Comprehensive Study of the Response of Outer Radiation Belt and Inner Magnetosphere to Sheath Regions of Coronal Mass Ejections

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The energetic electron content in the Van Allen radiation belts surrounding the Earth can vary dramatically on timescales from minutes to days, and these strong electron fluxes present a hazard for spacecraft traversing the belts. Electron dynamics in the belts is governed by various competing acceleration, transport and loss processes in which wave-particle interactions play an important role. The response of the belts to solar wind driving is yet largely unpredictable. We investigate here the response of outer radiation belt electron fluxes to driving by sheath regions preceding interplanetary coronal mass ejections and the associated wave activity in the inner magnetosphere. To employ the energy and radial distance resolved electron flux measurements of the Van Allen Probes, we consider events from 2012 to 2018. We perform a statistical study of the events using superposed epoch analysis, where the sheaths are superposed separately from the ejecta and are resampled to the same average duration. Our results show that the ULF wave power in the Pc5 and EMIC range, as measured by geostationary GOES satellites, peaks in the sheath and declines during the ejecta. On the other hand, chorus wave power (measured by Van Allen Probes) stays at about the same level during the sheath and ejecta despite on average stronger geomagnetic activity during the ejecta. The electron fluxes are primarily enhanced at source (tens of keV) and seed (hundreds of keV) energies throughout the outer belt, whereas depletion events are more common at MeV energies at larger radial distances. Depletion progresses to lower energies with increasing radial distance from the Earth. Geoeffective events, defined by the SYM-H index, result in enhancement and depletion of the outer belt electron fluxes more often than events that do not drive strong geomagnetic activity. Additionally, case studies of electron phase space density shed light on the dominating belt processes during sheath events.

Keywords: Radiation belt, ICME sheath region, energetic electrons, phase space density

