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On the Role of the Last Closed Drift Shell and ULF-Wave Radial Diffusion in Driving Fast and Repeatable Radiation Belt Electron Loss

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Dynamics of relativistic and ultra-relativistic electrons, trapped in the Earth's Van Allen radiation belts, have been actively studied since their discovery over 50 years ago. However, properly characterizing fast changes in electron flux during geomagnetic storms remains a significant challenge for accurately modeling their behavior. In this study, we show how magnetopause shadowing losses, enhanced by outward Ultra-Low Frequency (ULF) wave radial diffusion, can deplete the radiation belt electron fluxes within hours or even minutes, causing long-lasting impacts on the subsequent, post-dropout, belt dynamics. By resolving four geomagnetic storms with fast radiation belt losses using high spatial and temporal resolution electron flux data from the constellation of Global Positioning System (GPS) satellites we reveal a very strong correspondence between the location of the magnetopause, characterized by the location of the last closed drift shell (LCDS), and the loss patterns of trapped electrons in each storm. We generalize the results of these case studies by statistically analyzing seven years of data from the entire Van Allen Probes mission in the context of the LCDS and how these losses are much more organized, repeatable, and therefore potentially predictable than previously thought. We reveal that the electron loss propagates in a similar manner from one storm to the next, depleting the radiation belt electron flux by almost the same energy-dependent factor, with respect to the pre-storm redaction belt content, in every event. Combining this LCDS shadowing model with an energy-dependent ULF wave radial diffusion model, we show how such a similar and repeatable fractional loss of the pre-storm electron population in each storm can be reproduced and explained. This is especially important since underestimates of the loss intensity can also create over-estimated and unrealistic flux levels in models. This phantom electron radiation can lead to the prediction of an overly harsh radiation environment. More accurate characterization of fast and repeatable magnetopause shadowing losses, reported here, may therefore be used to improve radiation belt specification and forecast model accuracy.