AYORINDE IDOWU

Fall 2016

Signature Assignments: (Empirical and Quantitative Reasoning)

GEOL 1304 (Introduction to Meteorology) – all sections

GEOL 1345 (Oceanography) – all sections

Activity/Project

Weather Formation: "The Stories that Clouds Tell" (class and/or online activity) investigates the science and characteristics of Clouds and related weather in the Earth/Atmosphere system.

Introduction/Background Information

The investigation exercise involves a Hands-on-Approach to the Basic Concepts of Meteorology and Oceanography. It examines the science and characteristics of a cloud including different types of clouds and consequent weather types. A cloud does not float like a piece of paper in water, but a dynamic entity through which air is constantly moving while most clouds are constantly being created and destroyed. There are many things to watch for in the sky, and the clouds illustrated in this exercise are just a sample of the incredible variety one can see (refer to Attachment 1). You can watch a particular cloud for a long period of time to observe how it changes. You can also compare clouds move and others seem to stay in one place to encounter the fascinating stories being told by the clouds overhead.

Clouds come in many different shapes and sizes and tell us a great deal about what the atmosphere is doing in forming weather conditions. Some clouds can produce tornadoes and others are indicative of fair weather. This exercise on "The Stories Cloud Tell" is an investigation on what clouds are, how they form, and what we can learn by watching the sky.

Materials:

- "The Stories Clouds Can Tell" Book (Study Attachment 2)

Read pages 1 – 6 in the Book and answer the questions (Answer all Questions on Attachment 1)

[ATTACHMENT 1]

Investigation 10: The Stories Clouds Tell

In this Investigation:

A. What is a Cloud?

B. Types of Clouds

Introduction

Clouds come in many different shapes and sizes and can tell us a great deal about what the atmosphere is doing. Although they appear to float in the sky, they are actually constantly moving and changing. Some clouds can produce tornadoes and others are indicative of fair weather. "The Stories Clouds Tell" takes an in-depth look at what clouds are, how they form, and what we can learn by watching the sky.

A. What is a Cloud?

Materials:

- **"The Stories Clouds Tell" Book***

Read pages 1-6 in the book and answer the following questions.

1. Clouds can be made up of **[(*water droplets*) (*ice crystals*) (*either*)]**.
2. Falling **[(*snow*) (*rain*)]** is more difficult to see through because it more efficiently scatters light.
3. At the same pressure, cold air is **[(*less dense than*) (*more dense than*) (*equal in density to*)]** warm air.
4. Evaporation is a **[(*warming*) (*cooling*)]** process in which water absorbs heat. This explains why we feel cooled when getting out of a swimming pool. Condensation is a **[(*warming*) (*cooling*)]** process in which heat is released.
5. If the temperature in a cloud is **[(*warmer*) (*cooler*)]** than its environment, it will be buoyant and continue to rise.

B. Types of Clouds

Read pages 7-30 and answer the following questions.

6. [(***Smoke plumes***) (***Lenticular clouds***) (***Cumulus clouds***)] are lens shaped and form when the air in the cloud has been forced upward by a mountain or other barrier.

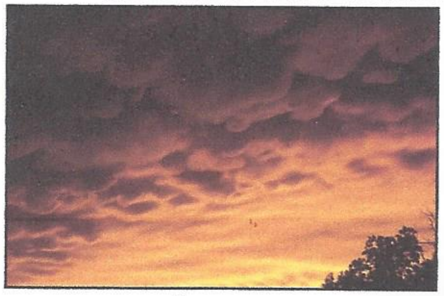
7. Cumulus clouds grow upward and are a form of [(***stable clouds***) (***unstable clouds***) (***ice clouds***)].

8. Large hailstones can form inside of a thunderstorm and are associated with [(***strong***) (***weak***)] updrafts.

9. [(***Cumulus***) (***Cirrus***) (***Mammatus***)] clouds are made up of ice crystals and are found very high in the atmosphere.

