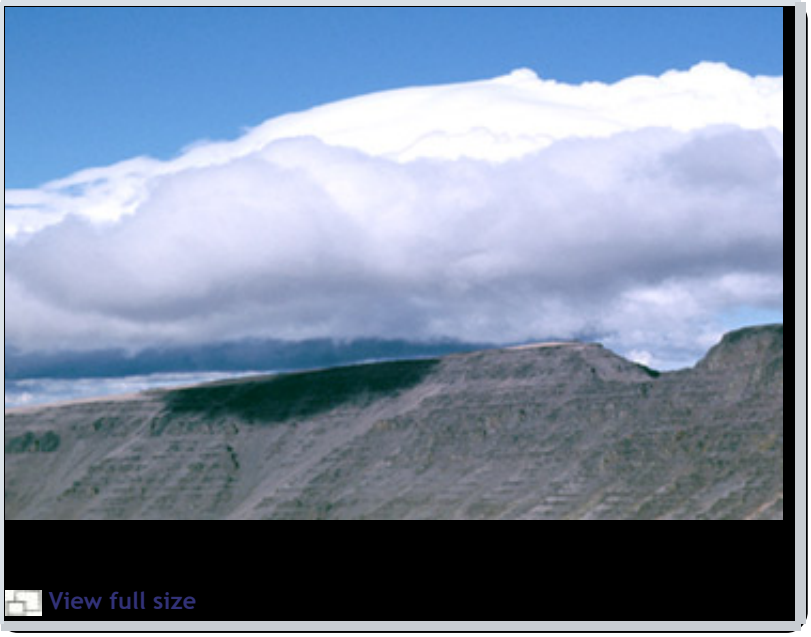
USGS science for a changing world

The USGS Water Science School

Back to previous page

Condensation - The Water Cycle



New!

Water cycle for kids poster.

Condensation is the process by which water vapor in the air is changed into liquid water. Condensation is crucial to the water cycle because it is responsible for the formation of clouds. These clouds may produce precipitation, which is the primary route for water to return to the Earth's surface within the water cycle. Condensation is the opposite of evaporation.

You don't have to look at something as far away as a cloud to notice condensation, though. Condensation is responsible for ground-level fog, for your glasses fogging up when you go from a cold room to the outdoors on a hot, humid day, for the water that drips off the outside of your glass of iced tea, and for the water on the inside of the windows in your home on a cold day.

The phase change that accompanies water as it moves between its vapor, liquid, and solid form is exhibited in the arrangement of water molecules. Water molecules in the vapor form are arranged more randomly than in liquid water. As condensation occurs and liquid water forms from the vapor, the water molecules become organized in a less random structure, which is less random than in vapor, and heat is released into the atmosphere as a result.

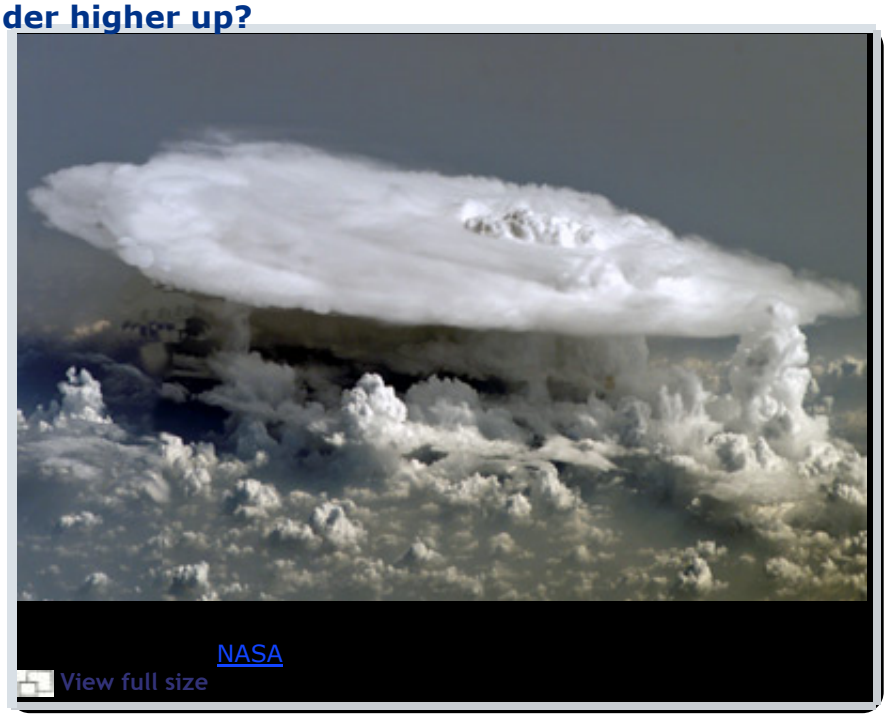
The little cloud that could—but why? (Why does this cloud exist?)

