Lab 7 for GEOL 1147 (Introduction to Meteorology Lab)

1.Introduction

Stability refers to the way a system responds to a disturbance. If the system spontaneously attempts to restore itself to the condition prior to the disturbance then the system is *stable*. If the system continues to move away from its initial condition after being disturbed then the system is called *unstable*.

When meteorologists refer to static stability they are interested in the way the atmosphere will respond to a disturbance that causes an air parcel to be displaced upwards or downwards. An air parcel can be lifted by a number of methods. One example is air that is forced to rise over a mountain barrier. If the air parcel continues to rise spontaneously after passing up and over the mountain, then the atmosphere is unstable (the air parcel continues to move away from its initial position after the disturbance is removed). If the air parcel returns spontaneously to its original elevation after passing over the mountain, then the atmosphere is stable. The response of an air parcel to a perturbation depends on the air parcel temperature and the environmental temperature (the temperature of the air surrounding the air parcel). If an air parcel is warmer than its surroundings, then it will be buoyant and will rise (since warmer air is less dense than cooler air). If the air parcel has the same temperature as its environment then the parcel will not move up or down. Finally, if the air parcel is colder then its environment, it will sink (since colder air is more dense than warmer air).

Meteorologists classify the atmosphere into four stability classes, according to the behavior of air parcels. These classes are **absolutely unstable**, **conditionally unstable**, **neutral**, and **absolutely stable**. The first two classes refer to situations where the air parcels that are lifted become warmer than their environment, and thus continue to rise. Recall from the thermodynamic diagram lab that an air parcel can be lifted via a dry adiabatic process or a moist adiabatic process. Also, remember that the temperature of the air parcel changes at a different rate for each of these processes. An air parcel lifted by a dry adiabatic process, cools at a faster rate than an air parcel lifted by a moist adiabatic process. Therefore, it is more likely for an air parcel that is lifted by a moist adiabatic process to remain warmer than the environment (since the air parcel cools off at a slower rate during this process). If an air parcel that is lifted by a dry adiabatic process is warmer than its environment, then the stability classification is **absolutely unstable**. If an air parcel is colder than its environment when lifted by a dry adiabatic process, but is warmer than its environment when lifted by a moist adiabatic process, then the stability classification is **conditionally unstable**. The *conditional* part of this classification arises because the instability is conditional on the air parcel being saturated and lifted by a moist adiabatic process. If an air parcel is lifted and has the same temperature as the environment then the stability classification is **neutral**. Finally, if an air parcel is lifted by either a moist or dry adiabatic process and is colder than its environment then the stability classification is **absolutely stable**. The following table summarizes the descriptions of stability classes in this section.

Stability Classification	Lifting Mechanism	Parcel Temperature compared to Environmental Temperature	Result
Absolutely Unstable	Dry Adiabatic Process	Warmer	Continues to rise
Conditionally Unstable	Dry Adiabatic Moist Adiabatic	Colder Warmer	Sink Continues to rise
Neutral	Dry Adiabatic Moist Adiabatic	Equal	Does not move
Absolutely Stable	Dry Adiabatic Moist Adiabatic	Colder	Sink

II. Exercises

1. Starting at the point on your thermodynamic diagram that has a pressure of 1000 mb and a temperature of 20°C, draw and label an environmental temperature profile up to 900 mb for each of the following conditions:

1a. An absolutely unstable condition

1b. A conditionally unstable condition

1c. An absolutely stable condition

2a. Plot the following data, collected by a radiosonde, on the thermodynamic diagram included at the back of this lab manual. The data represents the temperature structure of the atmosphere just before sunrise. Use the plotted data to answer questions 2b – 2e.

Pressure (mb)	Temperature (°C)
1000	0
950	4
900	0
850	-5
750	0

2b. Lift an air parcel dry adiabatically from 1000 mb, assuming that the air parcel initially has the same temperature as the environment, to a pressure of 900 mb. What is the temperature of the air parcel at 900 mb?

2c. Is the air parcel warmer or colder than the environment?

2d. What stability class would you use to describe the air parcel at 900 mb?

3a. Now, using the same sounding from problem 2, assume that the surface air has warmed to a temperature of 10°C by mid-afternoon, while the environmental temperatures at all other heights have remained the same. Lift an air parcel dry adiabatically from a pressure of 1000 mb with a temperature of 10°C, to a pressure of 900 mb. What is the temperature of this air parcel at 900 mb?

3b. Is the air parcel warmer or colder than the environment?

3c. What stability class would you use to describe the air parcel at 900 mb?

4a. Assume the afternoon temperature at the surface is still 10°C and the dewpoint is 3°C. What is the pressure at which clouds will begin to form if an air parcel with this combination of temperature and dewpoint is lifted dry adiabatically? Clouds will form at the CL, where the temperature and dewpoints are the same.

4b. Is the air parcel at cloud base warmer or colder than the environment?

4c. Will this air parcel continue to rise spontaneously from cloud base?

4d. Continue to lift the air parcel from cloud base, following a moist adiabat. At what pressure will the cloud top occur?

4e. How does the parcel temperature compare to the environmental temperature at cloud top?

5a. Plot the pressure, temperature, and dewpoint from the following table on the thermodynamic diagram included at the back of this lab manual. Use a solid line for sunset temperatures and a dashed line for sunrise temperatures. The data represents the temperature structure of the atmosphere at sunset and sunrise. The temperature change column is not plotted, but is there for a reference. You will use the temperature change data for question 5b

Pressure (mb)	Sunset Temp (°C)	Sunset Dew Point Temp (°C)	Temperature Change (°C)	Sunrise Temp (°C)	Sunrise Dew Point Temp (°C)
850	20	13	-12	8	8
800	15	11	-3	12	11
750	9	5	-2	7	5
700	5	0	-1	4	0
650	2	-7	0	2	-7
600	0	-15	0	0	-15

During the night, the temperature cools by the amount listed in the fourth column of the table in question 5a. Usually, the atmosphere cools most near the surface at night and much less aloft, as indicated in the table. The new morning temperatures based on the temperature changes are listed in 5^{th} column. If the air temperature cools to a value lower than the sunset dewpoint, we assume that water vapor condenses during the night as the air cools, at a rate that allows the dewpoint to decrease and remain exactly equal to the air temperature.

5b. Based on the sunrise temperature (fifth column) and dewpoint profile (sixth column) mark the layer that becomes foggy overnight. Realize that fog forms at all heights where the dew point and ambient temperatures are equal.

5c. Explain why fog usually forms overnight and not during the daytime.

5d. It is often observed that fog initially forms close to the surface and that during the night the depth of the fog increases. Why is this?