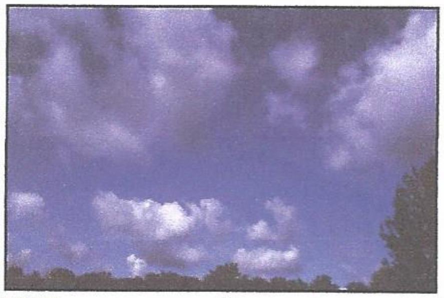
10. [(***Smoke plumes***) (***Contrails***)] are formed by the exhaust left behind by jet airplanes. They provide information on humidity and air motions at that level of the atmosphere.

11. Match the cloud types listed below to the corresponding pictures.
    [(***cumulus***), (***cumulonimbus***), (***cirrus***), (***mammatus***), (***contrails***)]



a.

b.



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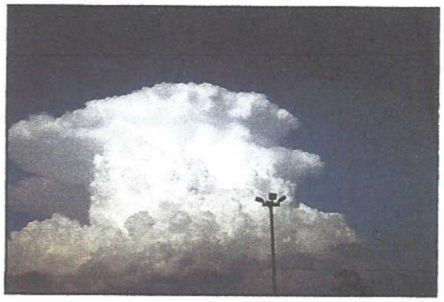


e.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

12. Walk outside and observe the sky. What do you see? Are there any clouds to analyze? What do they tell you about the stability of the atmosphere? If possible, estimate the height of the cloud base. If they are leaving shadows on the ground, estimate their width as well.

[ATTACHMENT 2]

What is a Cloud?

We can't see air move, but we can learn about the wind in other ways. We can watch leaves blowing or kites flying, feel the wind on our faces, and listen to the sound the wind makes. In much the same way, clouds greatly expand our ability to learn about what's happening in our atmosphere. They can be found from the surface to 10 kilometers (6 miles) and higher above Earth. Cloud shapes tell us whether the air is bumpy or smooth. Cloud movement tells us where the air is flowing and how fast. Cloud presence or absence can tell us where the moisture is. How clouds grow or die can give us an idea about whether a storm might happen. And clouds are always changing, so there is always something new to discover and enjoy.

How can you learn about the atmosphere from the clouds? The first requirement to learn about clouds is to take time to look up at the sky.

Somewhere in the atmosphere, lots of little water drops or ice crystals are forming together. Where there was clear sky, now we can see a patch of white take shape and grow. If the patch is above the ground, we call it a cloud. How does the cloud form? Why does it look the way it does? How long will it last? Let's explore these questions. With some basic information and a little practice, you will learn how to read the stories clouds tell.

Size

Clouds come in many shapes and sizes. Satellite pictures show that layers of clouds can be thousands of kilometers across. Clouds can extend from just above the surface to the top of the troposphere—a height of 5–20 kilometers (3–12 miles). Or clouds can be smaller than a few hundred meters across. We can estimate the size of a typical cumulus cloud rather simply by watching its shadow on the ground. Figure 1 shows the shadow of a cloud on the ground as observed by people on a nearby mountain or an airplane. In the figure, horizontal distances are easily estimated because the roads are about a mile apart. These so-called section roads are common in the flatter terrain of the Midwestern and Western United States. Thus the cloud is about 0.6 miles, or about 1 kilometer (1000 meters), across.

The tiny water droplets or ice crystals that make up a cloud are about one-hundredth the diameter of a typical raindrop, which is usually a few millimeters across or the size of a grain of sand.