Condensation in the air

Even though clouds are absent in a crystal clear blue sky, water is still present in the form of water vapor and droplets which are too small to be seen. Depending on weather conditions, water molecules will combine with tiny particles of dust, salt, and smoke in the air to form cloud droplets, which grow and develop into clouds, a form of water we can see. Cloud droplets can vary greatly in size, from 10 microns (millionths of a meter) to 1 millimeter (mm), and even as large as 5 mm. This process occurs higher in the sky where the air is cooler and more condensation occurs relative to evaporation. As water droplets combine (also known as coalescence) with each other, and grow in size, clouds not only develop, but precipitation may also occur. Precipitation is essentially water in its liquid or solid form falling from the base of a cloud. This seems to happen too often during picnics or when large groups of people gather at swimming pools.

Photograph by the National Weather Service, Grand Junction Weather Forecast Office, Colorado, U.S.A.

You might ask ... why is it colder higher up?



NASA

View full size

The clouds formed by condensation are an intricate and critical component of Earth's environment. Clouds regulate the flow of radiant energy into and out of Earth's climate system. They influence the Earth's climate by reflecting incoming solar radiation (heat) back to space and outgoing radiation (terrestrial) from the Earth's surface. Often at night, clouds act as a "blanket," keeping a portion of the day's heat next to the surface. Changing cloud patterns modify the Earth's energy balance, and, in turn, temperatures on the Earth's surface.

As we said, clouds form in the atmosphere because air containing water vapor rises and cools. The key to this process is that air near the Earth's surface is warmed by solar radiation. But, do you know why the atmosphere cools above the Earth's surface? Generally, air pressure, is the reason. Air has mass (and, because of gravity on Earth, weight) and at sea level the weight of a column of air pressing down on your head is about 14 ½ pounds (6.6 kilograms) per square inch. The pressure (weight), called barometric pressure, that results is a consequence of the density of the air above. At higher altitudes, there is less air above, and, thus, less air pressure pressing down. The barometric pressure is lower, and lower barometric pressure is associated with fewer molecules per unit volume. Therefore, the air at higher altitudes is less dense. As the total heat content of a system is directly related to the amount of matter present, it is cooler at higher elevation ... fewer air molecules exist in a certain volume of air higher up. This means cooler air.

Condensation near the ground

Condensation also occurs at ground level, as this picture of a cloud bank in California shows. The difference between fog and clouds which form above the Earth's surface is that rising air is not required to form fog. Fog develops when air having a relatively high humidity comes in contact with a colder surface, often the Earth's surface, and cools to the dew point. Additional cooling leads to condensation and the growth of low-level clouds. Fog that develops when warmer air moves over a colder surface is known as advective fog. Another form of fog, known as radiative fog, develops at night when surface temperatures cool. If the air is still, the fog layer does not readily mix with the air above it, which encourages the development of shallow ground fog.

Condensation on your glass (or your glasses)

You probably see condensation right at home every day. If you wear glasses and go from a cold, air-conditioned room to outside on a humid day, the lenses fog up as small water droplets coat the surface via condensation. People buy coasters to keep condensed water from dripping off their chilled drink glass onto their coffee tables. Condensation is responsible for the water covering the inside of a window on a cold day (unless you are lucky enough to have double-paned windows that keep the inside pane relatively warm) and for the moisture on the inside of car windows, especially after people have been exhaling moist air. All of these are examples of water leaving the vapor state in the warm air and condensing into liquid as it is cools.

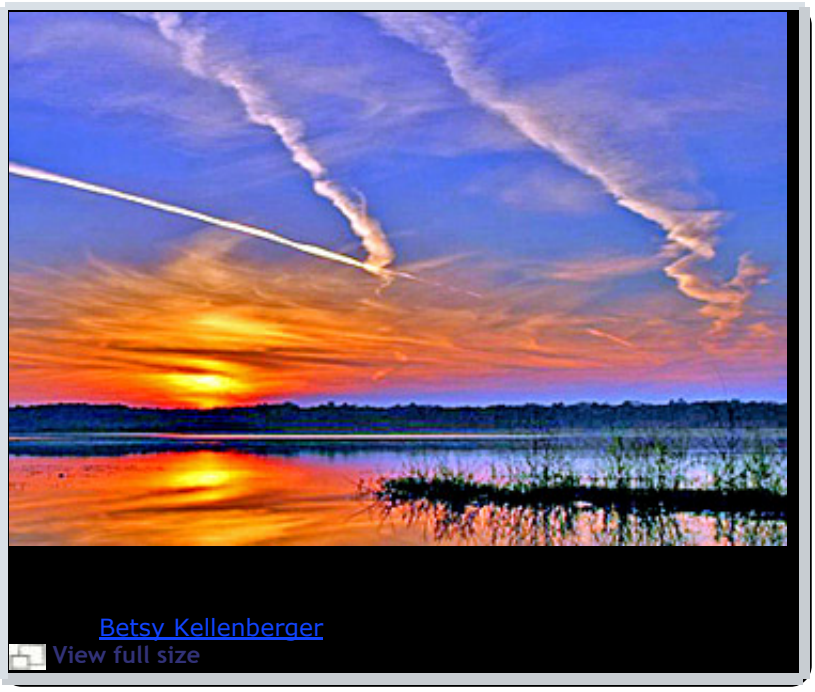
Why do clouds form and why does it rain?

