you classify as "Maritime" and which parts would you classify as "Continental".

Intuitive Answer Here:

Based on your observations and intuitive answer, describe the terms maritime and continental in terms of seasonal temperature and precipitation by filling in the table below. (Use Table 1 to support your descriptions.)

	Maritime	Continental
Summer Temperatures (Hot or Cool?)		
Winter Temperatures (Moderate or Extreme)		
Summer Precipitation (Dry or Wet?)		
Winter Precipitation (Dry or Wet?)		

Activity 2: Focus on South-Central Oregon.

Make some scatter plots to examine the annual climate data in Table 1 for the South Central Oregon section (stations include Madras, Redmond, Prineville, Bend, Klamath Falls, Burns, and Lakeview). Use the data for the listed weather stations to make scatter plots on the graphs provided for:

- Mean Annual Precipitation vs. Elevation (Figure 5a)
- Mean Annual Temperature vs. Elevation (Figure 5b)
- Mean Annual Temperature vs. Mean Annual Precipitation (Figure 5c)

The graphs have already been scaled for you. Plot a point for each south-central weather station on each graph. Label the point with the name of the station. Or you can enter the data in a spreadsheet program, and use its chart function to make the graphs.

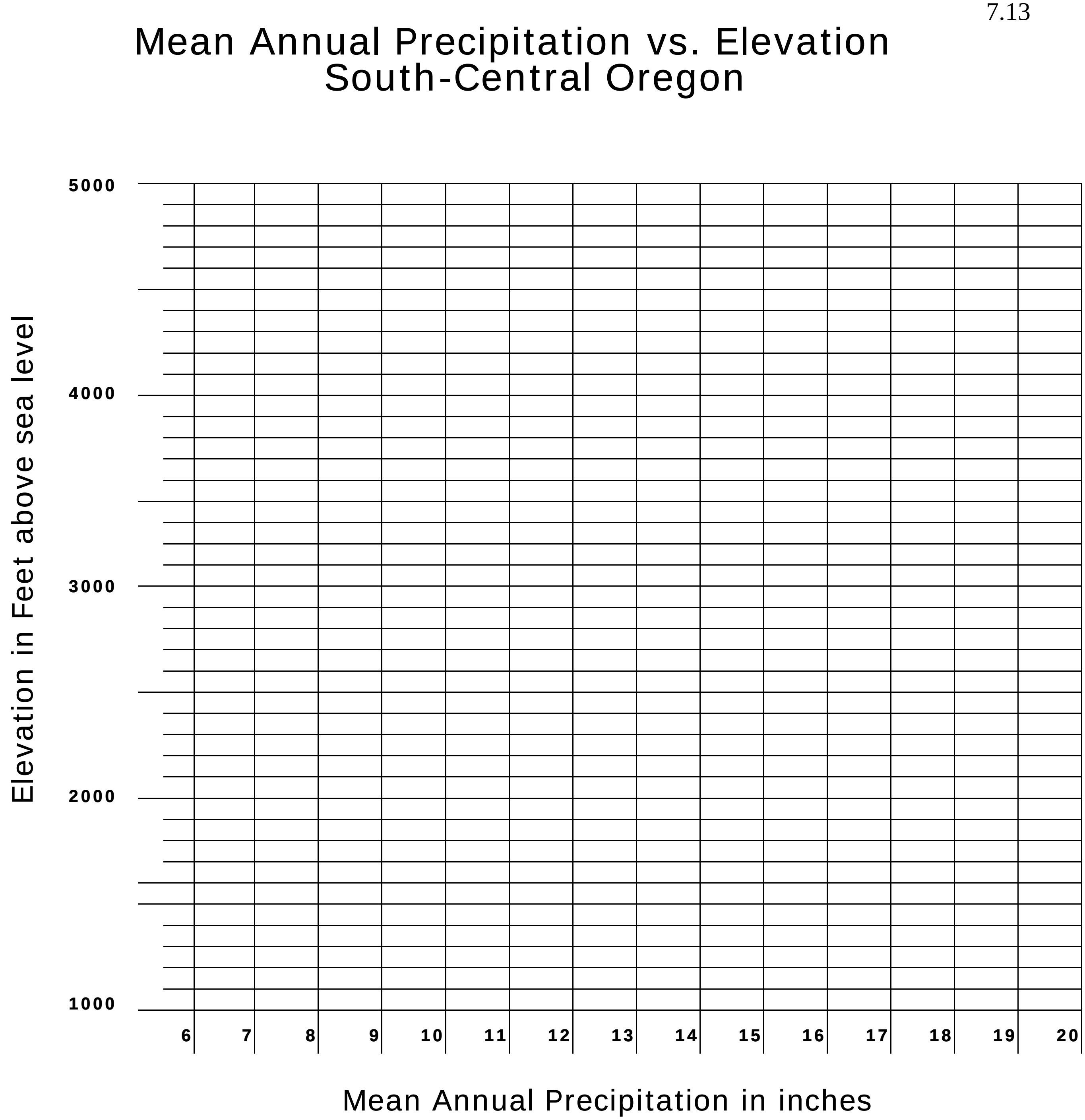


Figure 5a: Plot of Precipitation vs. Elevation—South-Central Oregon

Mean Annual Temperature vs. Elevation
South Central Oregon

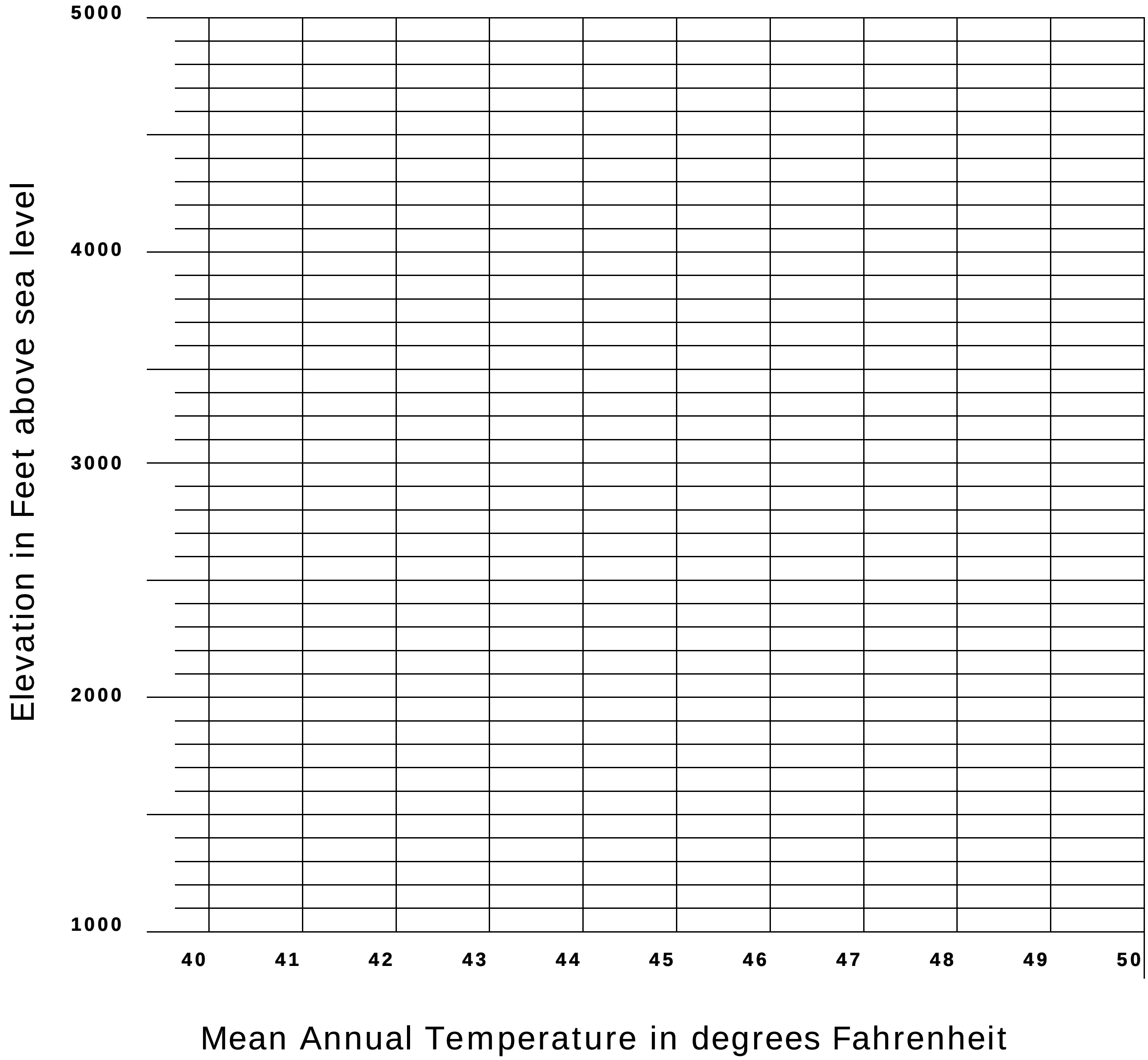


Figure 5b: Plot of Mean annual Temperature vs. Elevation
—South-Central Oregon

Mean Annual Temperature vs. Precipitation
South-Central Oregon

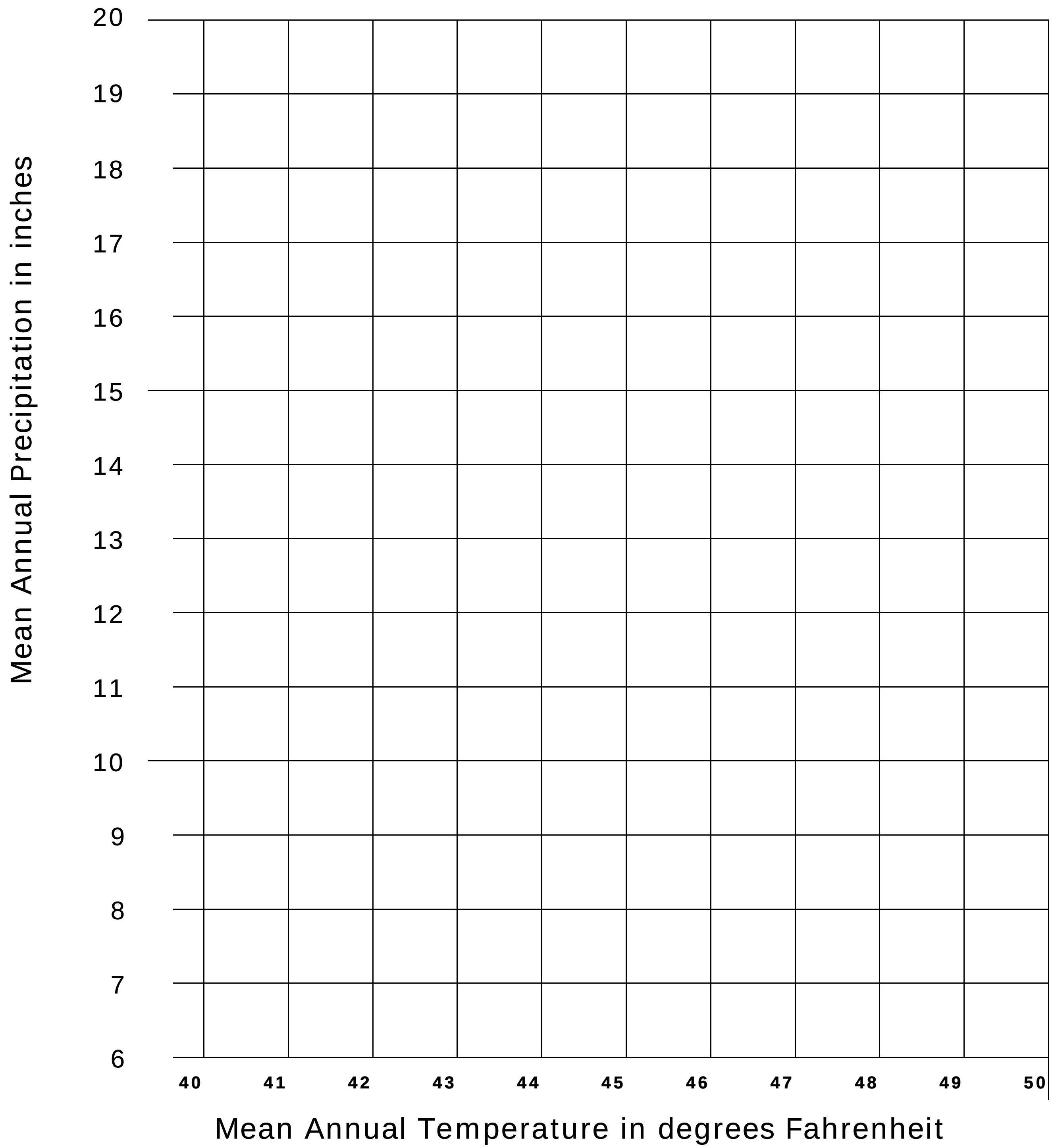


Figure 5c: Plot of Mean Annual Temperature vs. Precipitation —South-Central Oregon

Questions

1. Does precipitation relate to elevation in south-central Oregon? (That is, how consistent is the relationship in your data set: good fit, moderate fit, or poor fit?) Draw a 'best fit' line **if** there seems to be a correlation. **Do not draw a "best-fit" line if the data points are scattered in a "shot-gun" pattern.** (The shotgun pattern indicates little relationship between the two parameters).

2. Does mean annual temperature relate to elevation in south-central Oregon? That is, how consistent is the relationship in your data set: good fit, moderate fit, or poor fit?) Is the data relationship as convincing as the Precipitation-Elevation data?

3. Does mean annual precipitation relate to temperature in south-central Oregon? (How consistent is the relationship given your data set: good fit, moderate fit, or poor fit?)

4. Given last week's concepts of evaporation, forceful lifting, atmospheric elevation, dew point, relative humidity, and precipitation, write a summary paragraph explaining your graph observations in terms of atmospheric physics.

Name_________________________

Lab Day/Time_____________________

POST-LAB ASSESSMENT

1. Using what you have learned in lab today, look at the South American continent on a map and explain the existence of the Atacama Desert west of the Andes.

2. Given the location of St. Paul, Minnesota, predict what the general climate conditions should be like for that city. What will the summers be like? What will the winters be like? Justify your answer based on concepts from today's lab.

