Garrett Sickles and James Hogan
Lab 04
GPGN 303
09/22/2014

Introduction

In this lab exercise, we were assigned the task of interpreting gravity data with differing noise affecting the data. We used MATLAB to code and play with this data, and used the idea of forward modeling to further advance our knowledge and understanding of gravity response data and graphs.

Objectives

There are a few objectives in this lab exercise. The first is to practice interpreting data via forward-modeling, using the method of trial-and-error. The second is to identify and discover the differences between geometry, recovered density, and the depth of the object of interest, during an interpretation of gravity data, given a specific set of error bars. Lastly, we wanted to quantitatively interpret the data from Lab 03, and try and match it over another set of data, and see if it is possible that this data was taken over one of the famous CSM steam tunnels.

Procedure

In order to start our lab exercise, we were required to do a few things: since it was a computer lab, we needed to open MATLAB and download the given files and copy them to our working directory. Given files include (**polymod.m), (obs1.grv), and (obs2.grv).**

There are three parts to this exercise.

Part 1: Trial and Error

In part 1, the first step was to open **(obs1.grv),** by entering it into your command window. Then once the graph appeared, you would click around on the lower portion of the graph and create a polygon. Note: be sure to click points in a clockwise direction and to right click on your final point.

Using these constraints:

> *"(1) Find a dipping slab with four vertices and a density contrast of 1.0 g/cm^3*
> *(2) Find a similar body with a density contrast of 0.6 g/cm^3 and a few more vertices. You can start from the model you generated in (1).*
> *(3) Find a model that has a density of 1.4 g/cm^3, and a flat top."*

Try and achieve a fit between the observed data and the predicted data. You can be sure it is a 'fit' when the predicted line goes through every single error bar on the graph of the observed data. The results appear in figure 1, figure 2 and figure 3 below. Each of these figures plot the gravity response in green of the shape in the lower section of the figure with the data from (**obs.grv**) in blue.

