Probing 3-d Electrical Conductivity of the Mantle Using 6 Years of Swarm, Cryosat-2 and Observatory Magnetic Data and Exploiting Matrix Q-responses Approach

Alexey Kuvshinov (✉ kuvshinov@erdw.ethz.ch)  
Institute of Geophysics, ETH Zurich Sonneggstrasse, 8092 Zurich, Switzerland  
https://orcid.org/0000-0002-4341-2123

Alexander Grayver  
ETH Zurich: Eidgenossische Technische Hochschule Zurich

Lars Toffner-Clausen  
DTU: Danmarks Tekniske Universitet

Nils Olsen  
DTU: Danmarks Tekniske Universitet

Full paper

Keywords: Electromagnetic induction, Three-dimensional conductivity models, Matrix Q-responses, Inversion, Time-varying magnetic field, Magnetospheric ring-current source, Satellite data, Observatory data

Posted Date: October 22nd, 2020

DOI: https://doi.org/10.21203/rs.3.rs-94930/v1

License: © This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Version of Record: A version of this preprint was published on March 9th, 2021. See the published version at https://doi.org/10.1186/s40623-020-01341-9.
Abstract

This study presents results of mapping three-dimensional (3-D) variations of the electrical conductivity in a depths range from 400 to 1200 km using six years of magnetic data from the Swarm and CryoSat-2 satellites as well as from ground observatories. The approach involves the 3-D inversion of matrix Q-responses (transfer functions) that relate spherical harmonic coefficients of external (inducing) and internal (induced) origin of the magnetic potential. Transfer functions were estimated from geomagnetic field variations at periods ranging from 2 to 40 days. We study the effect of different combinations of input data sets on the transfer functions. We also present a new global 1-D conductivity profile based on a joint analysis of satellite tidal signals and global magnetospheric Q-responses.

Full Text

This preprint is available for download as a PDF.

Figures

Figure 1

Location of 161 ground magnetic observatories used in this study. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.
Figure 2

Time series of estimated inducing (blue) and induced (red) coefficients up to degree $\text{Next} = 2$. Note the different y-axis ranges on the plots.
Figure 3

Multiple squared coherencies between a given induced coefficient, ilk k and eight inducing coefficients, "mn" obtained using different combinations of input data sets. Note different y-axis range in the plot for the term l01.
Figure 4

Estimated \textit{diagonal''} (dominant) matrix Q-responses (circles and triangles with error bars). Also shown are the \textit{upper limit''} responses from a perfectly conducting Earth model (dashed lines), and the responses from the recovered 3-D model (solid lines). Real and imaginary parts of the responses are depicted by blue and red colors, respectively. Estimated \textit{diagonal''} (dominant) matrix Q-responses (circles and triangles with error bars). Also shown are the \textit{upper limit''} responses from a perfectly conducting Earth model (dashed lines), and the responses from the recovered 3-D model (solid lines). Real and imaginary parts of the responses are depicted by blue and red colors, respectively.
Figure 5

Top and middle: Global maps of magnitudes of the observed and predicted (modeled) M2 radial magnetic field component. Predicted fields are obtained using the "joint" 1-D conductivity profile shown in Figure 7. Bottom: Residuals, i.e., magnitude of the difference between observed and predicted M2 radial magnetic field. Values are shown for a mean satellite altitude of $h = 430$ km. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or
area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 6

Model parametrization adopted in "Obtaining background 1-D conductivity model" section. The model consists of a top-most thin shell of laterally-varying conductance (right) and a number of laterally-homogeneous conductivity layers underneath (left). Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.
Figure 7

Mantle conductivity models obtained by inverting the dominant Q-responses and M2 tidal radial magnetic field separately and jointly. Gray lines show 95% confidence interval for the "joint" model.
Figure 8

Estimated (circles) dominant Q-responses and their uncertainties (error bars), and model predictions (solid curves). Predictions are for the 1-D profile obtained by jointly inverting the dominant Q-responses and tidal radial magnetic field (cf. Figure 7). Positive and negative values correspond to real and imaginary parts of the Q-response, respectively.
Figure 9

Estimated 3-D conductivity model. Conductivities are shown as $\log_{10} 3D/1D$ where 1D stands for the 1-D background conductivity. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.
Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- GraphicalAbstract.png