3. Sometimes, on a partly cloudy day in the Willamette Valley, you will see thick clouds to the west over the coast range. The clouds then seem to thin and break up in the Willamette Valley and then thicken to the east over the Cascades. What effect accounts for this pattern in cloud cover? Explain.

ES 106 Laboratory # 8
CLIMATE CHANGE

Introduction

A majority of observations and studies confirm that Earth's climate is rapidly changing, partly as a result of increases in greenhouse gases caused by human activities.

> **The scientific evidence is now overwhelming: climate change presents very serious risks, and it demands an urgent global response.**
>
> **The scientific evidence points to increasing risks of serious, irreversible impacts from climate change associated with business-as-usual paths for emissions of greenhouse gases.**
>
> **Climate change threatens the basic elements of life for people around the world -- access to water, food production, health, and use of land and the environment.** (Stern Review, 30 Oct 2006)

Here are some things everyone should know about climate change.

1. Earth's climate has constantly changed. Earth was warmer than it is now throughout much of the geologic past. Ice Ages have happened, and we may be in an inter-glacial period of one now.

2. Possible causes of climate variation and change that takes place over millions of years include shifting continents, volcanic activity, and mountain building. Most of these changes are explained by the theory of plate tectonics.

3. Glaciers have advanced and retreated many times during the past 2 million years. The last inter-glacial period was about 125,000 years ago, and lasted about 25, 000 years. Irregularities in Earth's orbit changes the amount of solar radiation reaching Earth's surface, and could be the main cause of glacier retreat and advance.

4. Volcanic eruptions can cool the global climate (for relatively short periods of time), and fluctuations in solar output (if large enough) can warm or cool the global climate.

5. Human influences of climate change include greenhouse gases and ozone (both warm the planet), and surface albedo and aerosols (both cool the climate).

6. Direct observations of current climate change include increasing global average air and ocean temperatures, widespread melting of perennial and seasonal snow and ice, and rising global mean sea level. From 1906 to 2005 the global average temperature increased 0.74°C, and the trend over the last 50 years has been 0.16°C per decade. The ocean has been absorbing more than 80% of the heat added to the climate system, warming the ocean to depths of at least 3000 m. In Antarctica and Greenland, the ice sheets are losing mass. Sea level rose at an average rate of 1.8 mm per year from 1961 to 2003, and 3.1 mm per year from 1993 to 2003.

7. The main cause of recent global warming (since about 1950) is increasing amounts of greenhouse gases, especially carbon dioxide. The increase in carbon dioxide is due primarily to fossil fuel consumption, with changes in land use also contributing.

8. During the next 20 years the global average temperature is projected to rise about 0.2°C per decade and sea level is expected to continue rising. During the next 100 years the global average temperature is projected to rise somewhere between 1.1°C and 6.4°C, and sea level is projected to rise somewhere between 0.18 m and 0.59 m. It is virtually certain there will be fewer cold days and nights, and warmer and more frequent hot days. It is very likely that the frequency of heat waves and heavy precipitation events will increase. It is likely that areas affected by droughts, the intensity of tropical cyclones, and the incidence of extreme high seas will increase.

9. The Intergovernmental Panel on Climate Change 2007 report considers a number of different emission scenarios, which tells us that what people do does matter. The most probable temperature increase in the next 100 years is somewhere between 1.8°C and 4.0°C, depending on what people do.

Useful Websites

- http://www.giss.nasa.gov/
- http://www.grida.no/climate/vital/index.htm
- http://www.ipcc.ch/
- http://epa.gov/climatechange/kids/carbon_cycle_version2.html
- http://www.physicalgeography.net/fundamentals/9r.html

Name_________________________

Lab Day/Time__________________

Pre-lab Activities – Complete the before coming to lab.

1. Read chapter 20, in *Earth Science, 14th ed.*, by Tarbuck, et al.
2. Define the following terms:
   A. Greenhouse effect:

   B. General circulation of the atmosphere

   C. Stratosphere

   D. Troposphere

   E. Ozone layer

   F. Carbon cycle

3. What gases are involved in the absorption of solar radiation by the atmosphere?

4. How does the wavelength of incoming solar radiation differ from heat reradiated from Earth's surface?

Part A

1. Briefly explain how greenhouse gases affect Earth's temperature (Heating the Atmosphere: The Greenhouse Effect, p.503-504, Fig. 16.23-16.24, Tarbuck, et al., *Earth Science 14th ed*.).

2. Before the Industrial Revolution carbon dioxide concentration in Earth's atmosphere averaged about 280 ppm (refer to p. 623-625, Figure 20.20 Tarbuck, et al., *Earth Science 14th ed*.) and Earth's average temperature was about 32°C warmer than it would be without greenhouse gases (that is to say that greenhouse warming was 32°C). Today carbon dioxide concentration is about 380 ppm. Calculate how much greenhouse warming would be today if greenhouse warming was *directly proportional* to the carbon dioxide concentration. (If you don't have a "feel" for the Celsius temperature scale, convert the temperatures to Fahrenheit.) Show all of your calculations.

