Global distribution of ULF waves during magnetic storms: Comparison of Arase and ground observations and BATSRUS+CRCM modeling

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The relativistic electron population in the Earth’ s outer radiation belt is drastically variable, especially during the active condition of the magnetosphere such as magnetic storms. One of the candidate mechanisms to cause the variation of relativistic electron flux is the radial diffusion of the electrons driven by ultra-low-frequency (ULF) waves in Pc5 frequency ranges (1.6–6.7 mHz). Previous studies have investigated the global distribution of ULF waves from statistical analysis using ground and/or direct measurements. However, the temporal and spatial variations of ULF wave distribution associated with the variation of relativistic electrons are still open to discuss. Therefore, the investigation using not only observational data but also numerical simulations is useful to understand how ULF waves contribute to the relativistic electron population in the inner magnetosphere.
In December 2016, Arase satellite was launched into the inner magnetosphere, and the campaign observations between Arase and ground observations are now operated. During the magnetic storm on 27 March 2017, both Arase satellite and several magnetometers detected ULF waves. Taking the advantage of this opportunity, we aim to reproduce ULF waves using the Comprehensive Ring Current Model (CRCM) with a global MHD model Block-Adaptive Tree Solar-wind Roe Upwind Scheme (BATSRUS) and investigate the temporal and spatial variation of the global distribution of ULF waves comparing with the Arase satellite and ground-based observations.
We confirm that CRCM with BATSRUS can reproduce ULF waves with the frequency of 2–3 mHz during 27 March storm, which is consistent with the result of Arase satellite. Comparing the waveform, however, the amplitude of magnetic field derived from the simulation result is a fourth or fifth of the observational result. In addition, higher frequency waves (i.e., Pi2 pulsations) cannot be reproduced. These results are caused by the rough Cartesian grid of BATSRUS.
Next, we estimate Pc5-range wave power from the simulation result and compare to the variation of relativistic electron flux and ULF wave activity derived from magnetometer data located at subauroral region. During 27 March storm, relativistic electron fluxes decrease during the main phase and then suddenly accelerate during the recovery phase. The Pc5-range wave power estimated from the simulation result is strong during the main phase, which is correspond to the variation of solar wind dynamic pressure. On the other hand, ground-based Pc5-range wave power is strong during not only the main phase but also the recovery phase. Note that ground-based ULF wave activity corresponds to the AE index. Since this model does not consider plasma instabilities, it is assumed that CRCM with BATSRUS can reproduce ULF waves triggered by the quasi-periodic compression of the solar wind.
We also compare ULF wave activities between 27 March and 4 April storms. Comparing to 27 March storm, relativistic electron fluxes do not recover to the pre-storm level during 4 April storm. Associated with this activity, Pc5-range wave power during the main and recovery phases is not so strong. Therefore, Pc5 ULF waves might play a role in accelerating relativistic electrons.

