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An illustration of the impact of sampling on precision

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Summary

The R.J. Smith airborne gravity test range at Kauring is used to illustrate the impact sampling has on precision in the context of airborne and ground gravity surveys.

Procedure and results

In sampling theory, measuring a signal at an interval of ***D/2*** is the minimum required to reproduce signals of wavelength ***D***. However, sampling at the minimum interval ***D/2*** is not necessarily sufficient to reproduce a signal of wavelength ***D*** with *precision*. Even if the individual measurements are perfect, the reconstructed signal at wavelength ***D*** can be imprecise when shorter wavelengths bias the longer wavelengths. The magnitude of the error depends on the magnitude of the shorter wavelength signals that are present at each measurement point. For geophysical surveys, a precise measurement point can be an imprecise representation of the surrounding area due to the near-station effects of inhomogeneity.

The ground data from the AG area of the R.J. Smith airborne gravity test range (Daishsat Geodetic Surveyors, 2009) can be used to illustrate this. The free air gravity using all the ground stations with 500 m spacing is shown at left in Figure 1. At right, a 5000 m full-wavelength filter has been applied to the grid to create a 5 km full-wavelength 'regional' gravity field grid.

The ground data are then sub-sampled into five data sets of 2500 m spaced ground stations, offset from each other 500 m in the X and Y directions. The same 5000 m full-wavelength filter is applied to each. This is shown in Figure 2.

Each of these 2500 m spaced regional ground surveys reproduce the long wavelengths of the gravity field well, but there are differences in the shorter wavelengths approaching the 5000 m filter limit. The shorter wavelength signals at the measurement points are biasing the longer wavelengths.

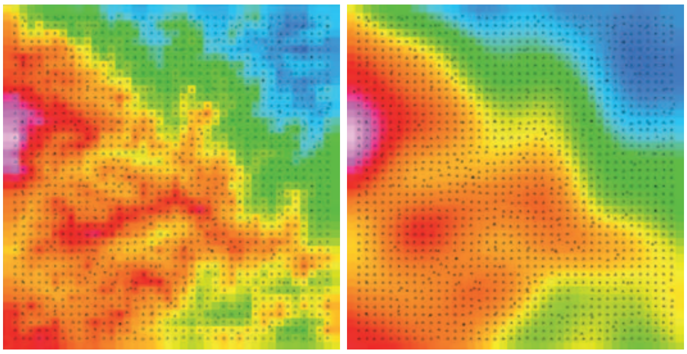

Figure 1. *Free air gravity from ground data stations at R.J. Smith airborne gravity test range.*

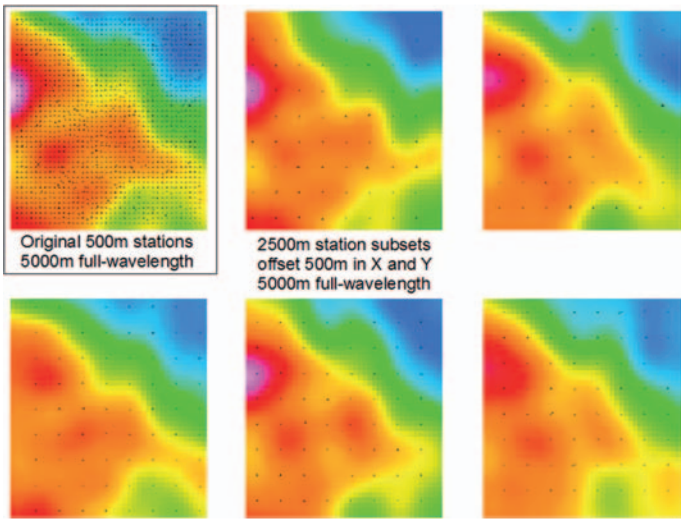

Figure 2. *2500 m station subsets each offset 500 m in X and Y.*

If sampling is increased by having lines of data, precision is improved. This is illustrated in Figure 3 using the ground data. The original 500 m sampling in the Y direction is kept to create lines with 2500 m spacing in the X direction, analogous to flight lines for an airborne survey. The same 5000 m grid filter is once again applied.

While there are still differences between each subset, the increased sampling using these north-south 'lines' visually reproduces the 5000 m wavelengths more consistently.

Quantitatively, the full 500 m spaced ground survey used in conjunction with the 5000 m full-wavelength filter can be considered to be a well-sampled regional 5000 m wavelength 'ground truth'. The standard deviations of the differences between this 5000 m filtered 'ground truth' (highlighted grid on the top left of the preceding two figures) and the collection of more sparsely sampled subsets (the other grids in those figures) are given in the following table (Table 1) in the blue columns.

