Geography 204
Winter 2015

Lab #3: Vertical Pressure Relationships, Stability and Adiabatic Processes in the Atmosphere (25 points)
(due by the end of class, Wednesday, 2/4)

Pressure versus Altitude

Atmospheric pressure or the density of air decreases with increasing altitude in the atmosphere. Average sea level pressure is expressed as 1013.25 mb (millibars) of mercury (sea level pressure can support a column of mercury, which is a way of expressing force per square unit of surface area). At sea level average or *standard* atmospheric pressure is expressed in several ways:

a) 14.7 lb per inch^2
b) 29.92 inches of Hg (mercury)
c) 1013.25 mb

Note however, that at any given time and place, the actual pressure curve would differ from the standard. It is those small differences that are most important in weather phenomena, creating wind, precipitation etc.

The standard atmosphere for pressure in millibars and altitude in kilometers is given on **Table 1**. Answer the following questions using the data from **Table 1**.

1) Using the graph provided in **Figure 1**, plot the relationship of air pressure decrease with altitude from the data provided from **Table 1**. After completing the plot, connect the data points with a line to create a pressure profile. **(2 points)**

2) Using the profile you have made, estimate the standard pressure in mb for each location below. Also calculate the elevation in feet using the conversion table in Appendix I (A.1-A.2 Table I-3) in your text. **(3 points)**

Mt. Si, WA	1,270 m	____ ft	____mb
Mt. Rainier, WA	4,392 m	____ ft	____mb
Mt. Everest	8,848 m	____ ft	____mb

3) At what altitude in meters and feet does the standard atmosphere reach 500 mb? **(1 point)**

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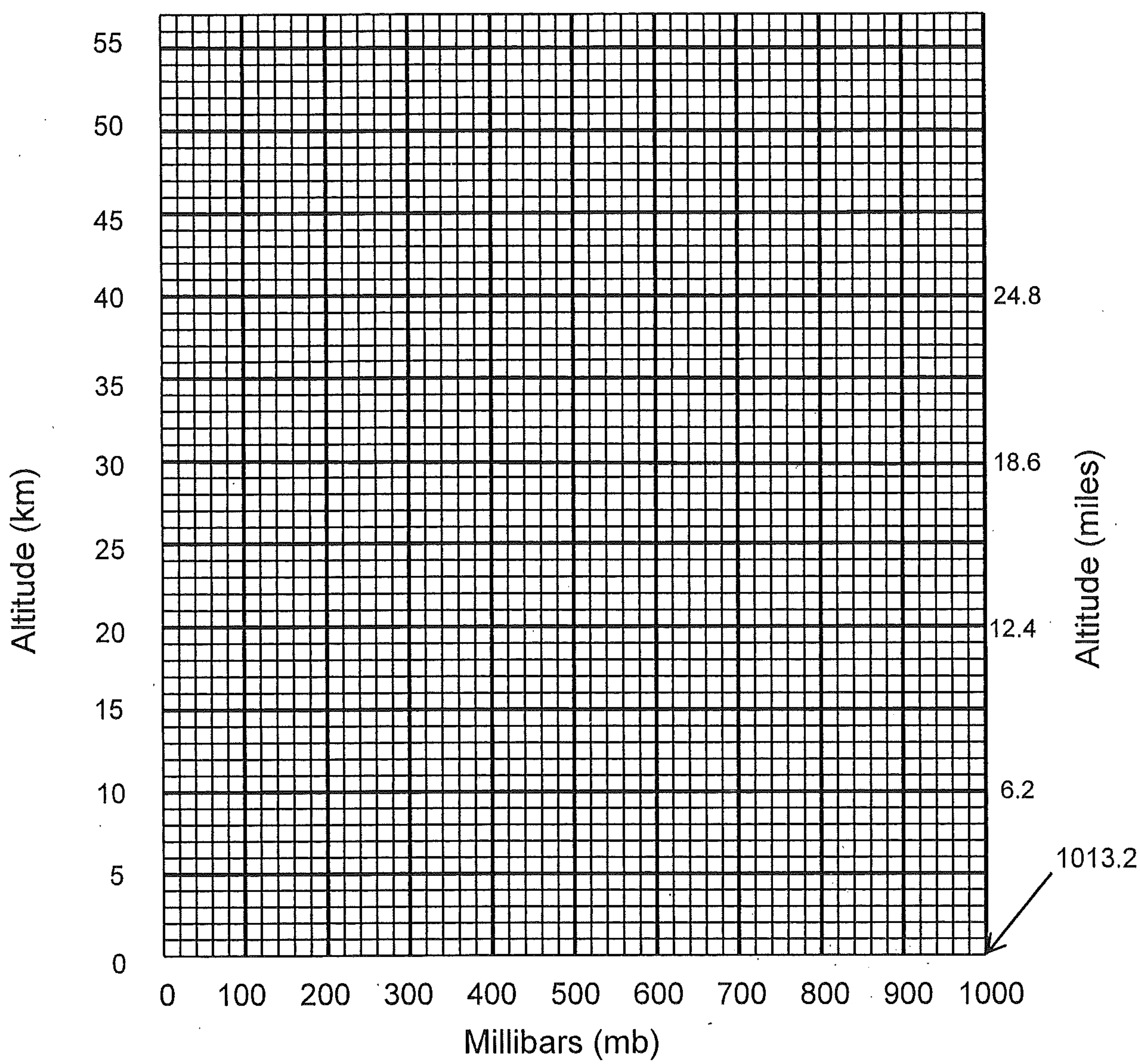
Table 1