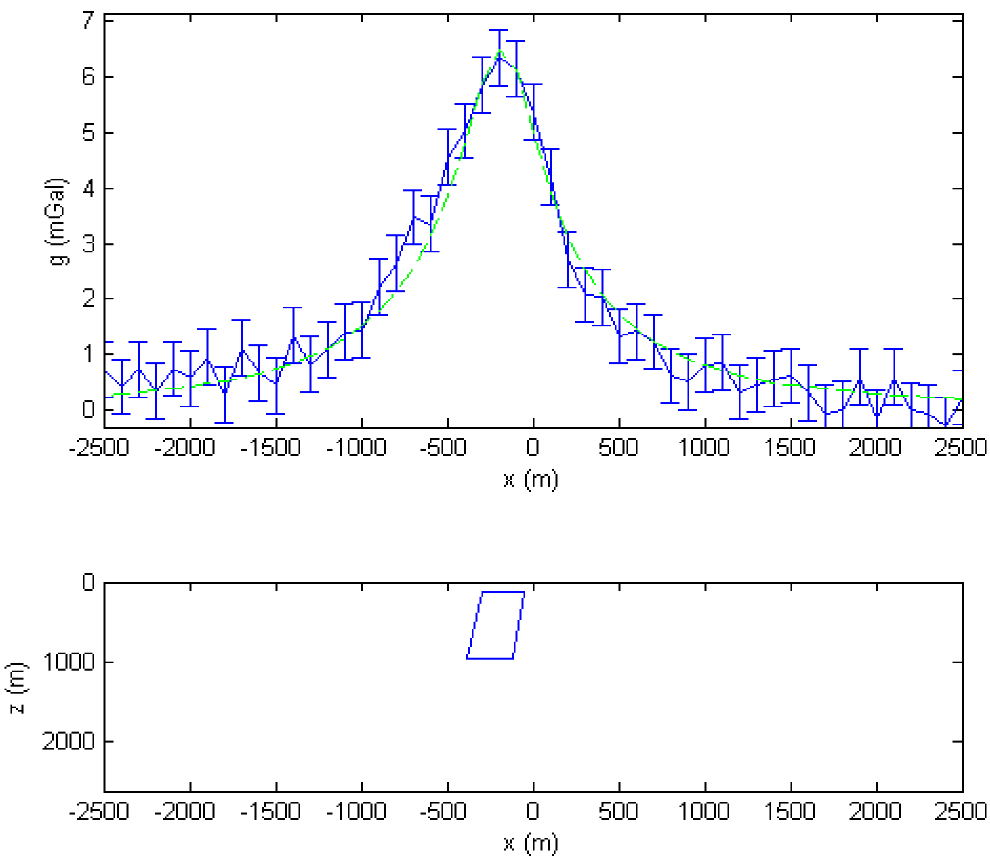

Figure 1: The gravity response of a left dipping polygon with a density contrast of 1.0 g/cm^3 plotted against the observed data from the file (**obs1.grv**). The forward model closely fits the observed data.

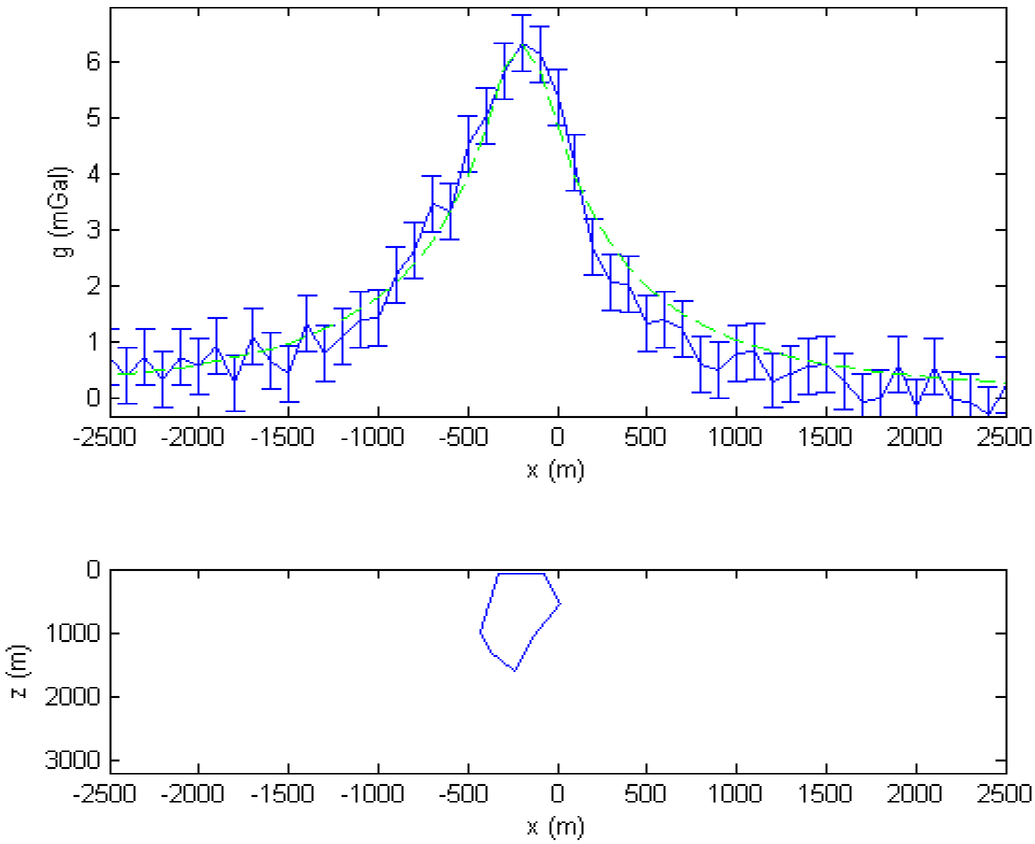

Figure 2: The gravity response of a polygon similar to the one from figure 1 with a density contrast of 0.6 g/cm^3 plotted against the observed data from the file (**obs1.grv**).. The gravity response plot of this predominantly left dipping feature also closely models the observed data.

