Results from FALCON® Airborne Gravity Gradiometer surveys over the Kauring AGG Test site

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SUMMARY

The Kauring Test Site in Western Australia was established in 2009 to provide a public benchmarking and comparison venue for new and existing airborne gravity and airborne gravity gradiometry (AGG) technology.

Fugro Airborne Surveys flew the fixed-wing FALCON® AGG system over the Kauring AGG Test Site over three periods in July 2011, November 2011 and February 2012.

Comparison between the FALCON AGG survey data and the high resolution ground gravity data over the Kauring AGG Test site indicates that the FALCON vertical gravity gradient, G_{DD}, has an error of $^{+}$/- 5.6 Eo, and that the FALCON vertical gravity, g_D, has an error of $^{+}$/- 0.18 mGal,.

Comparison between the digital elevation model (DEM) derived from the fixed wing FALCON survey laser scanner data, and a high-resolution third party DEM, indicates that the error of the vertical position of the FALCON differential GPS is less than 0.5m. At 60m terrain clearance this corresponds to a subsequent error in AGG terrain correction of less than 2 eotvos. This terrain correction error is well within the Kauring AGG Test Site FALCON survey noise envelope of 5.6 Eo.

Key words: Kauring Test Site, FALCON, Airborne Gravity Gradiometry, AGG, Airborne Gravity, AG, Digital Elevation Model, Digital Terrain Model.

THE KAURING TEST SITE

The Kauring Airborne Gravity (AG) and Airborne Gravity Gradiometry (AGG) Test Sites are located 115 km ENE from Perth's Jandakot Airport in Western Australia (Howard et al., 2010). The test sites were established in 2009 as a benchmark for testing established and emerging AG and AGG technologies against a comprehensive high resolution ground gravity data set.

The sites are located in a farming region around the hamlet of Kauring with gently rolling hills with some erosional incisions with an overall topographic relief of 115m.

An outer 25km by 25 km area has been surveyed extensively with ground gravity at 500m by 500m station spacing. This provides a test bed for AG systems which typically has a minimum spatial resolution in excess of 1,500m full wavelength. Within the central part of the AG test range, a smaller 5km by 5km AGG test range has been established with ground gravity at a station spacing increasing from 100m by 250m, in the northern and southern periphery, to 50m by 50m station spacing in the central part of the AGG test range (Figure 1). The variable station spacing is designed to accommodate both fixed wing and helicopter borne AGG systems, of which the fixed wing FALCON AGG system has spatial resolution of 300m full wavelength and the HeliFALCON system has a spatial resolution of 100m full wavelength (Dransfield, 2007).

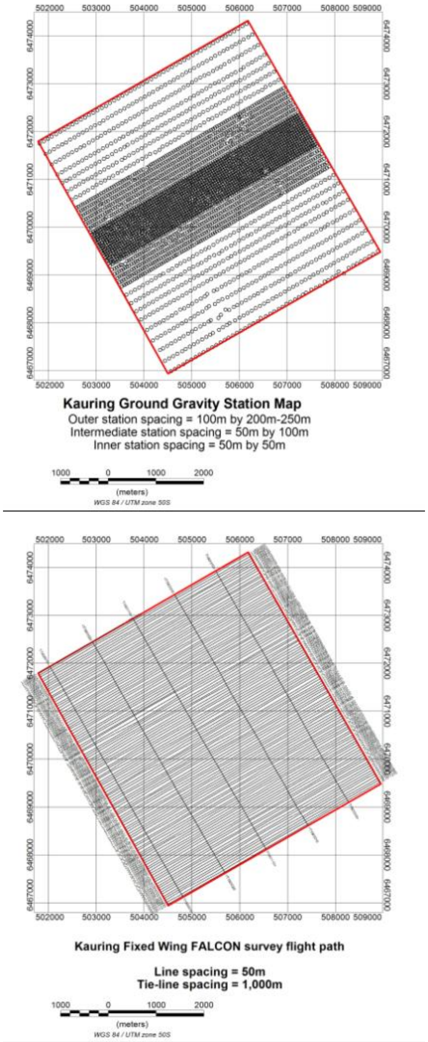

Figure 1. (*Top*) Map of the ground gravity stations in the Kauring AGG test site. (*Bottom*) Map of the FALCON survey flight path over the Kauring AGG test site.

