Ann. Geophys. Discuss.,
https://doi.org/10.5194/angeo-2020-21-RC2, 2020

Annales Geophysicae Discussions

Interactive comment on "Induced telluric currents play a major role in the interpretation of geomagnetic variations" *by* Liisa Juusola et al.

J. Miquel Torta (Referee)

jmtorta@obsebre.es

Received and published: 1 June 2020

Juusola and co-authors present evidence from the use of 25 years of 10s data from the IMAGE magnetometer network of the importance of separating external and internal fields when interpreting the measured geomagnetic variations, or when attempting to forecast them. Forecasting the field's time-derivative is certainly one of the current challenges in GIC research, and this paper shows how difficult it is, due to the complexity of the 3-D distribution of the electrical conductivity of the Earth. The authors do an admirable job of proving these facts with, first, an example event and, second, with several seemingly robust results from an impressive statistical sample of spatial models in Scandinavia every 10 s, provided dH/dt > 1 nT/s. Since, in addition, the manuscript is clearly and concisely written, clearly laid out and well presented, it has an important

Printer-friendly version

Discussion paper

educational value. The abstract is succinct and comprehensible; the manuscript is logically organized, and adequately illustrated; figures are understandable and readable; English usage and grammar is adequate.

I, therefore, believe this manuscript should be accepted for publication in Annales Geophysicae with minor revisions, or at least a response to the following noted concerns. Perhaps the authors could incorporate some additional references (provided throughout this review) that escaped their state-of-the-art examination of the issues at hand. I would like to stress that I am co-author of some of these papers.

- When I saw the title of the paper before reading it, I thought that it would mainly deal with the importance of properly separating internal from external fields when using geomagnetic variations to study the dynamics of the overhead current systems that originate them. However, as I emphasized above, and the authors acknowledge in their abstract, the results presented in this work show also how important is to accurately taking the 3-D distribution of the electrical conductivity of the Earth into account when attempting to predict the geoelectric field derived from the geomagnetic variations. This is of great importance today and, although I agree that this is not in contradiction with the concept of 'the interpretation of geomagnetic variations' in general, I think that the latter fact should be better recognized in the title and acknowledged in the final conclusions.

- l. 21-24. Neglecting the internal part and interpreting the ground field only in terms of ionospheric (and magnetospheric) equivalent currents has been common in space physics, not only because the typical internal contribution is only of about 10–30%, but also because, in general, the real and modeled separated fields are approximately in phase. When this occurs, the analyses can still afford reliable information about the dynamics of the overhead current systems.

- l. 39-50. A more recent reference on the importance of the effects in areas of sharp lateral conductivity gradients at ocean-land boundaries should be added (e.g., Gilbert,

Printer-friendly version

Discussion paper

2005, 2014, Pirjola, 2013).

Gilbert, J. L. (2005), Modeling the effect of the ocean-land interface on induced electric fields during geomagnetic storms, Sp. Weather, 2, 20–28, doi:10.1029/2004SW000120.

Gilbert, J. L. (2014), Simplified Techniques for Treating the Ocean-Land Interface for Geomagnetically Induced Electric Fields, IEEE Int. Symp. Electromagn. Compat., (6), 566–569.

Pirjola, R. J. (2013), Practical Model Applicable to Investigating the Coast Effect on the Geoelectric Field in Connection with Studies of Geomagnetically Induced Currents, Adv. Appl. Phys., 1(1), 9–28.

- l. 86. ‘all analyses in this study are carried out in the time domain’

- l. 93. ‘Because most IMAGE stations are variometers without absolute references to compensate for any artificial drift, . . .’

- l. 99. The geomagnetic field continuation method of spherical elementary current systems (SECS) is ubiquitous, and now nearly “traditional”, but the authors only cite Finnish papers when referring to it. Please, at least put ‘e.g.’ at the beginning of those citations.

- l. 101-104. With the poles of the elementary currents separated by the order of 100 km, and the measuring stations much more, placing the internal current sheet at only 1 m depth is, in my opinion, exaggerated. In the worst case (sea water conductivity and frequency 1 Hz) the skin depth is a few hundred meters. A few tens of km is probably a more reasonable value.

A problem with putting the elementary currents so close to the surface is that the vertical component of the field (Z) shoots up as one approaches them, and I wonder if this can get one into trouble when synthesizing the surface magnetic field from the model close to one of the SECS poles. Another question that comes to my mind related with this is: does the external-internal separation not depend on the depth at which these currents are placed if it can be so variable?

- l. 106-108. It is recognized that data gaps forced the waste of usable data. A way to deal with this inconvenience would consist in introducing a temporal dependence in the SECS formulation, in the way of Marsal et al. (under revision in Space Weather – AGU, https://www.essoar.org/doi/10.1002/essoar.10502437.1). This would probably provide smoother time derivatives than analyzing the data at snapshots, because the combined spatial-temporal inversion (using either singular value decomposition or regularized least squares) tends to better absorbing local artificial time-derivative peaks in the data.

- l. 154. Can you explain why the ionospheric and telluric Bz do not appear to be oppositely directed for approximately the last 20 minutes of Figure 4?

- l. 287-294. Yes, the external-internal separation is a problem inherent to any regional technique. However, the separation is better when the area of existence of the geomagnetic field variation is to some extent coincident with the region defining the analysis, or when some regional part of the global source field can be separated, because of its independence or symmetry, from the remainder of the variation source (see Torta and De Santis, 1996; Torta, 2020). Therefore, it would be desirable for the region with measurements to fully include the region in which auroral currents are confined. The effects of the uneven spatial distribution of magnetic data within the entire auroral cap could perhaps be reasonably avoided by SECS if the elementary currents were also spaced at varying densities (see Marsal et al., 2017). I would like to see more discussion about these facts in the paper.

Marsal, S., J. M. Torta, A. Segarra, and T. Araki (2017), Use of Spherical Elementary Currents to map the polar current systems associated with the geomagnetic sudden commencements on 2013 and 2015âĂŸSt. Patrick's Day storms, J. Geophys. Res. Space Physics, 122, 194–211, doi:10.1002/2016JA023166.

Torta, J.M. (2020), Modelling by Spherical Cap Harmonic Analysis: A Literature Review, Surv Geophys 41, 201–247. https://doi.org/10.1007/s10712-019-09576-2

Torta J.M., De Santis A. (1996), On the derivation of the earth's conductivity structure by means of spherical cap harmonic analysis. Geophys J Int 127, 441–451.

l. 314-315. The meaning of the sentence 'Separating the magnetic field into telluric and ionospheric parts has the effect that the ionospheric equivalent current density time derivative patterns become less broken than deriving them without the field separation' is not clear. In any case, can you give a physical or mathematical explanation for this fact?

Best wishes,

J.M. Torta

Interactive comment on Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2020-21, 2020.

Printer-friendly version

Discussion paper