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New transfer functions for probing 3-D mantle conductivity from ground and sea

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The C-response is a conventional transfer function in global electromagnetic induction research and is classically determined from local observations of magnetic variations in the vertical and the horizontal components. Its estimation and interpretation rely on the assumptions that the source of the considered variations is well approximated by a large-scale symmetric (magnetospheric) ring current that can be described by a single spherical harmonic, P_1^0, and that conductivity in the Earth is only a function of depth.

However, there is growing evidence for a more complex structure of the magnetospheric source. We investigate the variability of C-responses due to non-P_1^0 contributions to the source. We show that this variability, which we denote as “source effect” (as opposed to the well-known ocean effect), is significant and persists at all periods. If inverting estimated C-responses for mantle conductivity, this source effect will inevitably be mistaken for conductivity anomalies.

To overcome the problem connected with the assumptions for deriving C-responses, we introduce new transfer functions that relate the local vertical component of the magnetic variation to different spherical harmonic coefficients describing the magnetospheric source. The latter are derived from observations of magnetic variations in the horizontal components. The new transfer functions are subsequently estimated with a robust multivariate data analysis tool.

By analyzing 16 years of data, collected at the global network of geomagnetic observatories, we demonstrate that the new transfer functions exhibit a significant increase in coherence compared to C-responses, especially at high latitudes. The concept is easily extended to other data types. For example, by relating the voltage variations in abandoned submarine telecommunication cables to spherical harmonic coefficients in the same way as described above, one can define yet another array of transfer functions.

In spite of the fact that the newly introduced transfer functions allow for a consistent treatment of a complex spatial structure of the source, the sparse and irregular distribution of geomagnetic observatories and submarine cables impedes a reliable inversion of these data for 3-D mantle conductivity on a global scale. However, in combination with matrix Q-responses estimated from Swarm satellite data, the new transfer functions can be used to probe the 3-D conductivity structure of Earth’s mantle.