Comparing three approaches to the ground geoelectric field modelling due to space weather events

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In order to estimate the potential hazard to technological systems from space weather, it is necessary to understand the spatiotemporal evolution of the geoelectric field during geomagnetic disturbances. Once the geoelectric field is quantitively estimated, geomagnetically induced currents can be calculated from the geometry of transmission lines and system design parameters. To address the complex problem of the ground electromagnetic (EM) field modelling due to space weather events, it is necessary to consider the spatiotemporal structure of the source of the EM induction in a realistic way and take into account a realistic three-dimensional (3D) distribution of the Earth's electrical conductivity.

In this work we compare three approaches to the geoelectric field modelling. All approaches are based on the numerical solution of Maxwell's equations in Earth's models with 3-D conductivity distribution. The difference between them lies in different setting of the EM induction source. In the first two methods the source is represented by a laterally varying sheet current flowing above the Earth. The current in the first approach is computed on the base of 3-D magnetohydrodynamic simulation of near-Earth space. In the second one the source is constructed using ground-based magnetometers' data. In the third approach the geoelectric field is calculated using plane wave excitation. We carry out geoelectric field modellings for Kola Peninsula and Karelia using these three approaches. In our simulations we utilise the 3-D conductivity model of Fennoscandia (SMAP). The geoelectric field is computed using 3-D EM forward modelling code extrEMe based on a contracting integral equation method. We compare modelling results to EM field observations and discuss advantages and disadvantages of the considered approaches.