Upward and Downward Continuation of Magnetic Field Data

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Abstract

Magnetic field data can be used to locate anomalies with large economic benefits. Raw magnetic data often comes with regional effects that must be corrected for before more accurate geophysical interpretations can be made. Matlab is used as a processing tool to eliminate the constant regional effects in the X and Y directions of vertical component of magnetic field data obtained in a 450m by 430m region. Then the constant residual effect is removed. This data is then upward continued to obtain a smooth and stable 2-D contour plot to interpret an anomaly with a magnitude of 5.5nT centered at (240, 120). Downward continued data provided sharp and unstable imaging and isn't a good processing tool for the interpretation of the obtained field data.

Introduction

Raw magnetic data obtained from field measurements often contains noise that must be removed for accurate interpretations. Matlab is the primary tool used to perform processing in this investigation. The residual gravity of the region is first removed and then the data is upward and downward continued. Magnetic processing is done on the vertical component of magnetic data obtained in 30 meter increments over a 450m easting by 300m northing region. Removal of the regional variations provided a better image of the region than the raw data. Upward continuation improved imaging while downward continuation provided an incoherent image.

Theory

The vertical component of the magnetic field of a region (Fz) can be estimated using the vertical gradient of gravitation ($\frac{\partial g_z}{\partial z}$) obtained in the same region. In (1) μ_0 is the magnetic permeability (4π*10^-7 N*A^-2), G is the gravitational constant (6.674*10^-11 N*m^2*Kg^-2), M is magnetic moment density, and ϱ is the material density.

$$F_z = \mu_0 \left(\frac{M}{G\rho}\right) \frac{\partial g_z}{\partial z} \ (1)$$

A first order polynomial to the Fz vs i where i is the distance in the ith direction of the data is of the form (2) and gives the linear variation in the ith direction where a_0 is the intercept of Fz vs i plot and a_1 is the slope.

$$Fz = a_0 + a_1 i \ (2)$$

The linear component of the regional variation in the ith direction can be removed from data using (3).

$$Fz = Fz - a_1 i \ (3)$$

Field data can be upward continued using (4) where x',y' and h are the x and y coordinates of the upward continued data, and the height upward continued by respectively.

$$Fz(x', y', -h) = \frac{h}{2\pi} \iint \left[\frac{Fz(x,y,0)}{[(x-x')^2+(y-y')^2+h^2]^{3/2}}\right] dxdy \ (4)$$

Field data can then be downward continued by applying a finite difference approximation (5).

$$Fz(x',y',+h) \approx 6Fz(x',y',0) - [Fz(x'-h,y',0) + Fz(x'+h,y',0) + Fz(x',y'-h,0) + Fz(x',y'+h,0) + Fz(x',y',-h)]\ (5)$$

Procedure

Matlab is used to upload the raw data "goph_547_w2016_lab4_data.mat" which contains the vertical magnetic field (Fz_raw), the y-coordinate lay out (Y), and the x-coordinate lay out (X). 2-D contour plots of raw data are generated by using the contourf() function with X,Y and Fz_raw as inputs respectively. A color bar is added the figures by setting the variable h_c to colorbar. Then a ylabel is created with colorbar as one of the inputs. Fz versus X and Fz versus Y plots are created by simply using the plot() function and using X or Y as the x-input, and Fz_raw as the y-input.

A first order polynomial is added to the Fz versus X or Y plots by first finding the coefficients of the of the linear trendline of the data by using the function polyfit(). The inputs are Y, Fz_raw, and 1 respectively to find the linear trend line for Y. The coefficients are output to a variable Py which is used as the first input in the function polyval(). Y is used as the second input to get an output in the variable PyVal. Polyval evaluates the values at a given input (Y) using the coefficients saved in Py. This trend line is superimposed onto the Fz versus Y plot by simply using "hold on" and then using the plot() function with Y and PyVal as its respective inputs. The linear component of Y is then removed by using a double nested loop where the outer loop loops i from 1 to 11 and the inner loop loops j from 1 to 16. The loop functions by updating Fz_raw(i,j) at to Fz_raw at the current point (i,j) subtracted from the slope -calculated in Py multiplied by Y(i,j) as in (3). A 2-D contour plot, Fz vs Y, and Fz vs X are then obtained similarly to the first set of plots obtained. This is then repeated in a similar fashion to remove the linear regional variations in X. Finally, the constant component of the regional is find by setting the variable ConstantVal equal to min(min(Fz_raw)). A double nested loop is then used again where the outer loop starts from 1 to 11, and the inner loop starts from 1 to 16. Fz_raw at the ith,jth coordinate in the inner loop is then updated to Fz_raw(i,j) minus ConstantVal. A 2-D contour plot is obtained similarly to the way it was obtained in the first set of plots.

