

## Minimum gradient support functional based three-dimensional regularized magnetotelluric inversion

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Three-dimensional (3-D) magnetotelluric (MT) inversion has progressed fast in recent a few decades. Madden and Mackie (1993) developed first practical 3-D inversion of magnetotelluric (MT) data by using the conjugate gradients (CG) to solve equations of inversion. Newman et al. (2000) introduced non-linear conjugate gradients (NLCG) in 3-D MT inversion. Zhdanov (2000) used quasi-linear approximation in 3-D Electromagnetic inversion. Siripunvaraporn et al. (2005) proposed a new scheme of 3-D inversion in data space. Meanwhile, global optimization is also introduced to invert 3-D MT data, but none is practical yet.

Most of these inversion methods above are classified as a regularized inversion with smoothness constraint. These inversions give smooth solution, and are not suitable for clearly imaging geo-electrical interfaces. In this study we introduce a new stabilizer to solve this problem. Portniaguine and Zhdanov (1999) proposed the focusing geophysical inversion images by using minimum gradient support functional and used it in gravity and magnetic inversion. Zhdanov (2008) also applied it to invert gravity and electromagnetic data. Zhang (2009) used this theory to invert 2-D MT data and get results with clearly imaging geo-electrical interfaces. Here we apply the same functional in 3-D MT inversion.

In the forward calculation of the inversion process, the subsurface resistivity structure is divided by cubes. The conductivity in each cube is assumed uniform. Through changing the cube's volume, the resolution and accuracy of inversion can be ensured by their trade-off. The model parameter is defined as log of conductivity normalized by initial conductivity. Integral equation (IE) method by modified Neumann series (MNS) which was proposed by Singer (1995) and Avdeev et al. (2000) is used for forward calculation, which allows us to avoid calculation of large-scale linear equations. GPBi-CG is used to get the solution in modified Neumann series, and the efficiency is increased. The quasi-Newton method is used to optimize the objective functional. This approach is a kind of Newton method with simplified calculation of the Hessian matrix by using BFGS update (Koyama, 2002). In addition, BFGS update does not require search for the exact minimum point on line unlike the NLCG, and therefore iteration times of 3-D forward calculation can be reduced. For derivation of the sensitivity matrix, we use the method which was presented by Newman (2000).

We tested the performance of our code by using a synthetic model which consists of an anomalous body in a uniform half space, and by comparing with the results obtained by other smooth inversion code. From the comparison, we can find the geo-electrical interfaces are imaged more clearly and accurately by our code, while the conductivity of the anomalous body is estimated more or less similar to the result of smoothing inversion. The minimum data misfit value is also smaller than that of smoothing inversion. Comparing with smoothing stabilizing functional, the use of minimum gradient support functional for local geophysical study allows us to determine clear geo-electrical interfaces. Quasi-Newton method is found to be a stable and effective approach in optimizing the objective functional. It was also found that IE method by MNS decreases the time of forward calculation, which makes the inversion more effective.