3. Clearly this has not happened. Identify two concepts or ideas that might lead to an explanation of why it hasn't happened --or hasn't happened yet. (Think about Earth System Science, p.26-27 of Tarbuck, et al., *Earth Science 14th ed*., the concept of inertia from basic physics, and the specific heat of water.)

4. Tarbuck, et al., *Earth Science 14th ed*. (p. 631, Table 20.1) quotes a report published in 2007 by the Intergovernmental Panel on Climate Change (IPCC) that says the global average surface temperature increased by about 0.74°C in the twentieth century. What does the latest data from an American government source say? (HINT: See 'useful websites'.)

Part B

Use the data in Table 1 to plot a graph of Average Global Temperature versus Time. Do this on the graph paper provided in this lab, or enter the data in a spreadsheet program, and use it to make tables and calculations. Remember, the spreadsheet can calculate from numbers, like 1920 and 1930, but not from text entries like 1911-1920 and 1921-1930.

Table 1 Average Global Temperature 1881-2005, by decade
Source: Goddard Institute for Space Studies, NASA

Decade	Degrees C	Degrees F
1881-1890	13.81	56.9
1891-1900	13.71	56.7
1901-1910	13.73	56.7
1911-1920	13.79	56.8
1921-1930	13.92	57.1
1931-1940	14.03	57.3
1941-1950	14.02	57.2
1951-1960	14.00	57.2
1961-1970	13.94	57.1
1971-1980	14.04	57.3
1981-1990	14.29	57.7
1991-2000	14.39	57.9
2001-2005	14.65	58.4

5. Use you graph, or the data in the table, to calculate the following (express your results in degrees Celsius per decade (10 years):

a. average rate of warming from 1901-1910 to 1931-1940

b. average rate of cooling from 1931-1940 to 1961-1970

c. average rate of warming from 1961-1970 to 1991-2000

d. average rate of warming from 1991-2000 to 2001-2005.

6. Describe the rate of warming.

7. Compare your graph to Figure 20.22 on p. 625 of Tarbuck, et al., *Earth Science 14th ed*.).

a. Are they similar?

b. Why does the graph in the book show more variability?

8. While you're looking at Tarbuck, et al., *Earth Science 14th ed.*, check out Figure 20.20 on p. 624 and compare it to Figure 20.22 on p. 625.

a. What do you see?

b. Does a correlation prove cause and effect? (We assume you saw a correlation between the two graphs)

c. In this case (carbon dioxide concentration versus average global temperature) does scientific data indicate cause and effect?

9. Plot the data in Table 2 from six locations in the Willamette Valley on one graph. Use colors or symbols to identify location. How do our local temperature trends compare with global temperature trends?

Table 2 Average Temperature 1961-2005, by Decade
Willamette Valley Degrees Fahrenheit
Source: Oregon Climate Service

Decade	Portland Airport	Salem Airport	Eugene Airport	Forest Grove	Dallas	Stayton
1961-1970	53.0	52.0	52.7	53.2	52.1	52.6
1971-1980	53.4	51.8	52.5	52.4	51.8	52.1
1981-1990	54.2	52.4	52.9	52.4	52.2	52.5
1991-2000	54.6	53.5	53.7	53.6	53.1	53.0
2001-2005	54.8	53.3	53.7	53.9	53.5	53.6

Name________________________

Lab Day/Time_________________

POST-LAB ASSESSMENT

1. List five things you can do to reduce the amount of carbon dioxide you release into the atmosphere.

2. What percent of the land surface is presently covered with glaciers?

3. At the present rate of sea level rise, what year will Salem, Oregon (elevation 175 feet) become inundated by the sea?

ES 106
TOWN MEETING ACTIVITY

Introduction

In our modern society, at least in America, most of the aspects of our daily lives are governed by decisions that are made by a few individuals but are based on the consensus of a larger group. Every community, from the smallest village to the largest metropolis, sets current standards and future goals on such informed decisions. In a broader sense, decisions made on the local level can have an impact on the larger global community. To become more actively involved in decisions which affect the local and global community, you as an individual must make informed decisions on many issues.

During the course of this term, we have been examining not only Earth science, but we have also been discussing several impacts that humans have made upon the Earth system. Many of these stem from the use and abuse of Energy resources. The goals of the Town Meeting Assignment are to research a topic or issue related to Earth Science and to encourage students to take a more active role in the decision-making process that affects their community, the nation, and the world.

