Geophysical Research Abstracts
Vol. 19, EGU2017-3120-1, 2017
EGU General Assembly 2017

3D inversion of full magnetic gradient tensor data based on hybrid regularization method

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Recently, the magnetic tensor data can be directly measured due to the latest development of superconducting quantum interference device (SQUID) based sensors, which can collect five unique magnetic gradients components ($\partial H_x/\partial x, \partial H_x/\partial y, \partial H_x/\partial z, \partial H_y/\partial z, \partial H_z/\partial z$). More measurement date will bring more useful information of observed magnetic anomaly, however it still bear the computational instability problem because of the intrinsic ill-posed property in the magnetic inverse problem. Furthermore, most of research on magnetic regularization inversion only concentrate on total magnetic field or magnetic vector field, rather than the magnetic gradient tensor field. Therefore we introduce a novel 3D hybrid regularization method by MS-TV stabilizer for inversion of magnetic gradient tensor data, which is designed mainly based on the minimum support functional (MS) and total variation functional (TV), and the final regularization functional can be described as the following form:

$$\mathrm{J}(\kappa) = \frac{1}{2}(G(\kappa) - d, w_d(G(\kappa) - d))_{\Omega_P} + \alpha((1-\lambda)\varphi_{pMS}(\kappa) + \lambda\varphi_{\beta TV}(\kappa))$$
$$= \frac{1}{2}(G(\kappa) - d, w_d(G(\kappa) - d))_{\Omega_P} + \alpha(\frac{1-\lambda}{2}\int_{\Omega_Q} \frac{(\kappa-\kappa_{prior})^2}{(\kappa-\kappa_{prior})^2+e^2} d\Omega_Q$$
$$+ \lambda \int_{\Omega_Q} \sqrt{|\nabla\kappa|^2 + \beta^2} d\Omega_Q),$$

where κ is magnetic susceptibility and κ_{prior} is a reference model. Compared with three other conventional non-smooth stabilizers used in magnetic inversion, which are named as the the minimum support (MS) stabilizer, the minimum gradient support (MGS) stabilizer and the total variation (TV) stabilizer, our proposed stabilizer, in conjunction with boundary penalization, is capable of generating the recovered model with advantages. These merits include more definite boundaries, more focused images, better depth resolution and more evident structure depiction for geological magnetic anomaly inversion. The new method has been successfully verified by three different kinds of synthetic magnetic models. Primary results not only exhibit that this method resorts more precise results but also demonstrate a nice numerical advantage with less computational costs even with few prior information of the magnetic anomalies available. Furthermore, the comparison of different combination methods of data and model weighting matrix, and the different data misfit methods based on synthetic model indicate our inversion algorithm has better numerical stability over the others.