**Name: KEY** **Homework 5, GEL 161**

**Ch. 8–9 [45 pts]**

**Gravity Surveys** The table below shows data collected along a east-west gravity profile. Distances are measured from the west end of the profile, which has a latitude of 51°12′24″N. The density of the rock at the surface is $\rho = 2.7$ Mg/m$^3$. The calibration constant of the Worden gravimeter used during the survey is 0.3792 mgal per dial unit. Before, during and after the survey, base station measurements (marked BS in the table) were taken. The known absolute value of gravity at the base station 981144.22 mgal.

1. Make a list of describing each step required to transform the raw gravity measurements into the free-air and Bouguer anomaly profiles. For each step, briefly describe the equations used and why the step is required. [10 pts]

   (a) Time-scale: convert all times to minutes from start of survey:
   $t_{sta} = 60(t_{Hsta} - t_{Ho}) + (t_{Msta} - t_{Mo})$
   where H is hours and M is minutes. This is used for the drift correction.

   (b) Convert gravimeter readings to total gravity:
   $g_{total} = (r_{sta} - r_o) * 0.3792 + 981144.22$ mgal
   All values need to be in mgals before applying geological corrections.

   (c) Drift correction: calculate the drift correction from a plot of the repeated base station measurements versus time in minutes: $g_{drift} = f(t_{bs})$, where the drift correction is linear or other function of the time of the measurement. Then: $g'_{total} = g_{total} + g_{drift}$.
   This correction accounts for instrument drift and earth tides.

   (d) Latitude correction: $g_\lambda = 978031.8(1 + 0.0052024 \sin^2(\lambda) 0.0000059 \sin^2(2\lambda))$
   Note that since the profile is east-west, this value is the same for all stations.
   The corrected gravity is: $g_{cor} = g'_{total} + g_{drift}$ This correction accounts for the latitudinal dependence of gravitational acceleration due to the non-spherical shape of the earth and the extra centrifugal acceleration on a spinning earth.

   (e) Free-air correction: $\delta g_{fa} = 0.3086h$ mgal , where h is elevation (m) of station above/below sea-level.
   The free-air anomaly is: $g_{fa} = g_{cor} + \delta g_{fa}$
   This correction accounts for the $1/r^2$ decrease in gravity with distance from the center of the earth, and *adjusts* all measurements so it as if they were all taken at sea-level.

   (f) Bouguer correction: $\delta g_b = 0.04192 \Delta\rho h$ mgal, where $\Delta\rho$ is the density anomaly of topography with respect to air.
   The Bouguer anomaly is: $g_b = g_{fa} + \delta g_b$
   This correction accounts for excess or missing mass between the height of the station and sea-level.

2. Perform gravity reduction of the survey data. In doing this make a table that shows the original data, and then separately lists the value of each correction in one column and then applies the correction in the next column (as done in class). Hint, convert times into minutes since the start of the survey, so that the first base station measurement is at 0 minutes, and the last base station measurement is at 345 minutes. Please turn in a clearly labeled final table. [20 pts]

   In the table below time is in minutes and all gravity values are in milligals.

| time | $g_{tot}$ | $g_{drift}$ | $g'_{tot}$ | $g_\lambda$ | $g_{cor}$ | $\delta g_{fa}$ | $g_{fa}$ | $\delta g_b$ | $g_b$ |
|---|---|---|---|---|---|---|---|---|---|
| 35.00 | 981148.81 | 0.04 | 981148.85 | 981187.71 | -38.86 | 26.00 | -12.86 | 9.53 | -22.39 |
| 44.00 | 981146.80 | 0.06 | 981146.85 | 981187.71 | -40.86 | 26.80 | -14.05 | 9.83 | -23.88 |
| 55.00 | 981144.79 | 0.07 | 981144.86 | 981187.71 | -42.85 | 27.60 | -15.25 | 10.12 | -25.37 |
| 63.00 | 981142.78 | 0.08 | 981142.86 | 981187.71 | -44.85 | 28.72 | -16.12 | 10.53 | -26.66 |
| 129.00 | 981141.34 | 0.18 | 981141.52 | 981187.71 | -46.19 | 30.97 | -15.22 | 11.36 | -26.58 |
| 144.00 | 981141.83 | 0.20 | 981142.03 | 981187.71 | -45.68 | 31.14 | -14.54 | 11.42 | -25.96 |
| 153.00 | 981138.84 | 0.21 | 981139.05 | 981187.71 | -48.66 | 31.85 | -16.81 | 11.68 | -28.49 |
| 164.00 | 981136.98 | 0.23 | 981137.20 | 981187.71 | -50.51 | 33.13 | -17.38 | 12.15 | -29.52 |
| 272.00 | 981135.61 | 0.38 | 981135.99 | 981187.71 | -51.72 | 33.98 | -17.74 | 12.46 | -30.20 |
| 282.00 | 981133.98 | 0.40 | 981134.38 | 981187.71 | -53.33 | 35.46 | -17.88 | 13.00 | -30.88 |
| 300.00 | 981132.77 | 0.42 | 981133.19 | 981187.71 | -54.52 | 36.71 | -17.81 | 13.46 | -31.27 |

3. Plot (or draw on graph paper) a series of profiles of distance versus topography, observed gravity (before and after drift-correction), free-air anomaly and bouguer anomaly along the profile (i.e., 6 profiles). [6 pts]

   See attached plots.

4. Using the plots made in the previous step, comment on how each correction changes the shape and magnitude of the profile and why. [5 pts]

   (a) Drift correction: the values of this correction are small, so there is no visible difference in the profile.

   (b) Latitude correction: shape of profile is unchanged; values span -35 to -55 mgal.

   (c) Free-air correction: this correction amplifies the small anomaly, which has a magnitude of 1.5 mgal; the profile spans values of -13 to -18 mgal.

   (d) Bouguer correction: this correction subdues the small anomaly, which has a magnitude of about 1.0 mgal; the profile now spans -22 to -32 mgal.

5. Based on the Bouguer anomaly, what do you know about the density anomalies in the subsurface? [4 pts]
   The small anomaly at the center of the profile has a larger magnitude than the surrounding profile indicating the presence of a small positive density anomaly in the subsurface. The amplitude is only 1 mgal and the width is only about 25 meters, indicating a small volume and density anomaly. The surrounding profile has a negative Bouguer anomaly indicating a deeper, broader negative density anomaly.

Survey Data

| Station | Time | Distance (m) | Elevation (m) | Reading |
|---|---|---|---|---|
| BS | 08:05 | | | 2934.2 |
| 1 | 08:35 | 0 | 84.26 | 2946.3 |
| 2 | 08:44 | 20 | 86.85 | 2941.0 |
| 3 | 08:55 | 40 | 89.34 | 2935.7 |
| 4 | 09:03 | 60 | 93.08 | 2930.4 |
| BS | 09:40 | | | 2934.7 |
| 1 | 10:09 | | | 2946.3 |
| 5 | 10:24 | 80 | 100.37 | 2926.6 |
| 6 | 10:33 | 100 | 100.91 | 2927.9 |
| 7 | 10:44 | 120 | 103.22 | 2920.0 |
| 8 | 10:53 | 140 | 107.35 | 2915.1 |
| BS | 11:45 | | | 2935.2 |
| 9 | 12:32 | 160 | 110.10 | 2911.5 |
| 10 | 12:42 | 180 | 114.89 | 2907.2 |
| 11 | 13:00 | 200 | 118.96 | 2904.0 |
| BS | 13:50 | | | 2935.5 |

Plots for question 3.