Standard atmosphere for pressure and altitude.

Altitude (km)	Pressure (mb)
0.00	1013.25
0.50	954.61
1.00	898.76
1.50	845.59
2.00	795.01
2.50	746.91
3.00	701.21
4.00	616.60
5.00	540.48
6.00	472.17
7.00	411.05
8.00	356.51
9.00	308.00
10.00	264.99
12.00	193.99
14.00	141.70
16.00	103.52
18.00	75.65
20.00	55.29
25.00	25.49
30.00	11.97
35.00	5.75
40.00	2.87
50.00	0.79
60.00	0.23
70.00	0.06

Graph 1



Atmospheric Stability

In this section of the lab, students are expected to be familiar with the concepts of humidity, relative humidity, dew-point temperature and saturation in the atmosphere. These temperature and moisture relationships in the environment determine the all-important condition of atmospheric stablity.

Stability refers to the tendency of a parcel of air either to remain as it is or change its initial position by ascending or descending. An air parcel is called *stable* if it resists displacement or upward movement. On the other hand, an air parcel is considered *unstable* when it continues to rise until it reaches an altitude where the surrounding air has a density similar to its own.

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Important in understanding stability as well as abdiabatic processes is the idea of the *lapse rate*. The lapse rate refers to the decrease in temperature with increasing altitude. Recall the pressure profile from the first part of this lab, where we plotted this relationship. A lapse rate simply describes the rate of change of temperature over a vertical change in altitude. *The normal lapse rate* refers to the average decrease in temperature with increasing altitude which is 6.4°C per 1000 meters (or 3.5°F per 1000 feet). This rate of change however, can differ greatly under varying weather conditions, and so the actual lapse rate at a particular place and time is called **the environmental lapse rate**.

Both ascending and descending temperature changes are assumed to occur without any heat exchange between the surrounding environment and the vertically moving parcel of air. The warming and cooling rates for a parcel of expanding or compressing air are termed *adiabatic*. Adiabatic rates are measured with one of two dynamic rates depending on moisture conditions in the parcel: the **dry adiabatic rate** (DAR) is 10°C per 1000 meters (or 5.5°F per 1000 feet); the **moist (or saturated) adiabatic rate** (MAR) is 6°C per 1000 meters (or 3.3°F per 1000 feet). The DAR is used if the air is less than saturated; the MAR is used if the air is saturated.

