Excitation of High-*m* Poloidal ULF Waves in the Inner Magnetosphere during Geomagnetic Storms and Substorms: Importance of Radial Gradient of Proton Distributions in Drift-Bounce Resonance

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Abstract

The present thesis examines poloidal ultra low frequency (ULF) wave excitation associated with geomagnetic storm and substorm activities by analyzing data obtained from spacecraft and ground observations, and discuss the importance of the radial gradient of proton distributions in drift-bounce resonance.

Chapter 1 describes the characteristics of ULF wavesa and drift-bonce resonance. The objective of the thesis is also stated in this chapter.

The instruments onboard the spacecraft and the data from these instruments are described in Chapter 2. Data from ground magnetometer observations are also shown. Descriptions of the evaluation of the magnetic field measurements with the fluxgate magnetometer onboard the Arase satellite are also included in this chapter.

Chapter 3 explains an event study of compressional Pc 4 waves observed by the Arase satellite and ground-based magnetometers during the recovery phase of a moderate substorm. I show observational evidence of drift resonance between westward propagating compressional Pc 4 waves and protons at >50 keV. The azimuthal wave number (m-number) is estimated from ground observations to be approximately –50. The theory of drift resonance gives m = –49 for odd mode waves and ~110 keV protons, providing evidence that drift resonance indeed took

place in this event. I have also found a steep earthward gradient of the proton phase space density, which can quantitatively explain the wave excitation.

Chapter 4 describes an event study of poloidal Pc 4 wave excitation caused by substorm-injected protons. This event was obtained by the Van Allen Probe A observation near the magnetic equator at MLT ~ 13 hour. The *m*-number of the wave is estimated to be 220–260, and the wave propagated eastward. The wave is excited through drift-bounce resonance with substorm-injected protons at 10–30 keV. Temporal variations of the radial gradient of the proton phase space density are estimated through the ion sounding technique. The use of this technique reveals that the radial gradient is actually intensified due to the injected protons, and it is found that the temporal intensification can generate the wave packets. The observation also suggests that the wave excitation is related with the expanded plasmasphere where cold electron density is high (>100 cm^{-3}). The expanded plasmasphere is thought to be formed during a small geomagnetic storm that occurred 2 days before the wave event. Important roles of the geomagnetic storm in the generation of the wave are discussed.

Chapter 5 describes a statistical study of long lasting non-compressional poloidal waves that occur during geomagnetic storms. By introducing an automated method for the wave detection, I examined the data obtained by Van Allen Probe B during 6 years and 9 months. The estimated *m*-number of the detected wave ranges between –50 and –250. Observed proton flux oscillations and estimated *m*-number indicate that most of the detected waves are excited through drift-bounce resonance. A superposed epoch analysis has also been performed, and it is found that the long lasting poloidal waves are frequently observed 1–3 days after the main phase of coronal mass ejection-driven storms. This tendency is discussed in terms of the energy and radial gradients of the proton distributions.

Chapter 6 summarizes the results obtained from this thesis. The dynamic variations of particle distributions during geomagnetic storm/substorm activities can cause the steep radial gradient of the proton phase space density, which plays an important role in the excitation of the poloidal ULF waves.