2015 University of Manitoba Geophysics Field School
Selkirk Golden Boy Project: Data Reduction And Examination
May 3, 2015

The analysis for this project will involve the reduction of the data collected in the survey, followed by the examination of larger-scale gravity and magnetic results. In the first phase, the gravity and magnetic data will be reduced to profile plots of the Bouguer anomaly and the total magnetic field. This data reduction will be done by the whole data acquisition group, and will be done on the whole data set. Prior to the start of the analysis, each group should fully archive the data they collected (with README files, etc.) and prepare for it to be made available to the other groups.

Given our difficulties with gravity, last year's gravity data will be used; see
http://home.cc.umanitoba.ca/~frederik/Teaching/Field_School/Selkirk/Gravity_El_2014/

Gravity Reduction

It is necessary to correct the gravity data for the following factors: gravimeter/earth-tide drift, the instrument height above the ground, the latitude, and the free-air and Bouguer corrections associated with the elevation of each station. Because of the flat topography, terrain corrections will not be necessary.

1. *Gravimeter/earth-tide drift correction*

In order to correct for the drift, it is necessary to calculate the time-variation of gravity at the base station. This is done by assuming that the gravity varies in a linear manner between the repeated occupations of the base station.

(**a**) Enter the times and values of the base station readings into a spreadsheet. It is convenient to work in time values of minutes after an arbitrary reference time near the start of the survey.

(**b**) Average the time and gravity value for each set of base station readings (omitting any bad values).

(**c**) On a new spreadsheet enter the time and value for each survey station reading. Next we want to calculate the interpolated base station reading at the time of each survey station reading. This can done by graphing the base station readings vs. time, joining the points using a straight line, and reading off the interpolated value at each required time. Alternatively, it can be done using the formula for the straight line. If the (averaged) time and reading at two consecutive base station re-occupations are: (t_1,g_1) and (t_2, g_2) then the gravity at some other time t is given by:

$$g(t) = g_1 + (t - t_1)\left[\frac{g_2 - g_1}{t_2 - t_1}\right] \qquad \text{Eq. 1}$$

(**d**) Enter the interpolated base station readings into a new column of your spread sheet. Subtract the base-station value from the observed reading to give the time-corrected response (relative to the arbitrary base station).

(**e**) Multiply by the gravimeter calibration constant to convert the reading in gravity units (GU).

2. *Latitude*

The latitude correction is an *additive* correction that adjusts for the increase in gravity with increasing latitude. The sign of the correction is such that it decreases readings taken further north. For a survey of the size involved in this project, calculate the latitude correction using:

$$\delta g_{\phi}(\mathrm{GU}) = -8.136\sin(2\phi)\Delta x(\mathrm{km}) \qquad \text{Eq. 2}$$

where Δx is the distance north of some reference latitude φ in the survey area. (For larger surveys, one must adjust for the variation in ϕ across the survey area).

(**a**) Calculate the distance (in km) of each survey station north from some east-west reference line.
(**b**) Calculate the latitude correction and add it to the survey data.

3. *Instrument height correction*

This correction adjusts for the different height of the gravimeter relative to the ground at each site. To correct for the instrument elevation, include the height of the gravimeter at each survey station reading as a new column in the spreadsheet. Calculate the correction by multiplying the height above the ground (in m) by the free-air correction:

$$\delta g_{FA}(\mathrm{GU}) = +3.086\Delta z'(\mathrm{m}) \qquad \text{Eq. 3}$$

where $\Delta z'$ is the elevation **above** the ground.

4. *Elevation and Bouguer Corrections*

The elevation correction adjusts for the change in gravity associated with elevation changes between the sites (by increasing the readings at higher elevations). It is given by:

$$\delta g_{FA}(\mathrm{GU}) = +3.086\Delta z(\mathrm{m}) \qquad \text{Eq. 4}$$

where Δz is the elevation above some (arbitrary) reference level that is parallel to the geoid. The Bouguer correction adjusts for the additional mass beneath sites at different elevations (assuming the mass can be represented by a semi-infinite slabs). It decreases the readings at higher elevations. The correction is given by:

$$\delta g_B = -2\pi G\rho\Delta z = -4.193\cdot 10^{-4}\rho[\mathrm{kg/m^3}]\Delta z[\mathrm{m}]\,\mathrm{GU} \qquad \text{Eq. 5}$$

where ρ is the density of the material making up the elevation variations. The free air and Bouguer corrections can be combined to give:

$$\delta g_{FA}(GU) = \left[+3.086 - 4.193\cdot 10^{-4}\rho(\mathrm{kg.m^{-3}})\right]\Delta z(\mathrm{m}) \qquad \text{Eq. 6}$$

Depending on the density, the combined elevation correction should be around 1 to 2 GU/m.

(**a**) Calculate the relative elevation of the survey station points.

(**b**) Choose an appropriate density for the Bouguer correction. This should correspond to the density between the reference elevation and the observation points.

(**c**) Calculate the combined elevation correction

(**d**) Add the correction to the gravity values.

5. *Final Plots*

The gravity values you have calculated have an arbitrary base level (since they are all relative to an arbitrary elevation, arbitrary latitude, and arbitrary base station). You can subtract or add a constant value to all points to bring the numbers to a suitable level for plotting. Plot the gravity values.

Total Magnetic Field and Vertical Magnetic Gradient Data Reduction

It is necessary to correct the magnetic data for cultural anomalies and, if possible and necessary, for time variations of the magnetic field.

1. Enter all of the magnetic total field and vertical gradient values for both profiles into a spreadsheet. It may be convenient to subtract a constant (such as 50,000 nT) from all values prior to plotting.

2. Plot the raw data from each profile.

3. Remove any spikes in the total magnetic field data that can be definitively related to cultural features (e.g., as noted in log books or as indicated by anomalously high gradient values) and replot the data.

4. Using the appropriate internet sites and base station readings examine the magnetic field variations occurring during the two periods of data collection. Data for the Brandon Magnetic Observatory (49.870° N, 260.026° E) are available at

http://geomag.nrcan.gc.ca/plot-tracee/mp-eng.php?plot_type=magnetic

and the observed magnetic field variations at Brandon are expected to be similar to those at Selkirk. Note that Universal Time (UT) leads Central Daylight Saving Time (CST) by 5 hours. Comment on whether the time variations would have been a significant source of noise in the plotted profiles. If required and possible (i.e., if magnetic variations during the survey can be reasonably approximated in a linear manner or you can use the Brandon data in the case of more complex field variations) apply a time correction to the data, using the same approach as the gravity drift correction.

5. Determine whether there is any significant offset between the two magnetometers (remember that both instruments were at the base station at about the same time). Using the result, merge the two sets of magnetic survey data.