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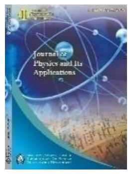

Comparative Study on Separation of Regional and Residual Magnetic Anomalies Using the Upward Continuation, Moving Average, and Polynomial Methods

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A B S T R A C T

Calculation of regional and residual anomaly separation on magnetic data has been carried out and compared with the upward continuation method available in the Magpick software. Separation of anomalies with moving average and polynomial methods is processed using Matlab code. The orders used in the polynomial method are first-order, second-order and third-order. Comparing process is done by calculating the correlation coefficient between the result of the upward method and both moving average and polynomial method separately. The chosen matching method is autocorrelation of residual magnetic anomalies resulting from upward continuation (Magpick) to moving averages, 1st-order polynomials, 2nd-order polynomials and 3rd-order polynomials are 0.9604, 0.9072, 0.9482 and 0.6057, respectively. The moving average and second-order polynomial methods can be used as a substitutive method of the upward continuation method

1. Introduction

Geophysics is the study of subsurface structures by measuring or observing physical properties measured on the surface of the earth. To carry out measurements of the earth's surface involves measurements on the earth's surface in the form of physical parameters owned by rocks on earth.

Geophysical methods can be used to model subsurface structures. Geophysical modeling is generally used for mining mineral exploration and also for geotechnical applications. One method that is often used for initial exploration surveys is the magnetic method.

The target of magnetic method data processing is extracting the anomaly of total magnetic field anomaly from the magnetic survey. This magnetic field anomaly will be used to interpret the geological structure below the earth's surface. However, its magnetic anomaly consists of mixture of anomalies caused by deep and shallow sources. Anomaly caused by deep sources is referred as regional anomalies, while anomaly caused by shallow sources is called as residual anomaly. Separation of regional and residual anomalies requires good methods to obtain accurate regional and residual anomalies for geological modeling of subsurface earth

The standart method of separation of magnetic anomalies is the upward continuation method. In this study, other separation method will be investigate namely moving average and polynomial methods. The accuracy are is compared by using the correlation method to determine the value of the match results from those method and the standart one.

2. Theory

2.1. Upward Continuation

Transformation of potential field data from one flat plane to another higher plane is the concept of the upward continuation method. The main principle of upward continuation is that a potential field can be calculated at any point in an area based on the nature of the field on the surface surrounding the area [5].

Upward continuation is assumed as a potential field measured on the surface $z = z_0$ and a potential field located at a point above the surface with $\Delta z > 0$. $\Delta Z_{(x',y',z')}$ is potential field in the plane of upward continuity, z is the elevation height to the new plane and $R = \sqrt{(x-x')^2 + (y-y')^2 + z^2}$.
The equation of the upward continuation is written as follows.

$$\Delta Z = \frac{|z|}{2\pi} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \left(\frac{\Delta z(x',y',z')}{R^2}\right) dx'dy'dz' \qquad (1)$$

Upward continuation will be more optimal if processed in the Fourier domain [2].In the upward process, the z surface can be chosen but it should not be too high. Higher z surface can reduce the local anomaly. The local or residual anomaly is the main target of the magnetic separation process [10-11].

2.2. Moving Average Method

Moving averagemethod is averaging the anomaly values. Indirectly, the moving average filter is operated by dividing by a number limit derived from an input signal to produce each limit on each output signal, the equation can be written as follows:

$$g[i] = \frac{1}{M}\sum_{j=0}^{M-1} x[i+j] \quad (2)$$

Where x[i,j] is the input, M is the average of input value, *g[i]* is the value of the regional anomaly.

The moving average method requires window size [*i*,j] in the calculation process. Window size as the amount of data include in averaging process. Window width is determined by spectrum analysis. In the spectrum analysis, a Fourier transformation processis carried outto change a signal into the sum of several signals. The Fourier transformation process is carried out with the aim of changing data from the time or spatial domain into the frequency domain or wavenumber. The results of this transformation will be in the form of amplitude and phase spectrum so that the value of wavenumber (k) in equation (3) and amplitude (A) can be used to calculate the width of the filter window in equation (4), which then becomes input data in filtering process, regional-residual anomaly separation.

$$k = 2\pi f \quad (3)$$

$$A = \sqrt{Re^2 + Im^2} \quad (4)$$

The logarithmic results show that the average depth of the field of mass density discontinuity will be proportional to the slope of the spectrum graph. The illustration of determining the depth of data regression from Fourier Transform results as shown in Fig. 1.

