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Advantages of horizontal directional Theta method to detect the edges of full tensor gravity gradient data

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ABSTRACT

Full tensor gravity gradient data contain nine signal components. They include higher frequency signals than traditional gravity data, which can extract the small-scale features of the sources. Edge detection has played an important role in the interpretation of potential-field data. There are many methods that have been proposed to detect and enhance the edges of geological bodies based on horizontal and vertical derivatives of potential-field data. In order to make full use of all the measured gradient components, we need to develop a new edge detector to process the full tensor gravity gradient data. We first define the directional Theta and use the horizontal directional Theta to define a new edge detector. This method was tested on synthetic and real full tensor gravity gradient data to validate its feasibility. Compared the results with other balanced detectors, the new detector can effectively delineate the edges and does not produce any additional false edges.

1. Introduction

With the developing of the full tensor gravity gradient measuring techniques, more and more gravity gradient tensor data have been widely used in geophysical exploration for its large amount on information and containing higher frequency signals than traditional gravity data. The full tensor gravity gradient technique can simultaneously measure six gradient components. Each component has its own geophysical meaning. The high frequency gravity gradient tensor data can be used to delineate the small scale anomalies and investigate the geological structure details.

Edge detection is a required task in interpreting the potential field data, and has been widely used in exploration technology for discovery of mineral resources, energy resources and regional tectonics. The main geological edges are fault lines and the boundaries of geological or rock bodies of different densities, magnetic natures, etc.

Many traditional methods are employed to outline the edges. Most of them are based on the horizontal derivatives and vertical derivative of potential field data, such as total horizontal derivative, analytic signal, and so on (Evjen, 1936; Cordell, 1979; Cordell and Grauch, 1985; Roest et al., 1992). However, all of them cannot equal the amplitude of the edges of shallow and deep geological bodies simultaneously. In order to display the edges of large and small anomalies simultaneously, some balanced filters have been proposed (Miller and Singh, 1994; Verduzco and Fairhead, 2004; Wijns et al., 2005; Cooper and Cowan, 2008; Ma and Li, 2012).

However, in order to make full use of the full tensor gravity gradient data, new edge detection method is required to interpret these data, especially for small geological structures. The maximum eigenvalue is a widely used tool to interpret the edges. Oruc et al. (2013) and Zhou et al. (2013) used the maximum eigenvalue of the curvature of the gravity gradient tensor data to delineate the edges. Wang et al. (2015) make some changes, using the principal component analysis of curvature of the gravity gradient tensor data, to identify the edges. Sertcelik and Kafadar (2012) and Yuan et al. (2014) used the eigenvalue of structure tensor of gravity gradient data to outline the edges. Zuo and Hu (2015) used the eigenvalue of the gravity gradient tensor matrix to extract the edges. Beyond these, some directional methods have been used to interpret the full tensor gravity gradient data. Cooper and Cowan (2006) and Oruc and Keskinsezer (2008) have defined the directional tilt angles to delineate edges, but only the vertical direction tilt angle, namely the tilt angle described by Miller and Singh (1994), can get the good results. Mikhailov et al. (2007)and Beiki (2010) proposed the directional analytic signal to extract the edges. However, this method cannot equal to the edge amplitude size of different anomalies. Yuan and Yu (2015) have made an improvement on the directional analytic signal. They defined second order directional analytic signal and proposed a normalization method, which can effectively enhance the large and small amplitude anomalies. Marson and Klingele (1993) have pointed out that the resolution of total horizontal derivative is higher than analytic signal. Therefore, Yuan et al. (2015) defined the directional total horizontal derivative and enhanced directional total horizontal derivatives

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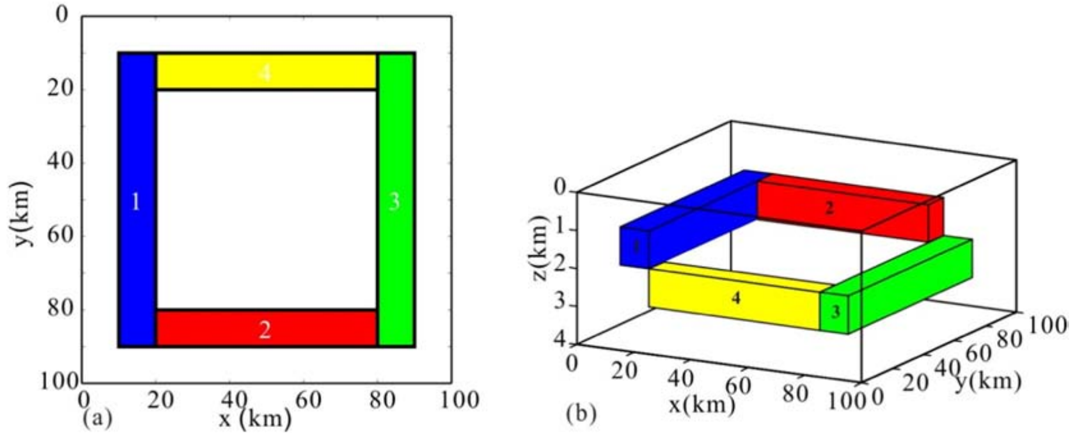

Fig. 1. Plan view and 3D view of the synthetic model.

and use them to define new edge detectors. In order to remove the additional false edges, they introduce a constant parameter in the denominator of the normalization method. However, this removing false edge method is subjective. In this paper, we propose the directional Theta method, and use the horizontal direction Theta to define a new edge detector to delineate the edges of full tensor gravity gradient data.

