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Excitation of magnetosonic waves in the Earth's dipole magnetic field: 3D PIC simulation

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Magnetosonic (MS) waves, also referred to as equatorial noise, are common electromagnetic waves in the Earth's inner magnetosphere. These waves have a frequency range from several Hertz to several hundred Hertz, roughly between the local proton cyclotron frequency and the low hybrid frequency. The dominant magnetic field component of the waves is along the ambient magnetic field, with average amplitudes of ~50 pT. MS waves have been receiving more attention recently because of their potential importance in both accelerating and scattering relativistic electrons in the radiation belt through Landau resonance, transit time effects, and bounce resonance. Satellite observations and numerical simulations have revealed that the MS waves can be excited by the ring distribution protons with energy in the vicinity of 10 keV.

The self-consistent excitation of MS waves has been studied by 2D particle-in-cell simulations in the meridian[1] and equatorial plane[2] of a dipole magnetic field. However, the 3D simulation of MS waves needs to be investigated since the previous 2D simulations artificially limit the direction of wave propagation. Here, we report the excitation and evolution of MS waves in the Earth's dipole magnetic field based on a 3D general curvilinear particle-in-cell simulation. We find that the MS waves are excited near the equator and primarily confined at 3° of the equator. These waves propagate along both radial and azimuthal directions nearly perpendicular to the background magnetic field. In the linear stage, the growth rates of MS waves are almost equal in radial and azimuthal directions. The waves propagating along the azimuthal direction can grow for a longer time, resulting in the wave amplification dominated by the azimuthal direction after saturation. The simulation results provide a valuable insight to understand the self-consistent evolution of MS waves in the dipole magnetic field, and the findings are useful for understanding the plasma wave-particle interaction in the Earth's radiation belts.

References

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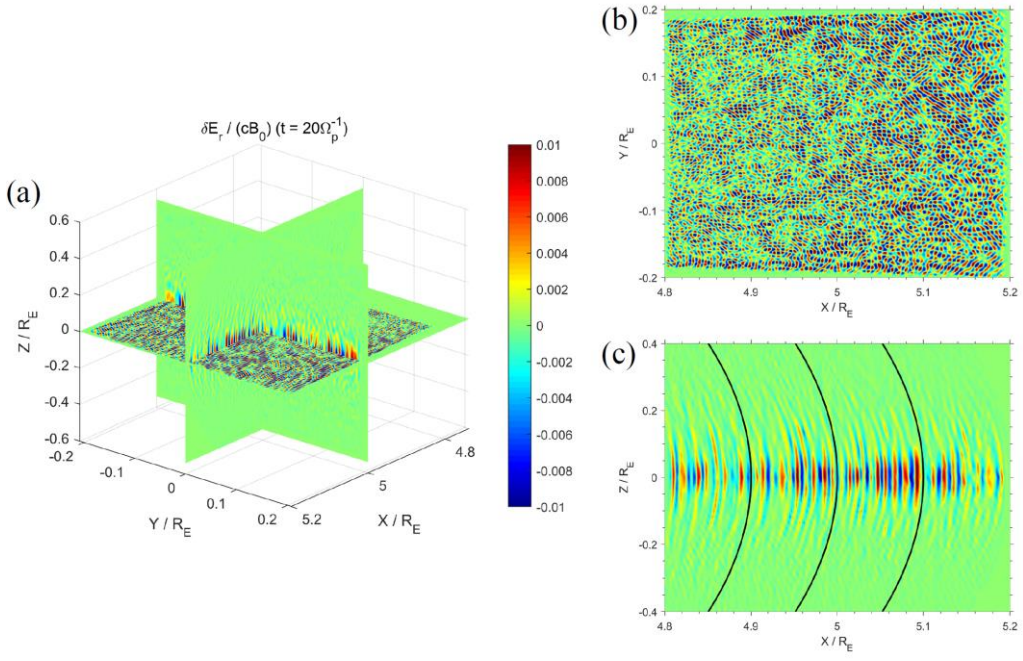

Figure 1. The spatial distribution of δE_r of MS waves for 3D PIC simulation in (a) the 3D Cartesian coordinates, (b) the equatorial plane, and (c) the meridian plane at $\Omega_p t = 20$.