The magnetics data corrected for residuals is then upward continued using (4). First the variable xmin and xmax corresponding to minimum (0) and the maximum x coordinates (450) is initialized. Then ymin and ymax are initialized. Then an 11X16 matrix of zeros is initialized using the function zeros() with 11 and 16 as its inputs. The zeros matrix is output to the variable Fz_upward_continued. A double nested loop with the outer loop "i" looping from 1 to 11 and inner loop "j" looping from j=1 to j=16 is then made. Next a function fun is created which is a function of x and y (coordinates of data at datum) and evaluates the result of the variables in (4). The upward continuation is finally computed by using the matlab function integral2() using fun, xmin, xmax, ymin, and ymax as its respective inputs in the inner loop. The result of this integral is used to update the initialized matrix Fz_upward_continued at every i and j position. A plot of

the upward continued data is then obtained by using the contour() function with X, Y and Fz_upward_continued as its inputs resepectively.

A downward continuation is evaluated using (5). First a matrix Fz_downward_continued is to be initialized using the zeros() function with 11 and 16 as its respective inputs. A double nested loop with the outer loop "i" looping from i=2 to 10 and inner loop "j" looping from j=2 to j=15 is made. This is to avoid an error for going out of index. In the inner loop Fz_downward_continued is updated using the function in (5). In this scheme however, h corresponds to 1 since h=30 and when the loop increments by 1, the value of the X and Y coordinates also increment by a value of 1. Additionally, if change by h is desired in the x' direction, a change by 1 would be applied to the jth index since j corresponds to the x' direction.

Results and Discussions
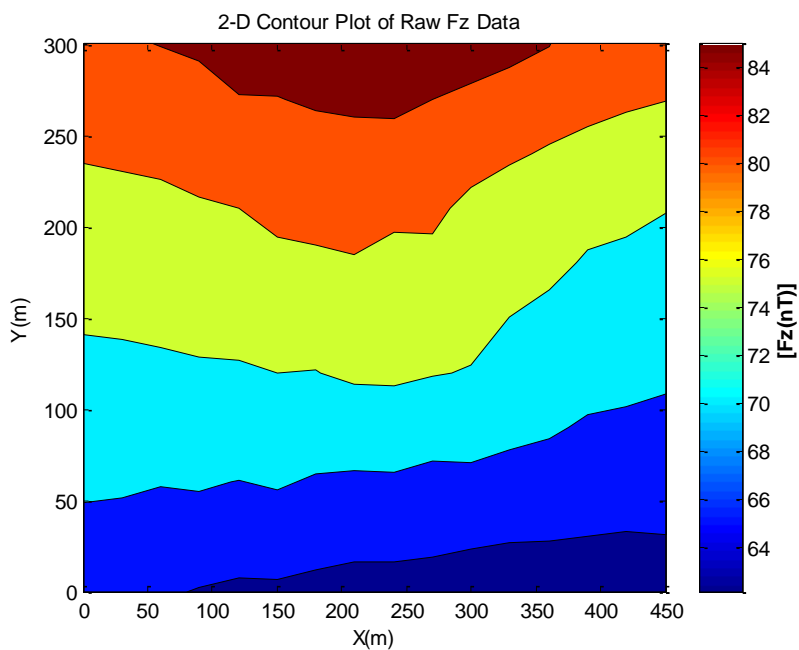
Figure 1: A 2-D contour plot of data obtained showing the vertical Magnetic variations in the region

