ON THE GEOELECTRIC HAZARD OVER THE ROMANIAN TERRITORY

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Geomagnetically induced currents (GICs) became of concern especially after catastrophic breakdown of power networks during geomagnetic storms. In the present paper we determine, for the Romanian territory, the surface geoelectric field associated to geomagnetic variations during the largest storm in solar cycle 23 (1996–2008), namely the November 20–21, 2003 one (Dst = -422 nT), as an estimate of the geoelectric hazard induced by geomagnetic storms in the 12-year timespan of the cycle. Geomagnetic information from the Surlari geomagnetic observatory and MT information on the underground electric conductivity have been used in the attempt.

Key words: geomagnetic storms, geomagnetically induced currents, geoelectric hazard, solar cycle 23, Romania.

1. INTRODUCTION

The interaction of the solar wind and of the heliospheric magnetic field with the magnetosphere and ionosphere results in variations of the geomagnetic field that induce hazardous electric currents in grounded technological systems (*e.g.* electric energy transport networks, hydrocarbon transport pipelines), the so-called geomagnetically induced currents (GIC). These currents have been long studied, but the interest has increased in Canada and in the northern countries in the years following the catastrophic breakdown of the power network in Quebec, Canada, during the severe magnetic storm of March 13/14, 1989 (Pirjola, 2002; Viljanen *et al.*, 2012; and references therein), as these countries are most affected by GICs. Information on GIC research in other areas can also be found in Viljanen *et al.* (2012). Recently it has been shown that the effects of induction could be significant at more southern latitudes (British Isles, South Africa) too (*e.g.* Beamish *et al.*, 2002; Beggan *et al.*, 2013). The computation of GIC in a given system of conductors is done in two steps: (1) the determination of the electric field associated to geomagnetic variations, and (2) the determination of GIC in the given technological system. A project at European level regarding continental scale modelling of geomagnetically induced currents (EURISGIC) was presented by Viljanen *et al.* (2012, 2014). Dobrică *et al.* (2016) approached the geophysical part of evaluating this type of space weather hazard, namely determining the surface electric field, at the European scale, based on recordings from the European geomagnetic observatories network during 16 intense (Dst < -150 nT) geomagnetic storms during the solar cycle 23 (1996–2008). Also, the largest geomagnetic storm of the solar cycle 23 (Dst = - 422 nT, November 20–21, 2003) was investigated as regards the evolution of the induced electric field during the storm and the contribution of solar wind and magnetospheric ring current to the observed geomagnetic disturbances.

In the present paper, we aim at evaluating the geoelectric hazard affecting the Romanian territory; we analyse the case of the surface geoelectric field induced by the above mentioned largest geomagnetic storm in the solar cycle 23. Recordings provided by the Surlari geomagnetic observatory and information on the electric conductivity of the Romanian lithosphere were used.

2. METHOD

The induced surface geoelectric field was calculated by the method of Viljanen and Pirjola (1989), shortly described in the following.

In general, the horizontal electric field (Ex, Ey) produced by the variable geomagnetic field (Bx, By) through the impedance Z(ω) of the

Earth's interior, subject to the action of the plane wave that approximates the depth propagation of the geomagnetic disturbance, is given by:

$$E_x(\omega) = \frac{Z(\omega)}{\mu_0} B_y(\omega), E_y(\omega) = \frac{Z(\omega)}{\mu_0} B_x(\omega).$$

For a half-space Earth of conductivity *σ*, the surface electric field is described by

$$E_y(t) = -\frac{1}{\sqrt{\pi\mu_0\sigma}} \int_{-\infty}^{t} \frac{g_x(u)}{\sqrt{t-u}} du,$$

where *g* is the time derivative of the field B.

The integral is transformed in a sum that allows calculating 1-minute values of the time derivative of the inducing field and the corresponding electric field E. A dedicated code has been developed.

To get information concerning locations in a denser network than the observatory one, two methods are currently in use (Viljanen *et al.*, 2014) and (Matandirotya *et al.*, 2014).

3. DATA

3.1. INDUCING SOURCE

In the present study 1-minute values of geomagnetic elements X (northern component) and Y (eastern component) provided by the Surlari geomagnetic observatory, a member of the INTERMAGNET network, for six days encompassing the major storm of November 20–21, 2003 have been used. They are available at http://www.intermagnet.net. It is generally considered that recordings of a geomagnetic observatory are representative for a ~500 km radius area around the observatory. Having in view that the storm time effect of the magnetospheric ring current at the geomagnetic latitude θ is described by Dst*cosθ, and the Romanian territory spreads in latitude between 43.5 and 48.3 degrees North, we corrected Surlari data to account for the latitudinal dependence of the geomagnetic storm, in case of each station of the network, by multiplying the extracted disturbance at the geomagnetic observatory with the factor $\cos(\theta_{STATION})/\cos(\theta_{OBSERVATORY})$.

