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A new efficient method for topographic distortion correction, analytical continuation, vertical derivatives and using equivalent source technique: Application to field data

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ABSTRACT

In general, potential field data are noisy due to the surveys in rugged topography. Standard reduction techniques are not fully adequate to eliminate this problem. Most of the interpretation techniques require the observations measured on the horizontal surface. Furthermore, upward and downward continuations, and vertical derivatives can improve the ambiguity in the potential field data. In present, there are methods for the application of the analytical continuations and derivatives, but these are not successful enough due to technical restrictions and unwanted edge effects. In this paper, an easy and efficient technique known as the equivalent source is applied to the observations made over the rugged topography. The presented method is tested on synthetic example using an anomaly of a sphere located below the synthetic topography. At first, our method is applied only to obtain a topographic distortion corrected map by moving forward windowed parts of the area. Afterwards, analytic continuations of the topographic distortion corrected map are obtained.

Finally, a vertical derivative map is obtained from the analytic continuations of the topographic distortion corrected map. Amplitudes are controlled along profiles on top of theoretical and calculated spheres. A good correlation can be observed from the amplitude values. This method is also applied to the field data. The second vertical derivative map is produced from the topographic distortion corrected and 5 km upward continued gravity map of the region. We note that by the interpretations identified faults in these map are in good agreement with the faults shown in the structural map of the region.

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1. Introduction

Topographic distortion correction may not always be considered for the interpretation of the potential field data. However, it was suggested by Xia et al. (1993) that this can cause misinterpretation. On the other hand, analytical continuations, and vertical derivatives are frequently used. Many authors have suggested a lot of methods since old times (Bullard and Cooper, 1948; Elkins, 1951; Henderson and Ziets, 1949a, 1949b; Nettleton, 1962; Peters, 1949). Fuller (1967) used frequency domain for the analytical continuation, vertical derivatives and filters and he obtained the frequency domain coefficients over square grid and compared the results with previous studies. Oldham (1967) used the (sinx)/x (siny)/y method for the continuation of the potential field. Dampney (1969) used a similar method to the present study that he solved the linear equations by locating the equivalent sources to a known depth. Mendonca and Silva (1994) suggested that efficiency of the calculations decreases if the data lengths increase. Emilia (1973) used Green's functions for transforming the potential field data to observe the effect of the equivalent source on the observed data. Bhattacharya and Chan (1977) calculated the gravity and magnetic anomalies due to inhomogeneous distribution of magnetization and density. Later, Hansen and Miyazaki (1984); Leao and Silva (1989); Pilkinton and Urquhart (1990); and Cordell (1992) worked on the same topic. Cooper (2004) suggested three new methods based on derivative and comparison in order to reduce the noise coming from the Fourier transformation for the analytical continuation process. In these methods, downward continuation distance is small even though the signal noise ratio increases. Apart from these researches Fedi et al. (1999), Fedi and Florio (2002), Wang (2006), Xu et al. (2007), Zeng et al. (2007), and Aydemir and Ates (2005) worked on the analytical continuations.

In this paper, a method similar to that used in Dampney's (1969) study was used. In Dampney's method, an equation set covers all of the data at once and that is the main difference from the present study. We selected small windows on the observed data and located the equivalent sources under the grid points of these windows. We approximate the observed data by the field of the equivalent sources. The effect of the

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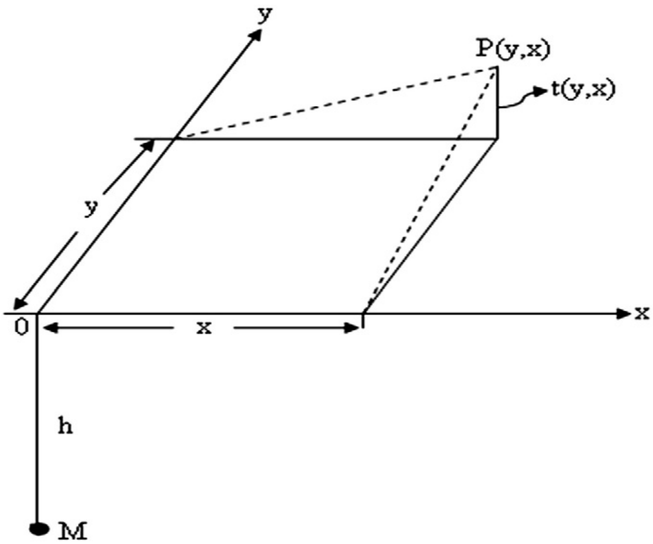

Fig. 1. General appearance of an equivalent source anywhere with rugged topography.

one equivalent mass was obtained only at the centre of the window by applying the topographic distortion correction, at a required depth or height. Later, downward and upward continuations were obtained by means of moving forward this window as convolution. Vertical derivative maps were obtained with the topographic distortion correction and analytical continuation. The suggested method was applied to a field data and successful results were obtained.

2. The equivalent source technique

The standard reductions applied to the potential field data measured on an irregular surface do not reduce the effect of masses under the ground to known horizontal surface. Xia et al. (1993) introduced a method of reducing the gravity data on a horizontal surface. They also represented the gravitational acceleration of the observed data over rugged topography with many equivalent point masses at known coordinate and depth (Xia et al., 1993).

