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Pitch angle scattering rates and energetic electron precipitation caused by chorus emissions in the inner magnetosphere

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Energetic electron scattering is highly affected by whistler mode chorus emissions in the Earth's inner magnetosphere. Whistler mode chorus emissions are usually observed with oblique wave normal angles (WNAs), and the different WNAs influence the electron motions. This study aims to reveal the relation between wave WNAs and energetic electron precipitation, and to verify the processes of nonlinear resonances that result in electron precipitation. We utilized test particle simulations and the Green's function method to trace energetic electrons scattered by a pair of chorus emissions. We apply 12 chorus wave models with four various WNA sets (the maximum WNA are 0 deg, 20 deg, 60 deg, and 90% of resonance cone angles) and three wave amplitude sets (the maximum wave magnetic fields are 2.1 nT, 300 pT, and 50 pT) at L = 4.5. Besides, we theoretically derive the pitch angle scattering rates of resonant electrons. According to the simulation results and the theoretical pitch angle scattering rates, we find that: (1) Wave amplitudes are the most important factor affecting energetic electron precipitation; (2) Under the same wave condition, in general, the precipitation rates of low-energy (tens of keV) electrons are higher than those of high-energy (hundreds of keV) electrons because the pitch angle scattering rates of the n = 1 cyclotron resonance is higher for low-energy electrons than for high-energy electrons; (3) For large amplitude waves, the precipitation rates of the very oblique chorus waves are about 1.5 times greater than those of the parallel waves and about 1.2 times greater than those of the slightly oblique waves. It is because of active nonlinear trapping (n = 0 and n = -1 resonances) and nonlinear scattering (n = 2 resonance); (4) In the large amplitude and very oblique case, electrons can precipitate from the initial equatorial pitch angles >40 deg around 100 keV because of the strong nonlinear trapping via the n = -1 cyclotron resonance.