Energetic electron precipitations showing ULF modulation observed by VLF/LF transmitter signals

*田中 健太郎[1]、大矢 浩代[1]、土屋 史紀[2]、塩川 和夫[3]、三好 由純[3]、西谷 望[3]、堀 智昭[3]、寺本 万里子[4]、Martin Connors[5]、Simon Shepherd[6]、中田 裕之[1]
*Tanaka Kentaro[1], Hiroyo Ohya[1], Fuminori Tsuchiya[2], Kazuo Shiokawa[3], Yoshizumi Miyoshi[3], Nozomu Nishitani[3], Tomoaki Hori[3], Mariko Teramoto[4], Martin G Connors[5], Simon G Shepherd[6], Hiroyuki Nakata[1]

1. 千葉大学大学院工学研究院、2. 東北大学大学院理学研究科惑星プラズマ・大気研究センター、3. 名古屋大学宇宙地球環境研究所、4. 九州工業大学、5. Athabasca University、6. Dartmouth College
1. Graduate School of Engineering, Chiba University, 2. Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University, 3. Institute for Space-Earth Environmental Research, Nagoya University, 4. Kyushu Institute of Technology, 5. Athabasca University, 6. Dartmouth College

Energetic electron precipitation (EEP; >100 keV) from radiation belts to the D-region ionosphere during substorms has been studied since the 1960s using very low frequency (VLF; 3 kHz to 30 kHz)/low-frequency (LF;30 kHz to 300 kHz) radio transmitter signals and riometers (Thorne and Larsen, 1976). The VLF/LF technique is most sensitive to the ionization of the D-region ionosphere, which is caused by energetic electron precipitation with energies typically >100 keV (Rodger et al., 2012). The low-latitude limit of particle precipitation is $L \sim 4.0$ (Berkey et al., 1974). Several studies have reported ionospheric modulations due to ultra low frequency (ULF) Pc5 and Pi2 modulations (Asnes et al., 2004). Modulation of D-region due to ULF waves during a substorm was reported (Miyashita et al., 2020). However, there was only one report for the EEP associated with ULF modulation using VLF/LF transmitter signals. In this study, we investigate the energetic electron precipitations associated with the ULF modulation that occurred on May 5, 2011, using the VLF/LF transmitter signals observed in North America. The three transmitters were NDK (frequency: 25.2 kHz, 46.37°N, 261.47°E, L=3.0); WWVB (60.0 kHz, 40.67°N, 254.95°E, L=2.3); and NLK (24.8 kHz, 48.20°N, 238.08°E, L=2.9). One receiver at Athabasca (ATHA), Canada (54.6°N, 246.7°E, L=4.3) was used. During 05:00-05:30 UT on May 5, 2011(magnetically quiet time), oscillations in amplitude and phase of VLF/LF waves with a period of 4-6 minutes were observed on the NDK-ATHA and WWVB-ATHA paths. This suggests that the EEP occurred over the two paths. The ground-based H-component magnetic field variations and Doppler velocity observed by the SuperDARN HF radars showed the there were small regions where the Doppler velocity was large near the WWVB-ATHA and NDK-ATHA paths during the VLF-LF oscillations. It is possible that the EEP occurred over the two paths. Based on ground-based magnetic field data, the propagation direction of the ULF wave was eastward (83.5 km/s) from the pre-midnight sector. In this presentation, we will discuss the cause of these VLF/LF oscillations.

