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Dependence of Electron Diffusion and Advection Coefficients on Chorus Wave Amplitude and bandwidth

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Whistler mode chorus wave is one of the most important electromagnetic waves driving the particle dynamics in Earth's radiation belts. Quasilinear methods are commonly used for simulating the interactions between energetic electrons and chorus waves, which assume that the modeled waves are incoherent, broadband, and low amplitude waves. Many studies have validated this assumption under different circumstances, suggesting that the assumption tends to fail for narrow band, intense chorus. In addition, diffusion coefficients calculated form the quasilinear theories are proportional to the square of the wave amplitude. Such relation is shown to overestimate the diffusion coefficients for large amplitude chorus waves. In this research, we use test particle simulations to quantitatively study the dependence of chorus induced scattering on its wave amplitude (10-2000 pT), as well as frequency bandwidth (0.01 – 0.2 fce). We show that for small wave amplitude, the quasilinear theory well describes the diffusive evolution of electrons due to chorus waves. For very large amplitudes, diffusion coefficients calculated from test particle methods are much smaller than those from quasilinear methods, due to the nonlinear wave particle interactions. For the intermediate amplitudes, test particle diffusion coefficients exceed quasilinear results. Non-zero average pitch angle and energy variations are seen for cases outside the quasilinear regime, and even for cases within the quasilinear regime for electrons with very small initial pitch angles. Such pattern varies for different electron initial energies and pitch angles, as well as different chorus wave bandwidths. Our study shows that nonlinear wave particle interaction effects need to be considered in the current diffusion models, even for broadband chorus wave with intermediate amplitudes (~100 pT).