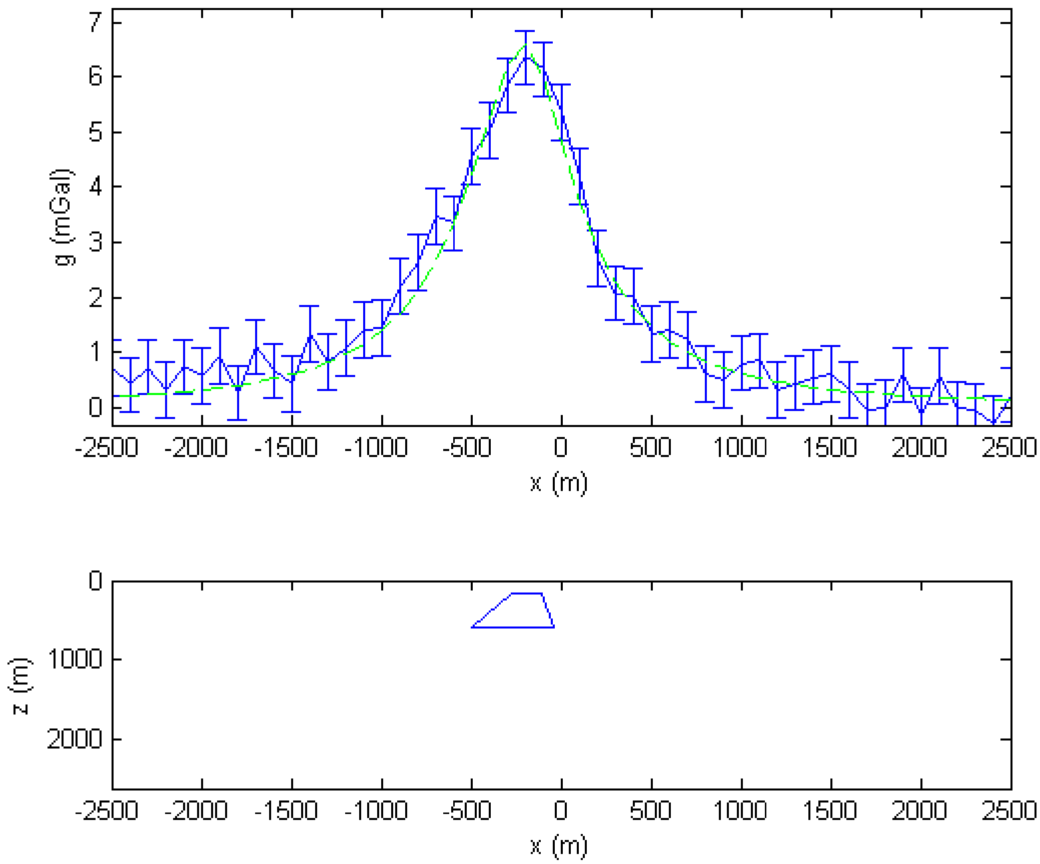

Figure 3: The gravity response of a flat-top trapezoid with a density contrast of 1.4 g/cm^3 plotted against the observed data from the file (**obs1.grv**). The gravity response plot of this also closely models the observed data.

The second part of this lab involved taking our shape data from part 1 and putting it over the data you receive when you run **(obs2.grv).**

Part 2: Comparison with Observation 2 gravimetry data

First, restart the **(polymod.m)** file, and then run the file, **(obs2.grv),** in the command window. Then input each of the three models we found in part one and explain whether or not they are valid models for interpreting the observed data from this second file. These cases appear in figure4 figure 5, and figure 6.

Second, pick a case that is relatively close, and create a new model that fits the data and discuss how you changed it.

