Dana Gallegos
Garrett Sickles
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Lab 02: Forward Modeling

Introduction

Gravity surveys offer valuable insight into the subsurface geology beneath our feet. Gravity response is directly related to the contrast of densities below the surface; therefore, it is possible to find distinctions between different mass bodies and densities. Without gravimetry, scientists would otherwise have to rely on geological insight to make similar conclusions. The main purpose of this lab was to become familiarized with scripting and forward modeling in Matlab and the different 2D gravity anomalies present with contrasting densities and shapes.

Objectives

- Become familiarized with Matlab and scripting, including the process of writing text input files with different data points.
- Master analytical conclusions concerning the gravitational response to contrasting densities and geometric shapes.
- Observe the anomaly change due to the superposition of two density bodies.
- Construct a gravity survey grid over the tunnel beneath Kafadar at the Colorado School of Mines.

Procedure

1. The first step in this lab was to upload the given files given in the lab into the program Matlab. These files included:

- poly.m → Program to compute the gravitational anomaly due to the polygonal cross-section bodies given in x,z coordinates.
- slab.inp → Input file containing a horizontal slab coordinates and density.
- dyke_v.inp → Input file containing a vertical dyke.
- dyk_r.inp → Input file containing a right dipping dyke.
- dyke_l.inp → Input file containing a left dipping dyke.
- twob.inp → Input file containing two vertical offset bodies.

2. Once the workspace and input files were uploaded, we were then able to run the code by right-click RUN and then choosing one of the input files provided. Due to the given written code, two graphs would then appear containing the coordinates in meters of the 2D feature and its gravitational response.

3. Each input file was then inspected using the RUN option. Results were saved and used for later examination.

4. In addition to the input files given, were also made up three more models containing the following details:

- A single body with more than four vertices in its polygonal cross-section.
- Two laterally-offset bodies with opposite density contrasts.
- A representation of a utility tunnel just beneath the surface, with a depth to the top of the tunnel of 0.25 m, height of 2 m, and a width of 1.35 m.