3.2. UNDERGROUND ELECTRICAL CONDUCTIVITY

In this first attempt to evaluate the geoelectric hazard on the Romanian territory, we shall use the information on the underground conductivity (120 km thick lithosphere) as provided by the MT study presented by Stănică *et al.* (this issue, Fig. 10). Another type of information on conductivity, that concerns a much larger depth range, is under evaluation (Dobrică *et al.*, 2016) based on a so-called magnetic induction model.

4. RESULTS AND DISCUSSION

The largest storm of cycle 23, namely the November 20–21, 2003 one, with Dst = – 422 nT, was produced by the interaction with the magnetosphere of an interplanetary coronal mass ejection (ICME), illustrated in Fig. 1 by means of solar wind parameters recorded at the Lagrangean Point 1, available on the site http://omniweb.gsfc.nasa.gov/. The evolution of the heliospheric magnetic field B, of its Bz component, and of the density, speed and dynamic pressure of the solar wind (N, V, and respectively Pw) is shown. The storm evolution is also shown, by means of the geomagnetic index Dst, which describes the effect of the magnetospheric ring current variability in the Earth's geomagnetic equatorial zone. The evolution of the geomagnetic index AE, which is a proxy for the intensity of the ionospheric auroral electrojet, is plotted too. A study by Greculeasa *et al*. (2013) showed that the influence of the ionospheric auroral electrojets is negligible at Romanian geomagnetic latitudes.

The evolution of the northern horizontal component at Surlari observatory is shown in Fig. 2 together with the time derivative dX/dt and with the surface geoelectric field Ey, calculated by means of the above mentioned computer code. The maximum value of the geoelectric field is reached at 17.05 UT on November 20, 2003.

Similar computations were performed for a 0.09/0.09 longitude/latitude degrees network, considering local values of the electrical conductivity extracted from the maps presented by Stănică *et al*. (this issue) and corrected evolution of the field according to geomagnetic latitude of the network points. The geographical distribution of the maximum geoelectric field calculated for the considered geomagnetic storm is shown in Fig. 3.

Being the most intense in the solar cycle 23 (1996–2008), the major geomagnetic storm of November 20–21, 2003 allows an assessment on the geoelectric hazard, represented by the surface electric field induced by such phenomena, not only for the storm timespan, but also for the time interval of 10–12 years corresponding to the entire solar cycle 23 (1996–2008). Consequently, the map of Fig. 3 is equivalent to the geoelectric hazard distribution on the Romanian territory for this time interval.

Evaluation of the geophysical effects of major geomagnetic storms in the solar cycle 23 (1996–2008) is but a first step of solving the problem of the hazard related to the occurrence of dangerous electric currents in electrical energy transport networks. Estimation of the actual currents that occur in concrete technological network, the engineering part of the problem, asks for inclusion in the study real data regarding the network under evaluation and will be approached in a future work.