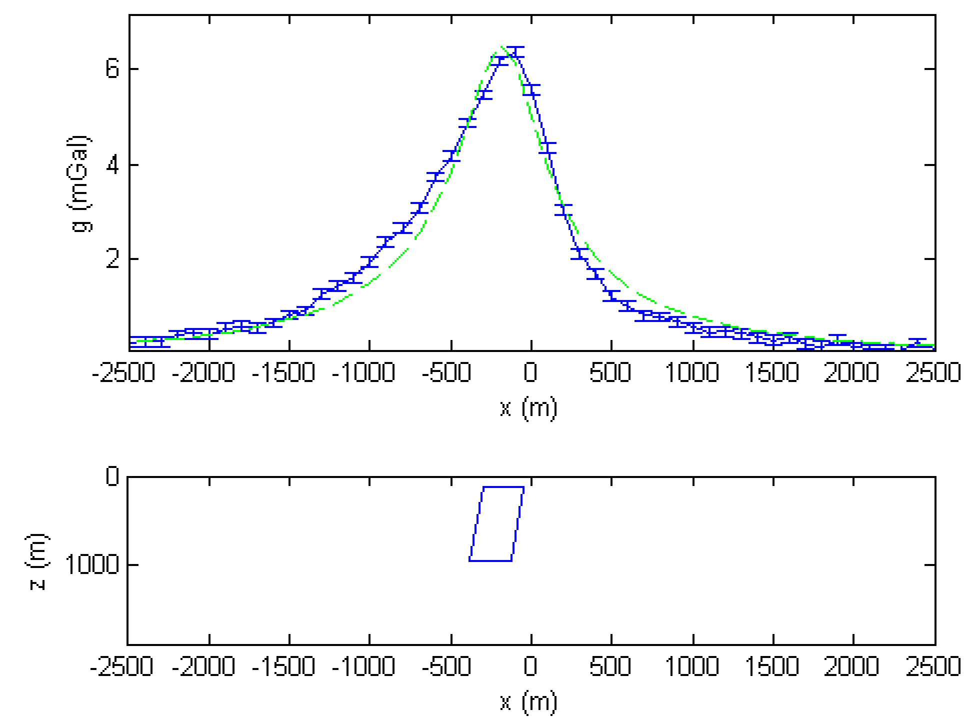

Figure 4: The gravity response of a left dipping polygon with a density contrast of 1.0 g/cm^3 plotted against the observed data from the file (**obs2.grv**)

The dipping slab model does not fit the data for observation 2. The peak is roughly 100 meters to the left of the observed peak. The left side is too concave; it decreases too quickly. The right side is not concave enough; it decreases too slowly.

