Determination of optimal window in spectrum analysis process with moving average method gravity data measurement

Rizki Agung Satrio Darmawan, Artono Dwijo Sutomo, Budi Legowo
Physics Department Universitas Sebelas Maret
Jl. Ir. Sutami 36A Keningan Jebres Surakarta 57126, INDONESIA

E-mail: pakbeel@staff.uns.ac.id

Abstract. Bouguer anomaly is separated by moving average method with MATLAB 13. In moving average method there is spectrum analysis process to get optimal window length. The window length value used is 5. The depth of the regional anomaly boundary area is 1871.75 m, while the depth of the residual anomaly boundary area is 359.33 m. After anomaly separation, 2.5D modeling was made with Oasis Montaj 6.4.2. The gravity anomaly data used to construct the model is the residual gravity anomaly. The result of 2.5D modeling is seen 4 formations of rock, among others Batilembu Formation with density 2.4 gr / cc, Batumadi Formation with density 2.37 gr / cc, Tangustabun Formation 2.42 gr / cc, and Molu Complex with density 2.7 gr / cc.

1. Introduction
The gravity method is one of the passive geophysical methods. The gravity method is done by measuring the variation of the earth's gravitational field. The variations in the earth's gravitational field are influenced by the unequal rock mass density of the earth's surface, the type of rock, the distance of the measuring point to the center of the earth and the difference in the topography of the earth's surface [1]. Separation of gravity anomalies can be done by several methods, including moving average, upward continuation, polynomial, and inversion methods [2]. This paper discusses the moving average method used to separate gravity anomalies. The moving average method uses optimal window width values to separate Bouguer anomalies into regional anomalies and residual anomalies. The optimal window width value is obtained by performing spectrum analysis process. In the spectrum analysis process, gravity data with spatial domains will be converted into frequency-dominated data. The problem found is to select a window width value to separate anomalies by approximate. However, basically optimal window width values can be obtained by slicing on the complete Bouguer anomaly map with varying amounts. The solution offered is to create a program that can help perform the process of spectrum analysis with MATLAB 13.

2. Experimental Methods
The theory underlying the gravity method is Newton's law of gravity. Where, the pull force between two mass is inversely proportional to the square of the distance. Mathematically can be written as follows:

\[ F = G \frac{m_1 m_2}{r^2} \] (1)
Gravity measurement data needs correction. It aims to eliminate the influence of terrain outside the earth and the effect of drift correction when measuring the value of gravity. There are several stages of correction of gravity data, among others:

a. Tidal Correction
   This correction is done to remove the influence of mass outside the earth that affect the results of gravity measurements. Mathematically can be written as follows [3]:
   \[ T_{dc} = \frac{3\pi\tau}{2} \left( \frac{2M}{3d^2} \sin^2 p - 1 + Mr/d^4 (5\cos^3 p - 1\cos p) + 2S/3D^3 (3\cos^2 q - 1) \right) \]  

b. Drift Correction
   This correction is done because of the fatigue factor of the tool during the acquisition of gravity data from a measurement point to another measurement point. Mathematically can be written as follows [4]:
   \[ D = \frac{g_{A2} - g_{A1}}{T_{A2} - T_{A1}} (T_{station} - T_{A1}) \]  

c. Theoretical Gravity Correction
   This correction is based on the effects of the Earth's rotation on the surface of the Earth ellipsoid. So that the earth experienced acceleration in both poles. Mathematically can be written as follows [5]:
   \[ g_T = \frac{g_0 (1 + k\sin^2 \varphi)}{(1 - e^2 \sin^2 \varphi)} \]  

d. Height Correction
   This correction is done because of the influence of altitude between the point of measurement of gravity to the earth's gravitational field. Mathematically can be written as follows [5]:
   \[ g_h = -(0.3087691 - 0.0004398\sin^2 \varphi)h + 7.2125 \times 10^{-8} h^2 \]  

e. Bouguer Correction
   This correction is done because of the mass between the datum and the point of measurement of gravity. The Bouguer correction value depends on the rock type mass and the height of the gravity measurement point [5]. Mathematically can be written as follows:
   \[ \delta g_{BC} = 2 \pi G \sigma h = 4.193 \times 10^{-5} \sigma h \]  
f. Terrain Correction
   This correction is performed due to terrain or topographic circumstances around uneven measurement points. Such as a hill or valley around the measurement point that will affect the value of gravity measurement. For terrain correction we can use Hammerchart or Digital Elevation Model (DEM).

The results of gravity data correction produce data called the complete Bouguer anomaly. However, the complete Bouguer anomaly value is still the sum of regional anomalies and residual anomalies. Regional anomalies associate with low frequency and deep coverage, whereas residual anomalies are associated with high frequency and shallow coverage [6]. In performing 2D or 3D interpretations residual anomalies are used. To obtain residual anomaly values, anomaly separation is necessary. Therefore, the process of separating anomalies is a necessary step. There are several methods of separating anomalies, including moving average, upward continuation, inversion and polynomial. But in this paper using moving average method.

