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New constraints in magnetotelluric inversion.

Eric Mandolesi (1,2) and Alan G. Jones (1)
(1) Dublin Institute for Advanced Studies (eric@cp.dias.ie), (2) NUI Galway

Non-uniqueness is one of the least governable features in inversion of geophysical data, and magnetotelluric models obtained from inversion are dramatically affected by problems of non-uniqueness. In order to reduce the dimension of acceptable model space in which the inversion model is selected, several solutions have been proposed with different degrees of success, usually by introducing some regularization terms in the defined objective function. Other strategies that had broad success involve implementation of joint inversion of different geophysical data.

The core idea implied in this latter strategy is that different properties of media inside the Earth are linked petrophysically. This idea is suggested by the observation that all the different methods used to produce models see the same Earth but in a different way. A possible trade-off between these two methods – regularization and joint inversion – consists of using a reference model to drive the inversion algorithm towards a model that is not too far from the reference model and that optimally fits the data. In order to achieve this result, we used mutual information to define the distance between two models that measure different parameters.

In probability and information theory, the mutual information of two random variables is a quantity that measures their mutual dependence. Given a reference image and a second image that needs to be put in the same coordinate system as the reference image, the latter is deformed until the mutual information between it and the reference image is maximized. In our scheme, information from a reference model is integrated in the inversion process in order to reduce non-uniqueness of solutions and to improve the robustness of the inversion results. While this process is not a formal joint inversion, it includes information from the reference model. The proposed inversion scheme is implemented by including in the objective function a term that maximizes the mutual information between a reference model and the electromagnetic model, so that it is possible to plot an empirical histogram that maps phase velocity in electrical conductivity in the considered profile. In this way the inversion scheme is driven to fit magnetotelluric data and to take the most possible advantage from information available from other data relative to the same profile.

Using this approach it is possible to use a linearized inversion scheme to invert data from a highly non-linear problem like magnetotellurics, keeping it in its whole complexity and obtaining results that allow appreciation of the empirical coupling between the reference image and the obtained (MT) model. Any reference model can be used in our approach during the inversion process, making this scheme suitable to use a reference model produced by a wide range of geophysical or other geoscientific methods. The scheme is applied to synthetic data and an interesting improvement in the inversion results – particularly reducing artefact constructs beneath areas of high resistivity – is highlighted and can be appreciated. Inverted data are generated from synthetic models that are compatible with the reference one, but it is interesting to note that it is not required to generate data from a model that shares exactly the same structure as the reference model. What is needed is a model that can be mapped in the reference one following a transformation without too many singularities. Also the robustness of the solution found is improved and less dependent on the starting model. In this sense it is possible to state that the term introduced in the objective function operates as a good constraint in the inversion process, reducing problems caused in the interpretation stage by non-uniqueness of magnetotelluric problem.

In summary, we have developed an inversion scheme suitable to invert magnetotelluric data including in the algorithm information from a reference model. The advantage of this scheme is that it is not required that the reference model has the same structure of the obtained one, but it has to share information with it in some areas.