Investigating Regional Variation Removal, Upward and Downward Continuation to Magnetic Survey Data

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Abstract

To understand the basic of analysing magnetic data, a code was developed in MATLAB to perform typical processing to vertical component magnetic survey data. These processes include removing the regional variation, upward and downward continuation to the magnetic data. Corresponding plots are created after each step.

Background / Theory

Magnetic survey is a geophysical method to image anomalies in the Earth's magnetic field caused by source bodies within the subsurface. This method exploits the contrasts in magnetization of subsurface rocks. The intensity of the magnetic field at the Earth's surface is a function of the location of the observation point in the primary Earth's magnetic field as well as from contributions from local or regional variations of magnetic material such as magnetite, the most common magnetic mineral (Hubbard and Linde, 2011). After correcting for the effects of the Earth's natural magnetic field, magnetic data can be presented as total intensity, relative intensity, and vertical or horizontal gradient anomaly profiles or contour maps.

Potential fields known at a set of points can be expressed at neighboring higher or lower spatial locations in a source free region using the continuation integral that results from one of Green's theorems (Blakely, 1995). The principal uses of this concept are to adjust altitude of observations to a datum as an aid to the interpretation of a survey through upward or downward continuation.

Upward continuation predicts the magnetic field at a higher elevation or surface (farther from sources) and emphasizes the longer spatial wavelengths - the shorter the wavelength, the greater the attenuation. This process tends to attenuate anomalies caused by local, near-surface sources relative to anomalies caused by deeper, more profound sources. Magnetic survey data can be transformed through upward continuation using Equation 1 where it involves double integration.

$$F_z(x',y',-h) = \frac{h}{2\pi}\int_y\int_x\left[\frac{F_z(x,y,0)}{R^3}\right]dxdy = \frac{h}{2\pi}\int_y\int_x\left[\frac{F_z(x,y,0)}{\{(x-x')^2+(y-y')^2+h^2\}^{\frac{3}{2}}}\right]dxdy \quad (1)$$

Downward continuation predicts the magnetic field at a lower elevation or surface (closer to sources) where it is useful as it tends to accentuate the details of the source distribution, especially the shallowest components. Magnetic survey data can be transformed through upward continuation using Equation 2 where it utilizes finite difference approximation.

$$\begin{aligned} F_z(x',y',+h) \approx\ & 6F_z(x',y',0) - \cdots \\ & \cdots - \{F_z(x'-h,y',0) + F_z(x'+h,y',0) + \cdots \\ & \cdots + F_z(x',y'-h,0) + F_z(x',y'+h,0) + \cdots \\ & \cdots + F_z(x',y',-h) \end{aligned} \quad (2)$$

Methods / Algorithm

A set of magnetic survey data file, **'goph_547_lab_3_data.mat'**, contains three arrays (**Fz_raw**, **X** and **Y**). The **X** and **Y** matrices contain the *x* and *y* coordinates, respectively, of each survey point in m. The **Fz_raw** contains the raw vertical magnetic survey data at each survey point in nT.

A contour plot of **Fz_raw** on the grid defined by **X** and **Y** is created using **contourf()**. Then, plots of **Fz_raw** against x and y coordinates is created. A first order polynomial is fitted using **polyfit()** to the **Fz_raw** vs **y** data of the form in Equation 3 and a corresponding line is added to the plot of **Fz_raw** vs **y** data.

$$F_z(y) = a_0 + a_1 y \tag{3}$$

The linear component of the regional variation in the *y* direction (a_1y) is removed or subtracted from **Fz_raw** and the result is saved as **Fz**. A contour plot of **Fz** on the grid defined by **X** and **Y** is created using **contourf()**. Then, plots of **Fz** against x and y coordinates is created. A first order polynomial is fitted using **polyfit()** to the **Fz** vs **x** data of the form in Equation 4 and a corresponding line is added to the plot of **Fz** vs **x** data.

$$F_z(x) = b_0 + b_1 x \tag{4}$$

The linear component of the regional variation in the *x* direction (b_1x) is removed or subtracted from **Fz** and the result is saved as **Fz**. A new contour plot of **Fz** on the grid defined by **X** and **Y** is created using **contourf()**. Then, plots of **Fz** against x and y coordinates is created.