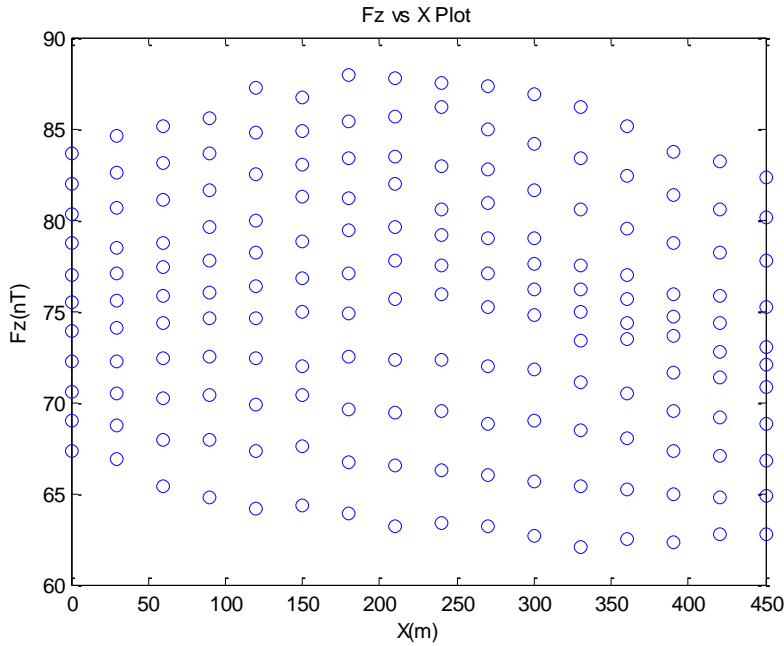*Figure 2: A plot of Fz vs X showing how Fz varies in the X direction. Multiple Fz is computed for the same location*
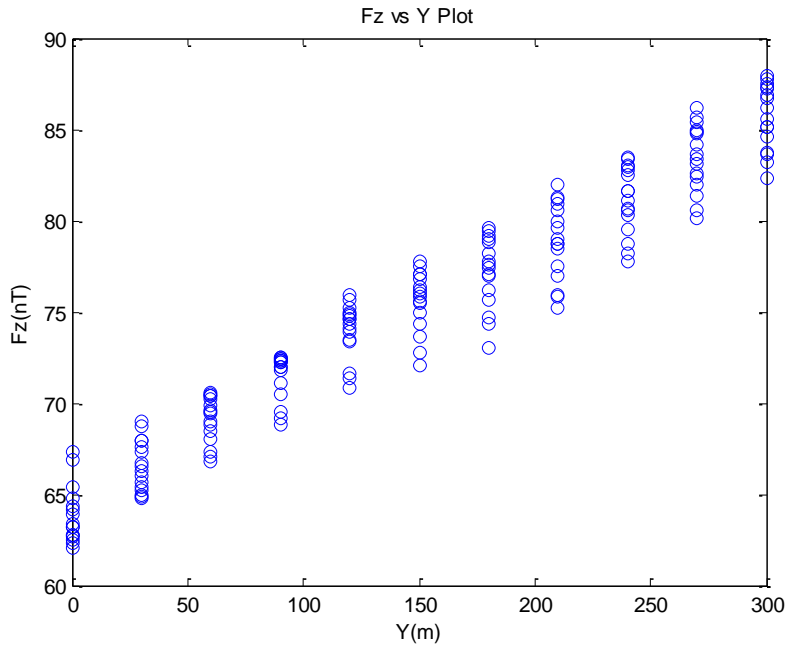

Figure 3: A plot illustrating the Fz changes in the Y direction

Figures 1 shows the 2-D contour plot of the raw vertical component of the magnetic field of the region. The magnetic field strength ranges from 60nT to 86nT. The map shows largely a linear variation in the Y direction. This is supported by Figure 3 where the field variation in the Y

direction is very linear. Figure 2 shows the variations in the X direction isn't linear. This sinusoidal variation in the X direction is also shown in Figure 1.
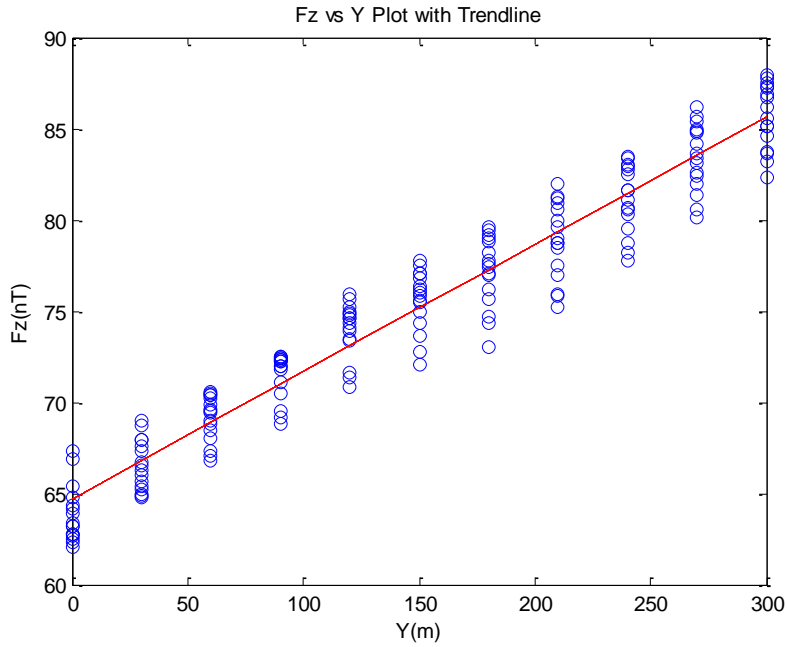

