Advances in SGL AIRGrav acquisition and processing

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Abstract

Sander Geophysics (SGL) has operated its AIRGrav airborne gravity system for over ten years and continues to work to improve the accuracy and resolution of the entire system. Recent advances in SGL's gravity data processing methods, involving advanced analysis of system dynamics and improved filtering, have enhanced the gravity data. These new processing procedures help to further reduce system noise and allow high quality, low noise raw gravity data to be acquired through a wider range of survey conditions than was previously possible. New data processing techniques have also allowed the extraction of the horizontal gravity components of the airborne gravity data in addition to the traditionally used scalar gravity measurement.

Introduction

Airborne gravity data have been collected since the late 1950's (Thompson and LaCoste, 1960). In the late 1990's, improvements in GPS processing and the introduction of a new gravity instrument, the AIRGrav system (Argyle et al., 2000) resulted in a significant reduction in airborne gravity noise levels. To date, more than 2,500,000 line km of AIRGrav data have been collected on surveys flown throughout the world.

'Standard processing'

The AIRGrav system uses three orthogonal accelerometers, mounted on a three-axis, gyroscopically stabilized platform in conjunction with a specialized data acquisition system to monitor and record the data and parameters measuring gravimeter performance. In this paper, 'standard airborne gravity data processing' refers to a sequence of processing steps that includes the subtraction of the vertical accelerations of the aircraft that are measured using high quality differentially corrected GPS data from the vertical accelerations measured by the gravimeter, and the application of standard corrections to remove the effects of the rotation of the Earth, the movement of the platform over the globe, and terrain effects (Sander et al., 2004). Standard processing techniques have proven successful at extracting gravity data from the very dynamic aircraft environment where accelerations can reach 1 m/s^2, equivalent to 100,000 mGal. High precision differential GPS processing techniques and a robust gravimeter system have resulted in final processed gravity grids with noise estimates of 0.1 to 0.3 mGal with a resolution of 2 kilometres.

'Enhanced processing'

A processing procedure, which we will call 'enhanced data processing', that involves advanced analysis and improved filtering, has been added to the data processing stream to lower the noise and improve the resolution of the gravity data. An airborne survey for hydrocarbon exploration was flown using the AIRGrav system installed in one of SGL's Cessna Grand Caravans. Data from this project were processed using the standard technique described above as well as the enhanced processing method, allowing a direct comparison to be made using the two resulting data sets.

On this project, a repeat test line was flown before and after each flight. An average test line response was computed by combining the data from each test line filtered using a 56 second line filter to create an "air truth" value for the test line in the manner described by Elieff and Ferguson, (2008). The RMS error for each individual test line was then calculated based on the difference in response for this pass along the test line and the average response. These calculations were repeated for data processed both in the standard and enhanced methods. The line data processed using the enhanced method shows better repeatability for all test lines. The average standard deviation for the test lines processed using standard processing was 1.26 mGal, whilst it was 1.08 mGal for the test lines processed using the enhanced method.