The constant component of the regional is removed by subtracting the minimum value of **Fz** from **Fz** after completing the previous step. A new contour plot of **Fz** on the grid defined by **X** and **Y** is created using **contourf()**.

The current **Fz** is then upward continued based on Equation 1 where h = 30 m. Nested loops are utilized to perform the integration in Equation 1 and the result is saved as **Fz_u**. A contour plot of **Fz_u** on the grid defined by **X** and **Y** is created using **contourf()**.

Finally, **Fz** is downward continued based on Equation 2 where h = 30 m. Nested loops are utilized to perform the finite difference approximation in Equation 2 and the result is saved as **Fz_d**. A contour plot of **Fz_d** on the grid defined by **X** and **Y** is created using **contourf()**.

Results and Discussion

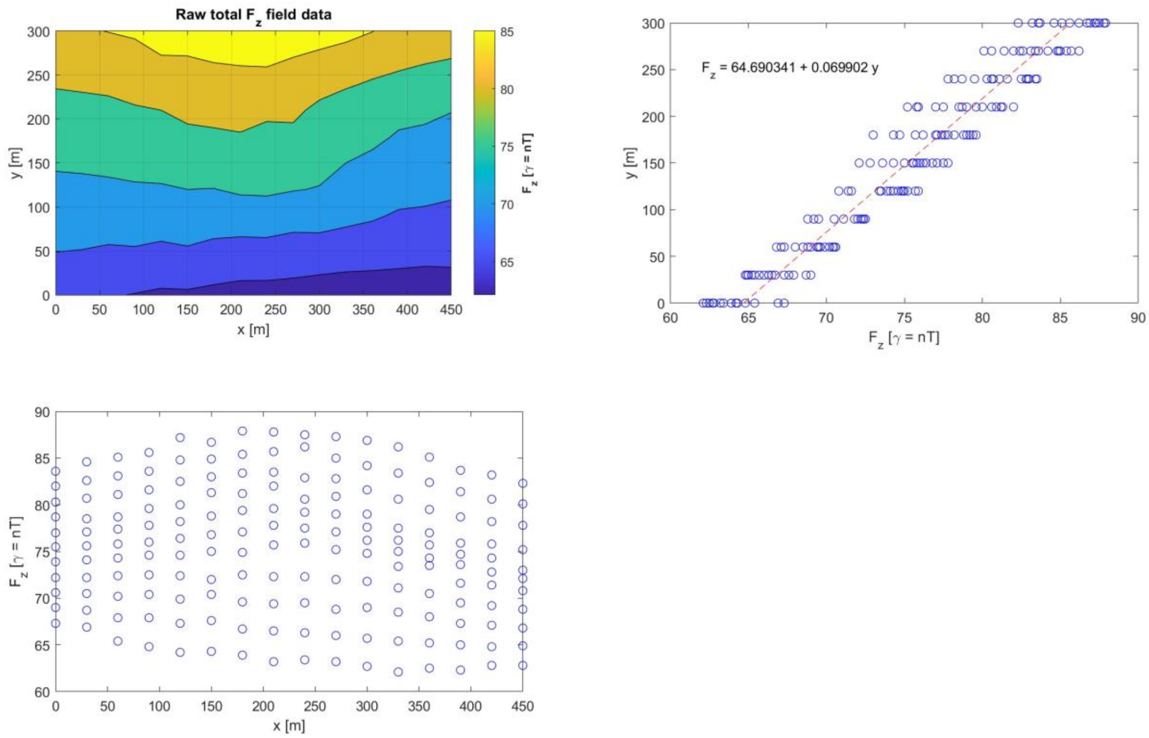

Figure 1 Contour plots of the raw magnetic data and the plots of raw magnetic data against *x* and *y* coordinates. A best fit line is drawn on the plot of the data against y coordinate.