Figure 4: A plot illustrating Fz with a linear trend line showing the linear variations in the region.
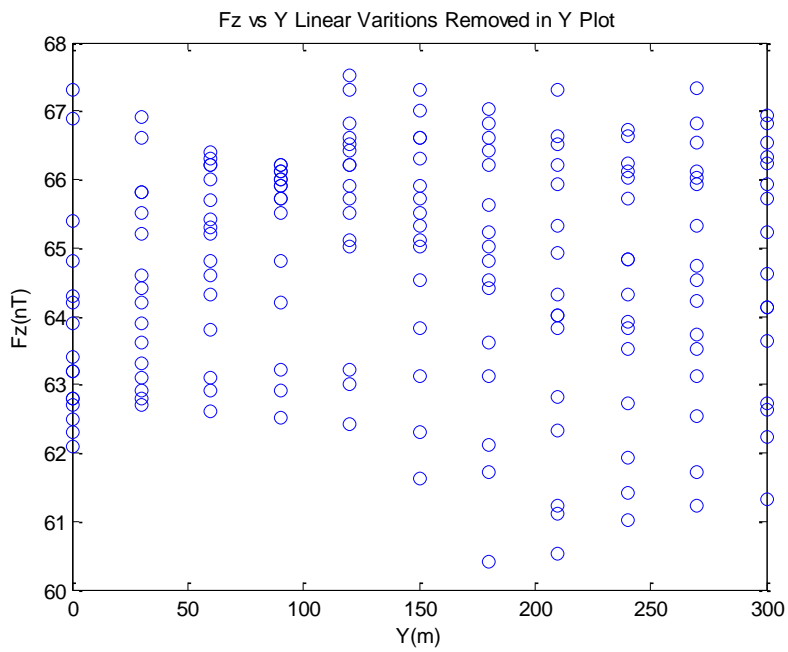

Figure 5: A plot showing the variations in Fz in the Y direction after the linear regional effects have been removed.

Figure 4 shows a plot of Fz versus Y with its trend line superimposed onto the figure. It is evident from the plot that there is a large linear variation as the trend line matches the shape of the overall trend of data well. Figure 5 illustrates the regional magnetic strength after the linear component shown in the trend line in Figure 4 has been removed. Figure 5 has a smaller magnetic field range (60.5nT-67.5nT) in comparison to when the linear regional effects have not been removed in figure 4 (63nT- 88nT). Additionally, the general trend in Figure 5 is much less linear now that the constant regional effect has been corrected for.
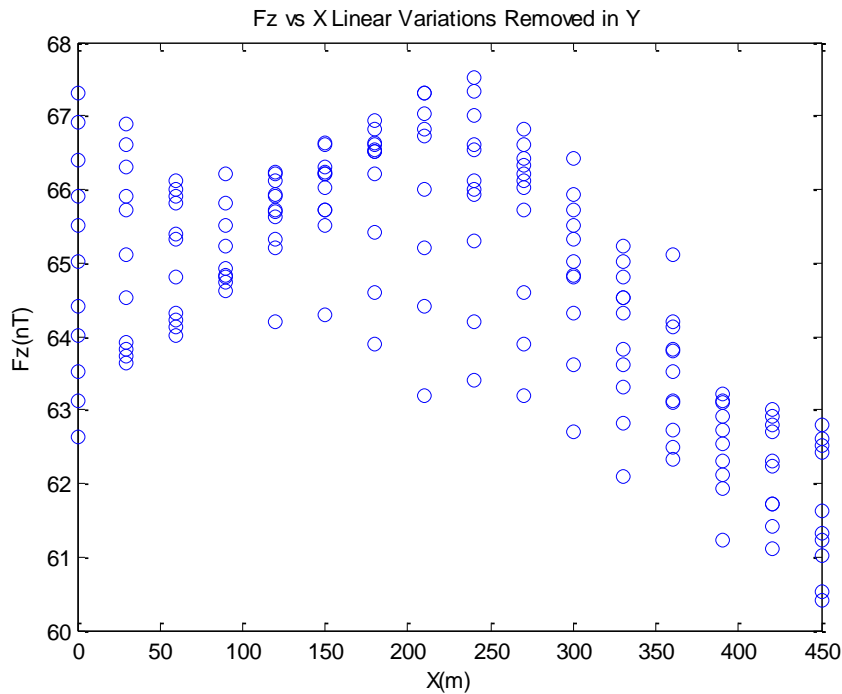

Figure 6: A contour plot showing a regional Fz variation in the X direction after Y linear variations have been removed.

