Analysis of Regional Anomaly on Magnetic Data Using the Upward Continuation Method

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Abstract. Separation of regional anomalies and residual anomalies are important steps in processing magnetic data. The better separation of the two anomalies resulting data which can be easily interpreting. The most commonly used in the separation of regional-residual anomalies is the upward continuation method. In this study, we used synthetic models I (consists of four blocks with different depths) and II (consists of four blocks with different susceptibility) to determine the height of uplift in the upward continuation method. The results obtained by the appointment that illustrate the regional anomaly in the model I are 50 to 90 meters, while model II at the lift height of 20 to 60 meters. The model I shows the lifting results of 50 to 90 meters almost close to the regional anomaly response which has a range of anomalous value of -0.703-2.408 nT. Among 50-90 meters, the lifting height of 90 m is closest to the contour and range of regional component anomalies. Model II shows the lift results that are close to the regional anomaly response at 20 to 60 meters. Model II shows the lift results that approach regional anomalies (-7,780-18,012 nT) at 20 to 60 meters, which most closely approximates the regional component anomaly range is the lifting of 40 meters with -6,152-16,629 nT. The correlation between these two models is very useful for analyzing the earth's magnetic field signal.

Keywords: Geomagnetic, Regional Anomaly, Synthetic models, Upward Continuation

1. Introduction

Magnetic method (geomagnetism) is done based on the measurement of magnetic anomalies caused by differences in susceptibility contrast. If there is a field value obtained has a contrast value from the value of the surrounding magnetic field, commonly called magnetic anomalies [1]. The magnetic field value measured in the field consists of two superposing components, regional anomalies, and residual anomalies. Components of regional anomalies that have low frequencies provide information about the source of anomalous objects at great depths. The residual anomaly component provides the opposite information [2].

Separation of regional-residual anomalies becomes a very important stage. Therefore, a data filter is needed that can be appropriate to obtain representative data results so that the results of the interpretation become better. There are several methods used to separate the two anomalies. But the most commonly used is the upward continuation method. Previous research using upward continuation like Purnomo, et al., 2013 [4], Hiskiawan, 2016 [5], Nurdin, et al., 2017 [6] and Satiawan, 2008 [2]. The separation between regional anomalies and local anomalies in processing using upward continuation will result in a more accurate interpretation of the existence of magnetic anomalies [3]. But there is one problem in this method is that there is no parameter to determine the results obtained is appropriate or not.

One of a way to find out the upward continuation results is that it is suitable to create a synthetic model that is almost the same as in the field. So that, the results obtained using synthetic models can be applied to the data obtained from field measurements. The model used in previous research [2] only uses depth parameters between regional anomalies and residual anomalies. Some blocks of residual anomalies have the same depth and block regional anomalies are only one block which cannot describe the situation in the field.
In this study the models are made by using the UBC-GIF Mag3D software. It is processed by using the upward continuation method. The resulting contour was analyzed using the krigging method. The purpose of this study is to determine the height of upward continuation lift in accordance with synthetic models.

2. Methodology

In this study using two synthetic models, the model I and model II (figure 1) consisting of two regional anomaly blocks and two residual anomaly blocks based on table 1. The distance between the anomaly residual and regional anomaly approximately 100 meters, the model was made in the area of 190 X 200 meters. The model is created using software UBC-GIF MAG3D based on table 1. The equation used to calculate the total magnetic field caused by the block is [7]

\[
\Delta T = C_m M \left[ \frac{\alpha_{22}}{2} \log \left( \frac{r-x'}{r+x'} \right) + \frac{\alpha_{12}}{2} \log \left( \frac{y-x'}{y+x'} \right) - \alpha_{12} \log (r + z_1) - \tilde{M}_x F_x \arctan \left( \frac{x'y'}{x'^2 + r^2 + z_1^2} \right) - \tilde{M}_y F_y \arctan \left( \frac{x'y'}{x'^2 - r^2 - z_1^2} \right) + \tilde{M}_z F_z \arctan \left( \frac{x'y'}{x'^2 + z_1^2} \right) \right] \bigg| \begin{align*} x' = x_2 \quad & \quad y' = y_2 \\ x' = x_1 \quad & \quad y' = y_1 \end{align*}
\]

(1)

Table 1. Coordinates of model I and model II

| Model | Block | Coordinates (m) | Susceptibility | Inc  | Dec  |
|-------|-------|-----------------|----------------|------|------|
|       |       | X   | Y  | Z         | (W b. A^-1. m^-1) | (°) | (°) |
| Model I | 1 | 60,80 | 80,100 | 150,180 | 0,1 | 45 | 0 |
|        | 2 | 100,120 | 140,160 | 120,150 | 0,1 | 1 |
|        | 3 | 40,80 | 160,180 | 50,70 | 0,1 |
|        | 4 | 140,160 | 120,140 | 30,40 | 0,1 |
| Model II | 1 | 60,100 | 100,120 | 150,180 | 0,3 | 45 | 0 |
|        | 2 | 140,160 | 60,80 | 150,180 | 1,4 |
|        | 3 | 80,100 | 100,120 | 50,70 | 0,3 |
|        | 4 | 140,180 | 40,60 | 50,70 | 1,4 |

Figure 1. (a) Model I and (b) Model II

The difference between model I (figure 1a) and model II (figure 1b) is the depth and value of block susceptibility. Before being processed using the upward continuation method, the two models are transformed Fourier (Figure 2). To simplify the analysis, the data in the space domain is changed to frequency dominance using Fourier transformation analysis. The results of Fourier transform still contain two regional and residual anomalies. Both components are comparable to determining the upward continuation results in accordance with the model. Because it is difficult to determine the results of upward continuation that match the model without comparison. So the comparison is necessary in this case the regional component of the model I. The response of regional anomaly is obtained by
removing two blocks of residual anomalies in the model (figure 3) as a comparison of the results of the upward continuation. This study will focus on comparing the results of regional anomalies.