Data Processing & Results

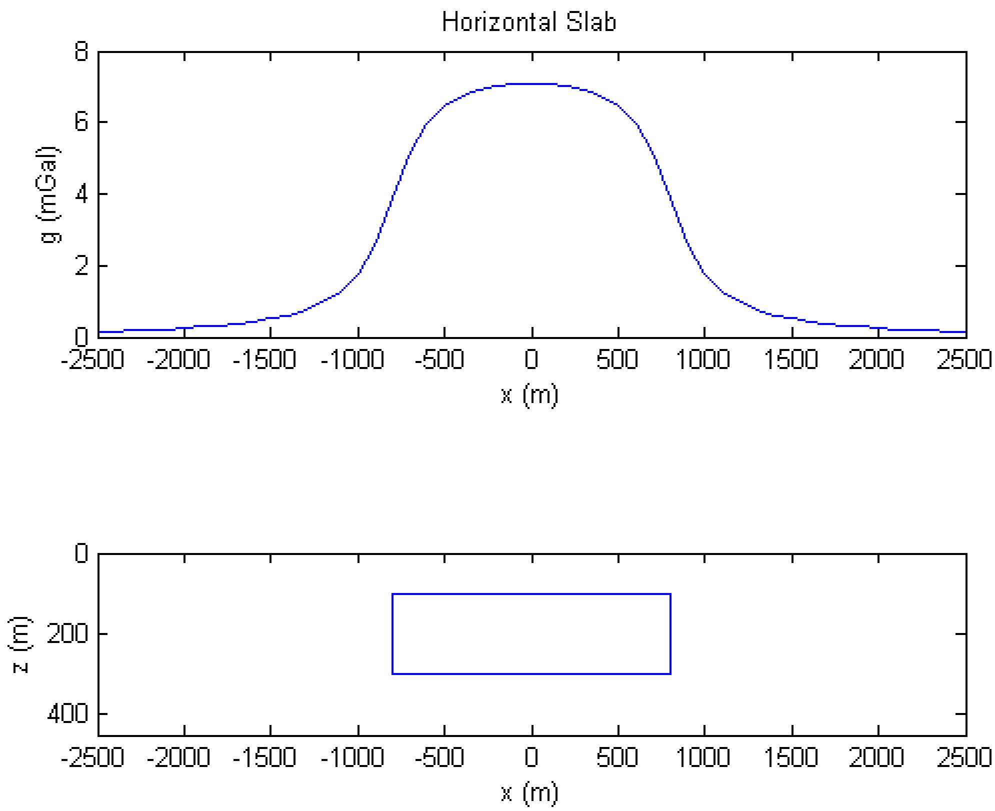

Figure 1: Horizontal Slab

Figure 1 represents a symmetric positive density distribution 1600 m wide and 200 m tall. The gravity response graph confirms this body's symmetry because it is also symmetrical about the same vertical axis. This gravity response graph was calculated on 100 m intervals totaling 50 measurements. 50 measurements still produced an accurate graph compared to smaller intervals and is a feasible amount of measurements for a gravity survey in the field.

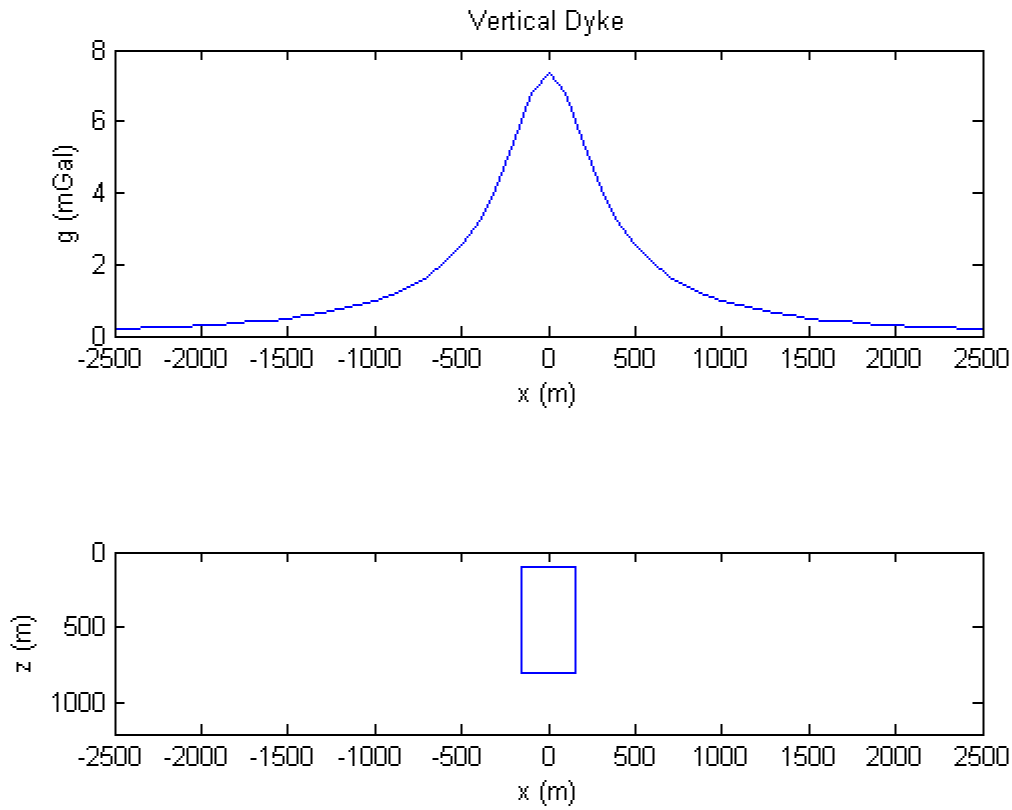

Figure 2: Vertical Dyke

Figure two represents the density distribution and gravity response for a vertical dyke. This body is 700 m tall and 300 m wide. The shape of the gravity response curve is very steep and compact representing the relatively high density from -150 m to 150 m and indicative of a distribution that is much taller than it is wide. The gravity response graph was computed on 100 m intervals totaling 50 measurements which provides an accurate graph compared to higher frequency intervals and is a feasible amount of measurements for a gravity survey in the field.