The Issue: Economic Expansion and Energy Production Alternatives

Suppose you live in a growing urban area like Portland. The city has been experiencing a rapid growth in both industry and population over the last 10 years, and there is no predicted end in sight. City, state, and federal government studies have shown that the energy sources that are currently in operation are presently working at the maximum output that could be expected of them. On top of this, those same energy sources are rapidly aging and will soon need major upgrading and repair. The community must consider issues such as construction and maintenance of new and/or alternative energy sources, fuel availability and cost, environmental pollution, health risks, and benefits from economic expansion. The city of Portland is now considering alternative solutions to the problem, and various interest groups in the city have criteria and agendas that they feel must be met. The Town Meeting has been called to allow the various interest groups to present their arguments and solutions relating to the problem in an open forum.

Organization

1. The class will be divided into groups of 3-4 students.
2. Each student group will represent a portion of the community, and each group will have its own unique set of goals, values, points of view, economic background and interests, etc.
3. The student groups will research the topic *independently* from their own personal point of view.

Group 1 - Power company wants to open and run a fossil-fuel burning power plant in the Portland area. Group represents fossil fuel interests.

Group 2 - Coalition of environmentalists and health care workers who are against the expanded and continued use of fossil fuels.

Group 3 - Power company wants to build a waste-to-power incineration plant in the Portland area.

Group 4 - Coalition of environmentalists and local residents who are opposed to the waste-incineration plant.

Group 5 - Power company wants to open and run a nuclear power plant in the Portland area. Group represents nuclear energy interests.

Group 6 - Coalition of environmentalists and local residents who are opposed to the nuclear power plant. Group strongly opposed to nuclear energy.

Group 7 - Group advocating alternative sources of energy production such as geothermal and hydrothermal.

Group 8 - Group advocating alternative sources of energy production such as solar and wind power.

Assessment:

One or more of the following assessment devices may be used to evaluate the Town Hall Meeting assignment. Your lab instructor will provide additional information.

The Group Presentation: The presentations will be organized in the format of a Town Hall Meeting. Each group of the community will have 7 minutes to present its case and then the floor will be opened for 3 minutes of open discussion. Each member of the group must participate in answering questions during the discussion. Individual grades for this portion will be based on the presentation and responses to the questions. Attendance is required!

Written Report: Students will be responsible for writing an essay on the topic from the point of view of their particular group. This essay should be no more than **1** typed page (12 point font, double spaced). When preparing your essay, be sure to discuss any relevant scientific issues and use scientific data to back your arguments whenever possible; this is a science class not an opinion poll. Use lecture notes, the textbook, and outside reference sources to support your arguments. Cite the references within the text and include a list of references that you used at the end of the written report. This portion of the assignment will be graded on individuality, style, factual content, grammar, and spelling.

Peer Review: Each member of the group will be evaluated by the other members of the group on participation and contribution. Each group will receive an evaluation of their presentation from the class. These will be tallied and added to your score.

ES 106
OCEAN CIRCULATION

Introduction to Ocean Currents

Moving masses of water on the surface or within the ocean are called *currents*. Ocean circulation has two primary components: (1) surface ocean currents and (2) deep-ocean circulation. While surface currents are driven primarily by the prevailing world winds, deep-ocean circulation is largely the result of differences in ocean water density. A density current is the movement of one body of water over, under, or through another caused by density differences and gravity. The primary generating force for surface currents is wind, whereas deep-ocean circulation is a response to density differences among water masses, which is controlled by salinity and temperature variations of ocean waters.

Surface currents develop when friction between the moving atmosphere and the water causes the surface layer of the ocean to move as a single, large mass. Many surface ocean currents flow with great persistence. Density currents result when water of greater density flows under or through water of a lower density. At any given depth, the density of water is influenced by its temperature and salinity.

