Geophysical Research Abstracts
Vol. 15, EGU2013-2336, 2013
EGU General Assembly 2013

On the storm time evolution of relativistic electron phase space densities in Earth's outer radiation belt

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We report on internal, magnetospheric processes related to markedly different storm-time responses of phase space density (PSD) in invariant coordinates corresponding to equatorially mirroring, relativistic electrons in Earth's outer radiation belt. Two storms are studied in detail, selected from a database of 53 events (Dstmin < -40 nT) during the THEMIS era thus far (Dec. 2007 - Aug. 2012). These storms are well-covered by a number of in situ THEMIS spacecraft and complemented by additional ground-based and in situ observatories, and they epitomize the divergent behaviors that the outer radiation belt electrons can exhibit during active periods, even during otherwise similar Dst and auroral electrojet (AE) profiles.

From our statistical results with the full database, the changes in the radial profile peak in PSD reveal notably consistent behavior with prior studies: 58% of geomagnetic storms resulted in PSD peak enhancements, 17% resulted in PSD peak depletions, and 25% resulted in no significant change in the PSD peak after the storm. For the two case studies, we examined the PSD at multiple equatorial locations (using THEMIS), trapped and precipitating fluxes from low-Earth orbit (using POES), and chorus, hiss, EMIC, and ULF waves (using THEMIS spacecraft, ground observatories, and the GOES spacecraft). This is a comprehensive dataset that we used to investigate the roles of various wave-particle interaction mechanisms on outer belt variability during multiple geomagnetic storms, and it sets the stage for future multi-mission analyses incorporating data from the new Van Allen Probes mission.

With the results, we show that: 1) peaks in PSD were collocated with observed chorus waves outside of the plasmapause during the most active periods of the PSD-enhancing storm, but not during the PSD-depleting storm, providing evidence for the importance of local acceleration by wave-particle interactions with chorus; 2) outer belt dropouts occurred following solar wind pressure enhancements during both storms and were consistent with losses from magnetopause shadowing and subsequent outward radial transport; during the PSD-enhancing storm, this revealed how the outer belt can replenish itself seemingly independently of the remnant of the pre-existing belt leftover after a dropout, which in this case resulted in a double-peaked outer belt distribution; 3) slow decay in PSD was associated with corresponding locations in L* and enhanced wave amplitudes of plasmaspheric hiss; 4) precipitation loss associated with wave-particle interactions with hiss and EMIC waves appeared to be significantly more important during the PSD-depleting storm than the PSD-enhancing storm; and 5) PSD transport during the recovery phase of both storms and throughout the PSD-enhancing storm was consistent with ULF-wave driven radial diffusion away from maxima in PSD; this indicates the importance of ULF waves in redistributing outer belt PSD after local acceleration occurs. We also discuss how these source, transport, and loss processes, individually well characterized by previous studies, do indeed appear to act in concert, leading to predominance of local acceleration in one case and loss in another.