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Calculation of stable vertical derivatives using the combination of finite difference and upward continuation, case study: gravity field data of the northern area of the Jalalabad iron ore mine, Kerman province

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Extended Abstract

The vertical derivatives of the gravity field are an important tool for the interpretation of potential field data. The first and second orders of the vertical derivatives of the gravity field, or various edge detection filters developed by combining different orders of the vertical derivatives with other functions, are used to process and interpret gravity field anomalies. However, the main drawback of these filters is their sensitivity to noise. In this study, by combining two finite difference methods and an upward continuation filter, a new and effective method for calculating the vertical derivative of the gravity field is introduced, which has greater stability to noise and is used to calculate the vertical derivatives. To this end, the ability of this method and other conventional methods to calculate the vertical derivative of the gravity field was investigated using synthetic gravity field data contaminated with 3 and 6% Gaussian noise. After theoretical confirmation, the methods for calculating vertical derivative along with edge determination filters such as horizontal tilt angle (TDX) and vertical derivative of Heaviside function (HSV) filter were also tested and investigated on the gravity field data of Jalalabad Zarand iron ore mine in Kerman province, Iran. The results of the synthetic gravity models with noise and the real data from the northern area of the Jalal Abad iron ore mine show that this technique is able to reduce the noise effect in the vertical gradient maps and better draw the edges of the buried sources.

Summary

To investigate the ability of the frequency domain, backward differences, Tran and Nguyen's filter, and the finite difference-upward continuation method to calculate the vertical derivative of the gravity field, two scenarios for synthetic data were considered in this study. First, the data of a synthetic gravity model generated from three buried prisms with different densities and depths and contaminated with 3 and 6% Gaussian noise were analyzed. These filters were then applied to the field data of an iron ore mine in Jalalabad, Kerman province, analyzed and compared with each other. The results of the synthetic and real data set show the performance of the finite difference-upward continuation method.

Introduction

The vertical derivative of the gravity field plays a fundamental role in the development of edge detection filters and in the introduction of some depth calculation methods (automatic and semi-automatic) for processing and interpreting gravity field data. The vertical derivative of the gravity field is calculated with finite element methods, B-splines and boundary elements in the spatial domain or with the FFT method in the frequency domain. These methods are sensitive to noise. The quality of these methods and proposed technique was tested with synthetic and field data.

Methodology and Approaches

In this work, the vertical gradients are calculated in the spatial domain using finite differences, while the vertical derivatives are calculated using the finite difference- upward continuation approach of Oliveira and Pham (2022), which uses a finite difference formula to attenuate the noise effects:

$$\frac{\partial f(z_0)}{\partial z} = \frac{c_1 f(z_1) + c_2 f(z_2) + c_3 f(z_3) + c_4 f(z_4) + c_5 f(z_5)}{\Delta z} + \mathcal{O}(\Delta z^4). \qquad z_i = z_0 - \beta\Delta z - (i-1)\Delta z$$

Where $c_1. c_2. c_3. c_4. c_5$ are given by:

$c_1 = (2\beta^3 + 15\beta^2 + 35\beta + 25)/12.$

$c_2 = (-8\beta^3 - 54\beta^2 - 104\beta - 48)/12.$

$c_3 = (12\beta^3 + 72\beta^2 + 114\beta + 36)/12.$

$c_4 = (-8\beta^3 - 42\beta^2 - 56\beta - 16)/12.$

$c_5 = (2\beta^3 + 9\beta^2 + 11\beta + 3)/12.$

$z_0$is the height of theobservation plane, $\Delta z = {}^{\Delta x}/_{10}$ of grid spacing and $\beta = 50$ (Oliveira and Pham 2022).

Results and Conclusions

In this study, different methods for calculating the vertical derivative were investigated and compared with noisy synthetic and field data set from the northern area of the Jalal Abad iron ore mine in Kerman. By combining these calculation methods for the vertical derivative, the quality of the TDX and HSV filters for determining the horizontal boundaries could be improved. Thus, by combining the two methods of finite difference and upward continuation, it is possible to produce better quality vertical derivative maps and edge determination filters.

References

Oliveira, S.P. and Pham, L.T., 2022, A stable finite difference method based on upward continuation to evaluate vertical derivatives of potential field data. Pure Appl Geophys 179(12):4555–4566.