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Whistler-mode Chorus Waves observed on the Cluster spacecraft in the Earth radiation belts

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VLF waves play a crucial role in the dynamics of radiation belts, and are responsible for the loss and the acceleration of energetic electrons. Modeling wave-particle interactions requires the best possible knowledge of wave energy and wave-normal directions in L-shells for different magnetic latitudes and magnetic activity conditions. In this work, we performed a statistical study for VLF emissions using a whistler frequency range for ten years (2001-2010) of Cluster measurements. We utilized the data from the STAFF-SA experiment, which spans the frequency range from 8.8 Hz to 3.56 kHz. We present distributions of wave magnetic and electric field amplitude and wave-normals directions dependences upon magnetic latitude, magnetic local time, L-shell and geomagnetic activity in a form of probability levels, which can be directly applied for diffusion coefficients calculation. We show that wave-normals are directed approximately along the magnetic field (with the mean value about 10-15 degrees) in the vicinity of the geomagnetic equator. The distribution changes with magnetic latitude, the angle for a given frequency tends to the resonance cone and as a result at latitudes about 30 degrees, wave-normals become nearly perpendicular to the magnetic field. The observed angular distribution is significantly different from Gaussian and the width of the distribution increases with latitude. Our results confirm earlier analysis of the strong dependence of wave amplitude on geomagnetic activity. An important new finding is the strong dependence of the wave normal direction and wave amplitude on the geomagnetic latitude. Due to this transition of propagation properties of the wave mode, wave electric field increases with latitude and has a maximum near 20 degrees. Wave magnetic field amplitude has minimum at the magnetic equator but increases rapidly with latitude, and has its maximum near 12-15 degrees.