Lightning Detection From Space
A Lightning Primer

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Characteristics of a Storm

LIGHTNING

As the ice particles within a cloud (called hydrometeors) grow and interact, they collide, fracture and break apart. It is thought that the smaller particles tend to acquire positive charge, while the larger particles acquire more negative charge. These particles tend to separate under the influences of updrafts and gravity until the upper portion of the cloud acquires a net positive charge and the lower portion of the cloud becomes negatively charged. This separation of charge produces enormous electrical potential both within the cloud and between the cloud and ground. This can amount to millions of volts, and eventually the electrical resistance in the air breaks down and a flash begins. Lightning, then, is an electrical discharge between positive and negative regions of a thunderstorm.

A lightning flash is composed of a series of strokes with an average of about four. The length and duration of each lightning stroke vary, but typically average about 30 microseconds. (The average peak power per stroke is about 10^{12} watts.)

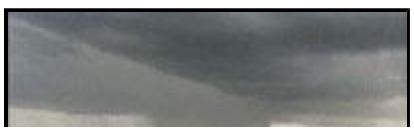
THUNDER

(48K wav)

Sound is generated along the length of the lightning channel as the atmosphere is heated by the electrical discharge to the order of 20,000 degrees C (3 times the temperature of the surface of the sun). This compresses the surrounding clear air producing a shock wave, which then decays to an acoustic wave as it propagates away from the lightning channel.

Although the flash and resulting thunder occur at essentially the same time, light travels at 186,000 miles in a second, almost a million times the speed of sound. Sound travels at the relatively snail pace of one-fifth of a mile in the same time. Thus the flash, if not obscured by clouds, is seen before the thunder is heard. By counting the seconds between the flash and the thunder and dividing by 5, an estimate of the distance to the strike (in miles) can be made.

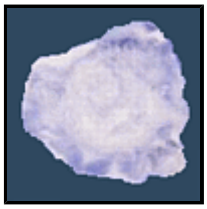
CLOUDS AND RAIN



When moisture-laden warm air is heated, it begins to rise. As these currents or bubbles of warm moist air rise higher in the atmosphere, both the surrounding air

pressure and temperature decrease. The air bubbles
expand, causing cooling of the moisture which eventually condenses to form clouds. As the cloud cools further, more moisture condenses and the water droplets making up the cloud grow and merge until some become so large and heavy that the air currents within the cloud can no longer support them. These water droplets begin to fall as rain.

HAIL



Air currents in cumulonimbus clouds can be very violent. Even when lightning is not produced, pellets of ice may grow by the accumulation of liquid droplets. When the updrafts are very strong, the growing ice pellets can be suspended for long periods, allowing them to grow larger. Eventually some may become too large for a given updraft and begin to fall as hail. Diameters are typically 5 to 10 mm, although a l40 mm hailstone has been recorded.

Types of Lightning Discharges

THE MOST COMMON TYPES OF LIGHTNING

Cloud-to-ground lightning is the most damaging and dangerous form of lightning. Although not the most common type, it is the one which is best understood. Most flashes originate near the lower-negative charge center and deliver negative charge to Earth. However, an appreciable minority of flashes carry positive charge to Earth. These positive flashes often occur during the dissipating stage of a thunderstorm's life. Positive flashes are also more common as a percentage of total ground strikes during the winter months.

Intra-cloud lightning is the most common type of discharge. This occurs between oppositely charged centers within the same cloud. Usually the process takes place within the cloud and looks from the outside of the cloud like a diffuse brightening which flickers. However, the flash may exit the boundary of the cloud and a bright channel, similar to a cloud-to-ground flash, can be visible for many miles.

The ratio of cloud-to-ground and intra-cloud lightning can vary significantly from storm to storm. Storms with the greatest vertical development may produce intra-cloud lightning almost exclusively. Some suggest that the variations are latitude-dependent, with a greater percentage of cloud-to-ground strikes occurring at higher latitudes. Others suggest that cloud-top height is a more important variable than latitude.

Details of why a discharge stays within a cloud or comes to ground are not understood. Perhaps a flash propagates toward the Earth when the electric field gradient in the lower regions of the cloud is stronger in the downward direction.

Depending upon cloud height above ground and changes in electric field strength between cloud and Earth, the discharge stays within the cloud or makes direct contact with the Earth. If the field strength is highest in the lower regions of the cloud a downward flash may occur from cloud to Earth.