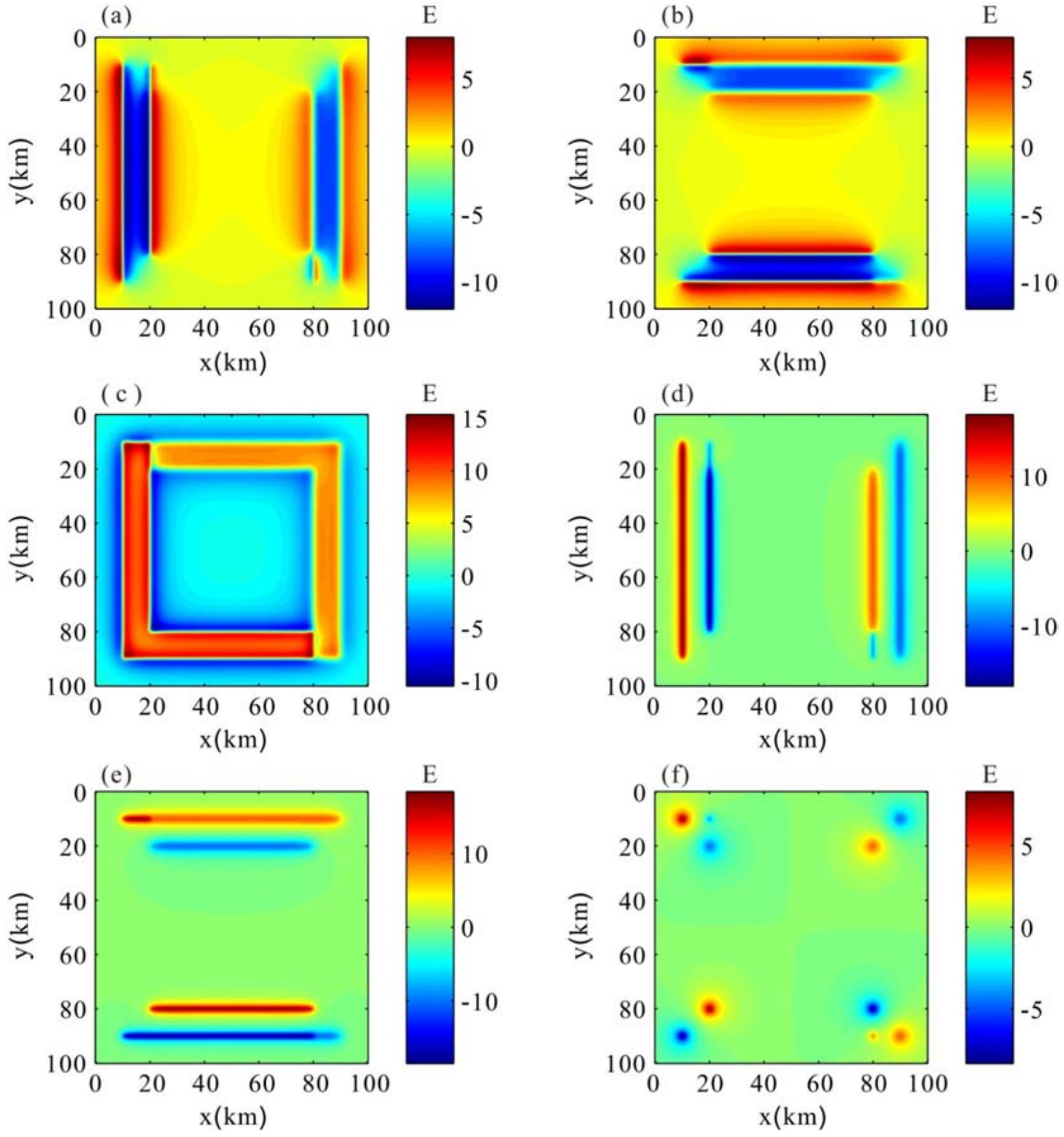

Fig. 2. Synthetic gravity gradient tensor data of model 1. (a) G_{xx}; (b) G_{yy}; (c) G_{zz}; (d) G_{zx}; (e) G_{zy}; (f) G_{yx}.