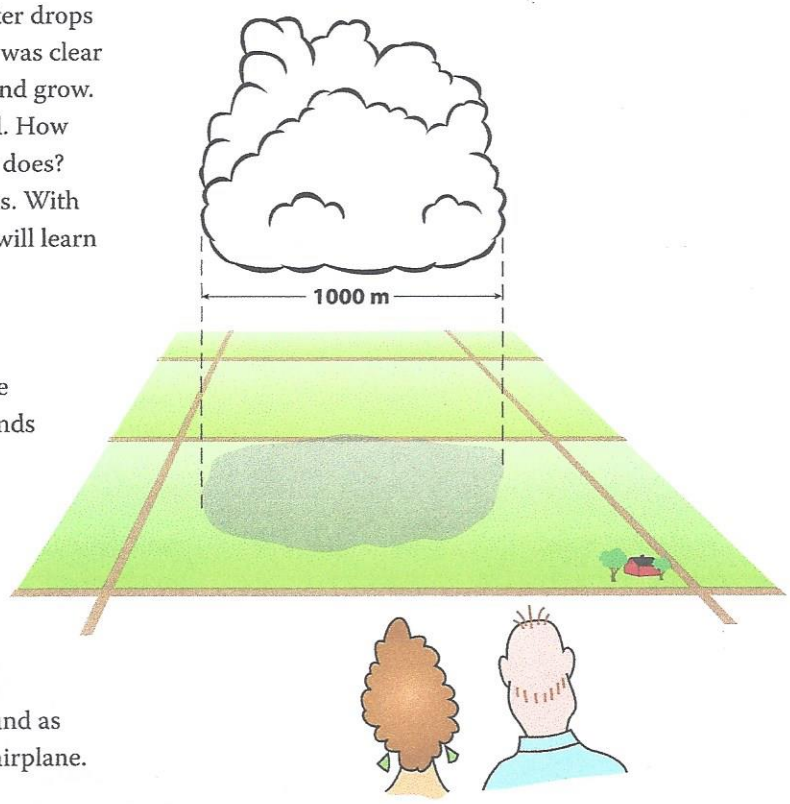


Figure 1. Schematic of cloud over section roads in the western United States. Since section roads are 1 mile apart, the cloud is roughly 0.6 miles or 1000 meters across. The picture shows that it is also about 1000 m deep. Thus, we idealize the cloud as a cube.

Mass

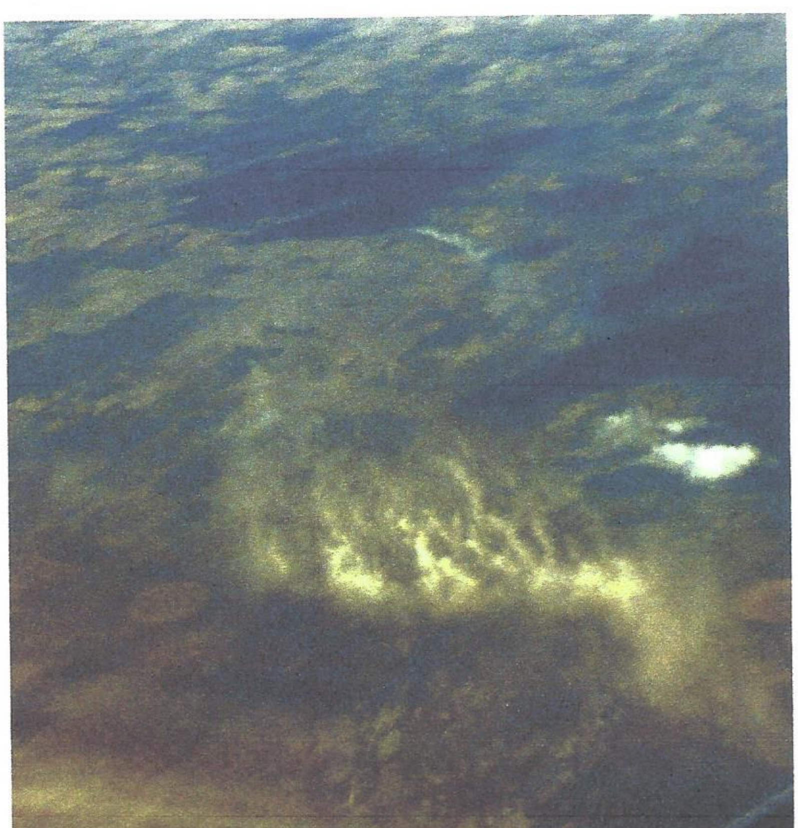
Typically, clouds like this have about 0.5 grams of liquid water for each cubic meter of air. The mass M of the water in the cloud in Figure 1 is:

> M = (0.5 grams per cubic meter) × (1000 m) × (1000 m) × (1000 m) = 500,000,000 grams or 500,000 kilograms. This is about 110,000 pounds or 550 tons, about the weight of a fully loaded Boeing 747 aircraft. (See *The USA TODAY Weather Book*, by Jack Williams.)

