High-Energy Atmospheric Physics Theory and Modeling

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High-Energy Atmospheric Physics (HEAP), which traces its origin to the work of C.T.R. Wilson in the 1920's, is the study of the production, propagation and effects of high-energy particles and radiation within the Earth's atmosphere. The fundamental building blocks of HEAP are the runaway electrons, which are produced when the rate of energy gain from an electric field exceeds the rate of energy loss in air. As the electrons propagate they create additional runaway electrons in the form of relativistic runaway electron avalanches (RREAs). RREAs may be seeded by external sources such as cosmic rays or radioactive decays, or by runaway electrons produced in the high-field regions near leaders or streamers, or by a positive feedback effect from backward propagating positrons and x-rays. As the runaway electrons move through the air in the high-field region, they may gain many tens of MeV in energy and generate bremsstrahlung x-rays and gamma rays. These x-rays and gamma rays, which often travel far from the runaway electron source regions, have been observed in the keV range in the forms of x-ray emissions from lightning leaders and laboratory sparks, and in the MeV range as long lasting gamma-ray glows from thunderstorms and the powerful terrestrial gamma-ray flashes (TGFs) seen from space. Improved ground-based, space-based and airborne measurements in recent years have greatly improved our understanding of these phenomena. However, much uncertainty remains about exactly where and how these emissions are produced and what conditions inside thunderstorms or near lightning are necessary and/or sufficient for the emissions to occur. In this presentation, we shall review our current theoretical understanding of these phenomena and discuss current modeling efforts.