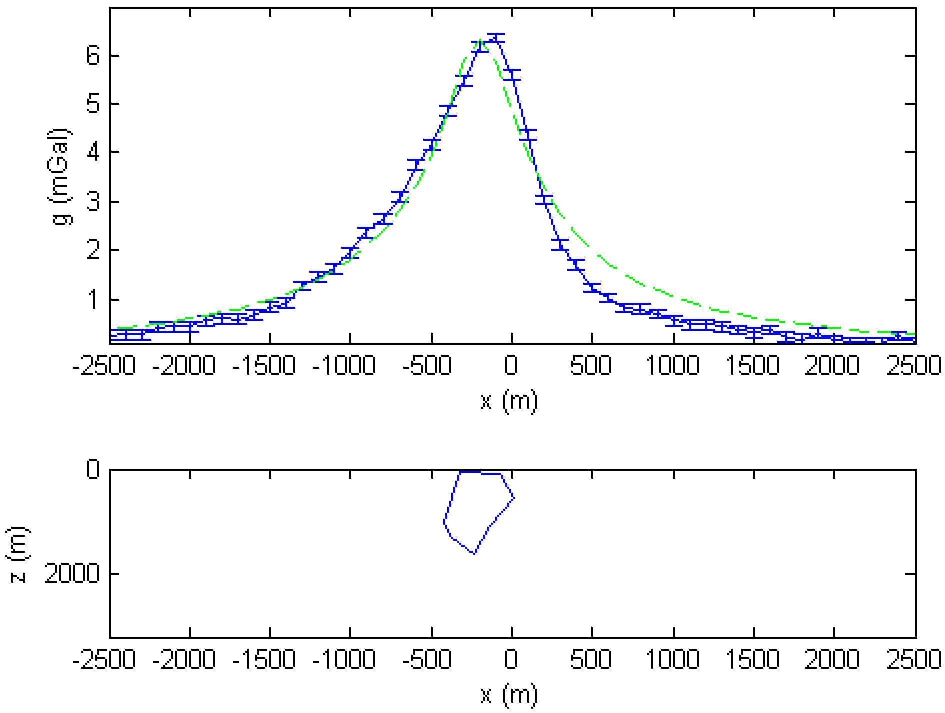

Figure 5: The gravity response of a polygon similar to the one from figure 4 with a density contrast of 0.6 g/cm^3 plotted against the observed data from the file (**obs2.grv**)

The polygon model fits the observed data better than the in figure 4, but is still not quite right. The peak is still 100 meters left of the observed peak; however, the left side seems to fit the observed data and is much more accurate than the first model. The right side is still not as concave as it needs to be; it decreases too slowly.

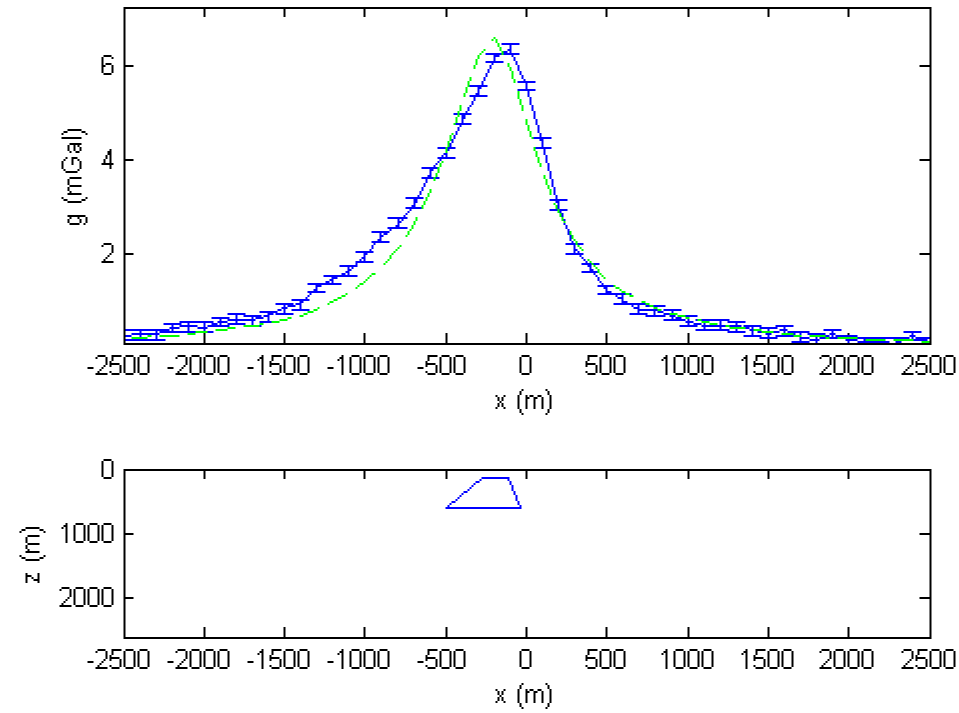

Figure 6: The gravity response of a flat-top trapezoid with a density contrast of 1.4 g/cm^3 plotted against the observed data from the file (**obs2.grv**)

The third and final shape consisting of a flat top still does not fit the observed data. The peak is still 100 meters too far to the left, and is too large. The left side doesn't fit, it is too concave; it increases too quickly. The right side fits a little better so it the closest of figures 4, 5, and 6. The shape was progressively altered in density and size until another four sided figure emerged as a good approximation of the data from (**obs2.grv).** This shape and gravity response model appear below in figure 7.