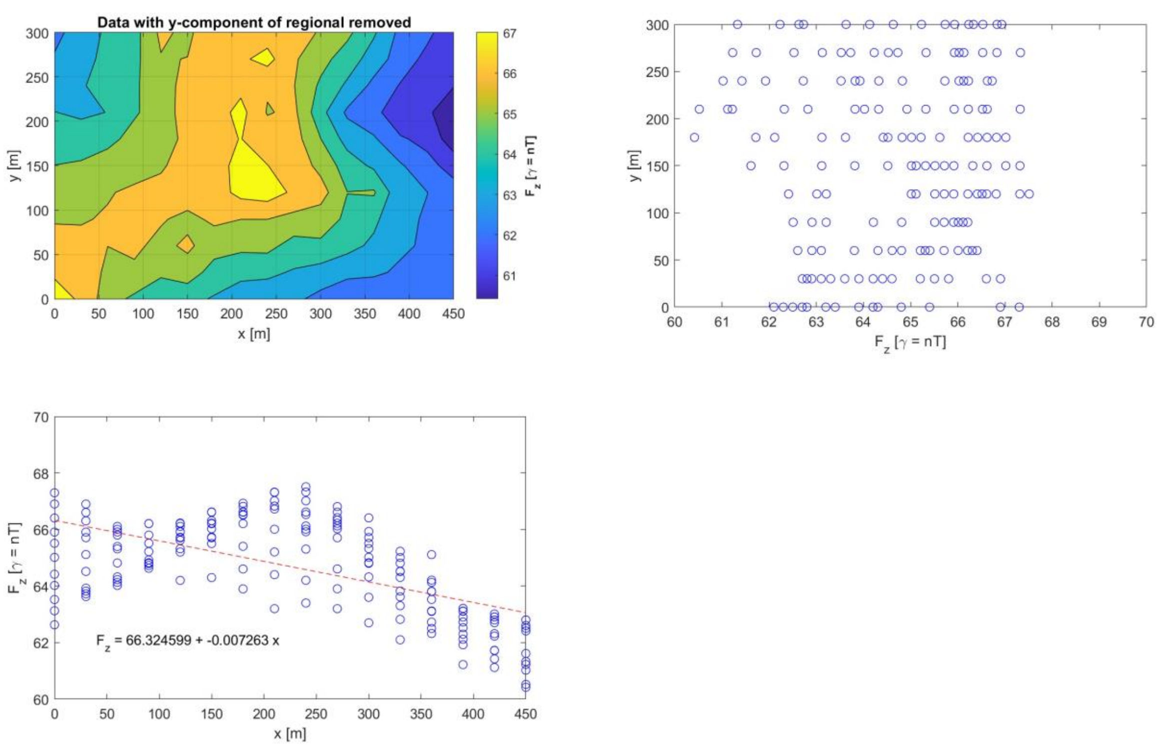

Figure 2 Contour plots of the magnetic data after removal of regional variation of *y* component and the plots of data against *x* and *y* coordinates. A best fit line is drawn on the plot of the data against *x* coordinate.

