Towards evaluation and simulation of geomagnetically induced currents (GICs) in high-latitude regions

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Geomagnetically induced currents (GICs) are potentially hazardous phenomena occurring in polar and subpolar regions caused by spaceweather events such as intense solar flares. Solar wind interacting with Earth's ionosphere and magnetosphere, at high latitudes causes geomagnetic disturbances known as subbstorms, which in turn generate induced currents in the ground, and pose a potential threat for man-made electric and electronic systems, including power electric grids and communication lines. Precise simulation and prediction of GICs requires high-detail regional conductivity grids. However, this problem also requires one to determine equivalent ionospheric source intensity, which is of global scale and therefore there is a need for a global 3-D conductivity model.

In this study, we apply a 3-D model compiled by [Alekseev et al., 2015] to evaluate the recovery of the ionospheric current distribution from magnetic response simulated at observatory stations, utilizing X3D global forward modeling code [Avdeev et al., 2002; Kuvshinov, 2008] and least squares optimization scheme. The conductivity model represents the subsurface structure in depth range of 0-100 km and has 0.25 x 0.25 degrees lateral resolution. At depth below 100 km it includes 1-D distribution inferred from geomagnetic sounding data. Model consists of a series of quasi-spherical layers, whose vertical and lateral boundaries have been specified based on available data, including global maps of bathymetry, sediment thickness, upper and lower crust thicknesses as well as lithosphere thickness. Once the geometry had been specified, each element of the structure was assigned either a certain conductivity value or conductivity versus depth distribution, according to available laboratory data and conversion laws. This a pripori model constructed from non-EM data, was then refined (within some particular regions) by incorporating the surface conductance model of Russia, as well as conductivity models of Fennoscandia.

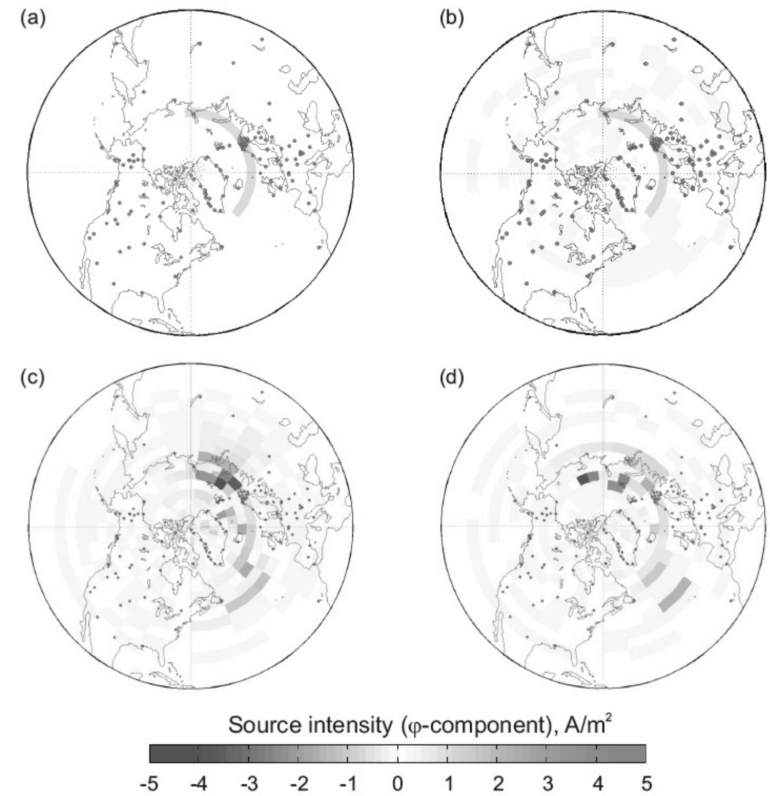

Figure 1. Source intensity (ionospheric current) inverted from synthetic magnetic resposnes. See text for explanation.

We illustrate how the precision of the model affects the accuracy of the current distribution being derived from simulated magnetic field. Fig.1 shows a simulation resuls in the form of the recovered source intensity (panels (a) to (d)). True model was assumed as a uniform current strip located at 110 km altitude, within the region confined between 24 and 28 deg magnetic colatitude, 48 and 192 deg magnetic longitude, the arch in panel (a). Then magnetic field was simulated in the frequency domain at somewhat 70 observatory locations (little circles) for a given ("true") source and a 3-D model described above. As the next step, all three components of the magnetic field at observatory locations were inverted assuming different conductivity models to derive ionospheric current distribution using regularized least squares. The conductivity models included original model (b), simplified 1-layer inhomogenous model, underlaid by background 1-D model (c), and background 1-D model only (d).

Obviously, variant (b) exhibits the highest precision of the solution, while both (c) and (d) contain some bias. However, (c) is closer to original configuration (a) then (d) is. This example confirms the importance of accurate representation of the model, required even for the source recovery, and, to even higher extent, for the subsequent calculation of electric field and GIC distributions. Thus one may see that knowing actual conductivity structure is crucial for appropriate , required for further simulation and prediction of GICs, which in turn is important for safety during intense spaceweather events in polar areas.

References

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