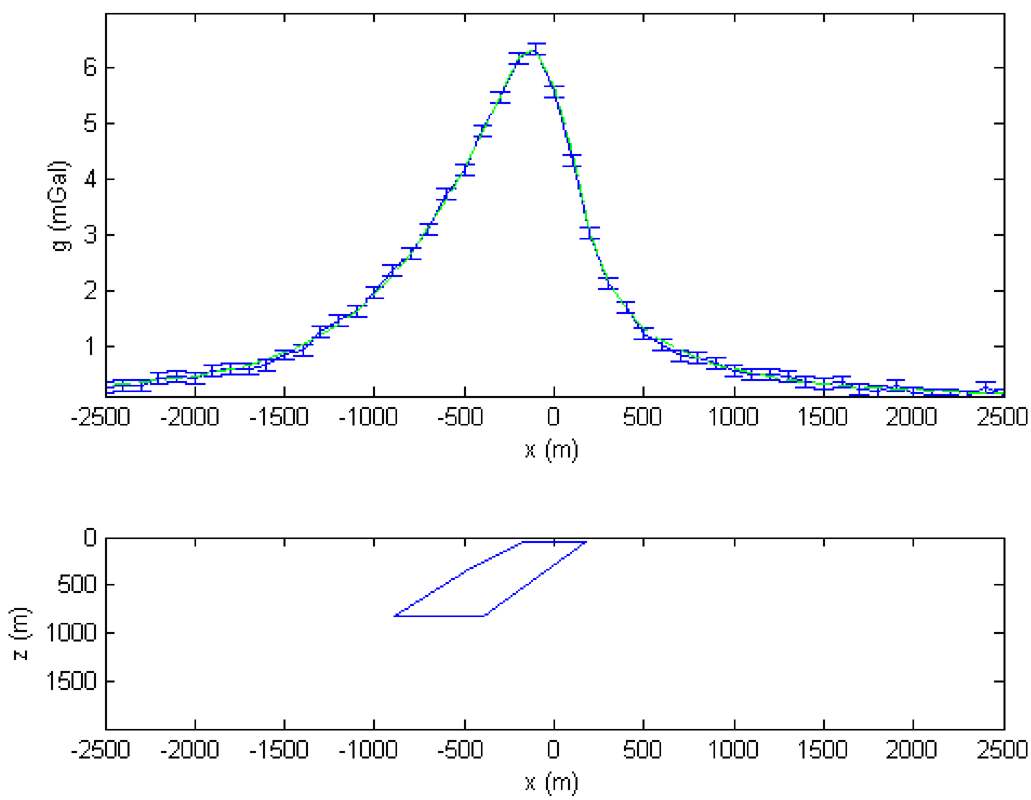

Figure 7: The gravity response of a nearly flat-top convex left dipping pentagon with a density of 0.6 g/cm^3 plotted against the observed data from the file (**obs2.grv**). This model is almost a perfect fit to the observed data.

Part 3: Modeling the tunnel

To start the begin part 3 you must restart the (**polymod.m)** file and input the data file containing the gravity data from our last lab, which we collected over the CSM steam tunnel.

First, create a model that resembles the tunnel and get a response within the error bars of our collected data from last week assuming appropriate density and the dimensions for the tunnel. The negative density contrast of 2.67 g/cm^3 was applied to the cross sectional area of both of the two neighboring tunnels in the gravity response model in figure 8.