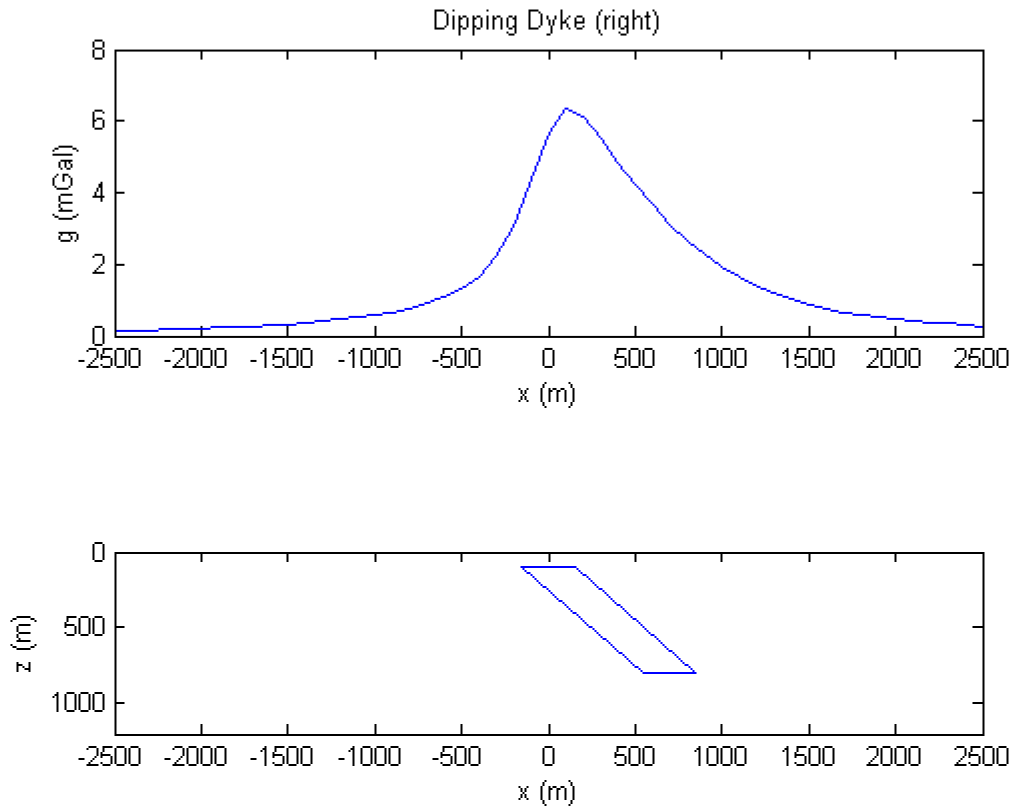

Figure 3: Right-Dipping Dyke

Figure two represents the density distribution and gravity response for a right dipping dyke. This body begins 100 m below the surface and ends 800 m below the surface. It is 200 m wide and shifts 700 m from left to right linearly as it gets deeper. The gravity response graph for the right-dipping dyke is relatively steep as the x position approaches the upper-left corner of the dyke. The gravity response reaches its maximum as the x value reaches the upper-right corner of the dyke. As the x value continues to increase the gravity response graph declines slowly compared to the approach from the left. This makes sense because as we continue to the left of the dyke there is still a significant amount of mass distributed below the surface that increase in distance as you continue left. After the x value is past the bottom-right corner of the dyke the gravity response asymptotically approaches 0 as is expected.

