Humidity

A lot of people find that the general topic of moisture in the atmosphere is the most difficult of the topics in Introductory Physical Geography. This little tutorial might help you understand the basics of these concepts a little better.

Water

Just a brief look at water and some of its properties.

Changes in State and Latent Heat

The physical states of water, and how energy is involved in changes of state.

Expressing Humidity

How do we describe the humidity of the air? Here are several ways to express humidity, including everyone's favorite, relative humidity. Also, a brief discussion of the relationship between humidity and temperature.

Adiabatic Processes and Lapse Rates

What happens to air when it is lifted? It is very important to understand how adiabatic processes work, if you want to understand what happens to moisture in the atmosphere.

The Mountain

Most physical geography classes have that mountain. Let's move up the mountain, lifting air up, cooling it off, wringing it out, then taking it down to the rainshadow on the far side.

Back to Home Page

mailto:jthorn@mail.sdsu.edu

08/01/02

Adiabatic Processes and Lapse Rates

Adiabatic Processes **Lapse Rates** **Key Points**

Adiabatic Processes

Let's look more closely at how the air changes temperature when it rises or subsides. We know that warm air rises, and when it rises it becomes cooler. If you remember that, you can reason your way through a lot of meteorology.

Rising air experiences a drop in temperature, *even though no heat is lost to the outside*. The drop in temperature is a result of the decrease in atmospheric pressure at higher altitudes. If the pressure of the surrounding air is reduced, then the rising air parcel will expand. The molecules of air are doing work as they expand. This will affect the parcel's temperature (which is the average kinetic energy of the molecules in the air parcel). One of the results of the Laws of Thermodynamics is that there is an inverse relationship between the volume of an air parcel and its temperature. During either expansion or compression, the total amount of energy in the parcel remains the same (none is added or lost). The energy can either be used to do the work of expansion, or to maintain the temperature of the parcel, but it can't be used for both. If the total amount of heat in a parcel of air is held constant (no heat is added or released), then when the parcel expands, its temperature drops. When the parcel is compressed, its temperature rises. In the atmosphere, if the parcel of air were forced to descend, it would warm up again without taking heat from the outside. This is called adiabatic heating and cooling, and the term adiabatic implies a *change in temperature* of the parcel of air *without gain or loss of heat* from outside the air parcel. Adiabatic processes are very important in the atmosphere, and adiabatic cooling of rising air is the dominant cause of cloud formation.

Lapse Rates

For the atmosphere, the drop in temperature of rising, unsaturated air is about 10 degrees C/1000 meters (5 ½ deg F per 1000 feet) altitude. If a parcel of air is at 24 degrees C at sea level, and it rises to 1000 meters, its temperature will go down to 14 degrees C. If it goes up to 2000 meters, its temperature will go down to 4 degrees C. Question: What will its temperature be at 3000 meters? Answer 1A.

This rate of temperature change of unsaturated air with changing altitude is called the dry adiabatic lapse rate: the rate of change of the temperature of rising or subsiding air when no condensation is taking place (we'll talk about the condensation part shortly).

If the air subsides, it also changes temperature. It *warms up*, and it is warming up at the dry adiabatic lapse rate. So, if the air at 4000 meters altitude has a temperature of -10 degrees C, and it subsides to 3000 meters, its temperature will warm up to 0 degrees C. If it continues to subside, then at 2000 meters, its temperature will be 10 degrees C. At 1000 meters, its temperature would be _________. Answer 2A.

Make sure you notice that we are talking about *moving air* (rising or subsiding), *not still air*. The change in temperature of still air (that is, air that is not rising or subsiding) follows the Environmental Lapse Rate, which varies considerably, but averages about 6.5 deg C/1000 meters (3.6 deg/1000 feet). In still air, if you went up in a hot air balloon, carrying a thermometer and taking the air temperature every 1000 meters, on average the temperature would drop 6.5 degrees C every 1000 meters. The rate of temperature change as you rise in still air is not as great as the rate of change of rising air; that is, the air parcel does not cool off as fast.
For instance, the air temperature at sea level is 28 degrees C. Climb into your balloon, release the tethers, and go up 1000 meters in the still air. On average, the air temperature 1000 meters up will be _________ degrees C. Answer 3A. If the air were rising, and the temperature at sea level was 28 degrees C, what would the temperature of the air be after it rose 1000 meters? Answer 3A1.