Figure 6 shows the Fz versus X after the linear regional effects in the Y direction have been corrected. It is evident from this plot that correcting for constant regional effect in one direction also affects the magnetic readings in the Y direction. A contrast of Figure 2 and Figure 6 shows this. Additionally, the maximum Fz in the X plot is also much smaller in Figure 6 than in Figure 2. This makes the general trend in the X direction easier to read in Figure 6.
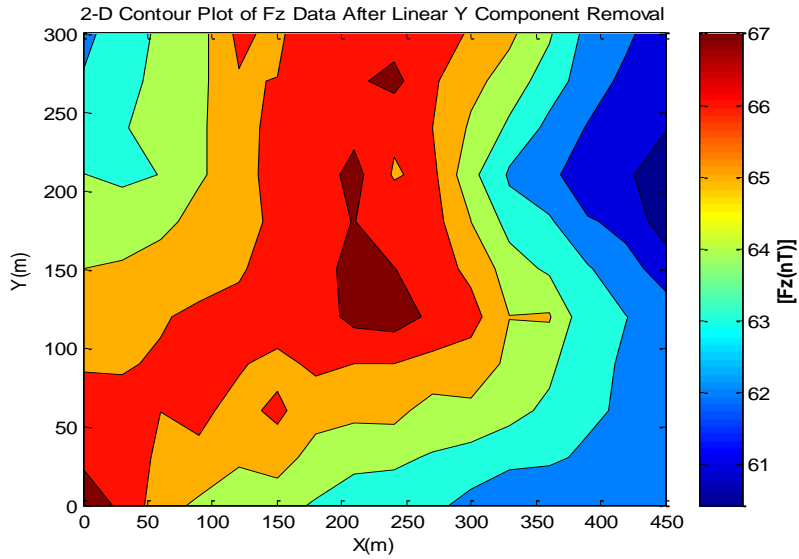
2-D Contour Plot of Fz Data After Linear Y Component Removal

Figure 7: A contour plot showing Fz in the region after the linear Y variations of Fz have been removed. An anomaly is now interpretable.

Figure 7 illustrates a 2-D contour plot of Fz data with linear regional effects in the Y direction removed. This figure is no longer linear like the raw data plot in Figure 1. A high magnetic anomaly of 67nT can now be seen in the middle of the surveyed region at coordinates (225, 140).
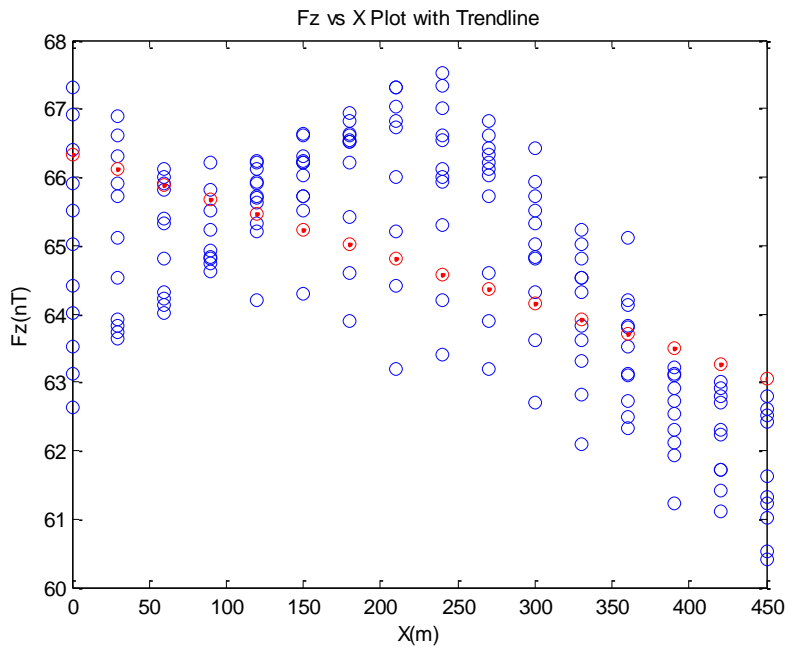

