

## Energetic electron precipitation during magnetic storm and substorm: Subionospheric VLF/LF observation

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Subionospheric VLF/LF radio observation is useful probe to investigate precipitation of high-energy (>100keV) electrons into the atmosphere and the observation at Ny-Ålesund, Norway (NAL) and Athabasca, Canada (ATH) are used to detect energetic electron precipitation in auroral and sub-auroral regions during storm and substorm. At the NAL station, radio signals which are transmitted in mid-latitude and propagate across the auroral and sub-auroral regions are recorded. During magnetic storms, the strong phase variation associated with the substorm induced electron precipitation has been detected and the phase change quantitatively corresponds to the precipitating energetic electron flux observed by the NOAA/POES satellites over the radio propagation path. Onsets of the phase change were delayed by ten to several tens of minutes from the substorm onset in the morning and noon sectors, which is consistent with the drift time of energetic electrons with energy of ~100 keV. On the other hand, the phase change in the dusk sector occurred shortly after the substorm onset and is often accompanied by Pc1 or Pi1B observed on the ground station near the radio path. These results show that the energetic electron precipitation is strongly connected with the dynamics of energetic ions and electrons and wave generations in the inner magnetosphere. The ATH station is located in the subauroral region and subionospheric signals from lower latitude are measured. The phase fluctuations with time scales of Pc5 or longer period were sometimes found during main and early recovery phases of magnetic storms. The phase fluctuations found on 5 June 2011 show good correlation with the GOES magnetic field data, suggesting Pc5 modulation of either electron injection or precipitation rates. Subionospheric radio observation provides opportunities to investigate various kinds of energetic electron precipitation processes. Part of observed data is provided through the IUGONET metadata database.