Water in the Troposphere
How to Make a Cloud

We must have a clear understanding of the relationship between pressure and temperature in the lower atmosphere before we can examine the process of cloud formation. To review, as air is heated its pressure increases and its density decreases. The decrease in density as air warms allows more space for water vapor to occupy. This is the reason warm air evaporates water faster than cool air.

Now we can explore how water in the lower atmosphere moves around as a result of heating from the surface. The result of this movement is the formation of clouds which move across the sky, transporting water from the oceans inland.

Clouds are liquid water droplets held up in the air by warm air rising. All the water in clouds comes from the surface of the earth. Heat evaporates liquid water, which rises in the warm air. The amount of water vapor in the air is described as humidity. The amount of water vapor air holds is related to the temperature of the air. Cool air, being more dense, cannot hold as much water vapor as warm air. With this in mind, we always describe the amount of water vapor in air relative to the temperature of the air. This amount of water vapor in air is measured as a percent of the total amount of water vapor air could hold at a given temperature. On the weather report humidity is described as relative humidity, meaning the percent of water vapor related to the temperature of the air.

When air is full of water vapor it is described as 100% relative humidity. Air at 100% relative humidity is referred to as saturated. This simply means the air cannot hold any more water vapor. Once air exceeds 100% relative humidity, the water vapor starts to turn back into liquid water, which we see as clouds. We can now identify two ways for an air mass to reach 100% relative humidity:

1. If we cool air its density increases, which lowers the amount of space for water vapor. So without adding any moisture to air, we can saturate the air by cooling it. By cooling air we reduce the area available for water vapor, resulting in liquid water droplets forming. We see this liquid water as clouds in the atmosphere.

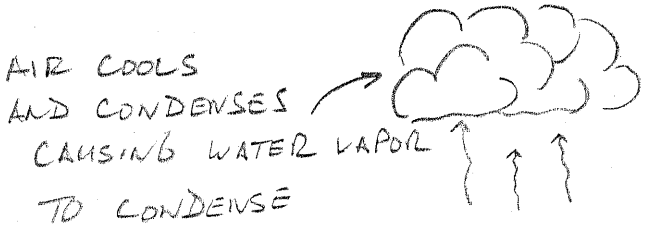
2. A second way to saturate air is to add more water vapor. This is easy to understand if we remember that air can only hold a certain amount of water vapor before the air is full. If we try to add water vapor to saturated air, it forms clouds.

These two processes cause clouds to form in the troposphere. Now we are ready to apply this understanding and determine some different ways to make clouds in the atmosphere. There are many kinds of clouds in the troposphere. The shape and color of clouds is the result of the size of water droplets and the state of the water in the clouds. Some clouds are made of ice, while others are liquid drops of water .

How to Make a Cloud

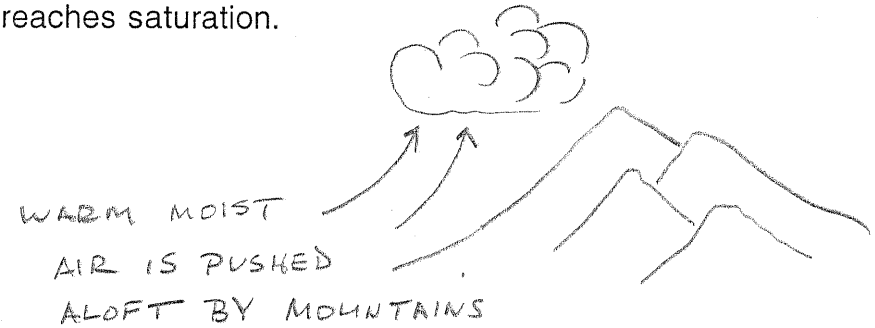
Clouds above the ground are generally formed by cooling the air. As warm air rises, it cools due to the lower pressure in the atmosphere. When air cools it becomes more dense, which lowers the air's ability to hold water vapor. Clouds form when the rising air reaches the saturation point or 100% relative humidity. There are a number of ways to lift air in the atmosphere. We will examine the three most common ways air is lifted in the troposphere around Castle Rock. The shape and location of clouds in the atmosphere are an indication of the lifting process at work.

1. Convective Uplift - This process relates back to the behavior of matter when it is heated. Anytime air is heated, it becomes less dense. The reduction of density causes the air to rise because it weighs less than the air above it. As the air rises, it carries water vapor with it that has been evaporated from the surface. Convective uplift is associated with heating at the surface of the earth. The earth's surface heats up in summer more than winter, so convective uplift is most common in the warmer months of the year. We see a specific kind of cloud form from convective uplift. Cumulus clouds are the result of warm air rising, due to heating at the surface. These types of clouds form near the surface, where sunlight is being converted to heat.