Data for this project were gridded and filtered using a range of low pass grid filters to evaluate the noise levels and the signal content. For this project, a detailed set of ground gravity data were available over part of the survey area. Figures 1 and 2 show the area of overlap, which is approximately 30 km by 30 km in size, and is covered by 2,200 line km of AIRGrav data acquired with 400 m line spacing, and 10,000 ground gravity points. The actual AIRGrav survey was much larger in size, but is not shown due to the client's request for confidentiality. Gridded ground gravity data were compared to the grids created from the airborne data with different filter lengths as an additional evaluation step. For both the standard processed data and enhanced processed data, a 1.25 km frequency domain spatial low pass filter was applied to gravity grids generated from 20 second filtered line data.
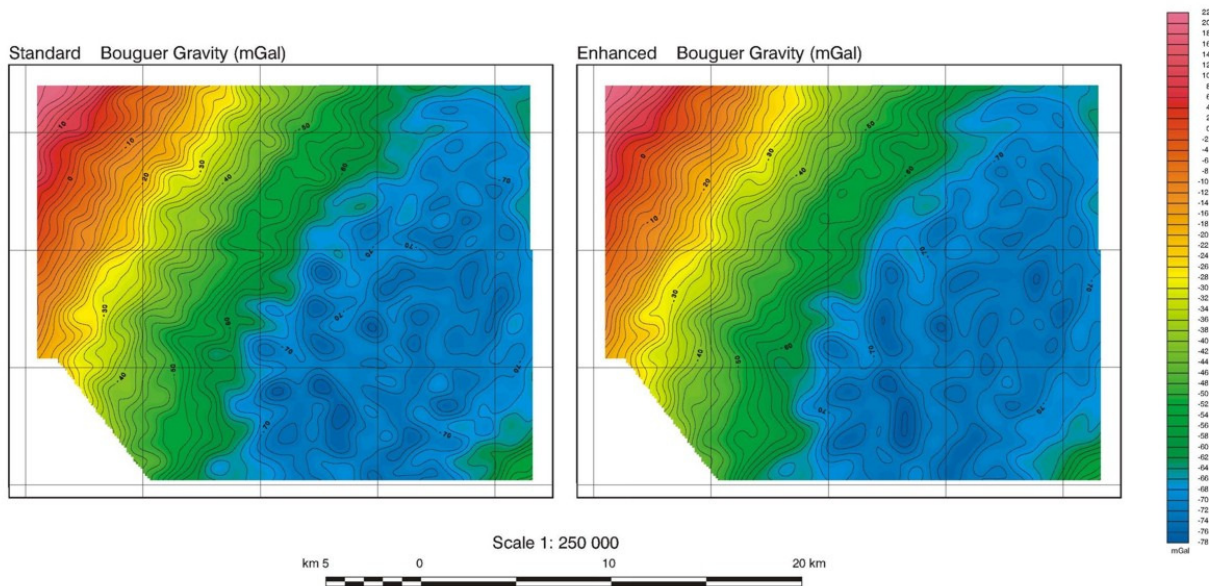

