Geophysical Research Abstracts
Vol. 14, EGU2012-13561, 2012
EGU General Assembly 2012

Magnetotelluric Inversion in a 2D Anisotropic Environment

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Abstract

In recent years several authors have proposed algorithms to perform magnetotelluric (MT) inversion in a 3D environment. The development of high performance computer (hpc) machines allows the solution of these inverse problems in a reasonable time, nevertheless the solution of a 3D problem remains at the present extremely challenging. Moreover it is proofed that any magnitude of anisotropy possibly present in the subsurface conductivity can be modeled by a sufficient dense discretization of a 3D isotropic domain, keeping the recognition of intrinsically anisotropic bulks virtually impossible for a 3D code. These arguments convinced us to develop a 2D inverse code able in assessing anisotropy and running in an affordable time, testing several scenario for the same dataset in the same time in which a 3D inversion code produces its first model. In this work we report results from synthetic tests we performed.

MT inverse problem is challenging because of several reasons. It is both highly non-linear, ill-conditioned and suffers of a severe non-uniqueness of the solution, therefore we developed an inversion algorithm based on the classic Levenberg-Marquardt (LM) strategy, minimizing the objective function

$$\phi(m) = \left(\frac{\sum G(m) - d}{\sigma} \right)^2 + \lambda_a L_a + \lambda_s L_s$$

in which m is the model, G the forward operator, d the data vector, L_* the regularization matrix and λ_* the trade-off parameter for respectively anisotropy and structure.

Usually LM method is used for medium size problems, mainly because it requires the explicit computation and storage of the Jacobian matrix J and the explicit knowledge of the product $J^T J$. To compute the Jacobian it has proofed that the electrical reciprocity theorem is a valuable tool, allowing to compute the full Jacobian with the evaluation of one forward problem per station in spite of one forward problem per parameter as usually done with the finite-difference method. Moreover the computation of the forward response can be easily performed in parallel, due the mutual independency of the different spectral components, storing the Jacobian in a distribute machine memory and solving at the same time the problem of the huge memory requirements used to store the product $J^T J$ and speeding up the whole process.

We performed tests on the simple synthetic model released with the code from *Pek and Santos [2004]*: an 84×100 cells grid, grouped in 3 up to 20 blocks sharing the same conductivities. Results proof the capacity of the algorithm in recovering the subsurface structure with good precision, reaching an RMS of the magnitude 10^{-5} for the 20 block case without the use of regularization. More tests will be presented and results highlighted.