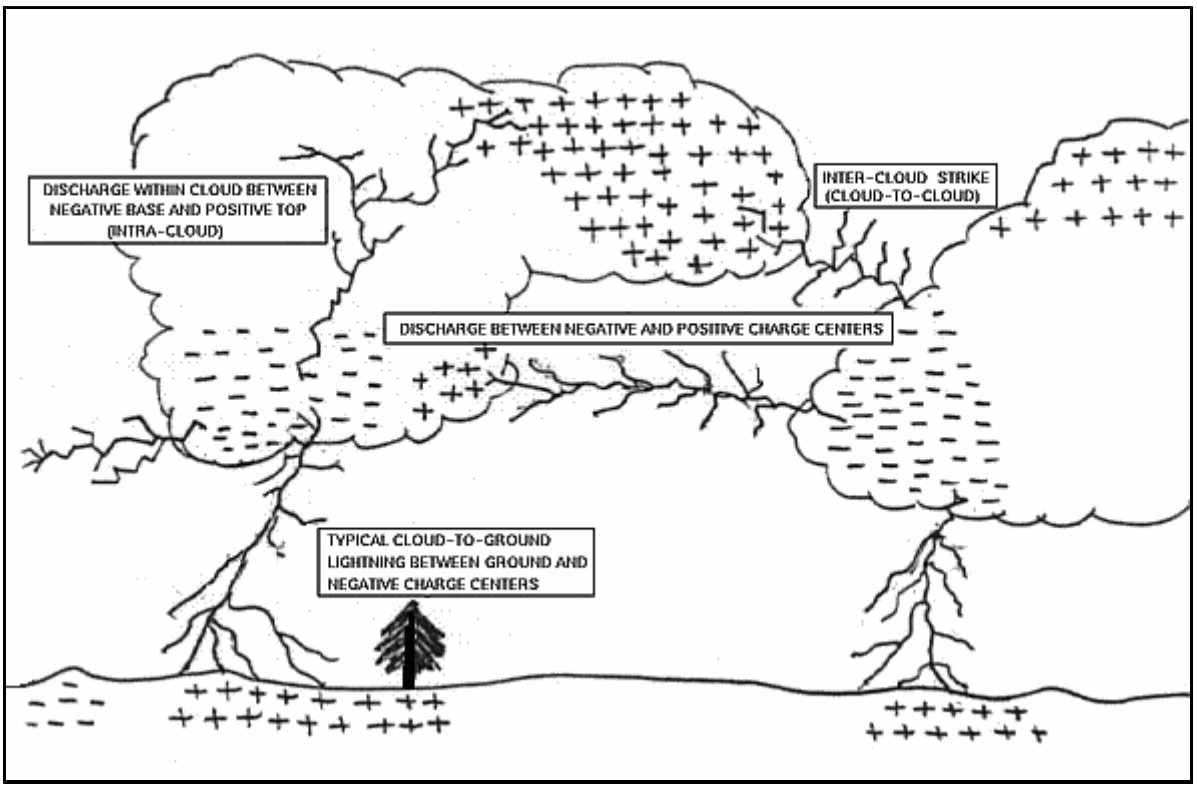
Inter-cloud lightning, as the name implies, occurs between charge centers in two different clouds with the discharge bridging a gap of clear air between them.

OTHER TYPES OF LIGHTNING

There are numerous names and descriptions of various types and forms of lightning. Some identify subcategories, and others may arise from optical illusions, appearances, or myths. Some popular terms include: *ball lightning, heat lightning, bead lightning, sheet lightning, silent lightning, black lightning, ribbon lightning, colored lightning, tubular lightning, meandering lightning, cloud-to-air lightning, stratospheric lightning, red sprites, blue jets, and elves.*

DESCRIPTION OF LIGHTNING DISCHARGE PROCESSES

With the initial breakdown of the air in a region of strong electric fields, a streamer may begin to propagate downward toward the Earth. It moves in discrete steps of about 50 meters each and is called a stepped leader. As it grows, it creates an ionized path depositing charge along the channel, and as the stepped leader nears the Earth, a large potential difference is generated between the end of the leader and the Earth. Typically, a streamer is launched from the Earth and intercepts the descending stepped leader just before it reaches the ground. Once a connecting path is achieved, a return stroke flies up the already ionized path at close to the speed of light. This return stroke releases tremendous energy, bright light and thunder. Occasionally, where a thunderstorm grows over a tall Earth grounded object, such as a radio antenna, an upward leader may propagate from the object toward the cloud. This "ground-to-cloud" flash generally transfers a net positive charge to Earth and is characterized by upward pointing branches.



The lower part of a thundercloud is usually negatively charged. The upward area is usually positively charged. Lightning from the negatively charged area of the cloud generally carries a negative charge to Earth and is called a negative flash. A discharge from a positively-charged area to Earth produces a positive flash.

The initial breakdown and propagation are similar for intra-cloud lightning, but the discharge generally occurs between regions of opposite charge. Without the benefit of air conducting Earth, intra-cloud lightning does not produce a return-stroke-like feature. Rather, it is characterized by slower propagating "recoil streamers" and "K" changes. Nevertheless, tremendous energy, bright light, and thunder are still produced by intra-cloud lightning.

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