Figure 2 the model that has been transformed (left) model 1 (right) model 2

Figure 3 komponen/respon anomali regional (left) model I (right) model II

3. Results and Discussion

3.1 Model I

To calculate the potential field generated in the upward continuation field by using the following equation [8]

\[ P(x, y, z_0 - \Delta z) = \frac{\Delta z}{2\pi} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \frac{Q(x', y', z_0)}{((x-x')^2 + (y-y')^2 + \Delta z^2)} \, dx' \, dy' \]  \hspace{1cm} (2)

The model I is lifted from a height of 20 to 90 meters. Then the contours of the regional anomaly upward results compared with the contours of regional anomaly response. Of all the contours produced, the contour at a lifting height of 80 meters (figure 4b) and 90 meters (figure 4c) are the closer to the contour of the regional anomaly response (figure 4a). Based on the results of Satiawan's research, 2009 [2] the more similar the contours produced by the results of upward to the contours of regional anomalies response, then the results are considered in accordance with the model made. In addition to contours produced, the range of anomalous values also determines the height of the right lift. When the range of anomalous values obtained is getting closer to the range of regional component values, the height of the lift is correct. At a lifting height of 90 meters anomalous value range is obtained -0.482 - 2.554 nT approaching the range of regional anomaly response values of -0.703-2408 nT. For more detail see table 2. The color difference in the contour shows the variation of the magnetic anomaly. The orange color on the contour shows a high anomalous field (2,408 nT). In this model, the red color indicates the location of the anomaly that has been made.

Table 2 Range values of regional anomaly upward results and regional anomalous responses model I

| Lifting height (m) | 80       | 90       |
|--------------------|----------|----------|
| Range Anomaly value (nT) | Regional anomaly upward result | -0.658 to 3,002 | -0.482 to 2,554 |
| | Regional anomaly response | -0.703 to 2,408 | |
The RMSE is used to determine the lifting height that is closest to the regional component between 80 and 90 meters slice is carried out the same coordinates (figure 4) so that the magnetic anomaly value curve appears (Figure 5). By using the RMSE equation (Root Mean Square Error) an error value is obtained between the upward lift height and the regional component. N is the amount of data, x is the upward result, x ‘is a regional component.

\[
RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (x - x')^2}
\]  

Figure 4. The track slice (a) contour response regional anomalies (b) the results of upward 80 meter contour (c) the results of 90 m contour

The error value generated in the 80-meter lift is 0.11198% while the 90-meter lift is 0.05394%. So that the lifting height that is closest to the regional component is 90 meters. The blue curve shows the regional component of model I while the orange color shows upward results.

3.2 Model II

The most difference between model II models I apart from the model depth is the susceptibility value which is very different between blocks (see table 1). The difference in susceptibility values which is quite large between 0.3 and 1.4 has an impact on the range of anomalies that are greater than that of model I. The model II is lifted to a height of 20 to 60 meters as model I.

Figure 5. comparison of regional component of model I curves with (a) 80 m and (b) 90 m
The resulting contour of 20-60 meters compared to the contour of the regional component of model II. As a result, lifting height of 30 meters (figure 6b) and 40 meters (figure 6c) have the contour that is most similar to a regional component (figure 6a). For more details see table 3. The orange color on the contour shows the location of the regional block anomaly (especially in blocks with 1.4 susceptibility values).

Table 3 Range values of regional anomaly upward results and regional anomalous responses model II

| Lifting height (m) | Regional anomaly upward result | Regional anomaly response |
|--------------------|--------------------------------|---------------------------|
| 30                 | -7,249 to 20,171               | -7,780 to 18,012          |
| 40                 | -6,152 to 16,629               | -6,152 to 16,629          |

Figure 6. The track slice (a) contour response regional anomalies (b) contour results upward to 30 meters (c) the results of 40 m contour

Furthermore, the lifting height is determined between 30 meters and 40 meters by slice the contour at the same coordinates (figure 6) so that the curve appears (figure 7). From the comparison of regional component curves with upward results, the error value can be calculated using RMSE. The error value on the 30 meters lift is 0.36724% while the 40 meters lift is 0.46236%.

From the results of the RMSE, the lifting height can be determined which is closest to the regional component of model II, which is 30 meters.

Figure 7. comparison of regional component of model II curves with (a) 30 m and (b) 40 m
In model II the distance between the top of the regional anomaly block and the bottom of the residual anomaly block is 80 meters. In contrast to the model I where upward results are closest when the two block residual anomalies are completely lost, in model II the lifting of 30 meters or 1/3 from the distance of residual and regional anomalies results in value contours and ranges that are closest to the regional component model II.

4. Conclusions
The model I lifting height which is closest to the regional component is 90 meters with the RMSE value of 0.05394% while the model II is 30 meters with RMSE 0.36724%. A large susceptibility value of 1.4 in model II produces a greater magnetic field value (-6.152 to 16.692 nT) compared to the model I whose susceptibility is only 0.1 (-0.482 to 2.554 nT).

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