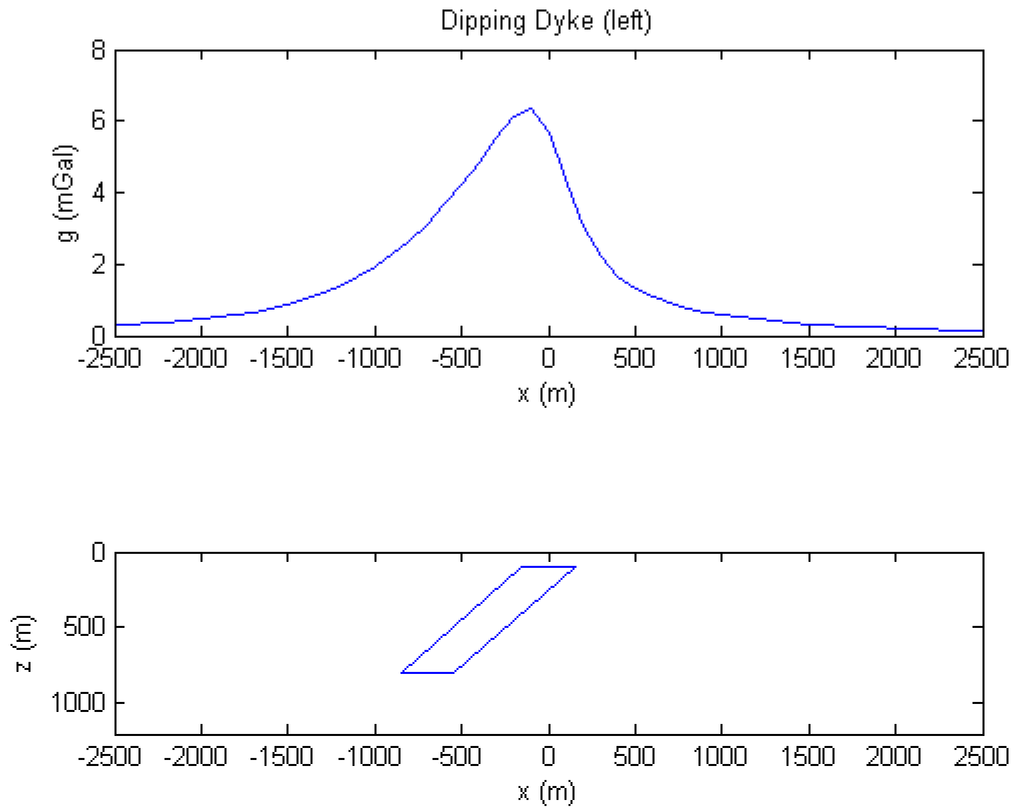

Figure 4: Left-Dipping Dyke

Figure 4 represents the density distribution and gravity response for a left dipping dyke. This body begins 100 m below the surface and ends 800 m below the surface. It is 200 m wide and shifts 700 m from right to left linearly as it gets deeper. The gravity response graph for this left-dipping dyke is relatively steep as x approaches zero near the upper right corner of this dyke.

As the value of x continues to decrease and the dyke dips deeper under the surface, the value of the gravity response declines more slowly compared to the approach from the right of the dyke. This is logical because the mass distribution is gradually increasing in distance from the observation point. as the x value continues to negative infinity the graph will more closely resemble that of a point mass.

