Temporal and spatial variation of the source region of IPDP type-EMIC waves: Case study on 19 April 2017

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Electromagnetic ion cyclotron (EMIC) waves are left-hand polarized waves with oscillations that include the Pc1-2 frequency range. They are excited near the magnetic equator by anisotropic ring current ions. EMIC waves are one of the interesting plasma waves in that they interact with both ring current protons and relativistic electrons. Clarifying the behavior of EMIC waves contributes to a comprehensive understanding of the variability of the inner magnetosphere, especially the ring current and the outer radiation belt. Electron scattering by EMIC waves has been considered as one of the mechanisms to cause the loss of the outer radiation belt. Evaluation of the contribution of EMIC waves to the electron loss is an important issue in understanding and prediction of the outer radiation belt variations.
Intervals of pulsations of diminishing periods (IPDP) are a type of EMIC waves characterized by an increase in frequency and occur in the dusk sector of the magnetosphere. Some studies suggested that IPDP-type EMIC waves are more likely to be associated with relativistic electron precipitation (REP) than other types of EMIC waves. However, the mechanism of increasing frequency and the reason why IPDP is associated with REP have been not clearly determined yet.
We investigated IPDP that occurred from the ground and the satellite to understand the mechanism of increasing frequency and evidence for understanding why IPDP is associated with REP. We analyzed the temporal and spatial variation of the source region of IPDP. IPDPs were observed by ground-based magnetometers installed at Kapuskasing, Pinawa, Ministik Lake, and Athabasca, Canada at 02:20-06:10 UT on 19 April 2017. Simultaneously, Van Allen Probe A observed He+ band EMIC waves in the overlapping region between the ring current and cold plasma population. The footprint was located to the west of Ministik Lake and Athabasca. Observations by POES and the ground-based magnetometers indicated that the increase in frequency of IPDP was caused by an inward shift of the EMIC wave source region. The EMIC wave source region moved inward along the midlatitude trough that was used as a proxy of the plasmapause location. This suggests that the inward shift of the source region is due to the enhancement of the convection electric field. From statistical analysis, we found that upper frequencies of IPDP show a positive correlation with maximum polar cap potential. These results suggest that increases in frequency of IPDP on the dusk side are explained by the inward shift of the overlap region between the cold plasma and the energetic ring current ions, which is the favorable region for EMIC wave excitation.
The development of the partial ring current is a necessary precondition for the occurrence of IPDP. This situation primarily occurs during the main phase of geomagnetic storms. In the main phase, the inner boundary of ring current ions and the outer boundary of the plasmasphere are overlapped, and the region becomes favorable for excitation of EMIC waves and the subsequent pitch angle scattering of relativistic

electrons by these same EMIC waves in the dusk sector. In addition to the above favorable conditions for EMIC wave-driven REP, we propose that the source region of IPDP correspondingly moves in the radial direction, causing even more favorable conditions for EMIC wave-driven REP. The inward drift of the source region allows EMIC waves to be distributed over a wide range of L shells in the entire event. This renders mode favorable conditions for EMIC waves to encounter high electron flux regions in the outer radiation belt. As a result, EMIC waves can scatter relativistic electrons over a wide range of L shells, leading to electron precipitation into the ionosphere. This mechanism suggests that IPDP is more effective to scatter relativistic electrons than other types of EMIC waves that are generated by other processes, contributing to the loss of the outer radiation belt electrons.

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