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Estimation of depth and location of anomalies resulting from ground electromagnetic data in the frequency domain by the depth from extreme points (DEXP) imaging method

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Extended Abstract

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Summary

Imaging methods have traditionally not used with EM fields because of a belief that EM fields obey the Maxwell's wave equations rather than Laplace's equation. However under some approximations, image methods could be applied on frequency domain EM data. We evaluated DEXP method to estimate location of subsurface targets. We tested the performance of the DEXP method on a synthetic dataset that was generated by the COMSOL multiphysics package for a horizontal cylinder, a vertical dike and a contact. The results show remarkable and accurate estimations of depths and horizontal locations of aforementioned models. This method was also tested on a real dataset and the results were compared with the one obtained from prior information.

Introduction

To investigate the internal structure of the earth, geophysicists rely mostly on the interpretation of measurements taken on the ground surface. This applies for deep soundings of hundreds of kilometers as well as for shallow studies of merely a few meters below the ground surface. The electrical conductivity of rocks is often the property of interest in these types of studies. For this reason, a great number of electrical techniques have been developed to infer the conductivity structure of the subsurface on the basis of ground surface measurements. One of these techniques is based on electromagnetic induction by means of an alternating current that is made to flow in a transmitting coil. This current generates an alternating magnetic field in the surrounding environment, which in turn induces an electromotive force both in the conductive ground and in a receiving coil. The frequency-domain loop–loop electromagnetic (EM) method has been developed for detection near surface targets. This nondestructive EM method is well known as low induction number (LIN) conductivity meter and electromagnetic induction (EMI) method. This method, because of its speed, ease of use, relatively low cost, and volume of data collected has been popular.

Methodology and Approaches

In EMI method, the in-phase and out-of-phase or quadrature-phase parts are either directly mapped at the survey area to perform a qualitative interpretation of the conductivity distribution at depth, or the inversion procedures of multi-frequency data sets are implemented to compute a conductivity model of the subsurface. The direct method of visualizing allows the mapping of the lateral extent of the anomalous features approximately. In this approach, the in-phase and quadrature components can be related to the magnetic susceptibility and conductivity of the subsurface, respectively. However, it has been shown that it is possible to obtain rather accurate images of the conductivity distribution of the subsurface by inversion of multi-frequency EM data.

Each of the above-mentioned approaches has its own advantages and disadvantages. The direct visualization technique has the advantage of presenting a fast image of the subsurface, but the vertical and horizontal resolutions are poor. Besides, the misidentification of anomalous sources is quite common. On the other hand, the inversion techniques have much better vertical and horizontal resolutions, but they are much slower, complicated, and need much data compared to direct visualization method. Here, we introduce an alternative way to overcome these problems. We used and analyzed DEXP method for detection of horizontal and depth locations of subsurface targets in non-potential (EMI) data. We first tested the performance of the method that we developed for EMI data with a set of synthetic models. We then applied it to the field data gathered at an industrial site in Italy.

Results and Conclusions

This study has considered a way in which the DEXP method has been used to estimate the depth and horizontal locations of subsurface targets in the quadrature component maps of the EMI method. This study using the DEXP method has indicated the simplicity of the technique in relation to the detection of concealed cylindrical goals (cable and iron pipe lines).