Statistical study of EMIC waves and energetic electron precipitation: ground-based magnetometer and subionospheric VLF/LF radio measurements at subauroral latitude

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Electromagnetic ion cyclotron (EMIC) waves are observed as Pc1-2 pulsations in the Earth's magnetosphere. These waves are excited due to the temperature anisotropy of ring current ions near the magnetic equator, and scatter the pitch angle of relativistic electrons through cyclotron resonance. This process causes the precipitation of high-energy electrons into the atmosphere, and is considered as one of the mechanisms to cause the loss of the outer radiation belt. There are two major questions left in this scenario. One is the amount of the contribution from the EMIC waves to the overall loss of radiation belt electrons. Another one is the conditions favorable to pitch angle scattering.
We performed a statistical study of EMIC waves associated with electron precipitations from November 2016 to December 2018. EMIC waves were observed by ground-based magnetometers installed at Athabasca, Canada (54.6°N, 246.7°E, L=4.3), which are operated by the PWING ('study of dynamical variation of Particles and Waves in the INner magnetosphere using Ground-based network observations') project. We used an automatic detection algorithm based on Bortnik et al. (2007) to identify EMIC wave events. Electron precipitation events were identified from the VLF radio waves propagating from transmitters at NDK, US (25.2kHz, 46.37°N, 261.47°E) and NLK (24.8kHz, 48.20°N, 238.08°E) to the receiver installed at Athabasca. Since these transmitted VLF waves are sensitive to ionization changes in the lower ionosphere, they are modulated when electrons with energies of > 100 keV precipitate above the propagation paths of VLF radio waves. In order to detect the electron precipitation events caused by EMIC waves, we identified the decreases in the amplitude of VLF signals temporally corresponding with the appearance of EMIC waves by visual inspection. In the period of analysis, we identified 999 EMIC wave events, and found 23 events clearly associated with electron precipitations. While total EMIC waves had higher occurrence rates in the dawn sector than in the dusk sector, most of the EMIC waves accompanied by electron precipitation occurred in the dusk sector during substorms. Theoretical study suggests that resonance energies of electrons interacting with EMIC waves decrease in the region of high plasma density (e.g. Summers and Thorne, 2003). Inside the plasmasphere, the resonant energy becomes down to several hundred keV. From statistical analysis and theoretical considerations, we suggestthat the ring current protons are injected inside the duskside plasmapause during substorms and excite EMIC waves in the high plasma density regions. These EMIC waves are likely to scatter relativistic electrons with energies from several hundred keV to a few MeV.

Keywords: EMIC waves, electron precipitation

