Real-time simulation of the electromagnetic field spatiotemporal evolution due to geomagnetic disturbances

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SUMMARY

We present a methodology for real-time simulation of the electromagnetic (EM) field spatiotemporal dynamics in a given 3-D conductivity model of the Earth and continuously augmented inducing source data. The formalism relies on the factorization of the source by spatial modes and time series of respective expansion coefficients, works both on a global and regional scale (i.e. in spherical and Cartesian geometries) and allows researchers to compute high-resolution EM field in a fraction of seconds.

To validate the formalism, we invoke a 3-D conductivity model of Fennoscandia and consider a realistic source built using the Spherical Elementary Current Systems (SECS) method as applied to magnetic field data from the IMAGE network of observations. The factorization of the SECS-recovered source is then performed using the principal component analysis. Taking the 7–8 September 2017 geomagnetic storm as a space weather event, we show that real-time high-resolution 3-D modelling of EM field is feasible, requiring less than 0.025 seconds to compute the field at a given time instant on a 512×512 lateral grid.

We also discuss an application of the presented technique to global-scale simulations of magnetic and electric fields.

Keywords: Numerical methods, EM induction, 3-D modelling, Now-casting