Temporal and spatial correspondence of EMIC waves and energetic electron precipitation observed by ground-based stations on 27 March 2017

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Energetic electron losses from the outer radiation belt occur during magnetic storms and substorms. One of the mechanisms is precipitation of the electrons into the atmosphere. The electromagnetic ion cyclotron (EMIC) wave is one of the candidates to cause pitch angle scattering of the energetic electrons. 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 and propagate along magnetic field lines to the ionosphere. While it has been theoretically studied that EMIC waves play an important role in the energetic electron precipitation, it is not easy to observe temporal and spatial proximities of these phenomena.

Here, we investigate relationship between occurrence of EMIC waves and energetic electron precipitation using multiple ground-based observations.

We used induction magnetometer data in North America (PWING and CARISMA stations) to find occurrence of EMIC waves. We also use artificial VLF/LF radio waves that propagate from transmitters to a receiver through reflection, between earth’ s surface and the lower ionospheric boundary at altitudes of 70-90km. Ionization caused by precipitating electrons on the radio propagation path results in changes in the propagation path and attenuation of the signal amplitude. Thus, precipitation of energetic electrons at energies higher than ~100keV causes deviation of the VLF/LF wave amplitude from that in undisturbed conditions. In this study, we analyzed VLF/LF wave signals received at Athabasca, Canada (latitude=54.7, longitude=246.7, L=4.45). An all sky imager at Athabasca (one of the PWING stations) was used to observe spatial and temporal characteristics of proton aurora which was useful to identify ionospheric sources of the EMIC waves.

During the main phase of a geomagnetic storm on 27 March 2017, Pc1 waves were observed at several stations: Kapuskasing (latitude=49.4, longitude=277.81, L=4.72), Pinawa (latitude=50.2, longitude=263.7, L=4.06), Thief River Falls (latitude=48.0, longitude=263.6, L=3.58), Ministik Lake (latitude=53.4 longitude=247.0, L=4.22) and Athabasca in 03:10-06:30 UT. Pc1 waves were initially seen at Kapuskasing and the observed locations moved westward. Simultaneously, energetic electron precipitations were detected by VLF/LF radio waves transmitted from several stations in the United States: WWVB (latitude=40.7, longitude=255.0, L=2.28, 60kHz), NDK (latitude=46.4, longitude=261.5, L=2.98, 25.2kHz) and NLK (latitude=48.2, Longitude=238.1, L=2.85, 24.79kHz).

Isolated proton auroras appeared on the VLF/LF radio propagation paths when energetic electron precipitation was detected. When the proton aurora propagated westward and departed from the radio propagation paths, the energetic electron precipitation ceased.

The data sets presented here indicate close temporal and spatial relationship between EMIC waves and energetic electron precipitation and support that the EMIC waves drive precipitation of energetic electrons and protons into the atmosphere.

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