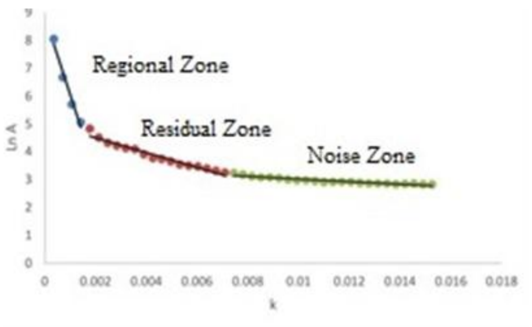

Fig. 1: Relationship between amplitude and wavenumber in spectrum analysis Polynomial

Figure 1 shows a graph of the relationship between amplitude and wavenumber in spectrum analysis. In the graph, there are 3 regression lines. The first regression line shows the regional zone, the second regression line shows the residual zone, and the third shows the noise [3]. The relationship of wavelength (λ) to k is shown by following formula [2].

$$k = \frac{2\pi}{\lambda} \quad (5)$$

$$\lambda = N.\Delta x \quad (6)$$

where N is the window width, the estimated window width is obtained by the following equation:

$$N = \frac{\lambda}{\Delta x} = \frac{2\pi}{k\Delta x} \quad (7)$$

2.3. Polynomial Method

The polynomial method is often called the least squared method. The polynomial method assumes that a polynomial surface can describe regional plane models that are smoother according to the chosen polynomial order [8]. One method that can be used to obtain residual anomalies with high resolution is the polynomial trend surface analysis (TSA) method [6] [9].

Regional anomalies are obtained from the polynomial equation of order n [1]. The polynomial equation is formulated as follows:

$$g_i = C_1 + C_2x_i + C_3y_i + C_4x_iy_i + C_5x_i^2 + C_6y_i^2 \quad (8)$$

Where i = 1,2,3,...,nis a number of stations, $g_i$is magnetic anomaly, x_i and y_i are coordinate and C_1,...,C_6 are polynomial constant.

The constant C1,...,C6 in the matrix formula is:

$$\begin{pmatrix} g_1 \\ g_2 \\ \vdots \\ \vdots \\ \vdots \\ g_i \end{pmatrix} = \begin{pmatrix} 1 & x_1 & y_1 & x_1y_1 & x_1^2 & y_1^2 \\ 1 & x_2 & y_2 & x_2y_2 & x_2^2 & y_2^2 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \ddots \\ 1 & x_i & y_i & x_iy_i & x_i^2 & y_i^2 \end{pmatrix} \begin{pmatrix} c_1 \\ c_2 \\ \vdots \\ \vdots \\ \vdots \\ c_i \end{pmatrix} \quad (9)$$

or

$$d=Gm \quad (10)$$

d is the vector of magnetic anomaly, G is a Kernel matrix and m is the vector of polynomial constant.

The polynomial formula has a contribution to subsurface geology. The higher polynomial order will have a correlation with more heterogeneous rock. It can be explained that at the shallower layer the contours will not be smooth.

3. Methodology

This study uses the secondary magnetic data of Mount Merapi with coordinates -7,648985 S to -7,485904 S and 110,3420407 E to 110,546314 E. Secondary data has been corrected with daily variation and IGRF correction to obtain total magnetic anomaly. Separation method is used to separate residual and regional anomalies.

Separation method used here are upward continuation, moving average, and polynomial. The separation results by using the moving average and polynomial methods are compared with the anomaly from the upward continuation method. The comparison process used the correlation method.

4. Results and Discussions

4.1. Upward continuation

The upward continuation filter in this study was chosen at 4000 meter of height, where the anomaly closure was smooth and was not influenced by the local anomaly. The upward method was done by using the Magpick software. Magpick is a standard software for magnetic separation. The results of regional and residual anomalies were mapped in Fig. 2 (a) and (b).

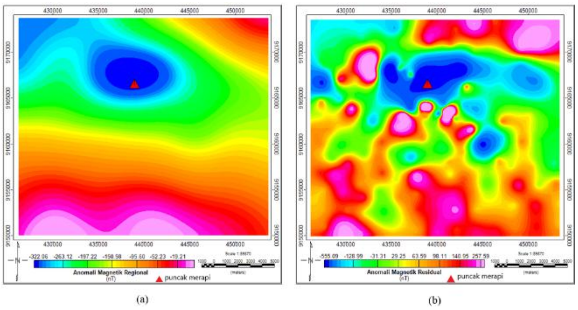

Fig. 2: Magnetic anomaly map use upward continuation method (a) regional (b) residual

4.2. Moving Average

Separation using the moving average method was done by a simple Matlab programming. The results of the magnetic field anomaly separation using the moving method were mapped in Fig. 3 (a) and (b).

