Clouds: What They Are and What They Mean

Susannah Lopez

Introduction to Meteorology

2 December 2008

Clouds: What They Are and What They Mean

Clouds are composed of tiny water droplets that form when warm air moves upward and the moisture condenses. Clouds occur at various heights and take various shapes and forms. There are a variety of causes for cloud formation, and a variety of ways to study them. Over time, clouds have become more and more scientifically explored and understood. New methods of examination have been developed, and are now used to understand what affects clouds and what clouds affect. While new techniques are thoroughly helpful, the original practice of simple observation and basic classification is still the basis for how clouds are described today. The observation of clouds can give important information about what is going on in the atmosphere. While cloud characteristics are endless, there are many ways to describe clouds, including their formation, their influence, what influences them, and what the ground observer sees in the sky.

Classification of Clouds

Despite the long length of time that clouds have existed on earth, it was not until the early 19th century that efforts were made to give names to cloud characteristics or to formally identify and classify them. In 1802, French a naturalist named Lamarck (1744 – 1829) developed the first known cloud classification system. However, his work received little attention, and was never widely accepted. Just one year later in 1803, a second cloud classification system was developed and published by the English naturalist Luke Howard (1772 – 1864) entitled "On the Modifications of Clouds." Unlike Lamark's, Howard's classifications were well received, and became the basis of the current classification. In 1887, Ralph Abercromby and Hugo Hildebrandsson published a classification system. Described by Pruppacher and Klett (1997), Hildebrandsson's use of photography to study the form of clouds can be considered the first introduction to the idea of a cloud atlas. Aberbromby and Hildebrandsson's work was a slight modification of Howard's system, and included photographs in the study of clouds. With only slight adjustments, the system they published is still being used today.

Luke Howard's Cloud Classification

Luke Howard's use of Latin words to describe clouds as they appear when viewed from the ground is still used in cloud classification today. Four main descriptions are used and combined to depict the cloud being observed. Howard used three of the words to explain the shape of the cloud, and the fourth word is used to describe a cloud that produces precipitation. He gave stretched out or sheetlike clouds the name stratus, the Latin word for "layer". Puffy clouds with flat bottoms and cauliflower tops he named cumulus, meaning, "heap" in Latin. He named curled or wispy clouds cirrus, Latin for "curl of hair". Nimbus, or "violent rain" in Latin, he used to describe rain clouds. The combination of words is used to describe the type of cloud. For example, a cumulonimbus is a cloud with pronounced vertical development that produces precipitation.

Modern Cloud Classification

With added terms, details, and specifications, Luke Howard's system of using combinations of the Latin words stratus, cumulus, cirrus, and nimbus is still used today. The four cloud descriptions are in combinations that make up ten principle cloud forms, and these forms are further categorized into four primary cloud groups: high clouds, middle clouds, low clouds, and clouds with vertical development. The division of the high, middle, and low cloud groups is based on the distance between the earth's surface and the base of the cloud. The group of clouds with vertical development is determined by the radio of width to height. In addition, more Latin terms are now used to describe other properties of clouds, such as their humulis (humble, small), congestus (swollen, developing), and fibratus (fibrous, forming in strands).

Cloud Identification

Each of the four cloud groups have specific qualities that determine which clouds fit in that category and/or that the clouds in the group have in common. The four cloud groups generally have traits that are shared by most of the clouds within that group, allowing us to estimate its group by the appearance. Height, cloud type, and characteristics all contribute to the make-up and definition of the cloud groups.

Height & Types

High clouds form above 20,000 feet. Within the high cloud group are cirrus, cirrocumulus, and cirrostratus clouds. Middle clouds have bases between about 6,500 and 23,000 feet. Altocumulus and altostratus belong to the middle cloud group. The altitude between middle and high clouds overlaps due to variations in latitude in different regions. Low clouds have bases below 6,500 feet. The low cloud group includes nimbostratus, stratocumulus, and stratus clouds. The final group is clouds with vertical development. These are clouds that are developed more vertically than horizontally and can grow to a height of 39,000 feet. Cumulus and cumulonimbus clouds are both in the group of clouds with vertical development.

Characteristics

Because of the cold temperatures at high elevations, high clouds are composed almost entirely of ice crystals. High clouds typically appear thin and white, however, near sunrise and sunset the underside of the clouds can reflect unscattered sunlight, causing them to appear colorful. Middle clouds are primarily composed of water droplets, which give them a sharp outline, although if temperatures drop low enough ice crystals may develop. Turbulent winds in the middle levels of the atmosphere can lead to wavelike patterns in some forms of clouds. Low clouds are composed primarily of water droplets, but if temperature drops low enough they sometimes contain ice particles and snow. Low clouds are layered, and often colored gray. Clouds with vertical development can provide the most extreme storms and weather.

