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Directional Total Horizontal Derivatives of Gravity Gradient Tensor and their Application to Delineat the Edges

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SUMMARY

Edge detection is a requested task in the interpretation of potential-field data, which has been widely used as a tool in exploration technologies for mineral resources. Potential field gradient tensor data offers nine components, which include higher frequency signals than potential field data. Therefore, their interpretations allow a high resolution and detailed investigation of the geological structures. This needs developing new methods to interpret them, especial the edge detection of small geology structures.In this paper, we define the directional total horizontal derivatives to outline the edges, and compare it with the directional analytic signals results.

Introduction

Edge detection is a requested task in the interpretation of potential-field data, which has been widely used as a tool in exploration technologies for mineral resources. The main geological edges are fault lines and the borders of geological or rock bodies of different density, magnetic nature, and so on.
In recent years, potential field gradient tensor data has been widely used. Potential field gradient tensor data can be either measured or numerically calculated from the potential field data. It offers nine components, which include higher frequency signals than potential field data. Therefore, their interpretations allow a high resolution and detailed investigation of the geological structures. This needs developing new methods to interpret them, especial the edge detection of small geology structures.
There are many filters are employed to detect and enhance the edge. The horizontal derivatives and vertical derivative are often used to enhance the edge features. The vertical derivative has been used to delineate edges in gravity and magnetic field data (Evjen, 1936). Total horizontal derivative was widely used to locate the edges (Cordell, 1979; Cordell and Grauch, 1985). Beiki (2010) define the directional analytic signal to delineate the edge, which shown better results than traditional analytic signal.
In this paper, we define the directional total horizontal derivatives to outline the edges, and compare it with the directional analytic signals results.

Directional total horizontal derivatives

The gradient tensor of potential field Φ can be written in the form:

$$G = \begin{bmatrix} \frac{\partial^2\Phi}{\partial x^2} & \frac{\partial^2\Phi}{\partial x\partial y} & \frac{\partial^2\Phi}{\partial x\partial z} \\ \frac{\partial^2\Phi}{\partial y\partial x} & \frac{\partial^2\Phi}{\partial y^2} & \frac{\partial^2\Phi}{\partial y\partial z} \\ \frac{\partial^2\Phi}{\partial z\partial x} & \frac{\partial^2\Phi}{\partial z\partial y} & \frac{\partial^2\Phi}{\partial z^2} \end{bmatrix} = \begin{bmatrix} G_{xx} & G_{xy} & G_{xz} \\ G_{yx} & G_{yy} & G_{yz} \\ G_{zx} & G_{zy} & G_{zz} \end{bmatrix} \quad (1)$$

Outside of the source, Φ satisfies the Laplace equation $\nabla^2\Phi = 0$, the trace of the tensor is equal to zero. Also, G is symmetric, so it contains only five independence components.
Similarity with directional analytic signals (DAS) defined by Beiki (2010), we define directional total horizontal derivatives (DTHD) *x*-, *y*- and *z*- directions.

$$THD_x(x, y, z) = \sqrt{(G_{xy})^2 + (G_{xz})^2} \quad (2)$$

$$THD_y(x, y, z) = \sqrt{(G_{yx})^2 + (G_{yz})^2} \quad (3)$$

$$THD_z(x, y, z) = \sqrt{(G_{zx})^2 + (G_{zy})^2} \quad (4)$$

The subscript *x*, *y* and *z* denote the directions. The maximum values of THD_x delineate the N-S edges. The maximum values of THD_y delineate the E-W edges. The THD_z is the traditional definition of total horizontal derivative (Cordell, 1979; Cordell and Grauch, 1985).

Synthetic model

We construct a prism model with dimensions 200×200×200 m^3 and the depth to the top of 20m and the residual density of 100 kg/m^3. Figure 1a shows the gravity anomaly of the prism. Figure 1b-1d shows the directional analytic signals in *x*-, *y*- and *z*- directions. Figure 1e-1g shows the directional total horizontal derivatives in *x*-, *y*- and *z*- directions. We can conclude that DTHD can get the edges of the geological bodies better than DAS, which have a higher resolution of edges. In order to get a higher resolution, we calculate the vertical derivatives of THD_x, THD_y and THD_z. Because directional total horizontal derivatives are nonharmonic functions, we cannot compute the vertical derivative of

DTHD by a vertical derivative operator in the frequency domain, $-|k|$(where k is a wavenumber vector). Florio (2006) called it as the *k*-function. Also, Florio gave a finite-difference algorithm to compute the vertical derivative of analytic signal. Here, we use this method to compute the vertical derivatives of DTHD: $dzTHD_x$, $dzTHD_y$ and $dzTHD_z$. Figure 1h-1j shows the vertical derivatives of directional total horizontal derivatives in *x*-, *y*- and *z*- directions.

