Conductivity models with sharp interfaces for 3D magnetotelluric inversions

M. Kangazian[1] and C. G. Farquharson[1]
[1]Memorial University of Newfoundland, St. John's, NL, Canada, Department of Earth Sciences.
mkangazianka@mun.ca, cgfarquh@mun.ca

SUMMARY

The magnetotelluric (MT) method uses the natural electromagnetic fields as a source to image the subsurface. This method has been used in mineral exploration, geothermal studies, oil and gas exploration, and lithospheric studies. Although some primary results can be extracted from data analysis, a comprehensive interpretation of MT data to obtain the subsurface resistivity distribution requires advanced inversion methods. The most common method to invert MT data is the minimum-structure, or Occam's style, inversion. This approach introduces a regularization function into the inverse problem to mitigate the non-uniqueness of the underdetermined inverse problem and to allow one to construct models with some preferred characteristics. This function is typically measured by the ℓ_2 norm, hence, the constructed models are smeared-out and fuzzy. Although these fuzzy models are useful in regions where little is known about the subsurface, they may not have a realistic representation of true subsurface structures in regions with complex geology or in regions in which it is known, from *a priori* information such as well-log information, that the subsurface structure consists of geologic units with sharp interfaces.

Researchers have proposed approaches such as quantifying the regularization term with non-ℓ_2 measures like an ℓ_1-type measure, focusing inversion, clustering physical property values, level-set approaches, and surface geometry inversion (SGI) and applied them to different types of geophysical data to construct piecewise-constant, or 'blocky', models with sharp interfaces. The last two of the aforementioned methods are perhaps best suited to single targets buried in simple backgrounds, whereas the first three methods are applicable to arbitrary models. Also, the first three approaches are formulated as extensions of the original ℓ_2 minimum-structure, Occam's style approach—an objective function dominated by a measure of model complexity is set up to be minimized—and thus aim to retain much of the robustness, reliability, and efficiency of the original minimum-structure approach. Previous studies have applied an ℓ_1-type measure to 1D and 2D MT inverse problems, the focusing inversion to 2D and 3D MT inverse problems and the clustering approach to 2D MT inverse problems, all in the context of structured meshes.

In this study, we apply these three methods to a 3D synthetic example and a real dataset that are parameterized with unstructured tetrahedral meshes to do a comparison between these approaches in terms of implementation, the convergence rate of each method, and *a priori* information that these approaches require to construct piecewise-constant models. The results indicate that the three methods work well at producing piecewise-constant models with sharp interfaces, with their own advantages and disadvantages, and, when used with unstructured tetrahedral meshes, allow the interfaces to be in an arbitrary orientation required by the data, unlike when they are used with rectilinear meshes.

Keywords: Inverse problem, magnetotelluric, piecewise-constant models, sharp interfaces.