Modeling the Wave Normal Distribution of Chorus Waves

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The propagation and attenuation characteristics of lower band and upper band chorus waves are investigated by ray tracing and the evaluation of Landau damping based on an empirical suprathermal electron model derived from THEMIS data. The rate of Landau damping is found to increase at larger L, for more oblique wave normal angles, and for higher geomagnetic activity. Damping is also larger on the nightside compared to dayside, and is more pronounced in the upper band than in the lower band. These features can account for the statistical pattern of chorus waves observed away from the equatorial source region. A physical model of the wave normal angle distribution along a field line is presented, which gives an insight on how the wave normal angle distribution varies as chorus waves propagate away from the equatorial source region. Our modeling shows that wave emissions at low latitude ($<\sim 30^\circ$) come predominately from the equatorial source on the same L-shell, and that their wave normal angles increase with increasing latitudes due to wave refraction caused by magnetic gradients and curvature. However, at high latitude ($>\sim 30^\circ$), the wave normal angle distribution along a particular field line will be affected by the equatorial chorus source at other fields line with lower L, because of significant cross-L propagation. As a consequence, the lower band wave normal angle tends to decrease with increasing latitudes and upper band wave normal angle can either increase or decrease depending on the equatorial source at lower L. The effect of cross-L propagation might also explain why observed wave normal angle distribution tends to become more field-aligned at high latitudes. Interestingly, upper band chorus at such high latitude originate from the lower band waves originating near the equator at lower L. A global model of wave normal variation along a field line is not currently available from observations, but is nonetheless critically important for evaluating bounced averaged diffusion coefficients for future radiation belt modeling.