ARM Atmospheric Radiation Measurement Program

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ARM Facilities Newsletter

Lightning – Nature's Light Show

Lightning provides one of nature's most spectacular displays of energy. Though fascinating to observe, lightning can be dangerous and deadly. Protecting ARM instruments from lightning damage is vital. Putting equipment worth millions of dollars into open fields and pastures without protection from potentially damaging lightning would be careless. Although nothing can be completely protected from the damage caused by a lightning strike, especially a direct hit, taking steps to minimize damage is crucial to a program like ARM.

(Photo: NOAA)

What Is Lightning?

High above Earth's surface, at an altitude of approximately 30 miles, is a layer called the *electrosphere*, where the electric potential becomes almost constant. A 300,000-volt potential difference exists between Earth's surface and the electrosphere. This potential difference is referred to as the fair-weather electric field. Because the Earth and its atmosphere are not good insulators, negative charge leaks from the surface and rises to the electrosphere at a rate of about 2,000 amps. At this rate, Earth's charge would dissipate in less than one hour. Lightning is responsible for restoring Earth's negative charge by returning negative electrons to Earth's surface.

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At any given time, 2,000 or more thunderstorms in progress around the world, producing about 40 cloud-to-ground flashes every second (3.5 million flashes each day) are transferring negative charge back to Earth. The way thunderstorms carry and separate

(Photo: NOAA)

electrical charges is not very well understood by scientists. However, we do know that convection in a thunderstorm separates small and large water drops. Negatively charged ions adhere to heavier drops, which gravitate to the base of the thunderstorm cloud. The top portion of the thunderstorm cloud becomes positively charged, while the lower portion becomes negatively charged. Negative electrons in the cloud base are returned to Earth by lightning strokes, while negative electrons in the air are returned through point discharges.

Point discharge occurs as electrons move from the air to pointed objects like church spires, tree leaves, antennas, or even blades of grass. Electrons are drawn toward pointed objects because it is easier for them to be transferred to sharp or jagged objects than to flat or smooth objects. This phenomenon produces a visible and audible corona or bluish glow that is referred to as *St. Elmo's Fire.*

When a negatively charged cloud base moves above the ground, it induces a positive charge in the ground with respect to the cloud base. The electrons in the cloud base are attracted to the ground, but the air, being a poor conductor, limits their flow. As the cloud matures, the negative charge at its base builds to the breaking point. Negative electrons eventually flow to the ground with an explosive force in the form of a lightning stroke.

A typical lightning flash lasts less than a half second and may release 1,500 kilowatt-hours of energy; enough to light a 100-watt light bulb continuously for more than a year. In this half second many things happen to produce the light display we observe.

A lightning stroke begins with the progression of a stepped leader downward as electrons in the cloud descend on the path of least resistance to the ground. As the stepped leader progresses downward, it ionizes its route, making a more conductive path for the electrons that follow. As the stepped leader comes within a few hundred feet of the ground, a streamer of positively charged electrons rises upward from the ground to meet the stepped leader and complete the electrical circuit from cloud to ground. This process is invisible to the eye. Once the circuit is complete, the negative electrons from the cloud can fill the ionized channel. Negative ions are deposited to the surface by being emptied from the channel from the ground up. This “draining” or rush of electrons produces the visible flash that we observe and is called the “return stroke.”

Subsequent lightning strokes can follow directly after the return stroke. A second leader, referred to as a “dart leader,” makes its way to the ground, usually following the same path as the stepped leader. The dart leader makes its way to the ground much more easily, because the stepped leader has already ionized the path. A second return stroke begins just as the first does, although the negative electrons deposited may come from a different region of the cloud. Multistroke lightning events are very common, but they happen so fast that we usually perceive them as a single flash. A single lightning stroke, from stepped leader to return stroke, can occur in as little as 0.003 seconds.

Lightning can be costly in that it can damage sensitive instruments at the SGP CART site. Fortunately, lightning damage occurs infrequently. Next month we’ll look at lightning safety and how ARM has dealt with this natural phenomenon.

(Photo: NOAA)