Multi-Year Measurements of Radiation Belt Electrons: Acceleration, Transport, and Loss

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A principal goal of the Radiation Belt Storm Probes (RBSP) mission was to develop a much deeper understanding of the structure and dynamics of Earth's radiation belts. Almost immediately after the late-August 2012 launch of the dual RBSP spacecraft into their highly elliptical orbits, it was discovered that a third Van Allen belt (or "storage ring") of highly relativistic electrons can exist near the inner part of the traditionally recognized outer Van Allen zone. This feature has been the subject of much theoretical investigation and speculation since its discovery.

In addition to morphological structures of the radiation zones such as the third belt, it has also been a major achievement of the RBSP program (renamed the "Van Allen Probes" mission in November 2012) to understand more thoroughly how ultra-relativistic electrons are accelerated deep inside the radiation belts due to various wave-particle interactions. Van Allen Probes studies have demonstrated that electrons up to energies over 10 megaelectron volts (MeV) can be produced over broad regions of the outer Van Allen zone on timescales of minutes to a few hours. The key to such rapid acceleration is the interaction of "seed" populations of ~10 to ~200 keV electrons (and subsequently higher energies) with electromagnetic waves in the lower band whistler-mode chorus frequency range.

Extended studies of Van Allen Probes data show that "source" electrons (in a typical energy range of one to a few tens of keV energy) produced by magnetospheric substorms play a crucial role in amplifying the chorus waves in the magnetosphere. It is repeatedly observed that these chorus waves then rapidly heat and accelerate the tens to hundreds of keV seed electrons that are injected by substorms into the outer Van Allen zone. Thus, we often see that geomagnetic activity driven by strong solar storms (coronal mass ejections, or CMEs) almost inexorably leads to ultra-relativistic electron production through the intermediary step of intense magnetospheric substorms.

In this presentation, we report observations of some of the largest geomagnetic storms of the last several years. Distinctive events that have had significant ring current development are discussed. We focus on storms that produced dramatic effects on the relativistic and ultra-relativistic electrons measured by the Relativistic Electron-Proton Telescope (REPT) sensors on board the Van Allen Probes spacecraft. This work describes the radiation belt acceleration, transport, and loss characteristics of these intense geomagnetic events. We emphasize features seen repeatedly in the data (3-belt structures, "impenetrable" barrier properties, radial diffusion signatures) in the context of acceleration and loss mechanisms. We especially highlight solar wind forcing of the ultra-relativistic ($E \gtrsim 5$ MeV) electron populations. We present pitch angle resolved data and energy-spectral analyses for key events. The presentation also includes animated segments portraying the mission-long time variability of the outer Van Allen belt emphasizing the remarkable dynamics of the system.