Air, even "clear air," contains water molecules. Clouds exist in the atmosphere because of rising air. As air rises and cools the water in it can "condense out", forming clouds. Since clouds drift over the landscape, they are one of the ways that water moves geographically around the globe in the water cycle. A common myth is that clouds form because cooler air can hold less water than warmer air—but this is not true.

As Alistair Fraser explains in his Web page "Bad Meteorology", "What appears to be cloud-free air (virtually) always contains sub microscopic drops, but as evaporation exceeds condensation, the drops do not survive long after an initial chance clumping of molecules. As air is cooled, the evaporation rate decreases more rapidly than does the condensation rate with the result that there comes a temperature (the dew point temperature) where the evaporation is less than the condensation and a droplet can grow into a cloud drop. When the temperature drops below the dew-point temperature, there is a net condensation and a cloud forms," (accessed on Sep. 12, 2003).

Contrails: Man-made clouds

You've seen the cloud-like trails that high-flying airplanes leave behind and you probably know they are called contrails. Maybe you didn't know they were called that because they are actually condensation trails and, in fact, are not much different than natural clouds. If the exhaust from the airplane contains water vapor, and if the air is very cold (which it often is at high altitudes),



then the water vapor in the exhaust will condense out into what is essentially a cirrus cloud.

As a matter of fact, sailors have known for some time to look specifically at the patterns and persistence of jet contrails for weather forecasting. On days where the contrails disappear quickly or don't even form, they can expect continuing good weather, while on days where they persist, a change in the weather pattern may be expected. Contrails are a concern in climate studies as increased jet traffic may result in an increase in cloud cover. Several scientific studies are being conducted with respect to contrail formation and their impact on climates. Cirrus clouds affect Earth's climate by reflecting incoming sunlight and inhibiting heat loss from the surface of the planet. It has been estimated that in certain heavy air-traffic corridors, cloud cover has increased by as much as 20 percent. (Source: National Weather Service: What is a contrail and how does it form?)

A cloud can weigh as much as an airplane? Why doesn't it fall?

Condensation causes clouds. The Oxford English Dictionary defines a cloud as "a visible mass of condensed watery vapor floating in the air at some considerable height above the general surface of the ground." You might ask "If clouds are watery vapor, and vapor has weight, why doesn't it fall on me?" Even though clouds float, the fact is that clouds do have weight - many tons, in fact. And they do "fall" on you, sometimes, when the fog rolls in.


Illustration by Slug Signorino

According to columnist Cecil Adams, "a modest-size cloud, one kilometer in diameter and 100 meters thick, has a mass equivalent to one B-747 jumbo jet." ("Can a cloud weigh as much as a 747?", http://www.straightdope.com/classics/a980313a.html, accessed on Sep. 11, 2003). But, with all that mass being spread over such a large volume of space, the density, or weight (mass) for any chosen volume, is very small. If you compressed that cloud into a trash bag, well, in that case, you would not want to be standing below it. Even though a cloud weighs tons, it doesn't fall on you because the rising air responsible for its formation keeps the cloud floating in the air. The air below the cloud is denser than the cloud, thus the cloud floats on top of the denser air nearer the land surface.

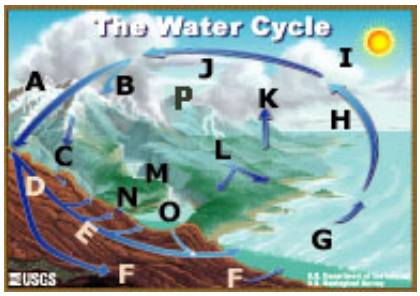
Sources and more information

- NASA Earth Observatory; The Water Cycle
- What is a contrail and how does it form? - National Weather Service

---

Choose a water-cycle topic

A - Storage in ice and snow **I** - Condensation



B - Precipitation
C - Snowmelt runoff to streams
D - Infiltration
E - Groundwater discharge
F - Groundwater storage
G - Water storage in oceans
H - Evaporation
J - Water storage in the atmosphere
K - Evapotranspiration
L - Surface runoff
M - Streamflow
N - Springs
O - Freshwater storage
P - Sublimation

To view PDF files, the latest version of Adobe Reader (free of charge) or similar software is needed.

U.S. Department of the Interior | U.S. Geological Survey
URL: http://water.usgs.gov/edu/watercyclecondensation.html
Page Contact Information: Howard Perlman
Page Last Modified: Friday, 02-Dec-2016 12:52:23 EST