High-Energy Emissions from Thunderstorms and Lightning

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Lightning is ubiquitous, striking our planet at least a billion times each year, sometimes hurting people and damaging property. Yet 269 years after Franklin’s famous kite experiment, there are still many basic questions about lightning that remain unanswered, including how it gets started inside thunderstorms, how it travels through air, and how it attaches to objects on the ground. Moreover, during the last few decades, a variety of new and strange high-energy phenomena have been discovered in and around thunderstorms. Terrestrial Gamma-ray Flashes (TGFs), short bursts of gamma rays produced inside thunderstorms, are so powerful they sometimes temporally blind gamma-ray instruments in low-Earth orbit, 600 km above the storms. As the TGF gamma rays travel through the atmosphere, they launch beams of electrons and positrons into the inner magnetosphere, where they are observed as Terrestrial Electron Beams (TEBs) by spacecraft thousands of kilometers away. In addition to TGFs, thunderstorms also produce gamma-ray glows that last from seconds to minutes and are routinely observed by instruments on aircraft and balloons, and from the ground. Some gamma-ray glows contain anomalously strong 511 keV lines, showing that large numbers of positrons are somehow produced by the storms. Finally, lightning leaders emit bright bursts of x-rays as they propagate through clouds and near the ground. Since none of these energetic emissions can be produced by conventional discharges in air, the presence of x-rays and gamma rays shows that other high-energy processes must be occurring. Specifically, it is thought that the energetic radiation is produced by bremsstrahlung emissions from relativistic runaway electrons accelerated in air by strong thundercloud or lightning electric fields. Because this runaway electron production is very sensitive to the electric field, x-ray and gamma-ray observations probe the charge distributions inside thunderstorms and near lightning, thus addressing key questions about lightning initiation, propagation and attachment. In this talk, I will give an overview of the high-energy emissions from thunderstorms and lightning, including how they are observed, how we think they are produced, and what effects they might have on thunderstorm and lightning processes, topics that are all part of the new field of High-Energy Atmospheric Physics.