Fz vs X Plot with Trendline

Figure 8: A plot illustrating the regional variation of Fz in the X direction with a trend line after the Y-linear effects are removed.
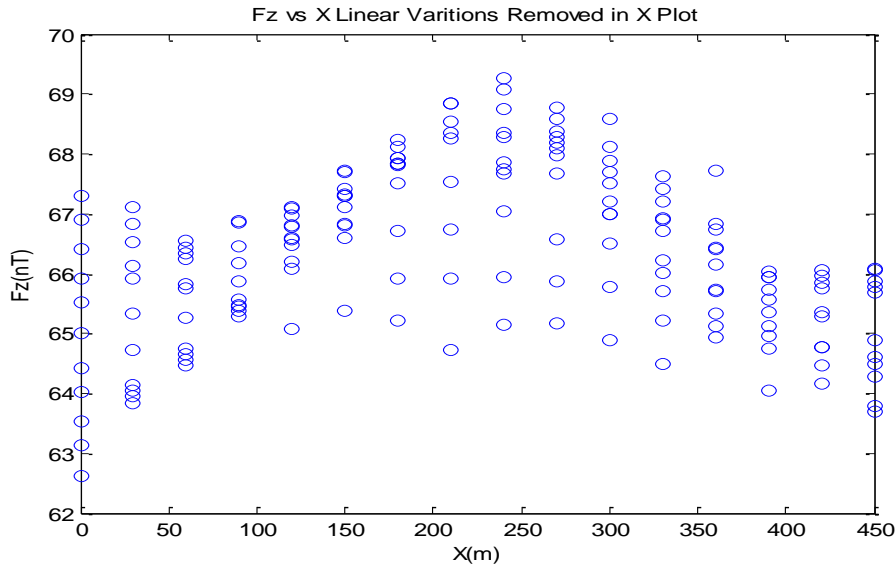
Figure 9: This figure shows the Fz variation in the x direction after the linear regional effects in the x and y directions are removed.

Figure 8 is a plot of Fz versus X with a linear trend line superimposed. The removal of the linear regional effects in this direction is expected to have less of an impact on the 2-D contour plot because the magnetic variation in the X direction isn't as linear compared to the variations in the Y direction. Figure 9 is a plot of magnetic field data in the X direction after corrections have been made by removing linear regional effects in the X direction. This plot still has the same general shape as the Y removed Fz vs X plot (Figure 7). However, the data plot seems more coherent and has a more sinusoidal shape.
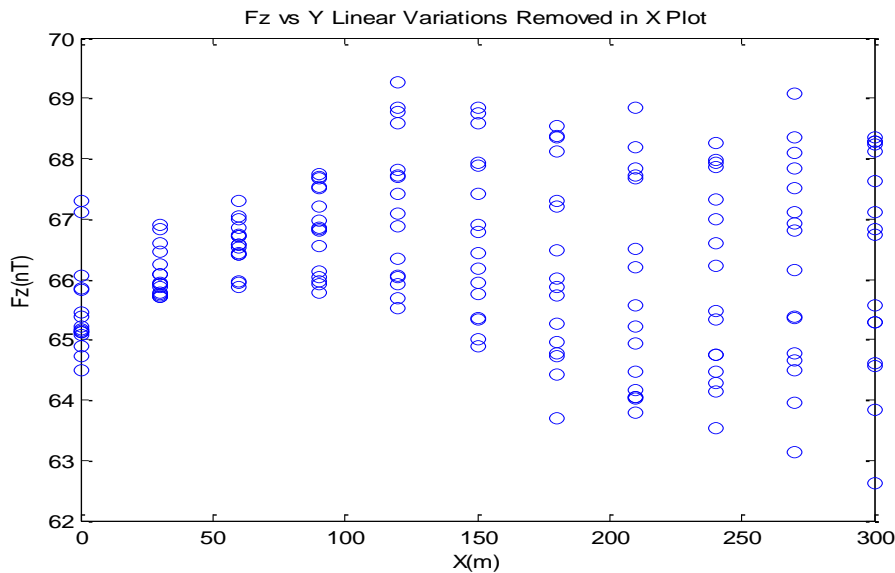

Figure 10: This figure illustrates the magnetic variation in the Y direction after the linear effects in the x and y direction are removed.