Gravity anomaly data is obtained from http://www.bandaarcgeophysics.co.uk/data-sources.html in ASCII format. In the data contained information of latitude, longitude, height of gravity station along with the measured gravity value. The data was gridded using Surfer 13. Then created a complete contour map of Bouguer anomaly. Separation of gravity anomaly is done by spectrum analysis process. Spectrum
analysis is done by converting spatial or spatial data into frequency-dominated data [7]. The process of spectrum analysis is done by creating a program on MATLAB 13. In gravity data, spectrum analysis is used to determine the width of the window and estimate the average anomaly depth. To determine the window width value, it is done by moving average method. The moving average method is one of the methods used to separate complete Bouguer anomalies into regional anomalies and residual anomalies. Mathematically the equation of moving average method can be written as follows:

\[
\Delta g_r(i) = \frac{\Delta g(i-n)+\Delta g(i)+\cdots+\Delta g(i+n)}{N}
\]  

(7)

3. Results and Discussion

Complete Bouguer anomaly map can be seen in Figure 1, which shows an anomalous range between -50 mGal to 25 mGal. The result is a varying rock density response in the area.

![Figure 1. Complete Bouguer Anomaly Map](image)

The process of spectrum analysis is done by making a slicing path on a complete Bouguer anomaly map. Here is the slicing path used:

![Figure 2. Trajectory of Slicing on Contour Map of Complete Bouguer Anomaly](image)
The amount of slicing used is six different tracks. Then, a spectrum analysis process is done to determine the window width and estimate the boundary plot of the gravity anomaly. Values obtained from the path can be seen in Table 1.

| No. | Track | Depth of Regional Anomaly Field | Depth of Regional Anomaly Field | Window Length |
|-----|-------|---------------------------------|---------------------------------|---------------|
| 1   | Track 1 | 1959.3                          | 309.8                           | 6.12          |
| 2   | Track 2 | 1695.5                          | 265.5                           | 5.87          |
| 3   | Track 3 | 2350.2                          | 572.06                          | 5.19          |
| 4   | Track 4 | 1879.9                          | 400.34                          | 5.90          |
| 5   | Track 5 | 1381.4                          | 281.83                          | 5.62          |
| 6   | Track 6 | 1964.2                          | 326.47                          | 6.70          |
|     | Average | 1871.75                         | 359.33                          | 5.90          |

Table 1 shows the average depth of the boundary area of regional anomaly is 1871.75 m, whereas the mean value of depth of boundary field of residual anomaly is 359.33 m. The result also shows the average value of window width is 5. After separation with moving average method, then gridding to get contour map of regional anomaly. Regional contour map and residual contour map can be seen in this picture.

![Figure 3. Regional Anomaly Contour Map](image1)

![Figure 4. Residual Anomaly Contour Map](image2)

To obtain the residual anomaly value can be by subtracting the Bouguer anomaly value with regional anomalies. Contour maps of regional anomalies can be seen in Fig.3 which shows an anomalous range between -45 mGal to 20 mGal. While the residual anomaly contour map can be seen in Fig.4 which shows an anomalous range between -18 mGal to 16 mGal. After obtaining residual anomaly then made the process of making a 2.5D model using the Oasis Montaj 6.4 and taking into account the geological information [8]. Model making is done using A-A 'path. Here are the tracks and models that have been created:
Modeling 2.5D is done to determine the subsurface conditions based on the selected path and based on existing geological information. The cross section of A-A' extends from the northwest to the southeast of the island. Derived from existing geological information, the path passes through 4 rock formations namely Batilembu Formation with density 2.4 gr/cc, Batumadi Formation with density 2.37 gr/cc, Tangustabun Formation 2.42 gr/cc, and Molu Complex with density 2.7 gr/cc. The density value parameter of 2.5D model refers to the density table [9].

4. Conclusion
Separation of gravity anomalies using moving average method can be done with the help of MATLAB 13. In the moving average method there is a spectrum analysis process used to determine the optimal window width value. Having obtained the optimal window width value, then can be separated gravity anomaly. The width of the window used is 5. The complete Bouguer anomaly value indicates the range of values between -50 mGal to 25 mGal. Modeling 2.5D is done by making slicing on the residual anomaly map. The trajectory of slicing extends from the northwest to the southeast. After the slicing, made a 2.5 D model based on existing geological information there are 4 kinds of rock formations. Rock formations that can be interpreted, among others, Batilembu Formation with density 2.4 gr/cc, Batumadi Formation with density 2.37 gr/cc, Tangustabun Formation 2.42 gr/cc, and Molu Complex with density 2.7 gr/cc.
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