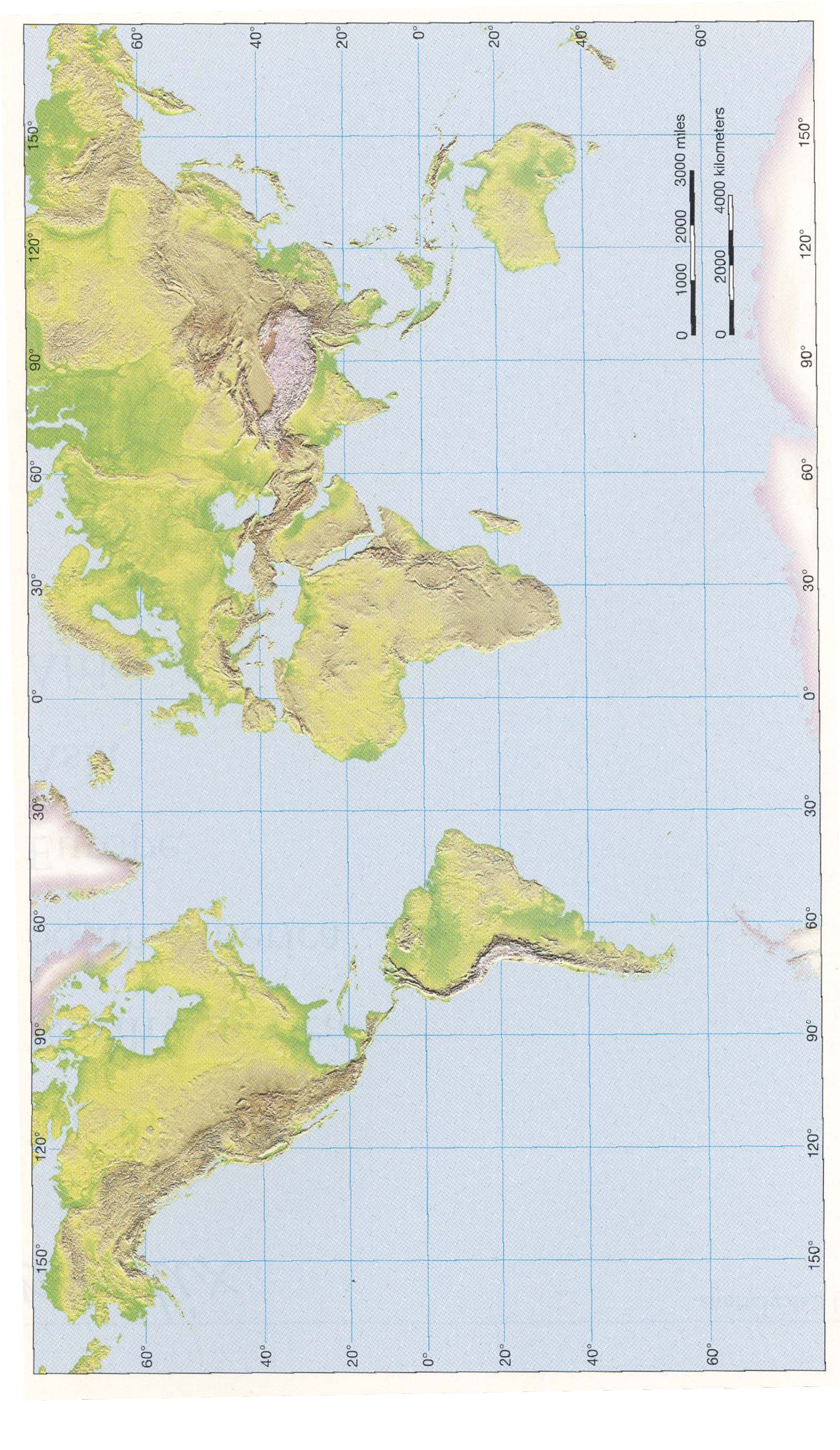
Activity

On the world map provided on page 10.2, draw arrows representing each of the following principal surface ocean currents. (See Figure 15.2, p. 455, Tarbuck & Lutgens, 14th ed.) Show warm currents with red arrows and cold currents with blue arrows.

Major Surface Currents of the World Oceans:
Equatorial, Gulf Stream, California, Canary, Brazil, Benguela, Kuroshio, West Wind Drift, Labrador, North Atlantic, North Pacific, Peru.

Questions:

1. Which surface ocean current travels completely around the globe (west to east) without interruption?
2. Which surface ocean current flows along the east coast of the United States? Is it a warm or cold current?
3. What is the name of the surface ocean current located along the west coast of the United States? Is it a warm or cold current?
4. The general circulation of the surface currents:
   In the North Atlantic Ocean, the circulation is in what direction? _______
   (clockwise or counterclockwise?)
   In the South Atlantic Ocean, the circulation is in what direction? _______


0 1000 2000 3000 miles
0 2000 4000 kilometers

ES 106
Introduction to Collecting Weather Data

1. To get started, you and your group will need to go outside to make some weather observations. Make careful weather observations in a period of 5-10 minutes. These observations will be discussed when you return to the classroom. Note the following:
   - *Air Temperature*
   - *Cloud Cover*
   - *Wind Speed*
   - *Wind Direction*
   - *Precipitation*
2. Based on your observations, make a weather forecast for the WOU campus for 2 hours from now. In your forecast, include the following:
   - *Air Temperature*
   - *Cloud Cover*
   - *Wind Speed*
   - *Wind Direction*
   - *Precipitation*
3. Based on your observations from outdoors, make a weather forecast for the WOU campus for 2 weeks from now. In your forecast, include the following:
   - *Air Temperature*
   - *Cloud Cover*
   - *Wind Speed*
   - *Wind Direction*
   - *Precipitation*

Internet Weather Assignment

Choose one 7-day period during the next ___________ weeks and collect weather data using one of the listed internet sites **and** by making your own weather observations. Complete the Weather Log on the next page of the lab and answer the questions below. On the weather log, be sure to indicate the location, for which the data is being collected, and the time and date that you collect your weather observations. This assignment is due ______.

