LF radio observation of storm-time energetic electron precipitation observed in the auroral and sub-auroral regions

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Low frequency (LF) radio observation has been started at Ny-Alesund, Norway (NIPR Rabben station) from Mar. 2010 and at Athabasca, Canada from Oct. 2010. Purpose of the observation is to investigate energetic electron precipitation from outer radiation belts to the atmosphere during magnetic storms and substorms. This paper presents energetic electron precipitation signature observed at both stations during magnetic storms. LF transmitter signal perturbation is caused by ionization in the lower ionosphere (D and lower E-region) and usually assumes to be sensitive to electron with energy of >100keV. To check the assumption, the phase perturbations of the LF signal are compared with the precipitation flux of energetic electron with energies from 30keV to 300keV measured above the transmitter-receiver path by NOAA/POSE satellites. The result shows that the LF phase variation is well correlated with the precipitation flux of 100 and 300keV electrons and sometimes shows no response to the 30keV electron precipitation. At Ny-Alesund, LF signals received come from UK and Germany and the radio propagation paths cross both auroral and sub-auroral latitudes. The phase variation shows clear signature of energetic electron precipitation during storm-time substorms. In the morning and noon sectors, onset of the precipitation is delayed ten to several tens of minutes from the substorm onset. The delay time is consistent with the magnetic drift velocity of energetic electron with energy of 100 keV. The electron precipitation in the dusk sector initiated at the time of substorm onset and accompanied broad band ELF noises, which implies the energetic electron scattering by ion plasma waves. Athabasca is located low latitude of auroral region and the LF radio measurement shows us energetic electron precipitation purely from the sub-auroral region. On 5 June 2011, during the main and early recovery phases of a small magnetic storm, the LF phase data shows fluctuation with the time scale of Pc5 range. Comparison of the phase fluctuation with the GOES magnetic field data shows significant correlation in the azimuthal magnetic field component, which implies the drift resonance of energetic electrons with Pc5 pulsation and subsequent energetic electron precipitation into the atmosphere.