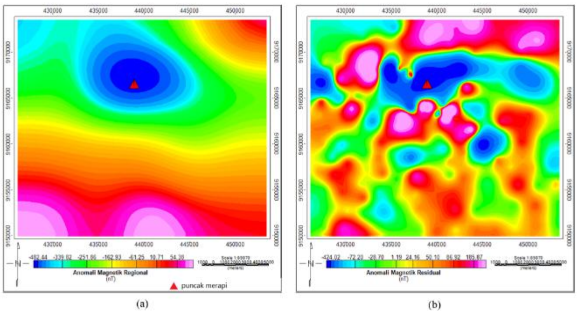

Fig. 3: Magnetic anomaly map use moving average method (a) regional (b) residual

4.3. Polynomial

Separation of anomalies using the polynomial method was done by using the n-order polynomial equation approach, in this study using polynomials of order-1, order-2, and order-3. Separation using polynomial methods was implemented in Matlab code. The results of the separation were shown in Fig. 4-6

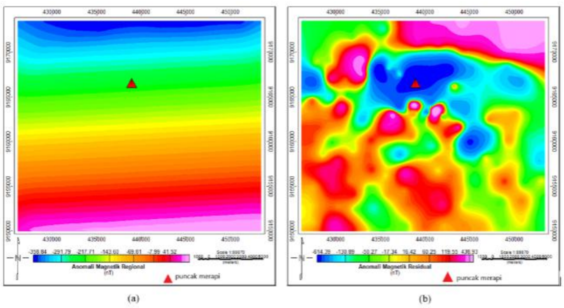

Fig. 4. Magnetic anomaly map use the 1st-order of polynomial method of (a) regional (b) residual

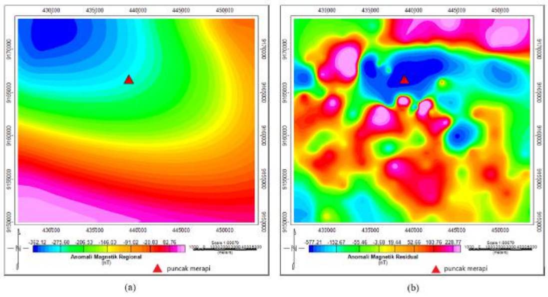

Fig. 5: Magnetic anomaly map use the 2nd-order of polynomial method of (a) regional (b) residual

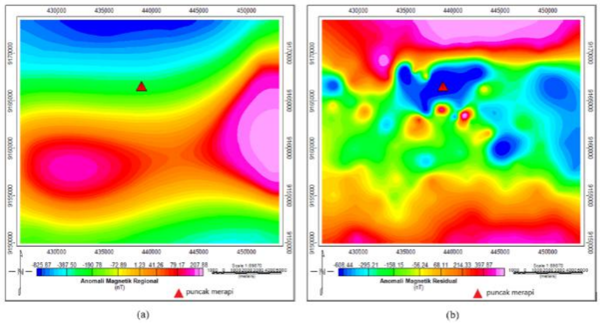

Fig. 6: Magnetic anomaly map use the 3rd-order of polynomial method of (a) regional (b) residual

Regional anomaly contour maps of moving averages and polynomials had the closest pattern to the contour of upward-continuation results. The distribution of contour patterns in regional anomalies was low anomaly values represented in blue in the peak region and high anomalies represented in red. High value regional anomalies are in the south of the study area.

The results of the two methods were compared with the upward residual anomalies. Residual anomalies were the target of the study. Residual anomaly, which a result of the moving average method and polynomial had the same contour pattern with the residual anomaly map by the upward continuation method. Closure on the magma reservoir in Merapi was shown clearly by using moving average and polynomial 2^{nd} order.

4.4. Correlation

The results of the correlation are shown in Table 1. The results of the correlation showed that the moving average and the second-order polynomial separation methods had a very good correlation value. Similarity was seen in the correlation coefficient close to 1. Correlations to regional anomalies produced no better value than residual anomalies. This was due to the contour pattern of regional anomalies that were very different from the upward results. The mathematical process influenced regional results. Regional anomaly results would affect the local anomaly. These three methods had the same principle, which was to bring the calculation value towards the regional anomaly. Simpler regional structures should provide better correlation values, but the mathematical processes in polynomials gave different results. The polynomial regional anomaly pattern that was most similar to the upward residual anomaly pattern was the 2nd order polynomial.

Table 1 Correlation value of the upward continuation residual anomaly map to the residual anomaly map of other methods

Separation Method	Correlation value of Residual Anomaly
Moving Average	0,9604
Polynomial 1st order	0,9072
Polynomial 2nd order	0,9482
Polynomial 3 order	0,6057
Separation Method	Correlation value of Regional Anomaly
Moving Average	0,9504
Polynomial 1st order	0,5172
Polynomial 2nd order	0,7082
Polynomial 3 order	0,3211

5. Conclusions

Based on the results of processing and interpretation conducted in this study, it could be concluded that the separation of regional and residual anomalies in magnetic data using the moving average method and the 2nd order polynomial method had almost the same results compared to the upward continuation method indicated by their correlation coefficient i.e.9482 and 0.9604. The moving average and the second-order polynomial methods can be used as a substitutive method of the upward continuation method.

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