Weather related web sites (circle the web site that you relied upon for this assignment):

http://www.weatherunderground.com
http://nimbo.wrh.noaa.gov/portland/ (just click observations)
http://www.weather.gov

Questions:

1. How do your own local weather observations compare to the internet weather data?

2. Evaluate the internet as a resource for gathering weather data. Do you think it provides the best weather information for the average person to use? Explain why you think so.

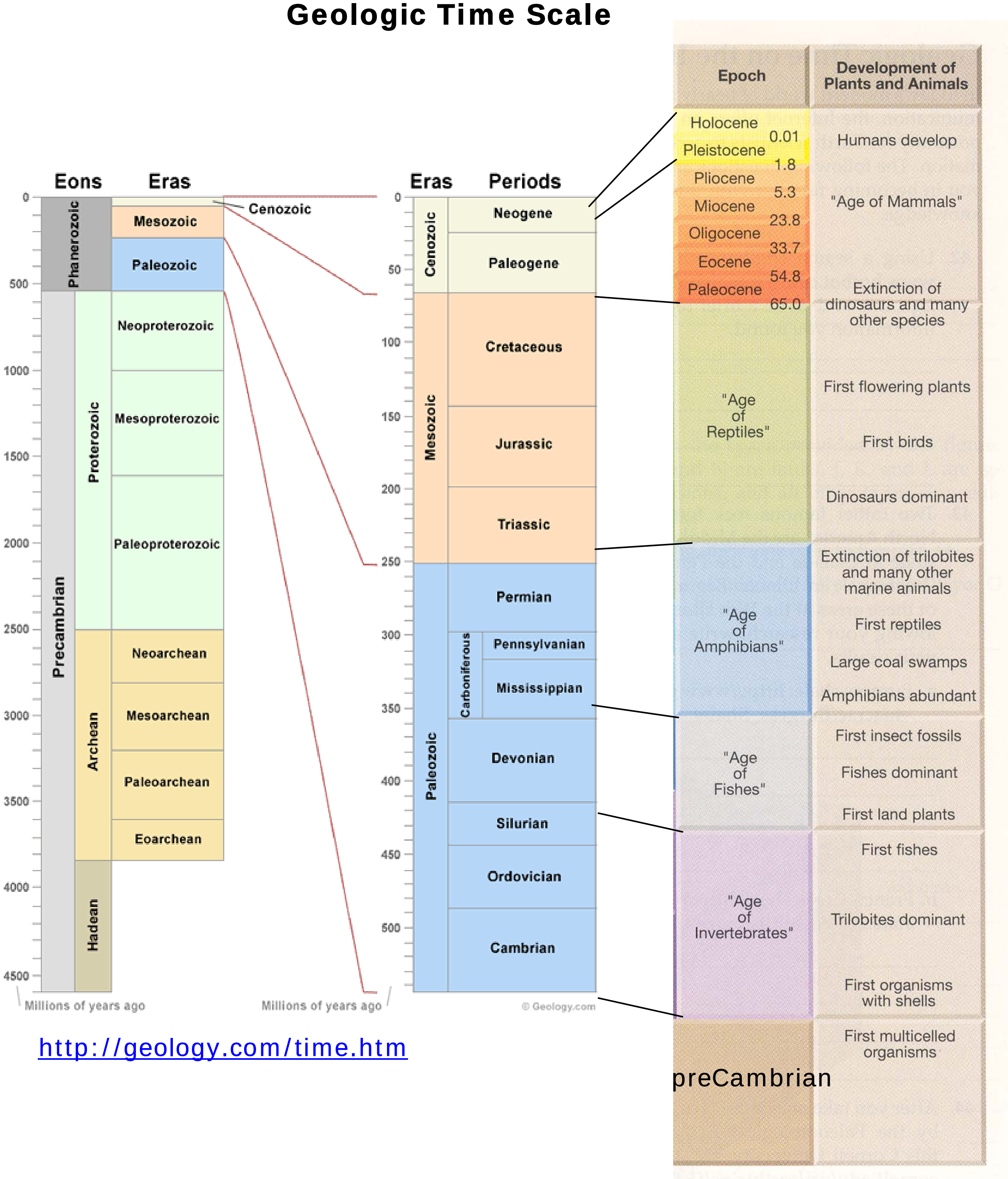
3. Interpret the weather data for your chosen time period. List and describe the data that you collected that supports the passing of a front or the presence of a high or low pressure system?

4. Find and describe the patterns in your weather data. For example, if the wind blows from a certain direction do we experience a certain kind of weather?

Data Table For Weather Log Assignment

Place	Date / Time	Wind speed	Wind directi	Temp	Clouds	Air Pressu	Precip	Other observatio
Own:								
Internet:								
Own:								
Internet:								
Own:								
Internet:								
Own:								
Internet:								
Own:								
Internet:								
Own:								
Internet:								
Own:								
Internet:								

ES 106
Geologic Time Scale



http://geology.com/time.htm