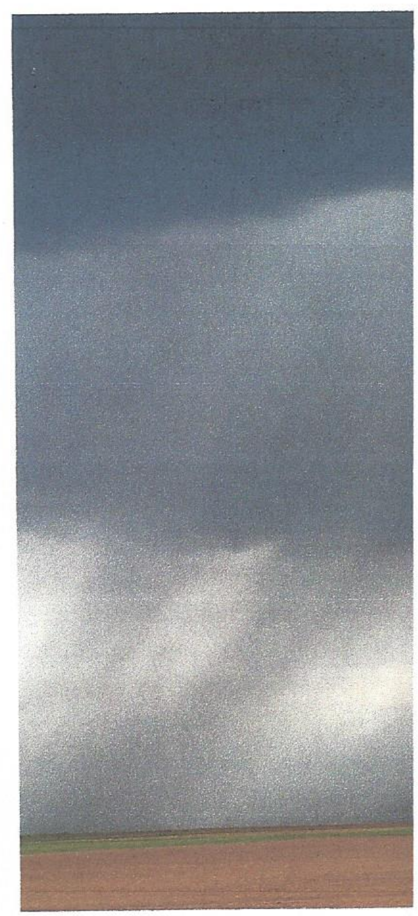
Since clouds are so heavy, why don't they simply fall to earth? This question can be answered by doing a simple experiment. Take a piece of paper, wad it up, and drop it. How fast does it drop? Now tear a corner off the paper, wad that up, and drop it. How fast does the smaller piece drop? Repeat this experiment with a tiny piece of the paper. What happens? The smallest piece falls most slowly. The cloud particles, being even smaller, need only weak air currents to keep them aloft. Thus a cloud, like the dust in Figure 2, shows how air moves.

Why is a cloud visible? A typical cumulus cloud has only 0.5 grams of water in a cubic meter. This is only l a cubic centimeter of water—or about the volume of a small marble. At first it is surprising that a cloud with little water would be visible at all. But the cloud is visi because the water is divided into so many tiny drople Think of a cup of flour. If you put it on the windowsill you can still see out the window pretty well. What if y wet the flour and divided it into marble sized balls, ar then threw them up in the air in front of the window? For a moment, your view of the outdoors would be partially blocked by lots of flour balls. If you went one step further, and had someone sift the flour in front o window, the many tiny particles would create a fog th would completely block your view. Or, if you wanted be systematic, you could use the cup of flour to coat t window. Dividing the flour–or water–into tiny partic increases the surface that can block your view.

Figure 2. Since cloud drops are so tiny, they move with the air's motions, just like the dust in this picture. Thus the shape of a cloud tells a lot about the air motion in the cloud.



(a)



(b)

Figure 3. Clouds and precipitation. (a, below) Cloud and rain over eastern Colorado. Although the rain has a similar liquid water content to the cloud, we can see through the rain because the water is concentrated into fewer, larger drops. Photo by Carlye Calvin. (b, right) Cloud with light to moderate snow over Delaware, photographed after driving 15 miles to the northwest of the system. Scattering by the many facets on the snowflakes make the snow opaque.

Raindrops are much larger than cloud drops, so you can often see through rain, even though the water content can be as high or higher than 0.5 grams in a cubic meter (gm/m^3). What is the water content of a typical rainfall? Suppose the rain is rather heavy, about 2.4 centimeters (just under an inch) falling in an hour. We're looking for water content in a cubic meter of raindrops, so we'll compute how much water falls on a square meter of ground in that hour. A gram of water occupies one cubic centimeter, so each square centimeter (cm^2) has 2.4 grams of water on it, which is the same as (2.4 grams/cm^2) × (100 cm/m) × (100 cm/m), or 24,000 grams of water per square meter. In one second, our square meter receives (24,000/3,600) or 6.67 grams of water. Raindrops fall at about 8 meters per second, so one cubic meter's worth of rain falls in one-eighth of a second, giving us (6.67/8) or 0.83 grams of water per cubic meter. Figure 3a shows a cloud with falling rain. Note that you can see through the rain, but not the cloud, because the rain water is concentrated in a few large drops.

