Full Spectrum Falcon – Measuring wide broadband airborne gravity data

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INTRODUCTION

Gravity measurements are an important tool for exploration and airborne exploration is a very efficient and cost effective means to collect gravity data. Both airborne gravity systems and airborne gravity gradiometer systems measure derivatives of the gravity potential. The size and depth of the exploration targets typically determine which of these technologies is most suitable as each system is better at measuring opposite ends of the gravity spectrum. The error model for airborne gravity (AG) decays as filter wavelengths increase, while the error model for airborne gravity gradiometry (AGG) increases as wavelengths increase (Boggs 2003). Figure 1 illustrates this relationship.

SUMMARY

Full Spectrum Falcon combines a Falcon AGG system and an sGrav AG system to deliver a low noise gravity dataset across all the exploration wavelengths. The noise of the vertical gravity data from an AGG system will increase as its wavelength increases, while the noise from an AG system decreases as wavelength increases. Where these two error responses meet is the wavelength to use in a pair of matched high-pass and low-pass filters to use before merging the two gravity datasets. The two systems have different noise measurements: Difference Noise for the Falcon AGG data and Test Line Repeatibility for the sGrav AG data. These noise estimation methods do not allow for a common noise measurement across both systems. Using a common noise estimation is necessary to determine an appropriate cross-over wavelength. We propose a modified Odd-Even Difference Method as that common measurement of the vertical gravity noise. This approach is demonstrated using results from a recent survey flown in Victoria Australia.

Key words: gravity, gradiometry, airborne, Falcon, sGrav

To combine the data, we apply matched high-pass and low-pass filters to the Falcon vertical gravity and the sGrav vertical gravity respectively. The Full Spectrum Falcon gravity product is the sum of these two filtered datasets ensuring the lowest error model while maintaining the most consistent measurement of the gravity spectrum. This process only requires choosing the best wavelength to use for the matched filter pair.

The best wavelength is the one at the cross-over point illustrated in Figure 1. In order to correctly choose this wavelength, we
require an understanding of the gravity data errors of each system at various wavelengths. With these error values, we re-create the two curves in Figure 1 and determine the cross-over wavelength. This evaluation needs to be done using the same error measurement. The Odd-Even Difference method is an ideal way to produce this common error measurement.

CGG recently completed the first Full Spectrum Falcon survey for the Geologic Survey of Victoria. Both AGG and AG data were collected at the same time on the same aircraft. The AGG system was a Falcon AGG and the AG system was an sGrav. The data will be used as an example to understand how the Full Spectrum Falcon data is measured, verified for quality and combined. The survey was flown along the southern coast of Victoria near the city of Warrnambool. The survey covered an area of 15,000km² at a line spacing of 500m.

SHORTER WAVELENGTH GRAVITY

The Falcon AGG system delivers the lowest noise gravity gradiometry data. By either integrating the gradient signal or using an equivalent source technique, the vertical gravity signal can also be derived. The limiting factor to either of these approaches is that the response at wavelengths greater than half the survey dimension is not accurate. Based on comparisons to ground gravity, the error model for Falcon derived gravity is 0.1 mGal / √km (Boggs 2003). This error model is dependent on the noise level of the measured gradient signal. The Falcon AGG system was purposely built to have two separate, near horizontal gradiometers incorporated into the design. The near horizontal design reduces the noise effect from standard aircraft turbulence. These vertical accelerations cause most of the noise in the predecessor AGG systems. The dual gradiometer design allows for continuous measurement of uncorrelated noise in the acquired data. Using these separate measurements, the overall noise for any survey is determined using the Falcon Difference Noise method (Christensen 2015). This method differences each of those two measurements to give an error channel and the Noise is defined to be half the standard deviation of that error channel. The results from this analysis are shown in Figure 2 plotted against turbulence. The average noise for the survey was 1.8E. Using these measured curvature components, the Falcon derived free air anomaly vertical gravity results from the survey are shown in Figure 3.

