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Joint inversion of surface and borehole magnetic amplitude data

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3D magnetic inversion for susceptibility distribution is a powerful tool in quantitative interpretation of magnetic data in mineral exploration. However, the inversion and interpretation of such data are faced with two problems. One problem is the poor imaging results of deep sources when only surface data are inverted. The other is the unknown total magnetization directions of sources when strong remanence exists.
To deal with these problems simultaneously, we propose a method through the joint inversion of surface and borehole magnetic amplitude data. In this method, we first transform both surface and borehole magnetic data to magnetic amplitude data that are less sensitive to the directions of total magnetization, and then preform a joint inversion of the whole amplitude data to generate a 3D susceptibility distribution.
The amplitude inversion algorithm uses Tikhonov regularization and imposes a positivity constraint on the effective susceptibility defined as the ratio of magnetization magnitude over the geomagnetic field strength. In addition, a distance-based weighting function is used to make the algorithm applicable to joint data sets. To solve this positivity-constraint inversion problem efficiently, an appropriate optimization method must be chosen. We first use an interior-point method to incorporate the positivity constraint into the total objective function, and then minimize the objective function via a Gauss-Newton method due to the nonlinearity introduced by the positivity constraint and the amplitude data. To further improve the efficiency of the inversion algorithm, we use a conjugate gradient method to carry out the fast matrix-vector multiplication during the minimization.
To verify the utility of the proposed method, we invert the synthetic and field data using three inversion methods, including the joint inversion of surface and borehole three-component magnetic data, the inversion of surface magnetic amplitude data, and the proposed joint inversion of surface and borehole magnetic amplitude data. The results show that the proposed method reduces the inherently nonuniqueness of magnetic inversion and likewise improves the imaging quality of deep resources in the presence of strong remanence compared with the other two methods.