Global drift kinetic simulations of internally driven ULF waves in the Earth's inner magnetosphere

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Ultra-low frequency (ULF) waves are electromagnetic pulsations that are widely observed in the magnetosphere and the ionosphere. The excitation mechanism and global distribution of ULF waves are keys to understand the variation of the outer radiation belt, since ULF waves in the Pc5 range (1.6-6.7 mHz) can drive radial transport of radiation belt electrons (MeV).

ULF waves can be generated by ring current ions associated with the injection from the plasma sheet during substorms, which are called as internally driven ULF waves. Theoretically, Southwood (1976) [1] proposed that drift-bounce resonance was a candidate excitation mechanism of ULF waves. Previous spacecraft observations suggested the excitation of internally driven ULF waves through the drift-bounce resonance. Previous studies of ULF waves assumed the simplified situations such as locally homogeneous plasmas and where and how ULF waves are generated by ring current ions in the inner magnetosphere are far from understood.

In this study, we have investigated the excitation of ULF waves based on the magnetosphere-ionosphere coupled model. In the magnetosphere, we used GEMSIS-RC model [2], in which 5-D drift-kinetic equation for ion phase space density (PSD) and Maxwell equations are solved self-consistently under the assumption that the first adiabatic invariant is conserved. GEMSIS-RC model is capable of describing the excitation and propagation of ULF waves, since the model can assume the force-imbalanced state. In the ionosphere, GEMSIS-POT model [3] was used, which is a global 2-D potential solver. The coupled model enabled us to simulate ion injection from the plasma sheet by the convection electric field. In order to investigate the effects of the dynamics of cold plasma on the excitation of ULF waves, we also implemented the simulation code to describe the dynamics of cold plasma into GEMSIS-RC model and compared simulation results between the case of constant density (Case a) [4] and the inclusion of the dynamics of cold plasma (Case b).

Simulation results showed the excitation of two types of Pc5 ULF waves in both cases. Figure 1 shows the global distribution of two types of Pc5 waves in Case a. First, we found the drift resonance excitation of Pc5 waves on the dayside. The waves were driven by positive energy gradient of ion PSD with the energy of 50-120 keV. Second, Pc5 waves were excited by the drift-bounce resonance on the duskside. The waves were driven by inward gradient of ion PSD with the energy of 50-80 keV. In Case b, by including the dynamics of cold plasma, the plasmapause was formed on the nightside. Simulation results suggested that ULF waves were also generated on the nightside and dawnside near the density gradient in addition to two types of Pc5 waves. We will also report on the effects of the dynamics of cold plasma on the excitation of ULF waves and future plans about the simulation of ULF waves of weakly magnetized planets.

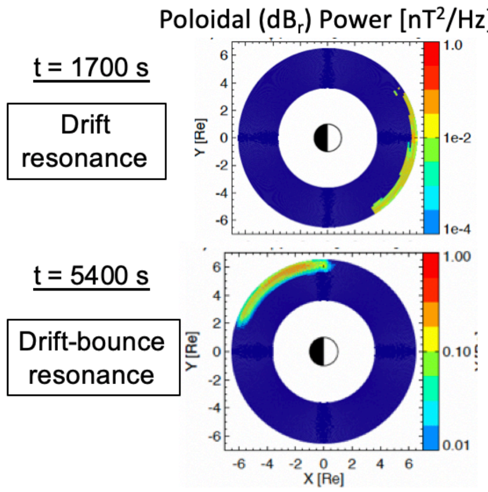

Figure 1. Global distribution of poloidal wave power spectra of two types of Pc5 waves in the plane with MLAT = 1° in Case a.

References
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