Figure 1: AIRGrav Bouguer gravity grids

A first vertical derivative of each gravity data set was calculated in order to remove the long wavelength regional field and to emphasize the higher frequency anomalies which are closer to the grid filter length (Figure 2). The enhanced grid shows a stronger correlation with the ground gravity grid, in particular with the higher frequency features in the regions with the highest density ground gravity coverage.
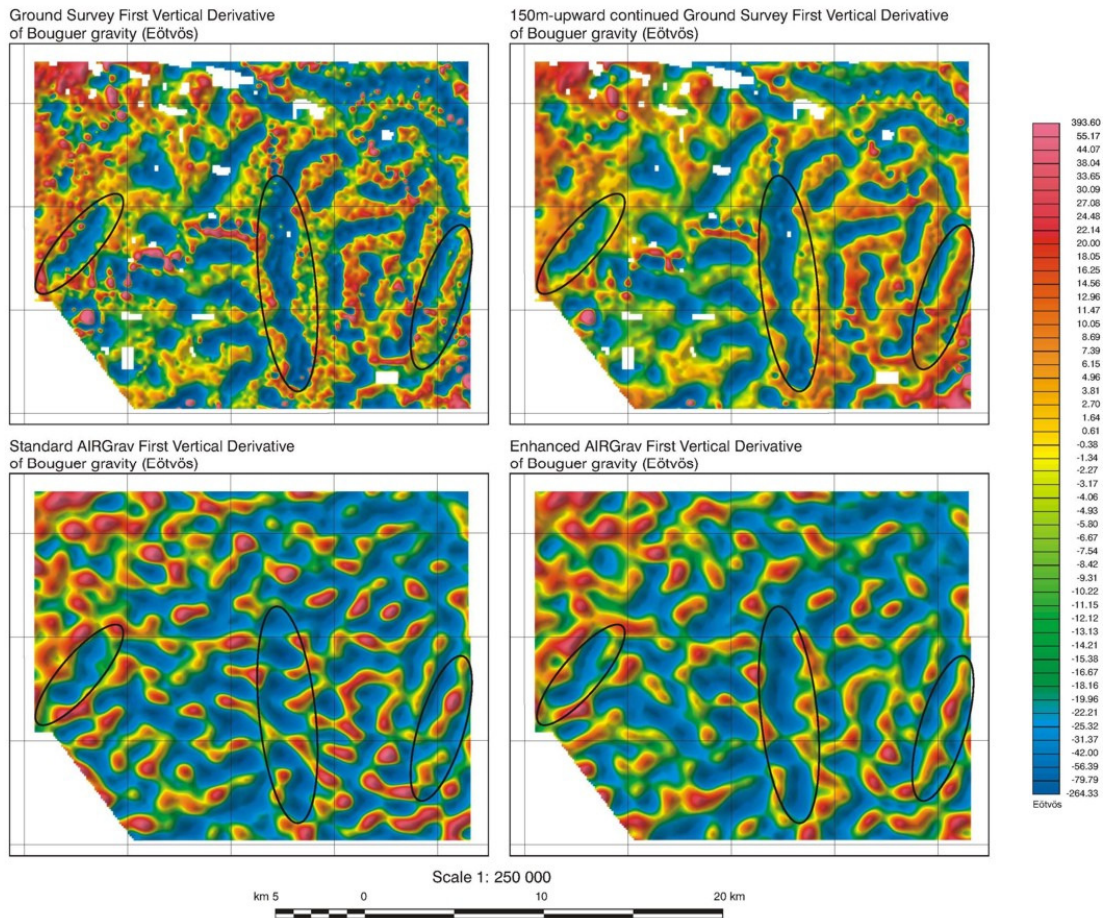
Figure 2: First vertical derivative grids of AIRGrav and land gravity data

Helicopter-mounted AIRGrav system

Airborne gravity data have traditionally been used to define regional scale geology, an application for which standard acquisition parameters using a fixed wing aircraft were adequate. However for mineral exploration, a higher resolution data set is preferable. Recently, the AIRGrav system was installed in a helicopter and six small survey blocks were flown at an extremely slow acquisition speed (30 knots, equivalent to 56 km/hr or 16 m/s, compared to typical fixed wing aircraft airspeed of 100 to 140 knots, equivalent to 185 to 260 km/hr or 50 to 72 m/s) with tight (50 m) line spacing. Scanning laser elevation data were concurrently acquired in order to create a high resolution 1 m grid cell size digital terrain model. This configuration, coupled with the enhanced processing technique, resulted in a gravity data set that met the requirements of this mineral exploration project with an accuracy of 0.4 mGal at a 300 m resolution. The accuracy was calculated using the even-odd grid comparison method (Sander et al., 2002). Figure 3 shows the gravity data superimposed on the derived terrain model for a small region of the survey. The results and interpretation of the data from this survey are discussed in greated detail by Baranyi and Ellis (2010).
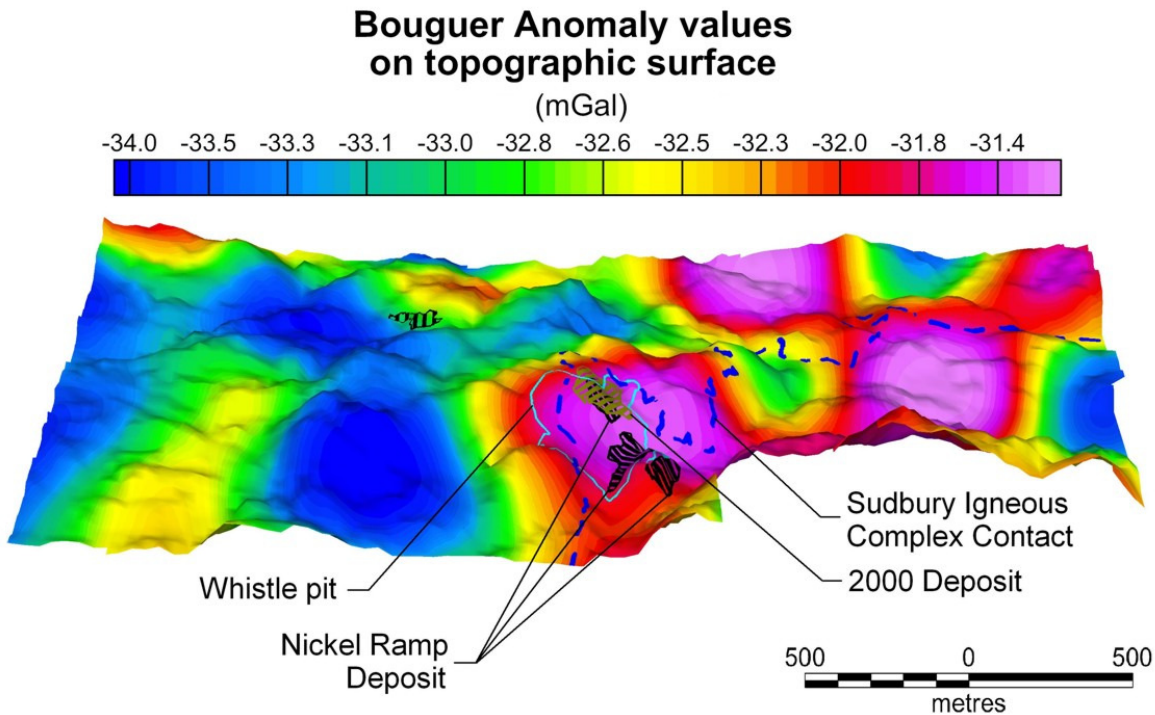
Figure 3: Bouguer gravity anomaly values for the helicopter-mounted AIRGrav survey of the Podolsky Mineral Exploration Project (300 m resolution gravity data).