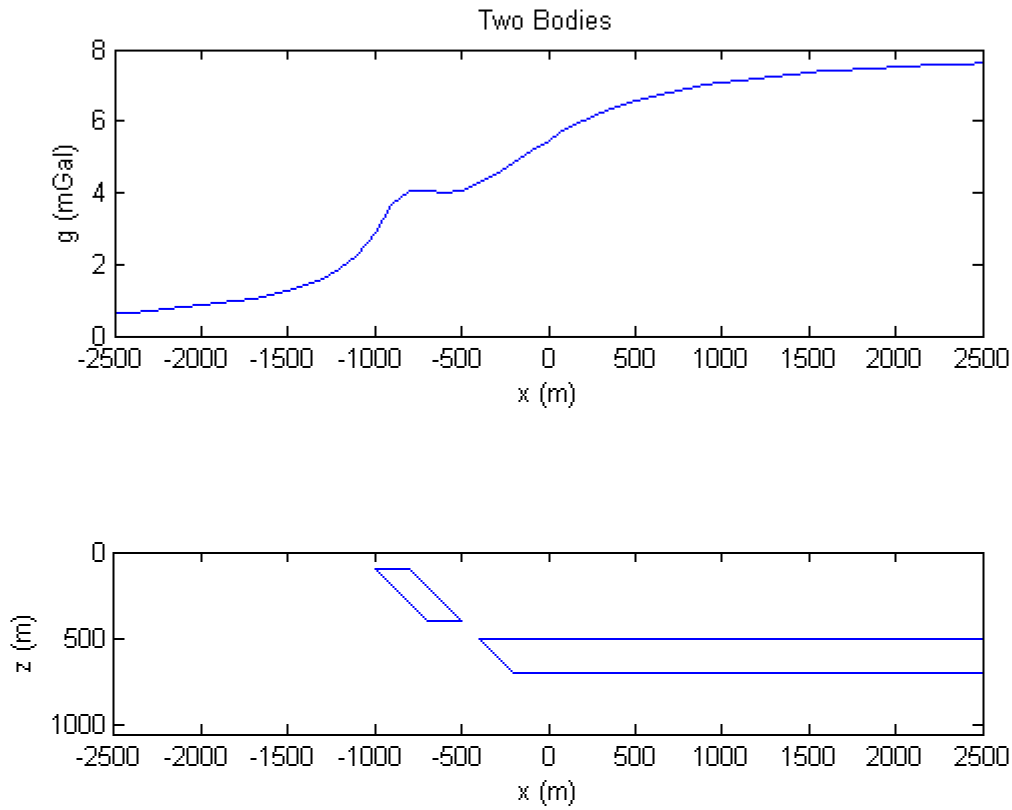

Figure 5

Figure 5 represents the density distribution and gravity response for two separate bodies. The first body is a right dipping dyke beginning 100 m below the surface and ending 400 m below the surface. The second body appears to dip in the same direction but extends almost 3000 m to the right staying within the same vertical bounds. The gravity response graph for these two bodies is similar to the right dipping dyke's graph as x approaches 0 from the left. Once the value of x peaks due to the right dipping dyke the gravity response begins to decline but quickly begins increasing due to extended density distribution from -250 m to 3000 m. As the value of x continues to increase, the gravity response asymptotically increases towards approximately 8.

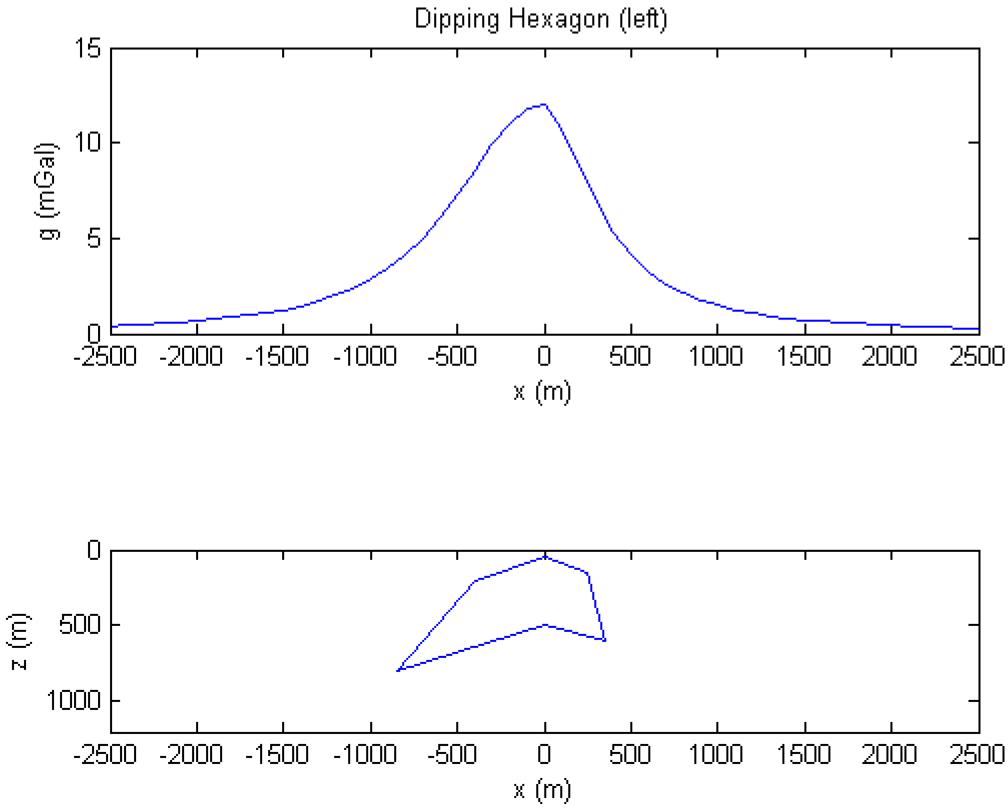

Figure 6

Figure 6 represents the density distribution and gravity response for a concave left-dipping hexagon with a density contrast of +2.5 g/cc. This distribution is the combination of two convex shapes sharing an edge at x = 0 m. As the value of x approaches zero from the left the gravity response increases relatively slowly, similar to the gravity response graph of the left-dipping dyke. The gravity response graph reaches its maximum at x = 0 m and then begin a relatively rapid decline similar to the left-dipping dyke.

