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Analysis of Radiation Belt Killer Electron Energy Spectra

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Killer (MeV) electrons are of intrinsic scientific importance in radiation belt dynamics and present one of the most serious space weather hazards to orbiting satellites. We model relativistic electron generation by means of chorus wave diffusion in a 1-D Fokker-Planck equation. Diffusion coefficients are derived for several forms of whistler-mode wave spectral density including Gaussian and power-law (with index q). We devise nine Fokker-Planck models (Models 1-9) of radiation belt electron dynamics. Models 1-6 incorporate the above forms of the wave spectral density. Models 7-9 contain special simplified diffusion coefficients that serve to facilitate the construction of analytic solutions to Models 1-6. The Fokker-Planck model equations depend on the important controlling parameter $k = D_0 T_0$, where D_0 is a diffusion parameter and T_0 is the timescale for electron loss. We solve the Fokker-Planck equations numerically and demonstrate that net electron energization occurs when k exceeds a critical value. We use classical methods to obtain asymptotic solutions of Models 1-6 for the electron distribution f that are valid for large energy E. Specifically, we obtain simple analytic forms for the electron spectra for the cases (a) a full-band whistler-mode spectrum, and (b) a lower-band chorus spectrum for both a Gaussian spectrum and a power-law spectrum. The asymptotic solutions are found to test well against full numerical solutions of the Fokker-Planck equation. We carry out a comparison of our model results with experimental satellite data. We show comparisons of the asymptotic and numerical solutions for Model 1 with four selected “events,” namely Storm 1 (October 9, 2012), Storm 2 (March 17, 2013), Non-storm (February 23, 2013), and average geosynchronous conditions. We find reasonable agreement between both analytic and numerical solutions with the experimental spectra for all four events. For future work, we suggest an extensive statistical study comprising the comparison of the analytic asymptotic spectra obtained here with experimental data from chorus-driven relativistic electron events during a large number of isolated magnetic storms. The Van Allen Probes era (2012-2019) would be a possible source of such storms. As a further project, since the asymptotic spectral forms derived here are strictly valid for large energy E, it would be interesting to compare the asymptotic forms with experimental spectra of ultra-relativistic ($>$ 10 MeV) events.