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3D joint inversion of gravity and magnetic data using Gramian constraint and L_1-norm stabilizer

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Extended Abstract

Joint Inversion
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Summary

The inversion of potential field data, gravity and magnetic, is a non-unique problem. An efficient approach to reduce the non-uniqueness of the problem, and to produce more reliable subsurface models, is based on the joint inversion of these datasets. This means gravity and magnetic data are simultaneously inserted into an inversion algorithm and, then, by relying on direct or indirect parameter interdependence, joint inversion can restrict the model space and produce results that satisfy the datasets and cross-linked characteristics of the model parameters. Here, we apply the joint inversion of gravity and magnetic data using Gramian constraints, which are based on the minimization of the determinant of the Gram matrix of a system of different model parameters. Application of the Gramian constraint enforces the linear relationships between the different model parameters, and/or their transforms. In fact, the joint inversion using Gramian constraints does not require a priori knowledge of the correlation between different model parameters, and instead provides this correlation during the inversion process, which is an important advantage for the algorithm. Furthermore, to produce sparse models with sharp boundaries, the L_1-norm stabilizer is used in the presented algorithm. We applied the joint inversion algorithm on synthetic models and real data case.

Introduction

Simultaneous joint inversion of gravity and magnetic datasets is an effective strategy for yielding a reliable subsurface model, as compared with individual inversion of each of these datasets. Many different techniques have been developed for simultaneous joint inversion of gravity and magnetic datasets. These techniques generally can be categorized into two main groups: (i) petrophysical, and (ii) structural approaches. Recently, Zhdanov et al. (2012) applied the Gramian constraint in the joint inversion algorithms, which enforces correlation between different model parameters and/or their transforms. In this approach, the correlation is enhanced by minimizing the determinant of the Gram matrices of multi-model parameters during the inversion process. In fact, joint inversion based on Gramian constraint is general; extant methods based on petrophysical correlations or structural approaches are special case reductions. Furthermore, unlike the case when performing petrophysical joint inversion, a priori information about the relationships between the different model parameters, and/or their transforms, is not required. In this study, we have used Gramian constraint in the joint inversion of gravity and magnetic datasets in the space of the weighted model parameters. Moreover, to produce localized and compact models, the L_1-norm of the model parameters is used in the stabilizer terms.

Methodology and Approaches

We suppose that the subsurface is discretized into a set of rectangular prisms with fixed size but unknown physical properties, density and susceptibility. The joint inversion for the determination of unknown model parameters is formulated as the minimization of a global objective function consisting of data misfits, regularization terms, and Gramian constraint. Three positive parameters are used to provide relative weights for stabilizers and Gramian constraint. Here, the joint inversion algorithm is implemented using the L_1-norm stabilizers that leads to reconstruction of the localized and compact subsurface models. Further, to counteract the rapid decay of the kernels with depth, the diagonal depth weighting matrices are used in the regularization terms. To minimize the global objective function, the iteratively re-weighted regularized conjugate gradient algorithm is used. Moreover, at each iteration of the inversion algorithm, upper and lower bounds for density and susceptibility are imposed.

Results and Conclusions

The joint inversion algorithm is validated for two three-dimensional synthetic models. The results are then compared with those of gravity and magnetic data inversion without application of the Gramian constraint. It is demonstrated that the presented joint inversion algorithm is practical and significantly improves the similarity between reconstructed models. Finally, the joint inversion algorithm is applied on gravity and magnetic data acquired over an iron ore deposit located in northwest of China.