Figure 10 shows the magnetic trends in the region after constant linear effects have been removed in the X and Y direction. In this figure, the magnetic trend is no longer linear and therefore it expected that the 2-D plot is largely contributed by anomalies in the surveyed region.
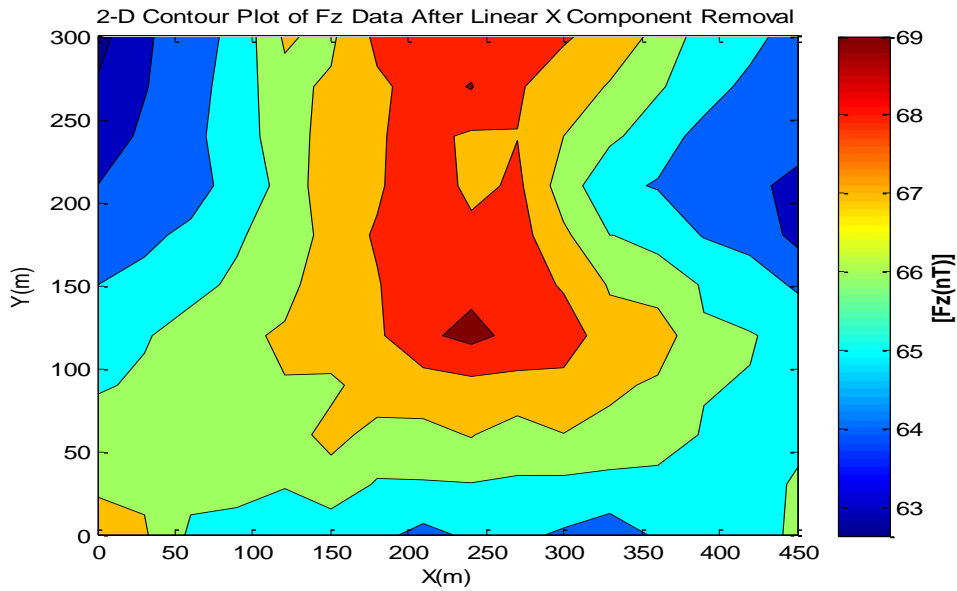

Figure 11: A 2-D contour plot of the regional vertical magnetic field component after the linear variations in the x and y directions are removed.

Figure 11 is a 2-D contour plot showing the variation of magnetic data in the region. The anomaly initially found in Figure 7 is still present at the same location. However, it is now centered into a smaller region and its magnitude is greater (69nT). Additionally, it is now easier to see that the anomalies are more linear in the Y direction in comparison to the X direction.
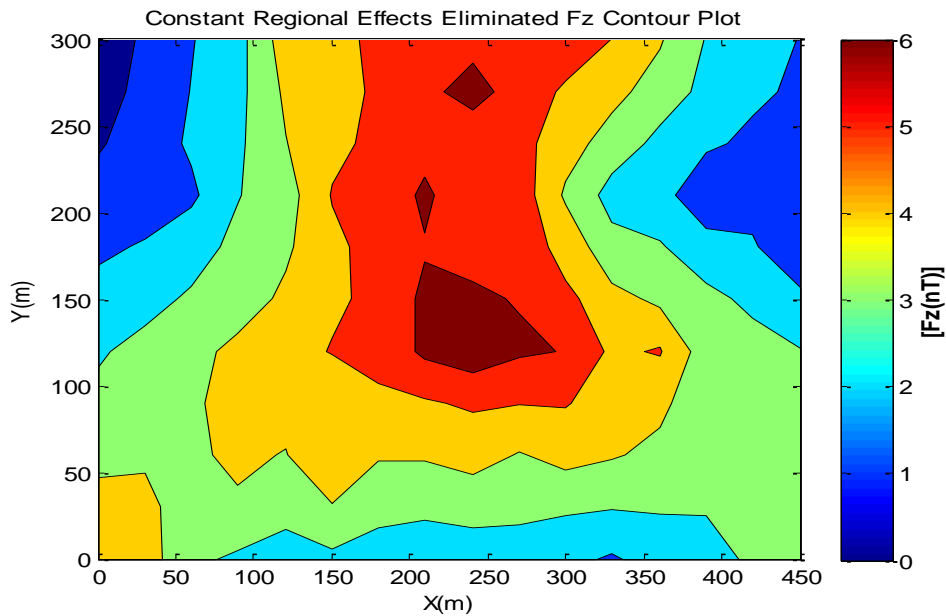

Figure 12: A contour plot of Fz after the constant regional effects have been removed.

