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Lower Ionospheric Perturbations Associated with Proton Aurora using Numerical Simulation of Subionospheric VLF Transmitter Signals

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It is known that Electromagnetic Ion Cyclotron (EMIC) waves generated around the magnetic equator in the magnetosphere scatter ring current protons and relativistic electrons in radiation belt due to wave particle interactions. The scattered particles lose energy and precipitate from the magnetosphere into the ionosphere. The precipitating protons produce the Isolated Proton Aurora (IPA). On the other hand, the relativistic electrons precipitated at the same time perturb the electron density in the lower ionosphere and are observed as amplitude/phase anomalies of electromagnetic waves from ground-based VLF/LF transmitter. However, VLF/LF transmitter wave is effective to monitor the lower ionosphere condition, the energy of the precipitating electrons cannot be determined directly. In this study, we construct the spatio-temporal model of the lower ionosphere based upon optical observations of the IPA, EMIC waves, and VLF transmitter wave magnetic amplitude data. The analyzed event is the propagation anomaly of NLK VLF transmitter signal associated with IPA observed on March 27, 2017 at Athabasca (ATH), Canada. Two-dimensional FDTD (Finite-Difference Time-Domain) is used for the numerical analysis and temporal change of the VLF transmitter amplitude for NLK-ATH path was calculated under various ionospheric conditions during IPA. The simulated amplitude time series was compared with that from observations. As a result, the simulated magnetic field amplitude attenuation due to the lower ionospheric perturbation (9.8 dB) agrees well with the observation (11.0 dB) when the perturbation altitude is assumed to be 60 km. And the correlation coefficient of amplitude time series between the simulation and observations is 87 %. The energy required for the electrons to precipitate to this altitude is believed to be in the MeV range. Observation of VLF/LF transmitter radio waves is a promising tool to continuously monitor the high-energy electron precipitation.