Energetic electron precipitation associated with Pc1/EMIC waves: Six-month LF-wave observations over North America

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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) wave is 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 and propagate along magnetic field lines to the ionosphere. After EMIC waves inject into the ionosphere, their wave mode is converted and part of them propagate horizontally in the ionospheric duct layer. While it has been theoretically studied that EMIC waves play an important role in energetic electron precipitation into the atmosphere, experimental observations have been too limited to support this idea.

Here, we investigated relation between occurrences of EMIC waves and energetic electron precipitation by means of ground-based magnetometers and low frequency (LF) radio wave propagation observation and found several events which occurred simultaneously.

We use induction magnetometers data in North America (PWING and CARISMA stations) to investigate occurrence of EMIC waves. LF radio waves propagate from transmitters to a receiver, reflecting between earth's surface and the lower ionospheric boundary (altitude of 70-90km). Ionization caused by precipitating electrons in the lower ionosphere results in changes in the radio propagation path and attenuation of signal amplitude. Thus, precipitation of energetic electrons (higher than 100keV) causes deviation of the LF wave amplitude from that in undisturbed conditions. In this study, we analyzed LF wave signals received at Athabasca, Canada (latitude=54.7, longitude=246.7, L=4.45) and Poker Flat, Alaska (latitude=65.1, longitude=212.5, L=5.95). LF radio waves received at Athabasca are transmitted from several stations in United States: WWVB (latitude=40.7, longitude=255.0, L=2.28, 60kHz), NAA (latitude=44.7, longitude=292.7, L=2.89, 24.0kHz), 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). LF radio waves received at Poker Flat are transmitted from NDK and NLK.

We compared occurrences of night time LF wave amplitude variations from the quiet day curve with substorm and Pc1 for six month from 1 January to 30 June 2017. In this study, 55 Pc1 events were identified from the induction magnetometer at Athabasca whose power exceeded $10^4 nT^2/Hz$. We also identified 107 substorms as the events whose AE indices were larger than 600nT and horizontal component values of the magnetic field at some stations in North America (magnetic latitude higher than 60^0) were lower than -200nT. We found 76 substorm events accompanied by the LF wave amplitude variation (71.0%) and five Pc1 events accompanied by LF variation (9.1%). While electron precipitation region detected by LF radio waves is localized on the propagation path from a transmitter to a receiver, Pc1 waves propagate in a horizontal direction widely outside the localized ionospheric source. This is one of reasons to explain the low occurrence of Pc1 event which accompanied the LF amplitude variation.

The five Pc1 events which accompanied LF wave amplitude variation occurred on 18 January, 22 February, 8 March, 21 March and 27 April 2017. We will analyze polarization and propagation direction of Pc1 using multiple induction magnetometer data to investigate spatial correspondence between location of Pc1 ionospheric source and that of energetic electron precipitation.

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