LONGER WAVELENGTH GRAVITY

The sGrav is a strapdown gravimeter that measures the long to medium wavelength gravity signal. It incorporates both a navigation grade inertial navigation system and CGG’s proprietary processing software to produce the gravity data necessary to complement the Falcon system. For the sGrav data, one of the industry standard methods is to have a test line that is flown at regular intervals throughout the survey in order to verify the repeatability of the gravity data. For operational reasons, three different test lines were used during the acquisition of this survey. The lines were all 50km in length and the data was filtered at 20km, 25km, 30km and 40km. A mean line is calculated by averaging the results of all the individual passes. Each of the individual passes is differenced from the mean line to give a set of residuals for each line. The repeatability of a gravity system is the standard deviation of those residuals. The repeatability for one of the repeat lines is shown in Figure 4. The repeatability of the sGrav on that line was measured to be 1.0mGal at 25km. The sGrav free air anomaly vertical gravity results from the survey are shown in Figure 5.
Figure 4. The repeatability results from one test line. Each pair of results shows all the passes of the repeat line and the mean line is a thicker black line. Each pass is differenced from the mean line to give the residuals plot. The top pair shows the results using a 5km low-pass filter; a repeatability of 1.7 mGal; the center pair shows the results using a 20 km low-pass filter; a repeatability of 1.1 mGal; the bottom pair shows the results using a 25 km low-pass filter; a repeatability of 1.0 mGal.

Figure 5 – This shows the sGrav measured free-air vertical gravity results.

NOISE EVALUATION

Full spectrum Falcon delivers a vertical gravity product that merges both the Falcon vertical gravity and sGrav vertical gravity to provide a low noise gravity product across all the exploration wavelengths. The Falcon vertical gravity is high-pass filtered and the sGrav vertical gravity is filtered using the matching low-pass filter. To ensure the most appropriate cross-over wavelength is chosen for the matched filter pairs, the noise needs to be directly compared. This requires a separate noise evaluation method that directly compares the vertical gravity data from each type of system.

One method to directly compare airborne gravity data is the Odd-Even Difference Method (Sander 2002). This method requires taking the complete database and splitting it into two separate databases of alternating lines (one set of odd numbered lines and the other of even lines). The entire data processing procedure is applied to each separate database and the two outcomes (one using the odd line database and one using the even line database) are differenced. As the difference is related to half the available data points, the Odd Even Difference Noise result is the standard deviation of that difference divided by $\sqrt{2}$.

To determine the best cross-over wavelength, we slightly modify this method. Using the outputs of the odd and even vertical gravity data, we apply a high-pass filter to the Falcon vertical gravity and a low-pass filter to the sGrav vertical gravity using the same cut-off frequencies. Calculating the Odd-Even Difference Noise value for a range of wavelengths in the range of 20km to 40km, we can build the corresponding error curves illustrated in Figure 1. The results are shown in Figure 6. The analysis shows that the most appropriate cross-over wavelength is about 30km and that using that will result in gravity noise under 0.6mGal for any wavelength in the spectrum of the acquisition.
Full Spectrum Falcon delivers the lowest gravity noise data available. It combines a Falcon AGG system to measure the short to medium wavelengths and an sGrav to measure the medium to long wavelengths. The AGG data is high-pass filtered and the AG data is low-pass filtered using a pair of matched filters (Figure 7). The Full Spectrum Falcon data is created by adding the two filtered products (Figure 8). Both AG and AGG systems have independent measurements of noise, but in order to benefit most from the combination of their measured gravity data, we require a common measurement. We introduce a slightly modified version of the Odd Even Difference Method to give that common and direct measurement of noise at various cross-wavelengths. The point at which the AG and AGG noise curves meet is the most appropriate cross-over point. In the case of this survey, the most appropriate cross-over wavelength for this survey was found to be about 30km and that ensures that the gravity noise is under 0.6mGal across the spectrum of gravity response in the data.

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REFERENCES