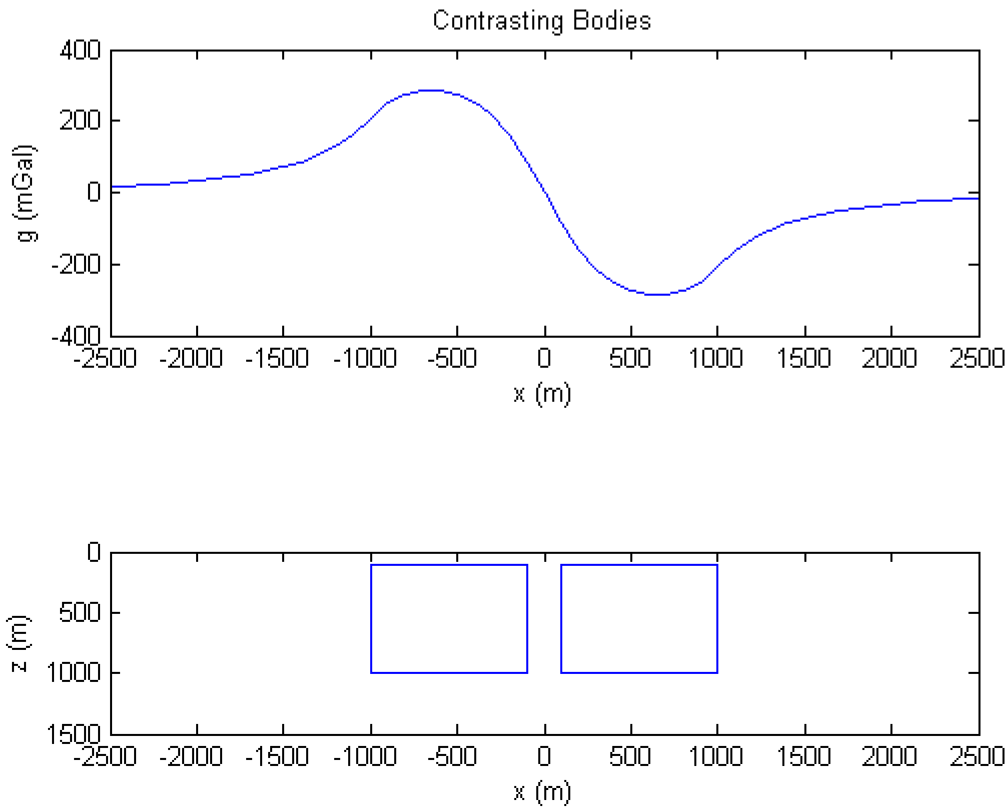

Figure 7

Figure 7 represents the density distribution and gravity response of two contrasting bodies +5 g/cc and -5 g/cc. This graph has what appears to be rotational symmetry about the point (0 m, 0 mGal). The gravity response slowly increases towards the left-center of the left body until it reaches its maximum. After this the value of the gravity response quickly declines towards its minimum in the right center of the right body. The magnitude of the gradient of the gravity response is greatest at x = 0 m while it approaches 0 as x goes to negative and positive infinity.