Cloud Development

Clouds form when air rises and expands when moving into an area of lower pressure. The expansion uses up energy, causing the air to cool. Cold air can hold less water vapor than warm air, so once it cools below a critical temperature, or dew point, moisture will condense and form a cloud droplet. Cloud droplets form on condensation nuclei, which are microscopic particles of things like dust, smoke, and salt from ocean spray. Droplets range in size and can be larger or smaller. These tiny droplets need very little lift to stay airborne, and are described by Ramsey (1990) as “easily supported and transported by air movements” (p. 58). An important factor in the development of clouds is stability. The level of stability in the atmosphere is a key factor in cloud activity. The more unstable the atmosphere, the more likely it is that clouds will form. This is because clouds form when air is moved upward by some type of lifting mechanism, and the more unstable the atmosphere is, the less of a lift is needed. Different levels of stability cause different types of cloud formations. Reynolds (2005) explains that how different clouds “look” is the result of how the rising air produced them. Cloud formation requires the rise of air, and there are four main mechanisms that are responsible for lifting the air upward.

Surface Heating and Free Convection

The first lifting mechanism is surface heating and free convection. Solar radiation warms the earth and thermals develop. The thermals break away from the ground and cool through expansion as they rise. As they mix with cooler, drier air, their upward movement slows, and they cool to the saturation point where moisture will condense. The thermal then becomes a cumulus cloud.

Uplift Along Topography

The second mechanism is uplift along topography. When air comes across a large obstacle it is forced upward, which is called orographic uplift. Ahrens (2008) gives the example of the Sierra Nevada and the Rockies as mountain chains that often create orographic lifting. As the air is lifted it cools, and when the air is humid enough, clouds form. These clouds are called orographic clouds.

Convergence of Surface Air

The third mechanism is convergence of surface air. In a low-pressure system, all wind moves in towards a center from all directions because air moves from high to low pressure. The air that is moving is pushes the air in the center upward because there is nowhere else for it to go. The air cools and expands, and becomes a cloud.

Uplift Along Weather Fronts

The fourth mechanism is uplift along weather fronts. Both warm and cold fronts can cause air to rise. Because cold air is denser than warm air, when the two contrasting masses meet, the cold air will end up below the warm air. With warm fronts, the warm air slides over the cold air to replace it, and as it is lifted upward some of the air will cool and become a cloud. Warm fronts most commonly form stratus clouds. With cold fronts, the cold air displaces the warm air by pushing it upward; the warm air that is forced upward will cool and expand, becoming a cloud. The development of cumuliform clouds and instability are associated with cold fronts.

Color

There are not only different shapes, sizes, and heights of clouds, but there are also varying colors. While a combination of factors affect cloud color, the two major contributors are the cloud droplets and sunlight.

White

Clouds most commonly appear white. The white appearance is produced because the clouds are optically thick, and allow very little unscattered light to get through them. They are also very poor absorbers of sunlight; instead, the cloud droplets scatter all wavelengths of visible sunlight in every direction. This distribution of scattered light causes clouds to appear white.

Dark

Clouds become darker when they get bigger and taller, allowing even less light to penetrate through. When little light reaches the underside of the cloud, less light is scattered, causing the base to appear dark. Rain clouds become especially dark because the droplets near the base of the cloud grow in size, causing them to be even poorer scatterers and better absorbers. Therefore, the little amount of light that eventually reaches the cloud base is absorbed instead of scattered, causing the clouds to appear much darker.

Green

A phenomenon less widely known is the existence of green clouds. Throughout history, green tinted clouds were reported to appear before large storms. These sightings were always considered myths or based on a color contrast with the surroundings, but in a 1995 – 1996 study, Gallagher (1998) discovered the reality of it. Using a spectrophotometer to measure the wavelength of light emitted from green-appearing thunderstorm clouds, he found that the color is not just a myth. His explanation that is most commonly believed now, is that green light can be formed from the mixture of reddish light from the sun and the absorptive properties of water.

Larger drops would cause blue-green storms, and smaller drops would cause yellow-green storms. Still, the belief that the green tint was the reflection of foliage was still under examination. Gallagher (2001) conducted another study of the green foliage and the green clouds, and found that the "visible spectral maxima of the two green lights do not coincide, indicating that, in the portion of the spectrum where human color vision is operating, the effects of ground reflection are minimal and light from the ground does not create the green light in green thunderstorms" (p. 781). While this explanation is logical, the subject is still being studied.