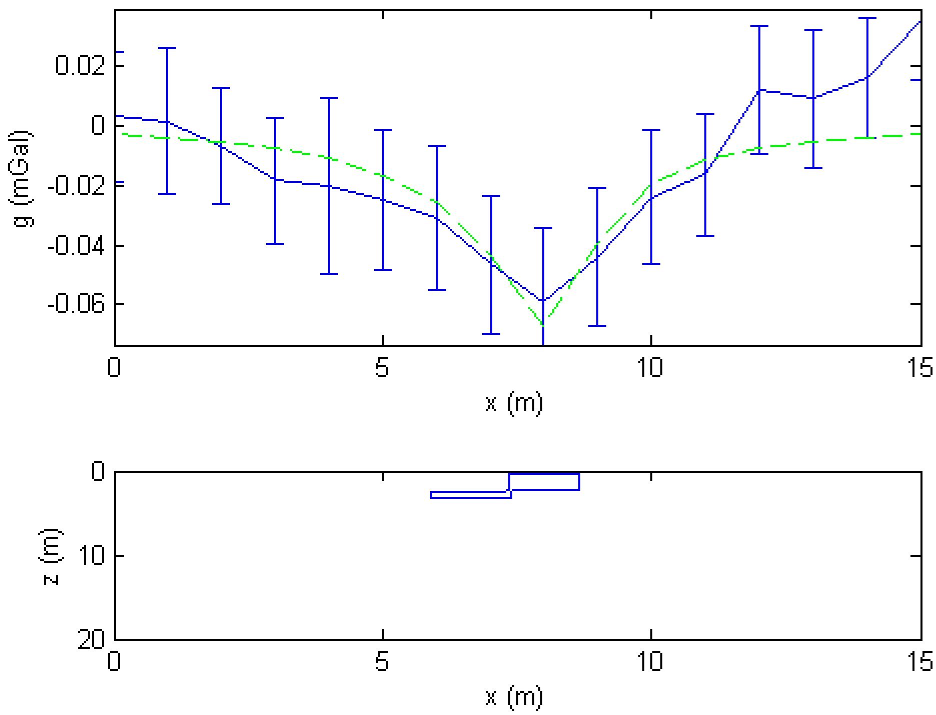

Figure 8: The gravity response graph of two rectangles modeling the steam tunnels from lab 3 with a negative density contrast of 2.67 g/cm^3.

The gravity response of the modeled tunnels fit within the error bars of the observed data from lab 3. The main problems with the graph are the the amplitude and the value of the gravity response when *x* is greater than 10 meters. The amplitude does not match the observed peak directly over the tunnel. Although the value is within the error bars, almost all of the data occurs within a 0.06 mGal window. A possible reason the modeled peak is lower than the observed peak is the absence of a dense concrete layer directly under the gravimeter and between the tunnel. The second problem with the data in figure 8 is the significantly higher gravity response from 10 to 15 meters compared to the gravity response from 0 to 5 meters. The expected behavior of this model is an asymptotic increase to the same value on both sides of the center of the tunnel. Instead the graph begins to spike when *x* is greater than 10 meters. Despite these discrepancies, the two tunnel model accurately fits data from lab 3 within the error bars.

Discussion

(1) How does the size of the model change as you decrease the assumed density contrast?

If you were to decrease the assumed density contrast, the amplitude of the model would change. Specifically, the size of the model would follow the proportion of the old density contrast and the new density contrast. For instance, if the density contrast was cut in half, the amplitude of the gravity response model be cut in half.

(2) Based on the Gauss' law, can you predict how the product of the density contrast and the area of the polygon will change? Will the area increase, remain the same, or decrease as you increase the density contrast to fit a data set?

Based on Gauss' Law, the change of the product of the density contrast and the area of the polygon can be predicted, but with little certainty. It is difficult to predict changes because there is no unique solution to these type of inversion problems. Gauss' Law can easily predict how the gravity response plot of polygon changes when the shape is held constant and the density changes. In this case the plot is simply scaled in amplitude by the ratio of the new density contrast to the old density contrast. On the other hand, predicting how the gravity response changes when the density is held constant and the shape changes is much more difficult. A change in the shape can alter the properties of the gaussian surfaces in question at each observation point, therefore altering the mass, flux, and gravity response plot.

