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Joint inversion of gravity and magnetic data using total variation stabilizer and cross-gradient constraint

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Extended Abstract

Summary

It is well-known that the solution of the individual potential field inversion problem, either gravity or magnetic, is non-unique. One efficient strategy to reduce the uncertainty of the solution, and to improve the obtained results, is the simultaneous joint inversion of two or more data sets. In this case, different geophysical data sets are used simultaneously in an inversion algorithm. Depending on the coupling between different model parameters, the algorithm provides the solutions, which satisfy the observed data and coupling constraint. Combined with regularization, this is an effective strategy to obtain a reliable subsurface model. In this study, an algorithm for the joint inversion of gravity and magnetic data using anisotropic total variation (TV) stabilizer is developed. The anisotropic TV stabilizer consists of the individual L_1-norm of the gradient of the model parameters in three orthogonal directions. Therefore, our algorithm preserves the edge of the subsurface targets and provides focus models. Here, the relationship between different model parameters is enforced using the cross-gradient coupling. This constraint uses the model topology in order to enhance the structural similarity of the reconstructed models. Then, the information from both data sets can be used to provide reliable models. This simplifies the interpretation of the subsurface targets. The developed algorithm is validated on two different synthetic examples. The results indicate that the algorithm is practical and can provide focus and similar models. Finally, we invert the gravity and magnetic data obtained over kimberlite pipes BK54 and BK55 in Orapa, Botswana. The reconstructed models are consistent with the geological and borehole information from the survey area.

Introduction

Potential field surveys including gravity and magnetic surveys have been used for many years as effective strategies for delineating subsurface targets. They can provide valuable information about geometric and physical characteristics of the subsurface targets. Joint inversion of gravity and magnetic data sets has recently received considerable attention in geophysical community. Indeed, a model consistent with both data sets is more reliable than a model, which is produced by only a single data set. In the joint inversion algorithm, the linkage between different model parameters can be imposed by either petrophysical or structural coupling approaches. In the petrophysical approaches, it is assumed that there is a direct relationship between different model parameters. On the other hand, the structural approaches use, instead, the model topology in order to enhance the structural similarity of reconstructed models. The cross-gradient coupling is a widely-used constraint in the structural approaches. The main idea is that changes, at any point in the different models, should occur in the same or opposite spatial directions, or alternatively, changes will only occur in one of the models. Therefore, the reconstructed models are as similar as possible. Different types of stabilizers have been developed for the inversion of potential field data, dependent on the desire model features that one wishes to recover. Here, we use anisotropic total variation (TV) stabilizer. Then, our joint inversion algorithm preserves the edge of the subsurface targets and provides focus models.

Methodology and Approaches

To formulate the problem, we divide the subsurface into a set of rectangular prisms with fixed sizes but unknown physical properties, density and magnetic susceptibility. The joint inversion is formulated as minimization of a global objective function comprising of data misfits, anisotropic TV stabilizers, and cross-gradient term. The depth weighting is also used in our algorithm. The objective function is minimized using an iteratively reweighted least square approach. In each iteration, the conjugate gradient algorithm is used to numerically solve the resulting linear system.

Results and Conclusions

The developed algorithm is validated on two synthetic models. The results illustrate the performance of the algorithm. The reconstructed models are focus and as structurally similar as possible. Finally, the algorithm is applied on real data obtained over two kimberlite pipes in Orapa, Botswana. The geometric and physical properties of both pipes are reconstructed well. The models are consistent with the borehole information available in the survey area.