Let's abandon the still air for the moment, and return to the air which is rising, and getting colder. Remember what happens to relative humidity when air temperature decreases? Ok, what does happen to the relative humidity of a parcel of air when the temperature decreases? (You have two choices here, either the relative humidity decreases or it increases. This is a VERY IMPORTANT point for you to understand, so stop and think about it before you rush off to click on the answer).

If you've thought enough, and are absolutely sure of your answer, check it: Answer 4A.

You can maybe see what's coming next. If the air is rising and cooling at a rate of 10 deg C/1000 meters, (5.5 deg/1000 feet), eventually, it's going to cool off enough for the relative humidity to reach 100%, and condensation can take place. The dew point is the temperature at which the air becomes saturated and condensation takes place (Note: dew point is a *temperature*, given in degrees C or F). The lifting condensation level is the altitude at which condensation begins (Note: lifting condensation level is an *altitude*, given in meters or feet). You can look up at the windward sides of mountains and see where the lifting condensation level is, because that is where you will see the bases of clouds that have formed.

Here's where it gets a bit complicated. Remember what happens when water changes state: when water evaporates, heat is __________ (Answer 5A). When water condenses, heat is _________ (Answer 6A).

So, if condensation is taking place, latent heat is being released to the surrounding air. So you have two opposing trends going on at the same time within this parcel of air. It's rising and cooling, but it's also condensing and being warmed. Which one will win out? That is, will the air get colder, or will it get warmer?

Well, what happens is that the air will still cool off, but not as fast. If water vapor in the air is condensing, the adiabatic rate is less. The air is only cooling off at a rate of about 5 degrees C/1000 meters (2.7 deg per 1000 feet). This is called the Saturated adiabatic lapse rate (or the wet adiabatic lapse rate, or the moist adiabatic lapse rate, depending on the textbook you are using). The saturated lapse rate varies with the original temperature of the air parcel, but 5 degrees C/1000 meters is a commonly used value.

So, let's assume a rising parcel of air reaches the lifting condensation level at 2000 meters, at a dew point temperature of 12 degrees C. At this point, clouds will form. As the air continues to rise, it will continue to decrease in temperature, but more slowly than it cooled off before condensation began. What will the temperature of this parcel of air be at 3000 meters? Answer 7A.

Question: if air is subsiding (say, it has gone over the crest of a mountain range, and is flowing down the leeward side of the mountains), will the temperature increase or decrease, and (assuming that all the moisture was removed from the air as it rose up the windward side) which lapse rate would you use to figure out the exact amount of change? (Two parts to this question; think about both before checking answer 8A).

Key things to remember:

- when air rises, its temperature decreases
- when air subsides, its temperature increases
- when the temperature of a parcel of air decreases, its relative humidity increases
- when the temperature of a parcel of air increases, its relative humidity decreases
- the normal environmental lapse rate applies to still air
- the dry adiabatic lapse rate applies to rising air, when the relative humidity is below 100%
- the dry adiabatic lapse rate also applies to air that is subsiding, if there is no moisture present, and no evaporation is taking place

- the saturated adiabatic lapse rate applies to rising air, when the relative humidity has reached 100%, and condensation is taking place

Now that you've got all that, try practicing moving air up and down a mountain, to see what happens.

Back to Humidity Start Page On to The Mountain

Back to Home Page

mailto:jthorn@mail.sdsu.edu

07/21/05

Answers:

1A. The temperature would be minus 6 degrees C.

2A. It's temperature would be minus 20 degrees C.

3A The temperature would be 21.5 degrees C.

3A1. The temperature of the rising air would be 18 degrees C, cooler than the still air; the lapse rate is greater.

4A. If the temperature of the parcel of air decreases, the relative humidity increases. This is a KEY point. If you did not answer this correctly, you really should go back and review the explanation of relative humidity.

5A. Absorbed.

6A. Released.

7A. The temperature at 3000 meters will be approximately 7 degrees C. The Saturated adiabatic lapse rate is given as 5 deg C/1000 meters, so if you go up 1000 meters, the air will cool off 5 degrees. 12-5=7.

8A. Air which is subsiding will be increasing in temperature. If we assume that there is no moisture left in the air (which may not always be the case), the applicable rate is the Dry Adiabatic Lapse Rate.