Determining the level of stability or instability involves measuring and comparing simple temperature relationships between conditions inside an air parcel and the surrounding air. The following three terms describe the possible combination of conditions that can influence the lifting of an air parcel due to temperature and density differences between a parcel of air and the surrounding atmosphere. An air parcel is considered **stable** if the rising air is cooler than/or the same temperature as the surrounding air. An air parcel is considered **unstable** if the rising air is warmer than the surrounding air. An air parcel is considered **conditionally unstable** if in rising, it becomes warmer than the surrounding air only after it begins cooling at the MAR.

3) On graphs provided in **Figures 2, 3 and 4** plot the following data, using <u>color pencils to distinguish the different rates</u>. Begin with a surface temperature of 25° C as marked on each graph. <u>Indicate which stability condition exists for each graph</u>. **(6 points)**

a) On figure 2, plot an environmental lapse rate of 11° C per 1000 m, and DAR of 10° C per 1000 m and a MAR of 6° C per 1000 m.

b) On figure 3, plot an environmental lapse rate of 4.5° C per 1000 m, and DAR of 10° C per 1000 m and a MAR of 6° C per 1000 m.

c) On figure 4, plot an environmental lapse rate of 8° C per 1000 m, and DAR of 10° C per 1000 m and a MAR of 6° C per 1000 m.

Figure 2

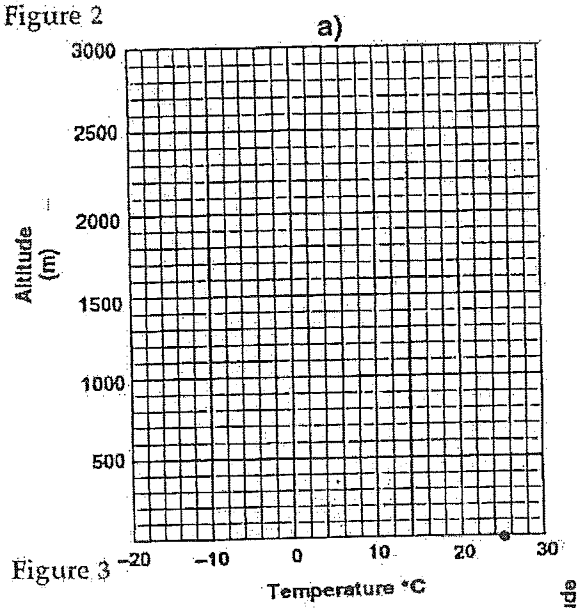


Figure 3

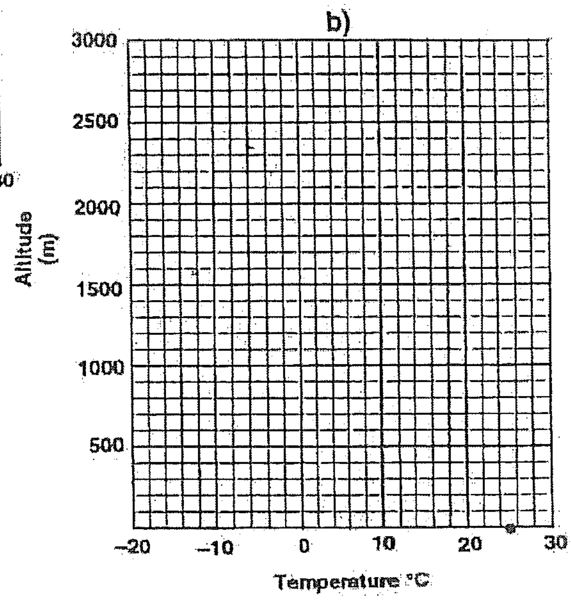
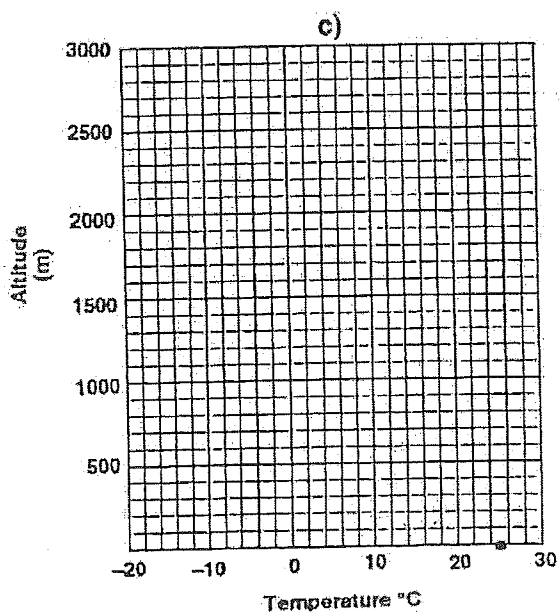


