High Energy Atmospheric Physics

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Until very recently, lightning was thought to be an entirely conventional discharge, involving only low-energy (a few eV) electrons. This picture changed with the discovery of intense x-ray and gamma-ray emissions from natural cloud-to-ground lightning, rocket-triggered lightning and thunderstorms. Indeed, the gamma-rays generated by thunderstorms may reach many tens of MeV and are so intense that bright bursts of these gamma-rays are observed from space, 600 km above the storms, as Terrestrial Gamma-ray Flashes (TGFs). In addition, it has been found that thunderstorms launch beams of electrons and positrons into the inner magnetosphere, where they are observed by spacecraft thousands of kilometers away. These energetic emissions cannot be produced by conventional discharges in air, and so the presence of x-rays and gamma-rays strongly implies that relativistic runaway electrons, accelerated in air by strong electric fields, play a role in thunderstorm and lightning processes. In this talk, I will give an overview of the x-ray and gamma-ray observations of thunderstorms and lightning, along with new results on terrestrial gamma-ray flashes. Finally, the physics of relativistic runaway electrons will be presented, including some very recent theoretical advances.