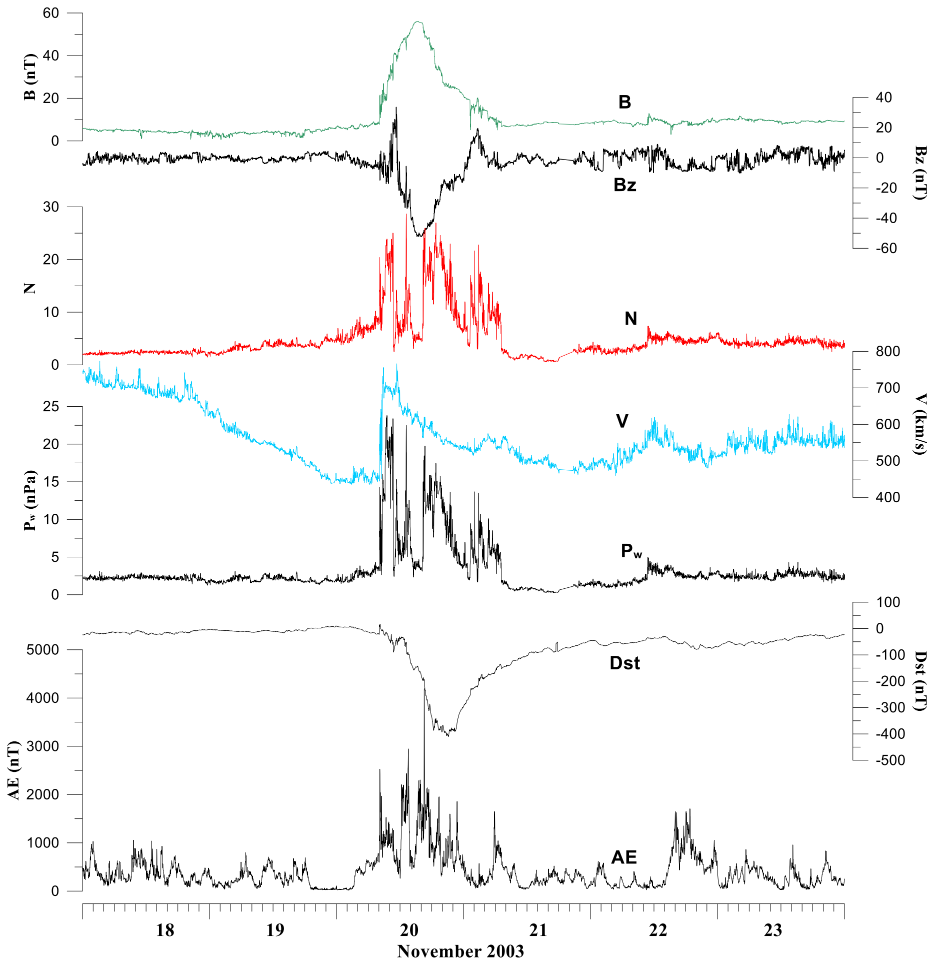

Fig. 1 – Evolution of solar wind parameters, of the Dst index, and of the AE index for the November 20–21, 2003 geomagnetic storm.