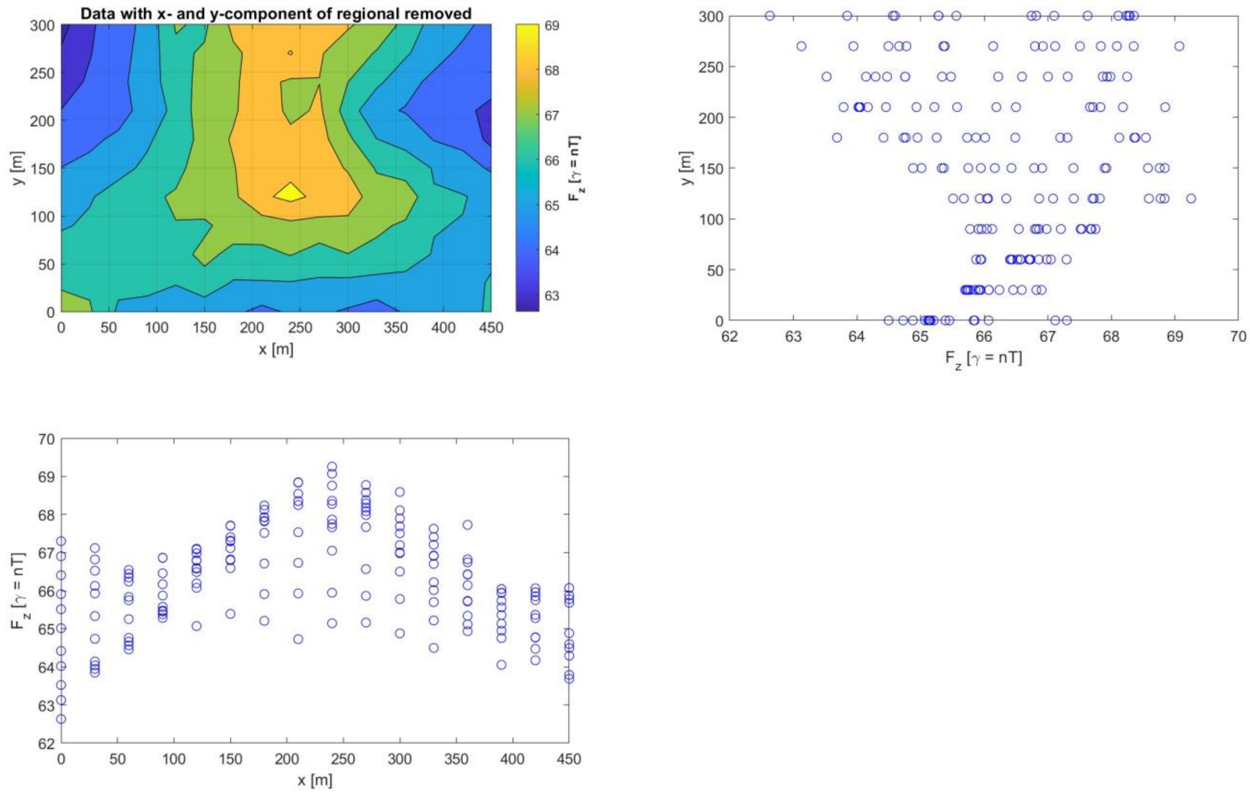

Figure 3 Contour plots of the magnetic data after removal of regional variation of *x* and *y* component and the plots of data against *x* and *y* coordinates.

From Figure 1, the raw magnetic data does not vary too much in the *x* direction while in the *y* direction, there are a lot of magnetic values variation. After removing the linear component of the regional variation in the *y* direction from the data, the variation in *y* direction cannot be seen anymore based on Figure 2. However, now the variation now can be observed in the *x* direction. Figure 3 shows the data after the removal of both regional variation in the *x* and *y* direction. Now, the regional variation in both directions has been accounted for and the regional variation is not as pronounced as in Figure 1 and 2.

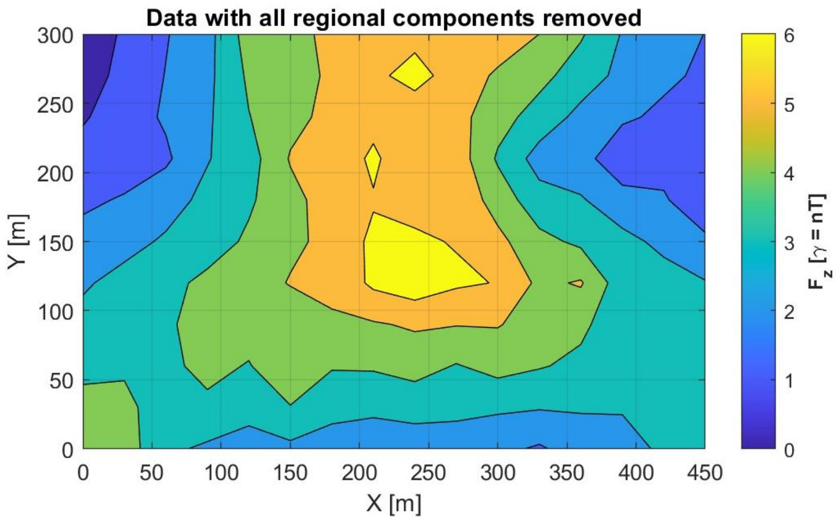

Figure 4 Contour plots of the magnetic data after removal of all regional variation components.

