EMIC waves-driven radiation belt electron precipitation into the atmosphere with ground-based observations in the subauroral region

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Energetic electron losses from the outer radiation belt occur during magnetic storm and substorm. One of the mechanisms is precipitation into the atmosphere and electromagnetic ion cyclotron (EMIC) waves are one of candidates to cause pitch angle scattering of energetic electron. EMIC waves ,which are observed in the Pc1–Pc2 frequency range (0.1–5Hz) are excited by the ion cyclotron instability in the equatorial region of the magnetosphere during the main and the recovery phase of magnetic storms. It has been theoretically studied that EMIC waves play an important role in energetic electron precipitation into the atmosphere, but there have been limited experimental observations to support this idea.
Here, we investigated relation between occurrence of EMIC waves and energetic electron precipitation by means of ground-based magnetometers and low frequency (LF) radio wave propagation observation and confirmed EMIC waves to be driving electron precipitation.
We use induction magnetometer data in North America (ISEE and CARISMA stations) to investigate occurrence of EMIC waves. LF radio wave signals transmitted from WWVB, United States(40.7˚N, 255.0˚E, L=2.28), are observed at Athabasca, Canada(54.7˚N, 246.7˚E, L=4.35) to investigate precipitation of energetic electron (>100kev) into the atmosphere. LF radio waves propagate, reflecting between earth’s surface and the lower ionospheric boundary (altitude=~70-90km). Ionization caused by precipitating electron in the lower ionosphere changes altitude of the reflection height, resulting in a deviation of the LF wave phase from that in undisturbed conditions.
We detected energetic electron precipitation from the LF radio wave observation in 07:00-09:20 UT on July 7, 2011 and EMIC waves were observed by the induction magnetometer at Athabasca in 05:35-10:55 UT on the same day. At the almost same time, EMIC waves were observed at some CARISMA stations. These observations indicate that EMIC waves are expected to cause detected electron precipitation.
Polarization characteristics of EMIC waves which reflect locations where the waves inject into the ionosphere and direction of subsequent horizontal propagation in the F-region were examined by cross-spectrum analysis of EMIC waves.
Based on time variations in intensity, frequency, polarization sense, and angle of the major axis, the period of EMIC appearance could be divided into six sequential events. This suggests that source of the EMIC waves observed in 05:35-10:55UT was not a single but consisted of multiple locations locations.
We found that time variation of the LF wave phase corresponds to that of EMIC waves, and the deviation of the LF wave phase only occurred during the 2nd, 3rd and 4th EMIC events. This result implies that the source locations of the three EMIC events were close to the Athabasca-WWVB radio wave propagation path and the EMIC-driven energetic electron precipitation caused the phase deviation of WWVB signal. Identification of actual source locations of the EMIC events is a future work.

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