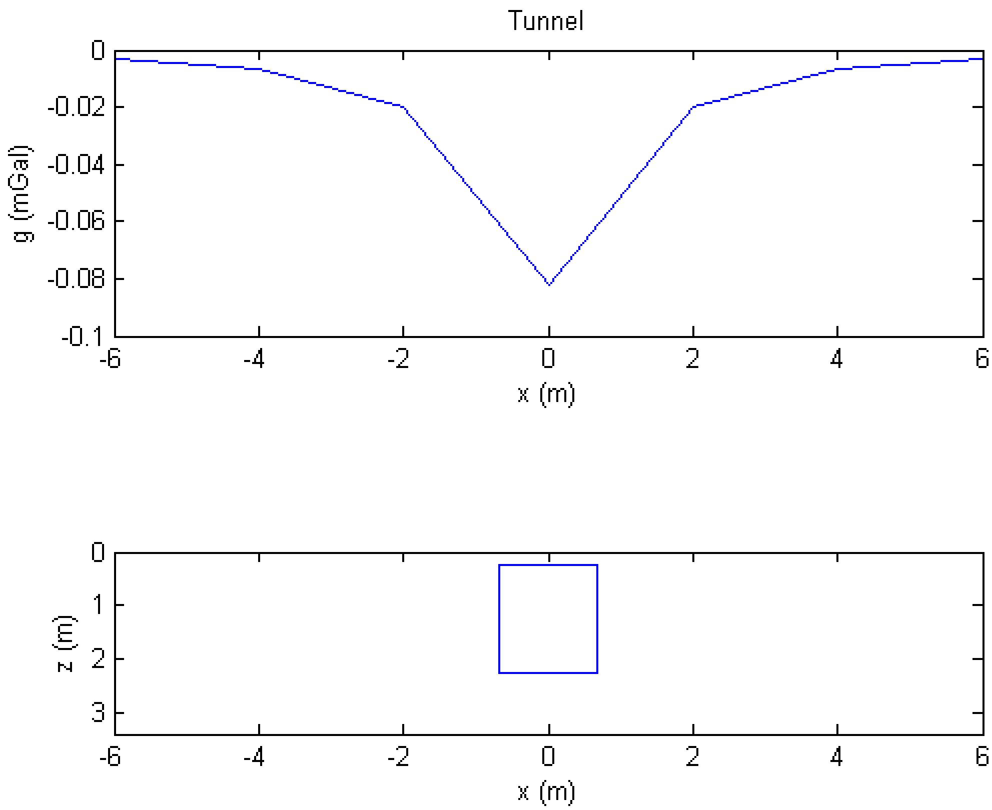

Figure 8

Figure 8 represents the gravity response and density distribution of the tunnel being surveyed in gravity lab 03. The graph was computed using a density contrast of 2.37 g/cc at 7 equally space iterations. The gravity response is linearly estimated between the 7 measurement points but appears to reflect the expected gravity response of the tunnel. The best way to model this problem may not be 7 equally spaced measurements but instead measurements increasing in frequency as x approaches 0 m.

Discussion

1. One of the most notable anomalies emanated by the various density distributions and related graphs is the comparison of the vertical, right, and left-dipping dykes. The vertical dyke has perfectly symmetrical slopes about the peak of the gravitational response. The right dipping dyke, however, has a much steeper slope on the left side of the peak than the right. The left dipping dyke is similar, however it has a steeper slope along the right side of the peak than the left. This makes sense because a right dipping dyke will have a sharp gravitational response, and as the dyke continues to dip down, the gravitational response will slowly lower as it travels along the dyke.
2. The type of data processing the two-body model is very similar to the distinctions we make against the background density, contrasting density, and the local density. It is important to be able to distinguish between the local and background anomaly, due to the importance of knowing the local anomaly. This is particularly important in oil and mineral exploration.
3. The recommended station spacing model was computed empirically by increasing the spacing in the MatLab model until the gravity response graph begin to lose its shape and resolution. This method resulted in spacing of 100 meters on all models except for Figure 8. 100 meters spacing is reasonable because many of the bodies are in between 1000 m and 1500m wide yielding approximately 20 measurements to capture the unique gravity response of the known anomaly. 20 measurements is a very reasonable number to gather in the field in a short period of time, for instance one day. The spacing for Figure 8 was computed knowing we have approximately 45 minutes to gather data for the gravity response of the tunnel. This frequency provides about 6 minutes and 30 seconds per gravity measurement. If each gravity measurement on the CG-5 takes 1 minute and 30 seconds then setup and takedown can combine for 5 minutes. Considering the distribution of the anomaly, gathering the data at regular intervals may not be the best way to capture the most accurate gravity response model. Spacing the measurements closer together as the distance from the center of the tunnel decreases would capture the gradient of the gravity response more accurately than equally spaced measurements further apart over the tunnel. If the center of the tunnel had the x coordinate 0 and the axis ran perpendicular to the tunnel then an effective spacing for gravity measurements could be 0 m , +/- 0.25 m, +/-0.6 m, +/- 1.0 m, and time permitting +/- 2.0 m like in Figure 9.

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   -2.0 m           -1.0 m     -0.25 m  0.25 m          1.0 m            2.0 m
|--------------------|--------|------|----|----|------|------------|--------------------|
                              -0.5 m   0.0 m     0.5 m
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Tunnel **Figure 9**

Conclusion

Modeling the gravity response of different geometries and density contrasts is a powerful way to help learn how to prepare for gravity surveys in the field and predict gravity response graphs ahead of time. Studying how gravity response modeling is affected by changes in measurement frequency and density distribution can help geophysicists visualize and optimize gravity response surveys.