Study of global spatio-temporal development of magnetospheric ELF/VLF waves for the 26-30 March 2017 storm based on ground and satellite observations and the RAM simulations

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The magnetospheric ELF/VLF waves are plasma waves generated by energetic electrons from several keV to tens keV with temperature anisotropy at magnetospheric equatorial plane of the inner magnetosphere. These ELF/VLF waves with frequencies lower than local half gyro frequency (lower-band) can propagate to the ground along magnetic field line. It is also known that the ELF/VLF waves interact with electrons drifting longitudinally in the inner magnetosphere, and help accelerating them to relativistic energies. Takeshita et al. [SGEPSS, 2018] statistically investigated the longitudinal extent of the magnetospheric ELF/VLF waves using six ground-based stations for two months, and showed the average extent of the ELF/VLF waves as ~90 degrees in longitude. However, Jordanova et al. [JGR, 2010] investigated the global distribution of linear growth rate of whistler mode chorus waves using global ring current-atmosphere interactions model (RAM), and showed that the region of large linear growth rate can extend ~180 degrees in longitude during the geomagnetic storm of 22 April 2001.

In this study we investigate the spatio-temporal distibution of the source region of magnetospheric ELF/VLF waves based on ground and satellite observations during the geomagnetic storm period from 26-30 March 2017, and compare it with global distribution of non-linear waves proxy of whistler mode chorus waves obtained by the RAM simulation. In this preliminary simulation, the simple dipole field and the Volland-Stern electric field are used as ambient magnetic and electric fields. And we assumed simply the Maxwell distribution as an energy spectrum using the empirical model of Tsyganenko and Mukai [2003]. In order to evaluate the non-linear wave excitation, we have estimated the optimum amplitude and the threshold value indicated by Omura and Nunn [2011]. We investigated the existence of lower band chorus waves using ground based observations at Athabasca (ATH; 54.7N, 246.4E, MLAT: 61.3N), Kapuskasing (KAP; 49.4N, 277.8E, MLAT: 58.7N), Kannuslehto (KAN: 67.7N, 26.3E, MLAT: 64.5N) and satellite-based observations by ERG with an apogee in the pre-dawn sector and RBSP-A and RBSP-B with an apogees in the post-dusk sector. We found the magnetospheric ELF/VLF waves exist from 3 MLT to 12 MLT for most periods from main- to recovery-phases of the magnetic storm. However, the RAM simulation did not predict wave generation during recovery phase of the storm. We compare the simulation and the ground-satellite observation in detail, and calculate the over-estimate rate (the ratio of wave existence period on the simulation to no wave period on the observation) and under-estimate rate (the ratio of no wave period on the simulation to wave existence period on the observation). We found the over-estimate rate become high (0.2~0.9) and under-estimate rate become low (0~0.4) in the main phase of the storm. This indicates that the longitudinal size of chorus source region predicted by simulation is larger than the observed size at the main phase. We also found that the over-estimate rate becomes low (0~0.2) and under-estimate rate becomes high (~1) during the recovery phase of the storm. This indicates that the simulation does not reproduce the wave existence during the recovery phase of the storm. Looking into the MLT distribution, the simulation predicts the wave existence from dusk to the midnight sector, but the waves were not observed in this local time sector during the main phase. In case of recovery phase, the simulation did not predict wave existence but the observation showed continuous wave existence from dawn to the noon sector.

キーワード：コーラス波動、ERG衛星、地上観測
Keywords: chorus, ERG satellite, ground based observation