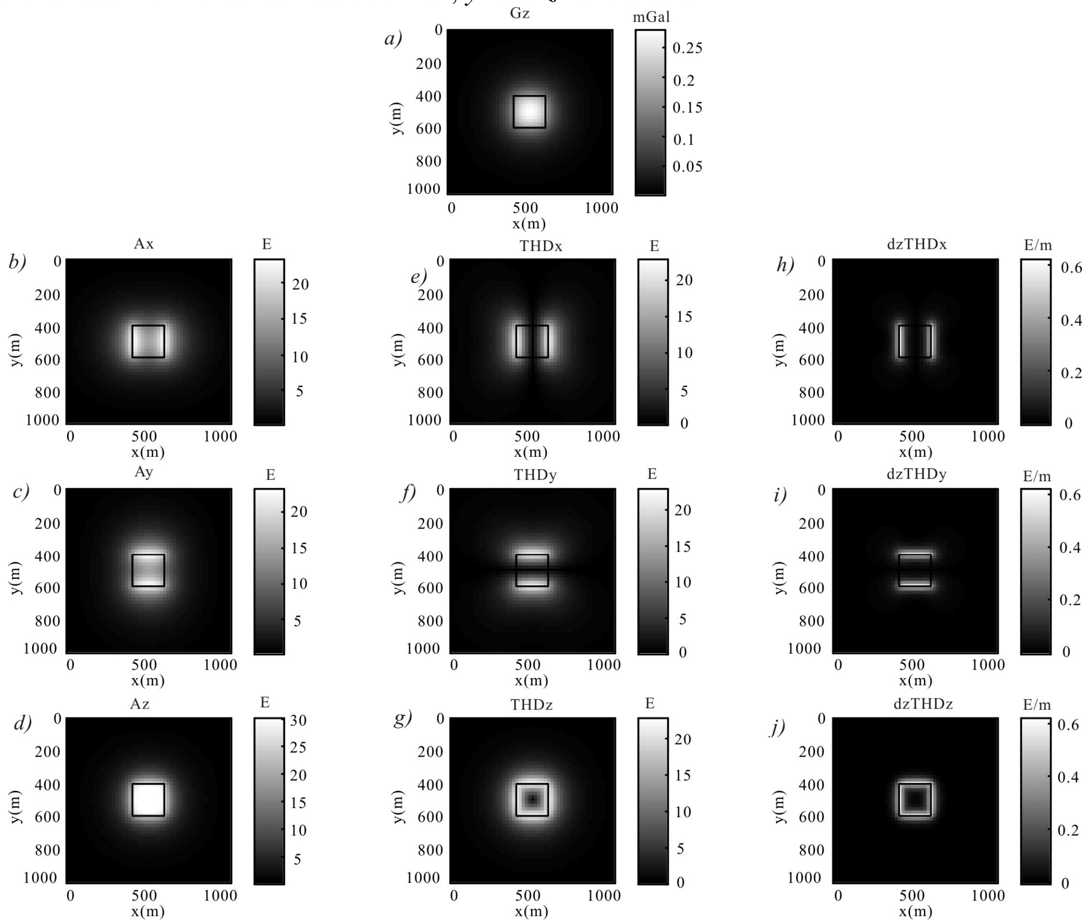

Figure 1 *DAS and DTHD of a prism with dimensions 200×200×200 m^3, the depth to the top of 20m and the residual density of 100 kg/m^3. (a) Gravity anomaly of the prism. (b), (c) and (d) DAS in x-, y- and z- directions. (e), (f) and (g) DTHD in x-, y- and z- directions. (h), (i) and (j) vertical derivatives of DTHD in x-, y- and z- directions.*

Conclusions

This paper first defines the directional total horizontal derivatives to outline the edges, and compare the outlined edges with the directional analytic signals results. We can get that the DTHD can get a better resolution than DAS. The vertical derivatives of DTHD can improve the resolution of edges.

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