Figure 12 is a 2-D contour plot of the vertical magnetic field strength after the linear residual effects in the X and Y directions have been removed with the constant component of the regional. An assumption was made that the constant component of the regional is simply the lowest magnetic point in the region. In This figure, an irregular circular anomaly with a magnitude of 6nT is found at (240, 130). Closer to the anomaly, the magnetic strength decays linearly in the Y direction.
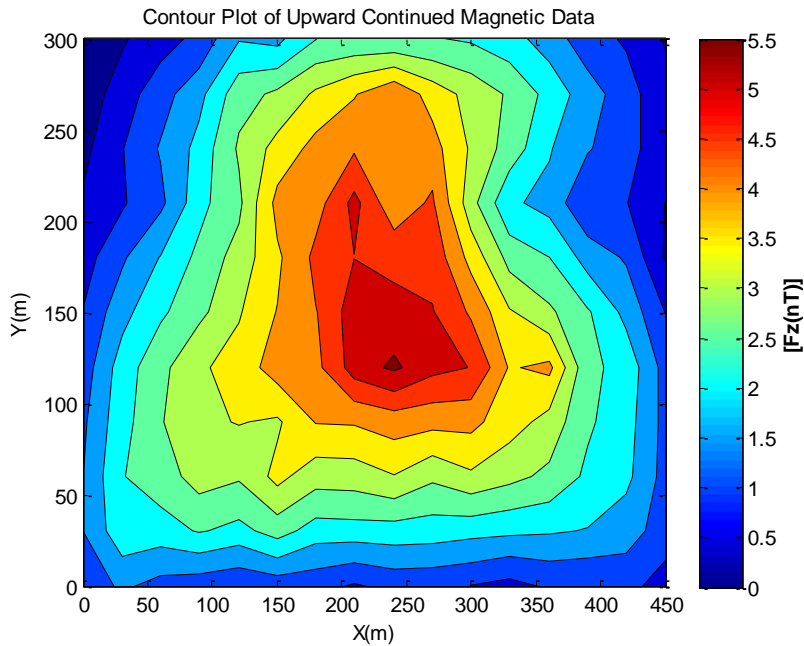

Figure 13: A 2-D contour plot of upward continued Fz by 30m. Prior to the continuation, the constant residual effects of the region have been corrected for.

Figure 13 is a 2-D contour plot of the upward continued magnetic data by 30m. This plot contains an anomaly centered at (240, 120) with a magnitude of 5.5nT. In contrast to Figure 12, the upward continued data is much smoother and is more stable (Roy et. al). Additionally, more contours are available to better illustrate the variation in Fz in the region. The general shape of the upward continued data is similar to the general trends seen in the constant residual effects removed contour plot. There is one area with a peak magnetic field strength in comparison to the three coordinates with peak magnetic field strengths in the previous 2-D contour plot.
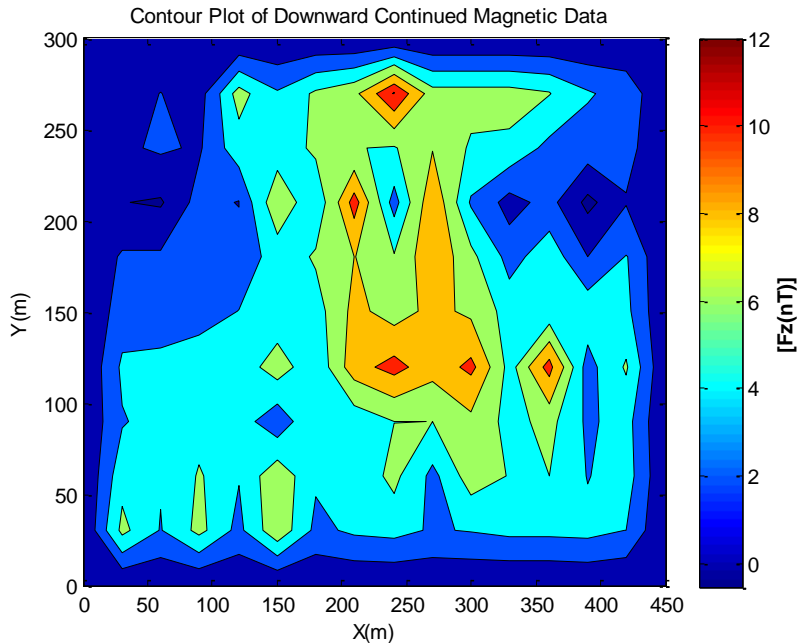
Figure 14: A downward continued 2-D contour plot of Fz by 30m after the constant residual effects have been removed.

Figure 14 is a 2-D contour plot of the downward continued magnetic data by 30m. The downward continued data has a much larger range (0-12nT) than the residual effects removed data (0-6nT). In comparison to the previous two plots, Figure 14 is much sharper and unstable and appears to be noisy. This is a property of downward continued data (Roy et. al). The large magnetic anomaly can still be seen in the same general coordinate, however it is centered in an ever smaller region. Additionally, there are more than one region with peak magnetic field strength in the downward continued data.

Conclusion

Raw magnetic field data contains effects not associated with the anomalies of interest in the region. Matlab is a powerful processing tool to obtain interpretable geophysical data. Linear removal of the regional variation and removal of constant effects allows us to obtain interpretable data. Upward continuation using the integral method provided a more stable and smooth contour plot illustrating an anomaly of 5.5nT centered at (240,120). Downward continuation using a finite approximation scheme provided sharpened data that isn't interpretable.

References

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