Snow is a different matter. Figure 3b shows a cloud with light to moderate snowfall. Snowflakes scatter light more efficiently than water drops of the same mass. Snowflakes are flat with many tiny facets exposed, providing much more surface area to scatter light. In addition, ice scatters light more efficiently than water. The result is that the falling snow is more difficult to see through.

Making Clouds

You can understand how a cloud is formed if you know a few basic facts.

First, regarding condensation and evaporation of water:

a. The maximum possible amount of water vapor in the air increases with temperature.

Molecules of liquid water need energy to evaporate (become gas). The kinetic energy of molecules goes up with temperature. So warmer water evaporates faster. Laundry dries faster in summer than winter. The hot pavement around swimming pools also quickly dries. But cold basement floors take a long time to dry.

This is why dew forms at night. Cooler temperatures allow for less water vapor, so the extra water vapor condenses (becomes water) as dew.

This is sometimes mistakenly phrased as "Warm air can hold more water than cold air." Why is this misleading? It's because the maximum amount of water vapor possible at a given temperature would be the same even if there were no air present. So, strictly speaking, the air doesn't "hold" the water vapor—but the air temperature does tell us how much water vapor could potentially be present.

b. When water condenses, it releases heat; when water evaporates, it absorbs heat.

Water molecules use energy to leave their liquid phase; this is observed as a drop in the temperature of the surroundings. Thus, we are cooled or even chilled when getting out of a bathtub, shower, or swimming pool (Figure 4), and perspiration cools us off as it evaporates. The reverse happens when water vapor condenses.

Second, regarding air:

a. Air cools as it rises and warms as it sinks.

The air in the troposphere moves up and down a lot. Sinking air warms, because its molecules gain energy as the air is compressed by the surrounding air. The opposite happens with rising air. Air cools as it rises because it expands, due to the air pressure decreasing with height (there's simply less air pushing down). When the air expands, it uses up energy by pushing the surrounding air outward as it expands. The molecules in the air lose energy and slow down.

Since temperature is a measure of the energy of the molecules, the temperature falls when the molecules slow down. As a result, the temperature normally decreases with height. We know this if we've ever driven up a mountain road in the summertime to escape the heat, or heard the pilot announce the outside temperature when a jet aircraft reaches cruising altitude.

Figure 4. The evaporation of water off our skin chills us when we get out of a swimming pool or shower. Cartoon by Sarah Gilman, age 10.

Rising air cools at a rate of 5.5 degrees Fahrenheit for each 1000 feet of altitude, or 10 degrees Celsius per 1000 meters (Figure. 5). On average, the air is not only cooler at greater heights, but drier as well. This is because less water vapor per unit volume can exist at colder temperatures.

b. When air rises high enough, it becomes cool enough for water vapor to condense.

We know less water vapor is allowed at colder temperatures. After air has risen high enough, it becomes cool enough for the water vapor to begin condensing, and a cloud forms.

The height at which water vapor begins to condense is called the lifting condensation level (LCL), or simply the condensation level (Figure 6). The vapor condenses on tiny dust particles that serve as nuclei for cloud drops that start off very small.

c. When water vapor is condensing in rising air, the air cools more slowly.

The release of heat by condensing water vapor partially cancels out the air's cooling from expansion. On average, the net or observed cooling rate is reduced to about 3°F per thousand feet, or 6 degrees Celsius each 1000 meters (Figure 7).

d. Warm air is less dense than cold air.

Higher temperatures mean more energetic molecules. These molecules, traveling at higher speeds, push each other apart.

e. Characteristics of the clear air surrounding the clouds.

As noted before, the temperature in the troposphere typically decreases with height. So does water vapor content. This is largely because water vapor condenses out of the air at colder temperatures. Roughly, the maximum possible water vapor content is halved for every 11°C (51.8° F) drop in temperature.

The temperature and water vapor content in the air near the surface change all the time. This is true for temperatures and humidities higher up as well. It follows that the rate at which temperature and water vapor content varies with height also changes.