Climate

Clouds have a very significant impact on our planet, affecting both the global climate, as well as local weather activity. Clouds contribute to the more consistent greenhouse effect, and also influence the varying everyday temperatures.

Greenhouse Effect

Clouds can very much enhance the greenhouse effect. Tiny liquid cloud droplets are good absorbers of infrared radiation but poor absorbers of visible solar radiation. These droplets are able to absorb wavelengths that water vapor and carbon dioxide fail to absorb. These clouds allow radiation from the sun to reach the surface of the earth, but absorb much of the earth's outgoing infrared radiation, blocking it from escaping into space, therefore keeping the earth warm. The greenhouse effect keeps the temperature of our planet at a level that allows life to exist.

Daily Temperature

In addition to affecting the planet as a whole, clouds also affect temperatures based on specific locations. Clouds, especially low, thick ones, are good emitters of infrared radiation. The tops of the clouds radiate infrared energy upward and the bases radiate back to earth's surface where it is absorbed, and in a sense, radiated back to the clouds. This process keeps calm, cloudy nights warmer than calm clear ones. If the clouds remain in to the next day, they block much of the sunlight from reaching the ground by reflecting it back in to space. This causes less heat on the ground, so cloudy, calm days are usually cooler than clear, calm days.

Satellite Cloud Observation

Clouds can provide valuable information about what is going on with the planet, and observing clouds from the ground is not always the *most* effective way to get the facts. One type of the helpful tool that is used to examine the aspects of clouds we are unable to study from the ground is the satellite. Satellites can show cloud images of areas where there are no ground-based observations, such as regions that are covered in water. People living in areas prone to severe storms are now able to receive more warning, where as before there was no way to see dangerous weather coming far in advance. Two primary types of weather satellites are used for viewing clouds: geostationary satellites and polar-orbiting satellites. New technology is also continuously being developed, such as infrared imaging.

Geostationary Satellites

Geostationary satellites, also known as geosynchronous satellites, are able to remain above a fixed spot by orbiting the equator at the same rate as the earth spins. They are about 36,000 kilometers from the earth, and because of their positioning, they are able to monitor a region continuously. They use a “real time” data system that can transmit images to a ground system as soon as the picture is taken. Putting the satellite images into a time-lapse movie sequence can create an animation of cloud activity that is helpful in forecasting large weather systems. The geostationary satellite can also help approximate wind directions and speeds by monitoring cloud movement.

Polar-Orbiting Satellites

Polar-orbiting satellites pass over the north and south polar regions on every revolution. As the earth rotates to the east under the satellite, each pass records an area to the west of the prior pass, eventually covering the entire earth. While the geostationary pictures are distorted because the angle at which they see the region, polar-orbiting satellites get sharp images in the polar regions by photographing clouds directly below them. The photographic information about objects such as cloud systems and violent storms is more detailed because they circle at a much lower altitude.

Infrared Imaging

The use of infrared cloud images to collect more detailed information is very helpful. High, middle, and low clouds have very similar reflectivity, so it is difficult to use visible light images. Infrared images to not show strong visible reflected light, but instead they produce an image of the actual radiating surface. Because warm objects radiate more energy than cold objects, regions that are warmer are artificially made to look darker in the image. Using this technique, it is possible to more clearly distinguish between warm low clouds and cold high clouds.

Conclusion

In the past, clouds have had a significant impact on the earth, and they continue to have a significant impact today. The study of clouds is far from complete, and while the understanding of clouds has increased dramatically since Howard's classification system, there are still many things to learn. Increased knowledge of clouds will lead to increased knowledge about what to expect in the future, which is crucial information when taking in to consideration how rapidly the earth is changing.

References

Ahrens, D. C. (2008). *Essentials of meteorology: An invitation to the atmosphere, fifth edition.* Belmont: Thomson Learning Inc.

Buckley, B., Hopkins, E. J., & Whitaker, R. (2004). *Weather: A visual guide.* Buffalo: Firefly Books Ltd

Klett, J. D. & Pruppacher, H. R. (1997). *Microphysics of clouds and precipitation.* New York: Springer.

Gallagher, F. W. (1998 October). *Colorimetric observations of green thunderstorms and their implications for current hypotheses*. [Electronic version] Paper presented at a University of North Dakota seminar, Grand Forks, North Dakota.

Gallagher, F. W. (2001, April). Ground reflections and green thunderstorms. *Journal of Applied Meteorology*, 776 – 782. Retrieved November 14, 2008, from American Meteorological Society Journals Online.

Reynolds, R. (2005). *Guide to weather*. Buffalo: Firefly Books Ltd.

Ramsey, D. (1990). *Weather forecasting: A young meteorologist's guide.* Blue Ridge Summit: Tab Books.