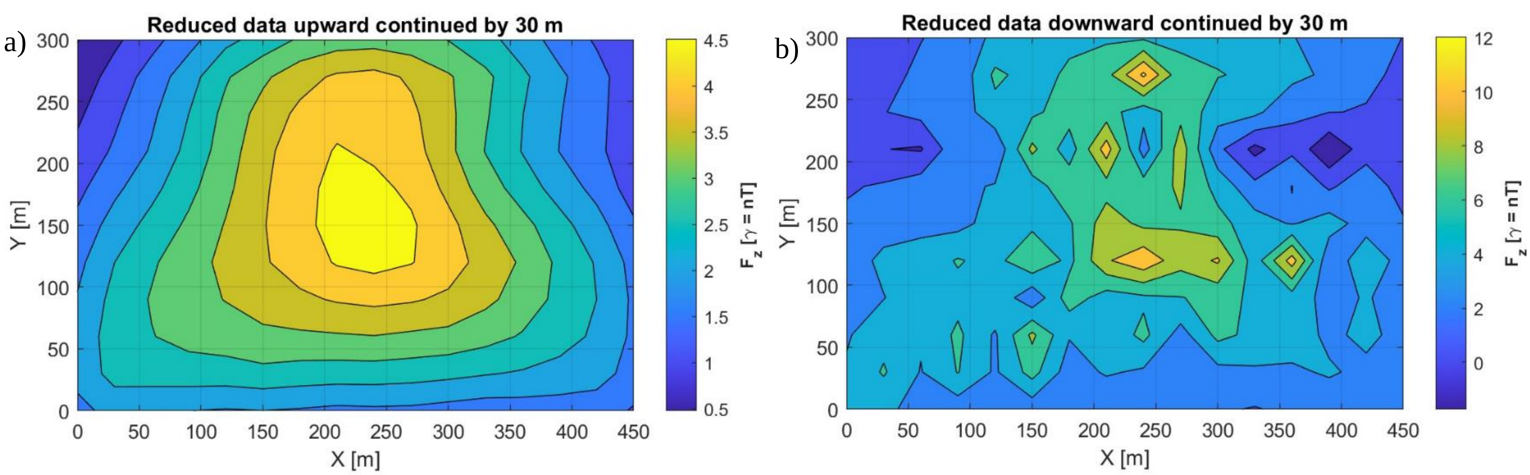

Figure 5 Contour plots of the magnetic data after a) upward continuation and b) downward continuation.

Figure 4 shows the contour plot of the magnetic data after removing all components of regional variation. The anomalous body (area of highest magnetic value) is more pronounced in Figure 4 compared to Figure 1 where any regional variation correction has not been applied. The scale of the contour plot has a maximum of 6 nT.

After applying upward continuation, the contour plot (Figure 5a) becomes smoother than Figure 4 where the transitions between contour area are more well-defined since this process removes the noise from the data. Essentially, this process is 'zooming out' into the area. From the figure, the area of anomaly is bigger (yellow area). Since upward continuation is attenuating the anomalies closer to the surface, this anomaly can be said caused by a deeper source in the subsurface. The scale of the contour plot also reduces in intensity (with maximum of 4.5 nT) showing that we are 'further' from the anomalies.

After applying downward continuation, the contour plot (Figure 5b) becomes rougher than Figure 4 as this process amplify the noise in the data. Based on the figure, there are only few small areas that has a magnetic value higher than 8 nT. Essentially, this process is 'zooming in' into the area, which might help pinpoint the locations where the anomaly signature is coming from, instead of just being seen as a large body in Figure 5a. The scale of the contour plot also increases in intensity (with maximum of 12 nT) showing that we are ‘closer’ to the anomalies. Downward continuation illustrates that, rather than just one large anomalous body, there may possibly be smaller separate bodies in the subsurface, which again aids our interpretation of the data.

Conclusion

Magnetic surveys are incomplete without performing corrections as it will make interpretation of the data difficult. The raw magnetic data cannot tell the complete information about the subsurface. The results of the investigation define the importance of correction to the data. Regional variation removal from the data enhances the data by showing the area of high magnetic intensity which is the magnetic anomaly. Upward continuation zoomed out of the survey area, which highlighted a big area of the anomaly while removing the noise in the data. Downward continuation zoomed in the survey area, which highlighted a few small areas of the anomalies while increasing the noise in the data.

References

Blakely, R. J., 1996. Potential Theory in Gravity and Magnetic Applications. Cambridge: Cambridge University Press.

Hubbard, S. S., and Linde, N., 2011. 2.15 - Hydrogeophysics, Treatise on Water Science, Elsevier.