Figure 5: The hiker at 10,000 feet (3050 meters) is more comfortable than the hiker at 6,000 feet (1830 meters) because the temperature cools with height.

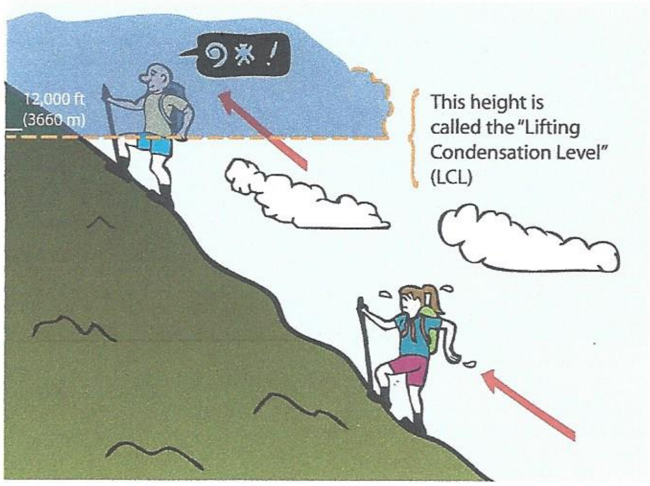


Figure 6. When the air is cool enough, the water vapor in the rising air condenses.

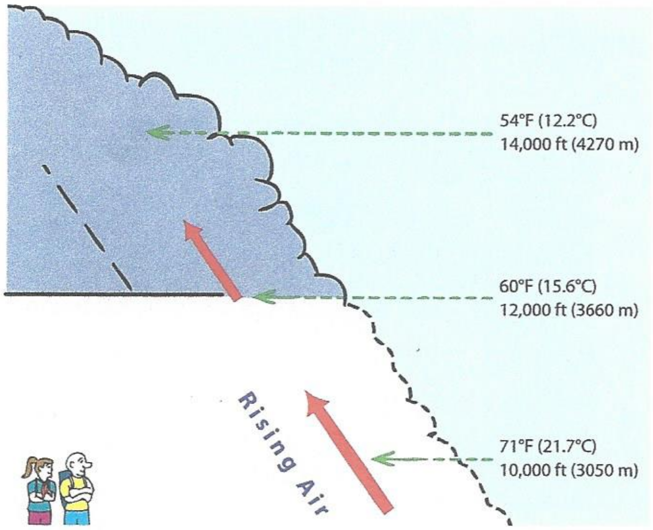


Figure 7. Because condensation releases heat, rising air cools more slowly.

The type of air motion in a cloud, and hence what a cloud looks like, is related to how the temperature compares inside and outside the cloud. If the temperature in the cloud is warmer than its environment, as in Figures 8a and 9, the air in the cloud is buoyant, and will continue to rise. While the temperature in the cloud decreases with height, the temperature in the environment decreases even faster. The rising air in the Figures is marked by the cloud's flat base. The base is sharp because of the many tiny drops. It is flat because all of the rising air at cloud base has the same water-vapor content and hence the same lifting condensation level. The billowing top of the cloud marks the top of the rising air currents. Note that the edges are still sharp, showing that many tiny drops are present. There are also larger bumps on top formed by the "bubbles" of rising air. This cauliflower-shaped cloud is called a cumulus congestus cloud.

In contrast, the air in the lens-shaped lenticular cloud in Figures 8b and 10 is colder and hence heavier than its environment. The temperature in the cloud decreases with height faster than the temperature in the environment. The air in the cloud rises and sinks simply because it has been forced over the mountain. The top as well as the bottom of the cloud is smooth. In this kind of cloud, the water in the air condenses on the upwind side and evaporates on the downwind side.