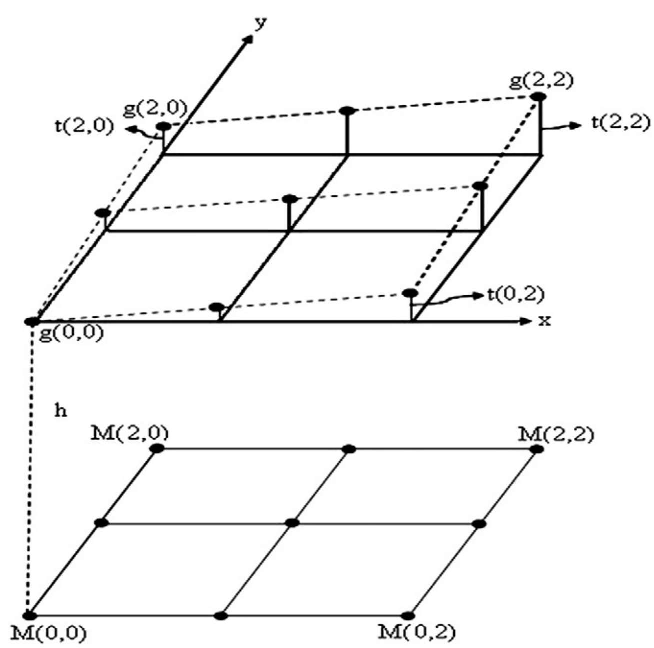

Fig. 2. A window with w × w dimension obtained from observation points over rugged topography and M equivalent sources located under the grid points at depth h.

Table 1
Parameters of the synthetic example.

Parameters of a buried sphere
Diameter (R) = 25 m
Depth (z) = 80 m
Density contrast = 1 gr/cm^3
Grid interval (dx) = 10 m
Equivalent source depth (h) = 200 m
Window length = 5 units

Gravitational acceleration of a single point shaped mass over rugged topography at P(y,x) (Fig. 1) is calculated as follows:

$$g(y,x) = M\frac{h+t(y,x)}{\{x^2+y^2+[h+t(y,x)]^2\}^{3/2}} \tag{1}$$

where, M is the point mass, t is the topographic height and h is the depth of the single point mass.

If equivalent point masses are located under all of the observation points with rugged topography, this can take a long time, the solution can have ambiguity and these can also have large errors at the edges. If a small window is selected on a corner of observed values with a w × w (w: must be an odd number) dimension and M values can represent the observed values, located under every grid points at h depth then it is possible to eliminate these disadvantages (Fig. 2).

This process can be formulised as follow;

$$g(j,i) = \sum_{p=1}^{w}\sum_{r=1}^{w} M(p,r)\frac{h+t(p,r)}{\{(j-p)^2+(i-r)^2+[h+t(p,r)]^2\}^{3/2}} \tag{2}$$

where; y = (j − p), x = (i − r) and j = 1,2,.....n − 2, i = 1,2....m − 2 (n: row number of observation values, m: column number).

Unknowns in the linear Eq. (2) array are only M and the solution of this equation yields that M g(a,b) is the centre of a window, if a = b = (w − 1) ⁄ 2 + 1.

Gravitational acceleration of ac (ac: analytical continuation) amount of below or above is:

$$g(a,b) = \sum_{p=1}^{w}\sum_{r=1}^{w} M(p,r)\frac{h+ac+t(p,r)}{\{(a-p)^2+(b-r)^2+[h+ac+t(p,r)]^2\}^{3/2}}. \tag{3}$$

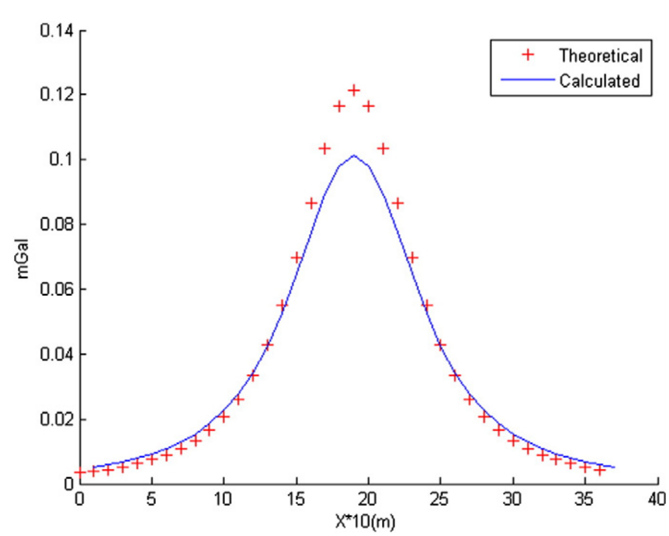

Fig. 3. A profile from centre of the anomaly map of the sphere at a depth of 80 m at −20 m downward continuation with h = 200 m, w = 5 unit (blue curve). Theoretically continued curve of a sphere with h = 60 m (red curve).

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