Van Allen Belt Punctures and their Correlation with Solar Wind, Geomagnetic Activity and ULF Waves

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Important space assets including GPS satellites are located at a of distance of 2-3 earth radii. This region is considered relatively free from accelerated energetic particles and safe for operations of space hardware. This is the so-called slot region, the gap between the inner and the outer radiation belts. A barrier to relativistic and ultra-relativistic electrons at the inner boundary of the outer radiation belt was noticed by numerous satellite missions in the past. A very clear identification of the barrier to ultra-relativistic electrons was recorded by the Van Allen Probes REPT instrument. Further analysis of Van Allen probes data showed that the rigidity of the barrier increases exponentially with respect to electron energies. Designers and operators of space assets in the slot region would like to know how reliable this barrier is and possibly a warning when the barrier would be breached.

In this paper, we investigate the rare events of sudden appearances of relativistic electrons (>700 keV), which are normally confined to the Van Allen belts, in the slot region. The frequency of occurrence of these events are on average 1-2 per year. To cope with the scarcity of events, in this study we examine 21 years of trapped relativistic electron fluxes available from the POES and MetOp Space Environment Monitor (SEM-2). Our statistical analysis show that these events can occur even during moderate geomagnetic activity. Occurrence of these events correlates with high speed solar winds or ICMEs depending on the phase of the solar cycle. Most importantly, we show that ULF wave activity plays a significant role in causing these events and the events could be predicted in 75% of the cases.