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Electron pitch angle diffusion and rapid transport/advection during nonlinear interactions with whistler-mode waves

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Radiation belt numerical models utilize diffusion codes that evolve electron dynamics due to resonant wave-particle interactions. It is not known how to best incorporate electron dynamics in the case of a wave power spectrum that varies considerably on a 'sub-grid' timescale shorter than the computational time-step Δt, particularly if the wave amplitude reaches high values. Timescales associated with the growth rate, γ, of thermal instabilities are very short, and typically Δt>>1/γ. We use a kinetic code to study electron interactions with whistler-mode waves in the presence of a background plasma with thermally anisotropic components, as frequently occur within the magnetosphere. For low values of anisotropy, thermal instabilities are not triggered and we observe similar results to those obtained in Allanson et al. (2020, https://doi.org/10.1029/2020JA027949), for which the diffusion matched the quasilinear theory over short timescales inversely proportional to wave power. For high levels of anisotropy, wave growth via instability is triggered. Dynamics are not well described by the quasilinear theory when calculated using the average wave power. During the growth phase (~0.1s) we observe strong diffusive and advective components, which both saturate as the wave power saturates at ~ 1nT. The advective motions dominate over the diffusive processes. The growth phase facilitates significant transport in electron pitch angle space via successive resonant interactions with waves of different frequencies. This motivates future work on the longer-time impact of very short timescale processes in radiation belt modelling, and on the indirect effects of anisotropic background plasma components on electron scattering. We suggest that this rapid advective transport during nonlinear wave growth phase may have a role to play in the electron microburst mechanism.

[Allanson et al, JGR Space Physics, 2021 (under review)]