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Regional rigorous 3-D modelling of ground geoelectric field due to realistic geomagnetic disturbances. An approach and implementation.

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Strong eruptions at the Sun's surface produce large release of plasma, which with a high speed (solar wind) flows into space. Solar wind interaction with the Earth's magnetosphere and the ionosphere leads to a continuous disturbance of the geomagnetic field. This fluctuating geomagnetic field induces a ground geoelectric field that in turn generates geomagnetically induced currents (GICs) in technological systems, such as power grids and pipelines. It is well known that GICs are one of the most dangerous factors affecting the operation of the above systems. Thus, an accurate modelling of the spatio-temporal evolution of the geoelectric field during abnormal (storm-time) geomagnetic activity is a key consideration in estimating the hazard to technological systems from space weather.

We present a numerical tool for regional modelling of the space weather influence on ground geoelectric field. The tool exploits realistic regional and global three-dimensional (3-D) models of Earth's electrical conductivity, and realistic global models of the spatio-temporal evolution of magnetospheric and ionospheric current systems responsible for geomagnetic disturbances. The tool involves four steps. First, we compute the spatio-temporal distribution of external magnetic field on a regular grid at the surface of the Earth using a magnetohydrodynamic model of the magnetosphere coupled to an electrostatic model of the ionosphere. Second, from the external magnetic field we compute the global source in the form of equivalent currents flowing in a thin shell above the Earth. Third, for a given global source and a given global 3-D conductivity model of the Earth we compute ground geoelectric field globally at a coarse grid (using spherical geometry). Finally, for a given source and a given regional 3-D conductivity model(s) of the Earth we compute geoelectric field regionally (using Cartesian geometry) at a dense grid utilizing the results from the global modelling. Both global and regional computations exploit numerical solutions based on integral equation approach. We implement a scheme to compute the fields for real geomagnetic disturbances and compare the modelling results with observations.