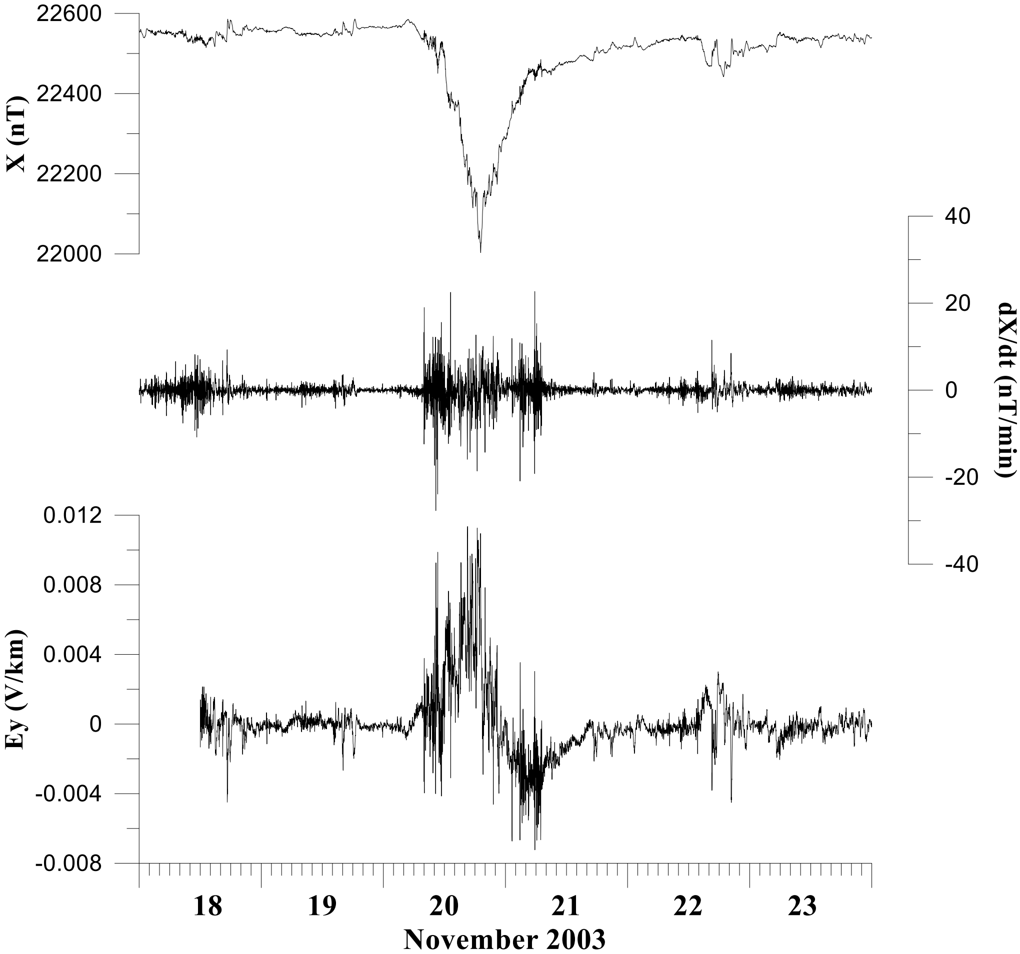

Fig. 2 – Evolution of the northern horizontal component, of its time derivative, and of the induced geoelectric field at the Surlari geomagnetic observatory, for a six days time interval that includes the storm of November 20–21, 2003.

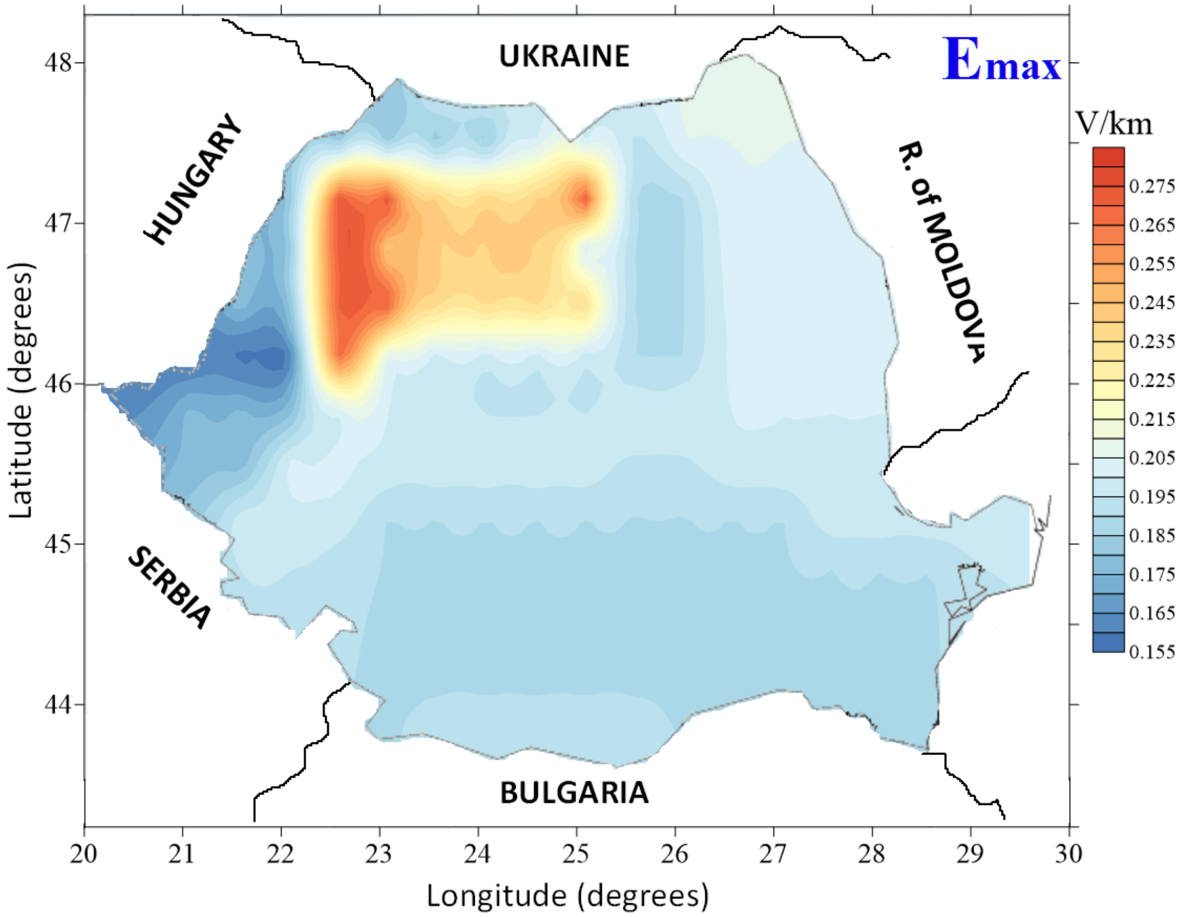

Fig. 3 – Maximum intensity of the surface geoelectric field induced by the geomagnetic storm of November 20–21, 2003 / Distribution of the geoelectric hazard for the solar cycle 23 (1996–2008).

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