Figure 4



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Humidity, Stability and Adiabatic Processes

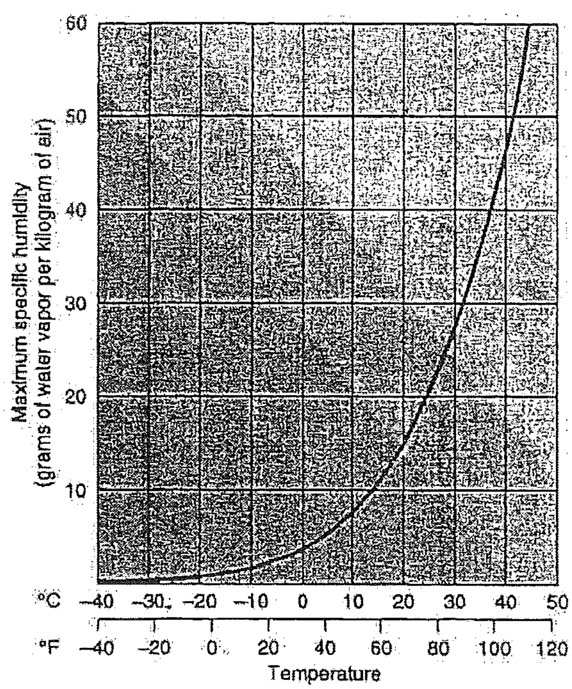
Humidity affects stability as can be seen in the following example. Refer to the graph accompanying **Table 2**. This shows the maximum specific humidity of air at various temperatures or in other words to maximum water vapor content of the air at various temperatures. For example, the maximum vapor content of air at 20° C (68° F) is 14 g (Vapor Capacity VC=14). If we know the actual vapor content of the air we can calculate the relative humidity for that parcel of air by dividing the specific humidity for that parcel (vapor supply or VS) by the vapor capacity (VC). For example, if a kilogram of air at 40° C has a specific humidity of 12 g, its relative humidity can be calculated:

VS ÷ VC = Relative Humidity

12 g ÷ 47 g = .255

.255 X 100 = 25.5 %

Table 2



Maximum specific humidity

Temperature	g/kg
-40	0.1
-30	0.3
-20	0.75
-10	2
0	3.5
5	5
10	7
15	10
20	14
25	20
30	26.5
35	35
40	47

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4) Assume that an air parcel has a specific humidity of 20 g/kg and a temperature of 26° C at an elevation of 0 meters. Assume a DAR of 10° C per 1000 m and a MAR of 6° C per 1000 m. Using the graph on **Figure 5** and **Table 2** answer the following. Note there is no ELR in this problem!

a) Determine the dew point temperature at which the rising air becomes saturated. **(1 point)**