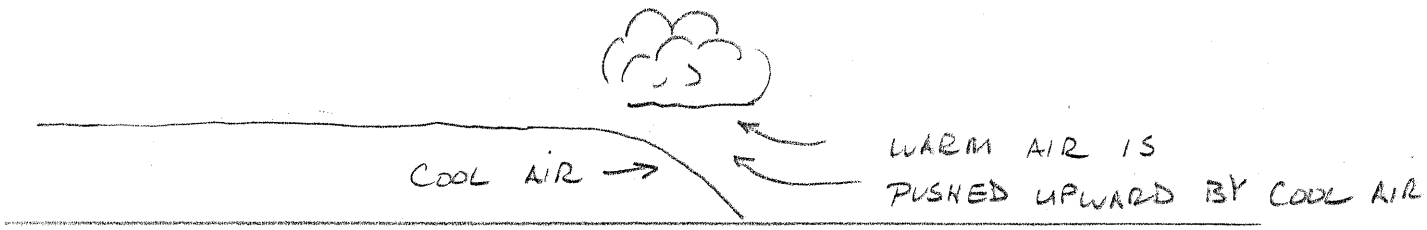


HEAT FROM SURFACE CAUSES AIR TO RISE

2. Orographic Uplift - This lifting process is common around mountains. The word orographic means related to mountains. If air is pushed against mountains, it must move upward, resulting in cooling. This process is often referred to as forced ascent, because the air has nowhere to go but up when it is pushed into mountains. We see clouds formed by this process in the foothills of the mountains to the west. In summer, air warms quickly in the lower elevations of the eastern plains of Colorado. As this air expands and rises, it pushes up against the Rocky Mountains and is forced upward. We see clouds form along the foothills of the mountains as the rising air cools and reaches saturation.



3. Frontal Uplift - This process lifts air by having cool air slide beneath warm air, which pushes the warm air upward. We have all heard the weather forecaster mention the word cold front on the T.V. newscast. A cold front is a mass of cool air that moves down from the north into Colorado. The cool air is more dense and, therefore, stays close to the ground. As this cool air collides with warm air, it pushes the warm air upward. The warm air contains more water vapor, and as this warm, moist air is pushed upward, it cools, resulting in saturation and the formation of clouds along the cold front. This type of uplift occurs in winter as well as summer.



We can now start to look at different kinds of clouds and where they form in the atmosphere. The height of clouds above the ground is an indication of the temperature and relative humidity at the surface. Let's examine some different kinds of clouds to determine how they are a product of the conditions at the surface.

When clouds form near the ground, it indicates that the air at the surface has a high relative humidity. The air does not need to be lifted very much to reach the saturation point and form clouds. We see this condition in humid climates like the eastern part of the United States during the summer months. The relative humidity is often above 80%, so the air only needs to be lifted a few thousand feet to reach saturation and form clouds.

When clouds form at high altitudes, it indicates the air near the surface has a low relative humidity. The height of the clouds means the air had to be lifted a lot to cool it enough to reach the saturation point where clouds form. To lift air to high altitudes, it also requires a high temperature at the surface. These high altitude clouds are often made of ice and look quite different than low altitude clouds.

In some cases, clouds form at the surface. We refer to this condition as fog. Fog can form a number of ways, but it always indicates a condition of 100% relative humidity at the surface. The air cannot hold the water vapor that is being evaporated from the surface because it is already saturated.

With this information we can now understand why clouds in Colorado form at a higher altitude than they do in a humid climate. A typical thunderstorm in Colorado will have a cloud base (the altitude of the bottom of the cloud) of 10-15 thousand feet above the surface. A thunderstorm in Florida normally has a cloud base of 5 thousand feet. The reason for the lower cloud base is the additional humidity in the air at the surface.

The process of air rising in the atmosphere to form clouds creates some new words to describe the location and temperature where water condenses from vapor to liquid form. When an air mass is cooled,d it eventually becomes saturated. This temperature where the air mass cannot hold anymore water vapor is referred to as the dew point. When an air mass reaches its dew point, clouds begin to form as water condenses to form clouds.

Dew Point - The temperature an air mass at 100% relative humidity.

We can also define another term that is related to the dew point of an air mass. In any air mass the relative humidity can be calculated at the surface. With this information we can determine the dew point of the air mass. As air is lifted in the atmosphere, it cools, due to the decrease in pressure, at a rate of -3.5 / 1000 ft. The altitude where a rising air mass cools to its dew point is referred to as the lifting condensation level of that air mass. The lifting condensation level is easy to see in the air, as this is the altitude where clouds start to form. The bottom of the clouds is the point in the atmosphere where rising air has cooled enough to reach the saturation point.

Lifting Condensation Level or (LCL) - The altitude of the dew point in an air mass.