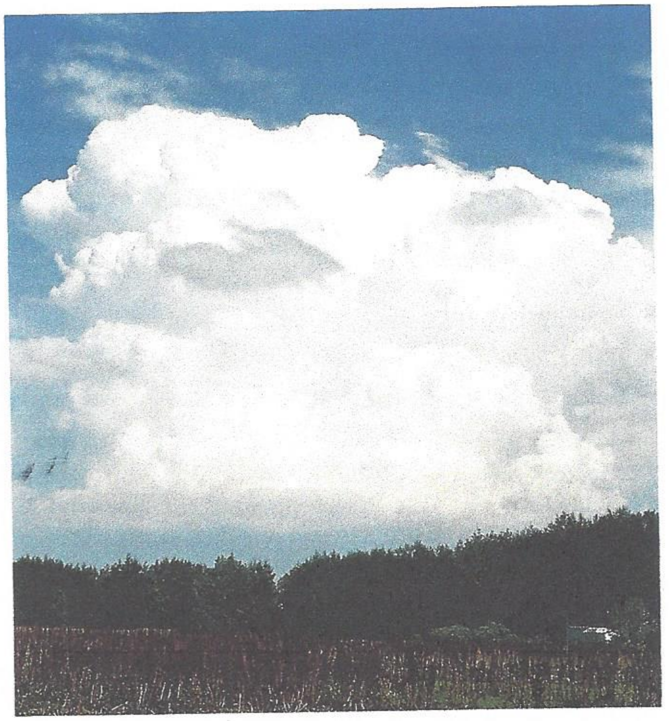


Figure 9. Growing cumulus congestus cloud. In this cloud, the rising air accelerates upward because the air in the cloud is warmer (lighter) than the air around the cloud.

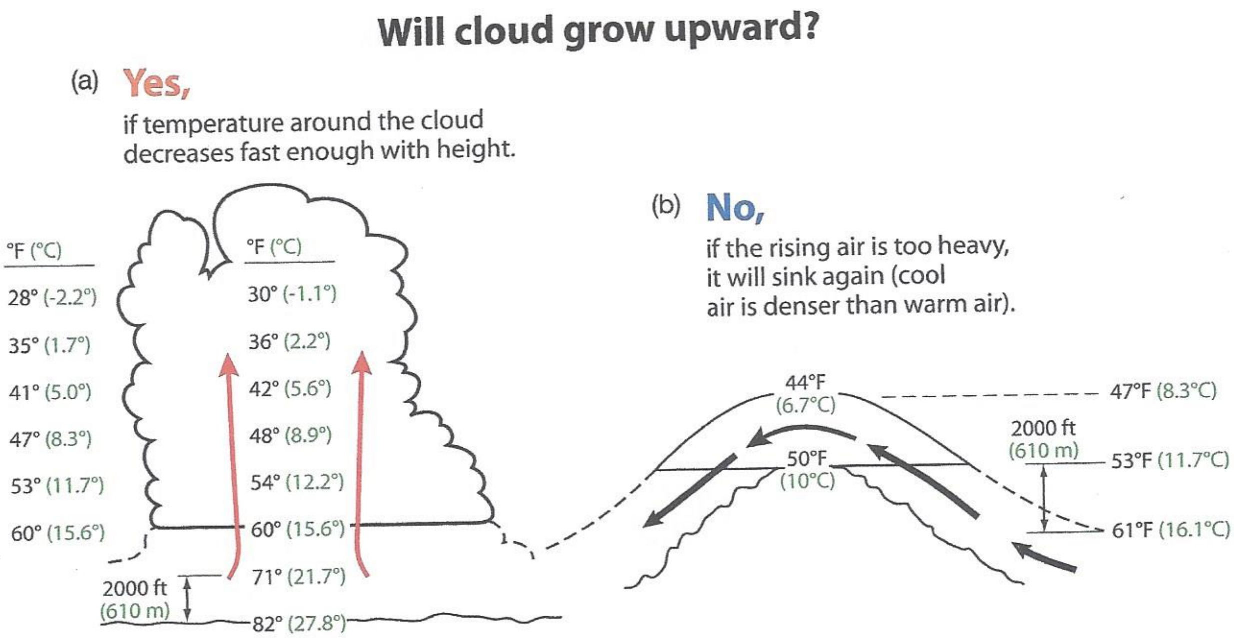


Figure 8.Schematics of (a) cumulus congestus cloud in Figure 9, (b) lenticular cloud in Figure 10. The environment is unstable in (a) and stable in (b).