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Zoom meeting B ：11/2 AM1 (9:00-10:30)
09:00-09:15

IMF dependence of multi-harmonic toroidal ULF waves: A Statistical study of the Arase satellite observations

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Multi-harmonic toroidal ultra-low frequency (ULF) waves have been reported by several event studies (e.g., Takahashi & McPherron, 1984; Engebretson et al., 1986; Takahashi et al., 2014, 2020). These waves are the standing Alfven waves and their excitation is related to small cone angle, and hence the ion foreshock is a possible energy source of them (Takahashi & McPherron, 1984). The characteristics of wave frequencies of the multi-harmonic toroidal waves may reflect the frequency spectrum of the wave source around the magnetopause, that is, fast mode perturbation which is coupled with toroidal mode oscillations in the magnetosphere as suggested by Hasegawa et al. (1983). Therefore, the characteristics of the multi-harmonic toroidal waves can be connected to the frequency dependence of energy transmission from the magnetopause to the earth's magnetosphere. However, why they have the harmonic frequency structure and what determines a frequency range of the harmonic spectrum is not fully understood from previous event studies.
In this study, we conducted a statistical study of the occurrence distributions and the characteristics of wave frequencies to understand the excitation mechanism of the multi-harmonic toroidal waves. We used the magnetic field and electron density data obtained from the Arase satellite. The Arase satellite has an inclined orbit with an apogee of ~6.1 R_E and covers a wide range of L-shell up to 10-11 (Miyoshi et al., 2018). This enable us to investigate global distributions of ULF waves beyond the geosynchronous orbit.
From the Arase observations, we found that the MLT distributions of toroidal waves with a single wave frequency (category a) and multiple frequencies (category b) show different response to the interplanetary magnetic field (IMF). At L = 7-10, the multi-harmonic waves (category b) are frequently detected on the dusk and dawn flanks and the occurrence rate on the dawn side is slightly higher than the dusk side for the Parker spiral IMF orientation. For the ortho-Parker spiral IMF orientation, the multi-harmonic waves are frequently detected on the dusk side. This IMF dependence of the MLT distributions of the occurrence rate implies that the multi-harmonic waves are related to the location of a quasi-parallel shock or ion foreshock. We also found that multi-harmonic waves more strongly depend on the cone angle and solar wind speed than the waves with a single frequency. This result suggests that the excitation mechanism of the waves in categories a and b is different.
We examined the wave frequency for categories a and b in detail. The wave frequency for category a is ~ 5 mHz at L = 7-10 and corresponds to the fundamental mode frequency predicted by Singer et al. (1981). The median values of wave frequencies for category b range from 15 to 25 mHz, and they are close to the third harmonic toroidal wave frequency at L = 7-10. Therefore, the wave frequency of category a is close to that of the waves excited by the KH instability, while the wave frequency of category b is close to that of the upstream waves. The central frequency of the frequency band of the multi-harmonic waves is positively correlated with the theoretical frequency of the upstream waves calculated from Takahashi et al. (1984) during a small cone angle. Therefore, we consider that fast mode perturbations with broadband frequencies around the upstream frequency propagate in the magnetosphere and are coupled with toroidal mode oscillations, resulting in the field line resonance.