Table 1. Standard deviations of the differences between the complete and sub-sampled grids

Free air 2500 m points	Free air 2500 m lines	Bouguer 2500 m points	Bouguer 2500 m lines
1.2 mGal	0.7 mGal	0.5 mGal	0.3 mGal

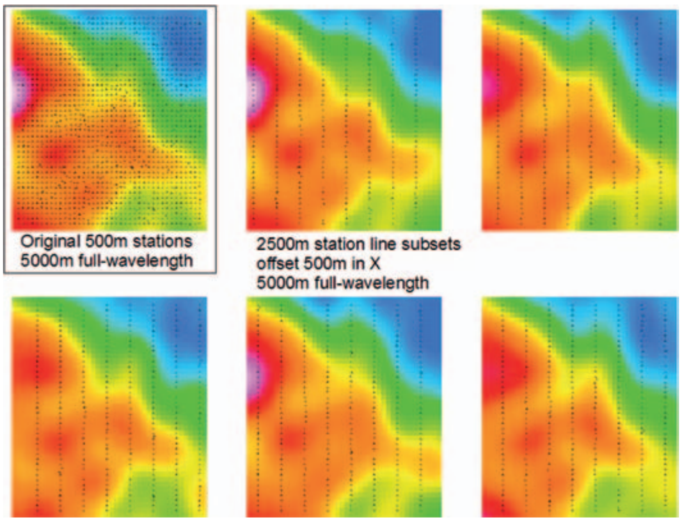

Figure 3. *2500 m station line subsets each offset 500 m in x-direction.*

Even though the individual points making up the subsets have perfect precision in this example, the subsets as a whole do not precisely reproduce the well-sampled 5000 m ‘ground truth’. The lines of data, having sampled the area better, are able to reproduce the ‘ground truth’ with more precision than the grid of points. The differences are reduced when the procedure is repeated for Bouguer gravity (green columns) since the removal of topographic effects reduces the amount of biasing short wavelength signal.

Discussion

In the context of the East Kimberley airborne gravity survey (GSWA 2016, 2017), an AG system with a full-wavelength along line resolution of 5 km and a line spacing of 2.5 km is not truly equivalent to ground gravity stations on a regular 2.5 km grid of observations. The additional sampling along the line direction improves precision of an AG system relative to a regular 2.5 km grid of observation points.

Obviously other considerations come into play, and the noise present in the AG survey lines may offset this intrinsic sampling advantage. This will depend on the specific circumstances of the survey: it is a function of measurement spacing (ground observations and AG line spacing), resolution, the noise present in the AG data, and the nature of the gravity signal itself.

For East Kimberley, results from airborne and ground data appear to be broadly comparable for the survey parameters used. This makes sense if we combine the sampling precision estimated here using Kauring with the estimated instrument measurement precision.

AIRGrav 5000 m full-wavelength profiles have an estimated 0.5 mGal precision. Adding the 0.3 mGal sampling precision estimated above for 2.5 km spaced Bouguer profiles, the combined precision is $\sqrt{(0.5^2 + 0.3^2)} = 0.6$ mGal. Similarly, for 0.02 mGal ground point precision, and adding the 0.5 mGal sampling precision estimated above for a 2.5 km spaced ground measurement grid, the combined precision is $\sqrt{(0.02^2 + 0.5^2)} = 0.5$ mGal. A small additional noise reduction in the AIRGrav grid results from across line reduction of noise because the 2500 m line spacing is within the roll-off of the 5000 m grid filter.

In any case, the 0.02 mGal precision of individual ground measurements should not be viewed as equivalent to the precision of the regional gravity field representation that can be created from those measurements.

Summary

Converting a database of individual ground points into a continuous profile or grid of the gravity field is a necessary step for users who want to work with and interpret the data. The precision of this representation of the gravity field can be significantly less than the precision of the individual measurement points because of sampling.

A profile that samples the gravity field continuously, and which has a low pass filter applied, is not the same as discrete ground points spaced at 1/2 the filter length. The additional along-line sampling and averaging improves the relative precision of the profile.

In the Kauring example, the individual ground points assumed to have perfect precision produced 5 km full-wavelength regional free air and Bouguer grids with 1.2 and 0.5 mGal precision respectively. Using lines of data improved the precision to 0.7 and 0.3 mGal. Including this sampling precision with the instrument measurement precision produces a comparable overall whole-of-survey precision of approximately 0.5 mGal for both the AIRGrav (Sander Geophysics, 2012) and ground data sets.

References

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Biography

Stefan Elieff is a physicist based in Ottawa at Sander Geophysics, specialising in data from the AIRGrav airborne gravity meter. He has a Master of Science in Astronomy from Saint Mary’s University in Halifax, Nova Scotia, Canada.