Statistical study of IPDP type EMIC wave-related electron precipitation at subauroral latitude

*Asuka Hirai[1], Fuminori Tsuchiya[1], Takahiro Obara[1], Yasumasa Kasaba[1], Yuto Katoh[2], Hiroaki Misawa[1], Kazuo Shiokawa[3], Yoshizumi Miyoshi[3], Satoshi Kurita[3], Martin G Connors[4]

1. Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku Univ. , 2. Department of Geophysics, Graduate School of Science, Tohoku University, 3. Institute for Space-Earth Environmental Research, Nagoya University, 4. Athabasca University

The outer radiation belt electrons disappear during the main phase of geomagnetic storms. One of the loss mechanisms of electrons from the outer belt is precipitation into the atmosphere due to wave-particle interactions. Electromagnetic ion cyclotron (EMIC) waves are believed to be important plasma waves that contribute to the loss of the outer radiation belt due to pitch angle scattering. They can scatter relativistic and ultra-relativistic electrons. However, there are still questions left about the contribution of EMIC waves to the whole loss of radiation belt electrons and possible conditions favorable to pitch angle scattering.

EMIC waves mainly propagate along magnetic field lines and are observed on the ground as Pc1 geomagnetic pulsations. Intervals of pulsations of diminishing periods (IPDP) are Pc1/EMIC waves that are characterized by frequency rise from 0.1 to 1–2 Hz in a period of ~1 h, and often occur during substorms. Recent studies reported that IPDP are preferentially associated with relativistic electron precipitation. However, the statistical relation between IPDP waves and relativistic electron precipitation, and their physical mechanism, remain open issues.

We investigated differences in characteristics between IPDP and other types of Pc1 by using an induction magnetometer and VLF radio wave data that is a proxy of electron precipitations at subauroral latitude from 1 November 2016 to 30 June 2018. We used the induction magnetometer of PWING (study of dynamical variation of Particles and Waves in the INner magnetosphere using Ground-based network observations) at Athabasca, Canada (54.6˚N, 246.36˚E, L = 4.39). VLF radio waves propagate from transmitters to receivers in subionospheric waveguide. The modulations of VLF signals are detected as occurrence of sub-relativistic and relativistic electron (>100 keV) precipitation due to ionization changes in the lower ionosphere along the radio wave propagation path. VLF radio waves are transmitter from NDK, U.S. (46.367˚N, 261.467˚E, L =3.13) and NLK, U.S. (48.2˚N, 238.083˚E, L =2.84) and received at Athabasca. We selected EMIC wave events on the basis of the following criteria: (1) EMIC wave power is higher than 10^{-5} nT^2/Hz. (2) Duration of EMIC waves is longer than 20 min. (3) Interval between one EMIC wave event and the next one is longer than 30 min. Electron precipitation was identified as a decrease in amplitude of VLF signals from the quiet day curve (QDC). We counted as EMIC wave-driven electron precipitation if we detect temporal correspondence with EMIC waves. In this period, we found 950 EMIC wave events, and 87 of total EMIC wave events were IPDP events (9.2%). Local time dependence of EMIC waves shows that IPDP often occurs in the afternoon and evening sector, while other types of Pc1 occur in all local time range, but with a maximum in 12–16 MLT, which is consistent with previous studies. Simultaneous observation of the magnetometer and VLF radio waves were available for 286 days, and we found 163 EMIC wave events. 19 of 163 EMIC wave events were clearly associated with electron precipitation (12%). Among 19 electron precipitation events, 15 events were caused by IPDP (79%). Also, the electron precipitation events were observed in the evening sector with similar local time dependence to IPDP. This result suggests that IPDP is more likely to cause electron precipitation than other Pc1 wave types. In previous studies, IPDP occurs due to ion cyclotron instability of ring current ions in the evening sector, and favorable region for electron scattering by EMIC waves is high density duskside plasmapause

and plasmaspheric plume because dense plasma lowers minimum resonant energy of electrons. It is assumed that occurrence region of IPDP is coincident with the preferential region for MeV electron scattering by EMIC waves. For this reason, it is expected that IPDP type EMIC waves significantly cause relativistic electron precipitations in the duskside.

Keywords: EMIC waves, electron precipitation, subionospheric VLF radio waves

