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Explaining the diverse response of ultra-relativistic Van Allen belt electrons to solar wind forcing

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The NASA Van Allen Probes have opened a new window on the dynamics of ultra-relativistic electrons in the Van Allen radiation belts. Under different solar wind forcing the outer belt is seen to respond in a variety of apparently diverse and sometimes remarkable ways. For example, sometimes a third radiation belt is carved out (e.g., September 2012), or the belts can remain depleted for 10 days or more (September 2014). More usually there is a sequential response of a strong and sometimes rapid depletion followed by a re-energization, the latter increasing outer belt electron flux by orders of magnitude on hour timescales during some of the strongest storms of this solar cycle (e.g., March 2013, March 2015). Such dynamics also appear to be always bounded at low-L by an apparently impenetrable barrier below $L \sim 2.8$ through which ultra-relativistic electrons do not penetrate. Many studies in the Van Allen Probes era have sought explanations for these apparently diverse features, often incorporating the effects from multiple plasma waves. In contrast, we show how this apparently diverse behaviour can instead be explained by one simple dominant process: ULF wave radial transport. Once ULF wave transport rates are accurately specified by observations, and coupled to the dynamical variation of the outer boundary condition at the edge of the outer belt, the observed diverse responses can all be explained. In order to get good agreement with observations, the modeling reveals the importance of still currently unexplained fast loss in the main phase which decouples pre- and post-storm ultra-relativistic electron flux on hour timescales. Similarly, varying plasmasheet source populations are seen to be of critical importance such that near-tail dynamics likely play a crucial role in Van Allen belt dynamics. Nonetheless, simple models incorporating accurate transport rates derived directly from ULF wave measurements are shown to provide a single natural and compelling explanation for such previously unexplained and apparently diverse responses to transient solar wind phenomena.