Horizontal gravity components

Six passes along a repeat line of about 95 km length were flown with the AIRGrav system installed in a Cessna Grand Caravan close to Alexandria, Ontario, with three passes made in each direction,. The test successfully demonstrated that the three spatial components of the gravity vector, or equivalently, the deflection of the gravity vector can be measured with high repeatability using the AIRGrav system and that the measured horizontal components agree well with geoid models of the highest order available. Data were processed using the enhanced procedure to extract the three gravity components, using AIRGrav data recorded at a 128 Hz rate and GPS data recorded using two aircraft receivers on different antennas, and a reference GPS ground station.

Ambiguity between the orientations of the Inertial Navigation System (INS) and the Earth reference frames was resolved by relating the AIRGrav data to CGG05 model data. Bias and drift for the data acquired on each pass were removed using a simple linear fit to the CGG05 reference data. The mean value of the standard deviation of the agreement of the AIRGrav East component data with the mean AIRGrav data for the six repeat lines was 0.286 mGal whilst the value of this statistic for the North component data was 0.344 mGal. Profiles of the East component data for the six repeat lines are shown in Figure 4.

The corrected mean AIRGrav East component data were compared to the East component gravity data calculated from two geoid models, the Canadian Gravimetric Geoid 2005 (CGG05; Huang and Véronneau, 2005) and the Canada HT2 geoid model (based on the CGG2000 geoid model; Véronneau, 2001) as well as to gravity components from the Earth

