GEOL 384.3 and GEOL 334.3

Lab #2: Gravity corrections

The file grav01_corr.txt is a portion of the gravity data collected at the geophysics field school in 2001. The latitude of the base station is 52.2025° and the longitude is 253.601°. The coordinates of each station are given in m North and East of a reference point, whose latitude is 52.1975° and longitude 253.601°. Elevations are in meters above the geoid.

Absolute gravity has been established at the base by repeat measurements between the base and a site where absolute gravity has been measured directly. Absolute gravity at the base is 981113.12 mGal. The base station data are in the first line (635N 100E, marked FLAG=B in the file).

These dial data have already been drift-corrected, and so you need to perform the following corrections: calibration, tie to absolute gravity, latitude, free air, and Bouguer. Except for the Bouguer, these corrections were tried in lab #1, although only for one pair of geographic coordinates.

Assignments

1) If you need a spreadsheet file, create it from grav01_corr.txt. In the table, add a new column, in which you calculate the times in hours from 10 am on August 28.

   GEOL334: try using Matlab or Octave matrices instead of spreadsheets. For Matlab users, the data file has been edited so that it can be directly loaded by command like `data = load('file_name','-ascii')`

2) **Calibrate each of the readings** as described in lab #1. The calibration table from lab 1 is repeated in Table 1 below. In your output worksheet (Excel spreadsheet or Matlab matrix), **add a column** with calibrated gravity values.

   Add another column for calibrated absolute gravity. These values should be obtained by adding a constant to the preceding calibrated gravity so that at the base station, you obtain the 981113.12 mGal mentioned above.

Table 1. Calibration table for UofS Lacoste Romberg 267G

Dial reading	*Value (mGal)*	*Factor for interval*
4300	4502.91	1.04853
4400	4607.77	1.04853
4500	4712.62	1.04848
4600	4817.47	1.04845
4700	4922.31	1.04844

4800	5027.16	1.04848

In each of the subsequent steps of gravity reduction, you will be adding two columns to the output worksheet. One column will contain the corresponding "gravity correction" (model for certain physical effects; see lectures), and the second column will be the resulting "anomaly", or "corrected gravity", such as the free-air or Bouguer gravity.

3) **Perform the latitude correction.** In this case, latitude correction is different for the different points of the survey.

Gravity varies with latitude in a predictable way, and because it is predictable, we can correct for it. The International Gravity Formula (IGF) defines a standard model of gravity on a reference Earth ellipsoid. At the latitude of the point marked as 0 North in our survey, the IGF gravity is 981265.34 mGal, and it increases towards the North by about 0.79 mGal /km. Thus, the latitude correction by the IGF equals

$$g_{\mathrm{lat}}(\mathrm{station}) = 981265.34 + 0.79 \times \mathit{Northing}(\mathrm{station}) \ \ [\mathrm{mGal}],$$

where the northings are in km relative to the point shown as North=0 in the data file.

Evaluate g_{lat} **for each station** and place it in a column in the output worksheet. Note that in the data file, northings are given in meters!

Then **subtract** g_{lat} **from the calibrated absolute gravity column and place it in the second column** output by this step. This is the latitude-corrected gravity. After the latitude correction, gravity values should be around –150 mGal.

4) **Perform the free-air correction.** Gravity on the IGF ellipsoid also varies with height, which is the altitude above the geoid or above the sea level. As you go higher, you are getting further away from the centre of the earth, and so gravity decreases by 0.3086 mGal per meter of height. For example, Saskatoon is nearly 600 m above sea level, and so gravity here is lower by about 185 mGal than it would be if Saskatoon were at the sea level.

Since this variation of gravity with height is predictable by the IGF, we can correct for it. The correction formula relative to the base station is:

$$g_{\mathrm{FA}}(\mathrm{station}) = -0.3086 \times \left[\mathit{Height}(\mathrm{station}) - \mathit{Height}(\mathrm{base})\right] \ \ [\mathrm{mGal}],$$

where the heights are in meters.

Evaluate g_{FA} **for each station** and place it in the output table.

Then **subtract** g_{FA} **from the latitude-corrected gravity column and place it in another output column** of your worksheet**.** This is the free-air corrected gravity.

In addition to the effect of height, there is also some attraction from the rock between each station and sea level. The correction for this is called the Bouguer correction. To evaluate the so-called "simple Bouguer correction", we assume that the attraction of the rock beneath the instrument equals the attraction of a flat slab of rock of the same thickness as height above the geoid, and all the rock between the station and sea level has the average crustal density 2670 kg/m^3. This value results in a further attraction of 0.1119 mGal/m. Thus, the Bouguer correction is:

$$g_{\mathrm{Bouguer}}(\mathrm{station}) = 0.1119 \times \left[\mathit{Height}(\mathrm{station}) - \mathit{Height}(\mathrm{base})\right] \ \ [\mathrm{mGal}],$$

This quantity is subtracted from free air gravity to give the “Bouguer gravity”.

As discussed in the lectures, the simple Bouguer correction is an approximation, and sometimes further correction for the curvature of the earth is needed (“Bullard B”). Finally, for precise work, a correction for topography near the station may also be made. If these curvature and topography corrections are also applied, the anomaly is called the “complete Bouguer anomaly”.

Calculate the simple Bouguer correction (add a column for it to the worksheet).

Add another column by subtracting g_{Bouguer} **from the free-air corrected gravity**. This is your (final) Bouguer gravity.

5) **Plot the raw** (calibrated absolute, prior to the latitude correction) in one plot, and the **latitude-corrected, Free Air, and Bouguer gravity vs Northing** in another plot. Use different colors and/or symbols. Note that the raw and corrected readings differ by about $9.8 \cdot 10^5$ mGal, but the range of gravity variation in each of these plots should be about 10 mGal.

For comparison, also **plot the heights of the stations along the profile versus northings**.

6) <u>From the graphs</u>, **comment about the correlation of each of the four forms of gravity** records with the latitudes and heights of the observation points. You can do this by filling out the following table:

Type of gravity	*Increases or decreases with latitude?*	*Increases or decreases with height?*	*Reason(s) if reality does not match expectations*
Raw	<u>Expected</u>: <u>In reality</u>:	<u>Expected</u>: <u>In reality</u>:	
Latitude corrected	<u>Expected</u>: <u>In reality</u>:	<u>Expected</u>: <u>In reality</u>:	
Free-air corrected	<u>Expected</u>: <u>In reality</u>:	<u>Expected</u>: <u>In reality</u>:	
Bouguer corrected	<u>Expected</u>: <u>In reality</u>:	<u>Expected</u>: <u>In reality</u>:	

When answering, note that some correlations may be incidental, because height also changes with latitude. Try discerning the true correlations.

You should see that the Bouguer anomaly has the least variation along the line and is uncorrelated with topography. This is because the raw gravity, latitude corrected gravity, and free air gravity, include large components from unimportant sources like the ellipsoid and elevation. These sources are common to all points within the survey area and do not aid interpretation.

By contrast, Bouguer gravity is due only to local geology. However, as discussed in the lectures, Bouguer gravity may also be not 100% due to the subsurface. A significant contribution to it may come from the topography of the terrain or from an inaccurate estimation of the Bouguer density (which we took equal 2670 kg/m^3 in this lab).

Hand in:

Brief answers to the questions highlighted in **bold** above with figures embedded in a Word or PowerPoint document by email.