Physics Spotlight

Lightning—Fields of Attraction

Scientists have observed and analyzed lightning for more than 100 years. In recent years, high-speed digital recording,* low-light television cameras,† and satellites that have synchronized clocks‡ have given atmospheric scientists new information about the events that occur with a bolt of cloud-to-ground, or CG, lightning.

A bolt of lightning strikes near an airport terminal. *(Tom Fox/Dallas Morning News/Corbis.)*

Thunderstorm clouds have layers of positive and negative charges and act like enormous, very powerful dipoles. CG lightning is usually negative charge from the lower part of a cloud that travels to the ground by ionization of the air. This charge is often "stepped" through the air with several pauses on the order of milliseconds. The visible bolt is a return positive *stroke* following the ionized path back up from the ground. Most flashes are 3 to 10 strokes back and forth between cloud and ground, several milliseconds apart. The strokes follow the initial path, as it already consists of ionized and heated air, and usually transfer a total negative charge of 20-35 C.# CG lightning strikes carrying negative charge to ground have been recorded with more than 1 million volts of potential difference.°

Some extremely powerful CG lightning strokes that carry positive charge to ground have transferred total positive charges of up to 400 C,§ and have been recorded with over 10 million volts of potential. In large supercell thunderstorms that have hail and tornadoes,¶,** a majority of CG lightning strokes carry positive charge from the tops of the clouds to the ground rather than carry negative charge from the lower middle of the clouds to the ground. This lightning is associated with strong bursts of energy radiated near the start of the lightning and with brief bursts of light many kilometers above the cloud tops shortly after the strokes.††

But very strong bursts of radiated energy have been observed microseconds before less powerful negative lightning.‡‡,##,°°,§§ Some bursts of energy repeat, detectable by satellite for up to nearly an hour after a lightning strike. Although the bursts last less than a millisecond, they are so energetic that they are associated with radio noise detected as far away as the opposite hemisphere of the planet.¶¶

Because high-energy electromagnetic radiation has repeatedly been measured in association with lightning, scientists are coming up with new models about how lightning is formed. One possible model involves "runaway breakdown." Because electric fields associated with thunderstorms are very large, it might be possible for a stray electron or ion to be accelerated by the electric field of a thunderstorm to approach the speed of light.*** At that speed, the electron would be so energetic that colliding with molecules in the cloud would not halt it, even as it ionized those molecules. The ions could then be further accelerated by the electric field within the storm to produce a shower, or burst, of energy. Many scientists feel that runaway breakdown explains the formation of CG lightning in clouds that have measured electric fields ten times lower than the required potential needed to overcome air's insulating ability.†††

Because the technology to detect and to time the energy bursts in relation to lightning flashes is recent, scientists are now developing ways to confirm or refute these new models. The study of lightning is a very attractive field with great potential.

* Wang, D., et al., "Observed Leader and Return-Stroke Propagation Characteristics in the Bottom 400 m of a Rocket-Triggered Lightning Channel." *Journal of Geophysical Research*, Jun. 27, 1999, Vol. 104, No. D12, pp. 14,369–14,376.

† Lyons, W. A., et al., "Upward Electrical Discharges from Thunderstorm Tops." *Bulletin of the American Meteorological Society*, Apr. 2003, pp. 445–454.

‡ Gurevich, A. V., and Zybin, K. P., "Runaway Breakdown and the Mysteries of Lightning." *Physics Today*, May 2005, pp. 37–43.

\# Uman, M. A., *Lightning*. New York: Dover, 1984.

° Uman, M. A., op. cit.

§ Rakov, V. A., "A Review of Positive and Bipolar Lightning Discharges." *Bulletin of the American Meteorological Society*, Jun. 2003, pp. 767–776.

¶ Lang, T. J., et al., "The Severe Thunderstorm Electrification and Precipitation Study." *Bulletin of the American Meteorological Society*, Aug. 2004, pp. 1107–1125

** Wiens, K. C., "The 29 June 2000 Supercell Observed During STEPS. Part II: Lightning and Charge Structure."[Need journal name, volume, pages.]

†† Lyons, W. A., et al., op. cit.

‡‡ Dwyer, J. H., et al., "X-Ray Bursts Associated Leader Steps in Cloud-to-Ground Lightning." *Geophysical Research Letters*, Vol. 32, Letter 01803, 2005.

\## Dwyer, J. R., "A Ground Level Gamma-Ray Burst Observed in Association with Rocket-Triggered Lightning." *Geophysical Research Letters*, Vol. 31, Letter 05119, 2004.

°° Greenfield, M. B., et al., "Near-Ground Detection of Atmospheric γ Rays Associated with Lightning." *Journal of Applied Physics*, Feb. 1, 2003, Vol. 93, No. 3, pp. 1839–1844.

§§ Gurevich, A. V., and Zybin, K. P., op. cit.

¶¶ Inan, U., "Gamma Rays Made on Earth." *Science*, Feb. 18, 2005, Vol. 307, No. 5712, pp. 1054–1055.

*** Inan, U., op. cit.

††† Schrope, M., "The Bolt Catchers." *Nature*, Sept. 19, 2004, Vol. 431, pp. 120–121.