Gravitational Model 2008 (EGM2008; Pavlis et al., 2008). Figure 5 shows the profile data and Table 1 lists the difference statistics. From these results we can conclude that the AIRGrav system has a repeatability better than the agreement of its estimates with the model data. The consistency of the short wavelength data in the AIRGrav data shows greater detail than the model data.
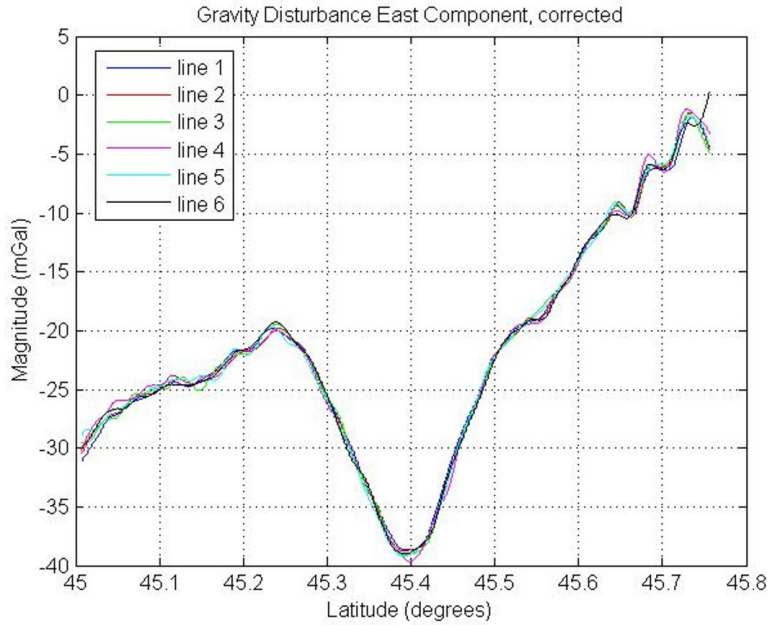

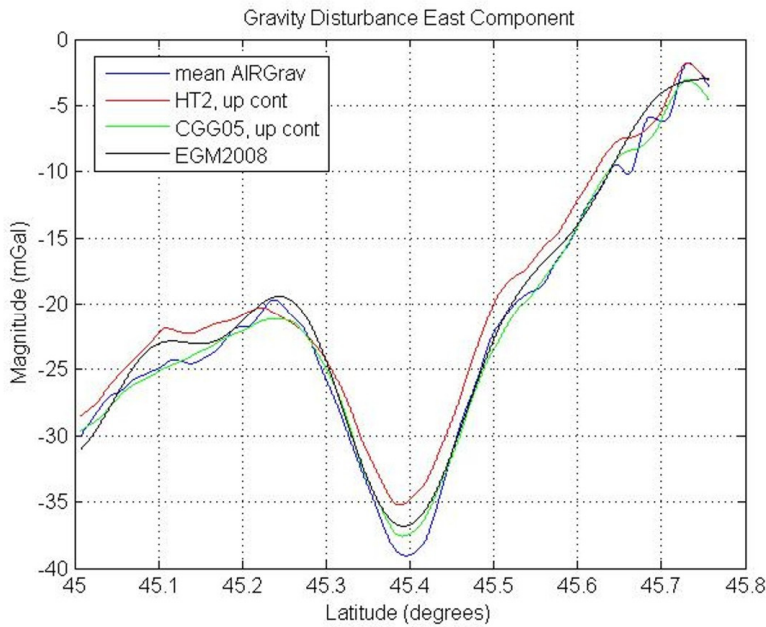*Figure 4: Gravity East Component, Alexandria Repeat Line.*

Figure 5: AIRGrav mean East component vs Models.

	Mean (mGal)	Standard Deviation (mGal)
Mean AIRGrav - HT2	1.734	1.193
Mean AIRGrav - CGG05	0.000	0.796
Mean AIRGrav - EGM2008	0.737	0.937
CGG05 - EGM2008	0.737	0.775

Table 1: Statistics of gravity East component comparisons.

Conclusions

Recent advances in SGL's gravity data processing methods have been shown to produce higher quality, lower noise gravity data. Modified survey design parameters involving the use of a helicopter rather than a fixed wing aircraft have been used to acquire data for a mineral exploration project resulting in an accuracy of 0.4 mGal at a 300 m resolution. The new processing techniques have also allowed horizontal gravity components of the airborne gravity data to be extracted.

Acknowledgements

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