This problem is much easier to predict when the density contrast is increasing because the area of the shape must decrease for the gravity response plot to stay the same. This is necessary because the mass inside the gaussian surface is the product of the decreased area and the increased density. This means the shape of the gravity response plot for the decreasing shape should approach the gravity response plot of a point mass of equal mass as the area of the shape continues to decrease and the density contrast continues to increase.

(3) Can you uniquely determine the shape of the source that originally produced input data without the knowledge of the density contrast? How does the situation change if you know the density contrast?

You cannot uniquely identify the shape of the source without the density contrast. In part 1 of the lab, we took the same gravity response, and created three models with varying shapes, depth, and density contrast. Despite this, we still created a very similar gravity response model. So, educated guesses can be made but knowing the density contrast is a much method to create an appropriate forward model. This is because with a constraint on the density contrast all that is left to deal with is shape and depth which can be easily manipulated and calculated.

(4) How do the errors in data affect your interpretation?

The errors in our data provides a range of gravity response plots able to accurately model the observed data. For instance, the error bars in (**obs1.grv**) were much greater than those in (**obs2.grv**). This became apparent when we tried to plot the gravity response of the three initial shapes made with the error bars and measurements of (**obs1.grv**) in mind against the data in (**obs2.grv**). The gravity response plots of the three initial shapes did not fit the measurements and error bars of (**obs2.grv**), observed in figure 4, figure 5, and figure 6.

The tunnel data from lab 3 also displayed the significance of error in our interpretation because the range of error was a significant proportion of the measured anomaly. This is why the gravity response plot of the modeled tunnel, in figure 8, spans a large portion of the error bars in the observed data.

Conclusion

Lab 4 illustrated how gravity response plots of different shapes and densities can model the same data set of observed gravity response and error. By using the trial and error method of modeling and matching observed data it quickly became apparent that there were no unique solutions to the observed data. Instead, there are an infinite combination of densities contrasts and shapes that can accurately model observed gravity response data. As the error in our observed gravity response data decreased, creating a combination to fit the observed data became much more rigorous. This indicates that as the number of quality data points increase and the error of each point decreases that the distribution of possible shapes and density contrasts also decreases. Although there are no unique solutions to gravity response inversion problems, quality data with small error can help narrow your search for an accurate shape. In the case of the observed data from the gravity survey of the utility tunnel, the error was so large that the approximation of the tunnel geometry matched the observed data. This tunnel survey does match the forward model. If we did not know the tunnel was already there the significance of the error in the gravity survey would have disabled us from accurately finding the two tunnels.

Appendix: Model Files

dipping1.mod

```
     4     1.00
-300.00  120.00
-50.00  120.00
-120.00  950.00
-380.00  950.00
```

Model 1: Model file of the left dipping shape in figure 1

flattop1.mod

```
     4     1.40
-270.00  155.00
-109.50  155.00
 -40.00  600.00
-500.00  600.00
```

Model 2: Model file of the flat top trapezoid in figure 3

polygon1.mod

```
     7     0.60
-324.38   71.46
 -76.45   87.34
  14.46  532.00
-138.43 1071.94
-241.74 1596.00
-373.97 1310.15
-427.69  992.54
```

Model 3: Model file of the polygon from figure 2

tunnel.mod

```
10     -2.00
7.35    0.30
8.65    0.30
8.65    2.30
7.45    2.30
7.40    2.40
7.40    3.20
5.90    3.20
5.90    2.40
7.25    2.40
7.35    2.30
```

Model 4: Model file of the two tunnels from Lab 03 in figure 8 polygon2.mod

```
       5     0.60
 -175.03   45.11
  175.02   55.90
 -390.50  826.75
 -892.15  817.30
 -500.00  350.00
```

Model 5: Model file of the left dipping pentagon from figure 7