Observations of High-Energy Particles and Radiation From Thunderstorms

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Reports of gamma rays and neutrons observed at ground level below thunderstorms have appeared in the scientific literature for the past several decades. There have also been observations of intense flashes of gamma rays and electrons associated with thunderstorms by at least four different orbiting spacecraft since 1994. These have been termed terrestrial gamma ray flashes (TGFs). The latest development in this area of research is a comprehensive set of ground-level measurements of the spectra of high-energy gamma rays and electrons, along with neutrons, from a large array of cosmic ray detectors on Mount Aragats, in Armenia. The relationship of ground-level radiation to spaceborne TGFs is unknown, and details of the origin of both phenomena are still highly uncertain.

A meeting was held at the conference center of the Mount Aragats cosmic ray facility near Yerevan, Armenia. The purpose of the meeting was to discuss recent observations of these phenomena, the theory associated with them, related phenomena, and future directions in this new and rapidly expanding field. The conference was organized by the cosmic ray division of the Artem Alikhanyan National Laboratory (formerly known as the Yerevan Physics Institute), the Armenian State Science Committee, the Skobeltsyn Institute of Nuclear Physics of Moscow State University, and the Committee on Space Research (COSPAR). There were 40 attendees at the meeting; most were from Armenia and Russia.

Most researchers in this field agree that the mechanism producing the high-energy radiation associated with thunderstorms is a process known as the relativistic runaway electron avalanche (RREA). In this process, electrons can be accelerated and multiplied via an avalanche process to very high energies and high intensities. The relativistic electrons produce high-energy gamma rays via bremsstrahlung interactions with air (bremsstrahlung, from the German bremsen, "to brake," and strahlung, "radiation," i.e., "braking radiation" or "deceleration radiation," is electromagnetic radiation produced by the acceleration of a charged particle, such as an electron, when deflected by another charged particle). There are also thought to be positive feedback mechanisms involving positrons and Compton-produced electrons that further increase the radiation fluxes. The RREA process occurs within the strong electric fields and presumably over long distances within or near thunderstorms. These fields are also responsible for lightning production. An unusual aspect of the ground-based observations is that the RREA process, the feedback mechanism, and TGFs all occur on time scales of milliseconds or less, whereas the ground-based radiation increases observed are on time scales of minutes. The RREA process cannot be duplicated in the laboratory because of the high electric fields and long-distance scales required.

The ground-based observations of high-energy radiation below low-lying thunderstorms were the primary topic of the meeting. Other talks included a review of space-based observations of TGFs, details of the RREA theory and simulations, broadband radio emission from thunderstorms and its detection, transient luminous phenomena in the upper atmosphere above thunderstorms, and cosmic ray relationships with space weather and possible climate change.

The fluxes of these high-energy particles (the highest-known energies of particles originating in the atmosphere) result in the deposit of these particles from the upper atmosphere to the ionosphere and magnetosphere. Participants agreed that these phenomena should be considered as an integral component of solar-terrestrial connections, because thunderstorms are largely driven by solar-induced convection. The investigation of the RREA process may be helpful for understanding a basic physical process that can inject high-energy radiation into space and is observable with instruments on the ground near thunderstorms.

The conference presentations are available at http://us.aragats.am/Conferences/tepa2010/Presentations. The meeting proceedings will be available in early 2011.

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