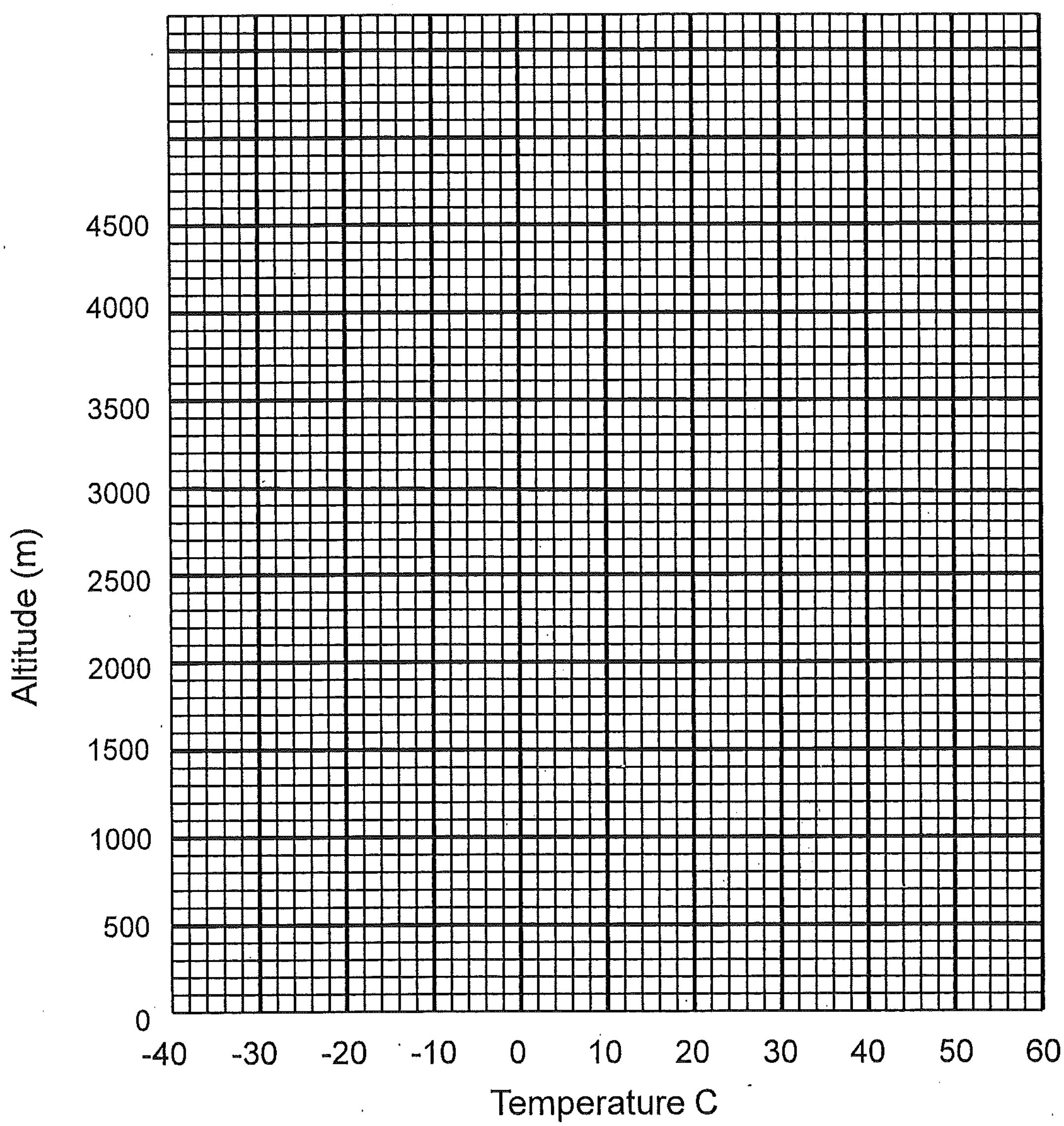
b) At what altitude will the saturation occur? **(1 point)**

c) At what altitude will clouds form? **(1 point)**

d) Assume this air mass is forced over a mountain summit at 3200 m. As the air parcel approaches the summit condensation and precipitation occurs and the air parcel has lost much of its water. In fact, at the summit our parcel now has a specific humidity of 2 g/kg. The air mass then descends down the lee side of the mountain. What will the temperature be after it descends down to 400 m? **(2 points)**

e) Briefly describe how *relative humidity* and *temperature* has changed in our parcel from when: 1) it first began to rise, 2) as it passed over the summit and 3) when it reached an interior basin at 400 m? Be specific as possible in your description. This is an example of what "effect"? **(8 points)**

Figure 5


4500
4000
3500
3000
2500
2000
1500
1000
500
0
Altitude (m)
-40
-30
-20
-10
0
10
20
30
40
50
60
Temperature C