THE FALCON AGG SYSTEM

BHP Minerals (now BHP Billiton) developed the FALCON AGG system in the 1990's in conjunction with Lockheed

Martin (van Leeuwen, 2000). Lee (2001) summarises the key features of the AGG instrumentation.

FALCON AGG was the first airborne gravity gradiometer system specifically designed with noise and resolution characteristics suited to minerals exploration (Dransfield and Lee, 2004). Test flights took place in 1999 and the first system commenced a production survey later that year. Five airborne FALCON AGG systems have since acquired over two million line-km of data over a range of exploration deposit styles on five continents. The systems were sold to Fugro Airborne Surveys in 2008, and are now offered to the industry on a commercial basis.

DATA ACQUISITION AND PROCESSING

Fugro Airborne Surveys flew the fixed-wing FALCON AGG system in a Cessna 208 Grand Caravan over the Kauring AGG Test Site over three periods in July 2011, November 2011 and February 2012. The purpose of the survey was to assess and demonstrate the accuracy of the FALCON AGG system against the high resolution, public domain, ground gravity data set. The site was flown with 50m line spacing and 1,000m tie-line spacing as a draped survey with a nominal terrain clearance of 70m (Figure 1). The RMS turbulence for the survey was moderate at 66 milli-g, yet average RMS difference noise levels in the measured G_{NE} and G_{UV} gravity gradiometer component data were only 2.3 eotvos.

The transformation of the measured G_{NE} and G_{UV} gravity gradient components to vertical gravity, g_D, and vertical gravity gradient, G_{DD}, was performed by standard potential field Fourier integration and derivative techniques (in the spatial and wave-number domains) onto the aircraft drape surface. The FALCON AGG data and the ground gravity data have been fully terrain corrected with a terrain density of 2.67 g/cm^3.

In order to effectively compare the FALCON vertical gravity, g_D, with the vertical ground gravity, it is necessary to upward continue the vertical ground gravity from the ground surface to the aircraft drape surface.

Likewise in order compare the FALCON vertical gravity gradient, $G_{DD,}$ data with the computed vertical gradient ground gravity, it is necessary to upward continue the vertical gradient ground gravity from the ground surface to the aircraft drape surface.

A method to effectively upward continue potential field data between two arbitrary surfaces by means of equivalent sources has been proposed by Xia et al. (1993). I have used the USGS software implementation of this method (Phillips, 1996 & 1997) in the work presented here.

SURVEY RESULTS

A map of the FALCON vertical gravity gradient, G_{DD}, is shown in Figure 2. The central part of the AGG Test Site is host to a distinct vertical gravity gradient anomaly exceeding 80 Eo at the northern limit of a NW-NNW striking linear vertical gravity gradient high. For comparison Figure 2 also shows a map of the corresponding vertical gradient of the vertical ground gravity, as derived from the original vertical ground gravity data using equivalent source methods and subsequently variably upward continued to the aircraft drape surface, again by equivalent source methods. Both data sets have been low-pass filtered with a 2nd order Butterworth filter with a cut-off wavelength of 300m.

There is good correspondence between the FALCON vertical gravity gradient, G_{DD}, and the corresponding upward continued vertical gradient of the vertical ground gravity; not only along the high amplitude central structure, but also with more subtle NE-SW trending features of lesser amplitude. This general correspondence is reflected in the final map in Figure 2 showing the difference between the FALCON vertical gravity gradient, G_{DD}, and the corresponding upward continued vertical gradient of the vertical ground gravity. The range of the difference map is [-24Eo, 27Eo], the mean is 0.0 Eo and the standard deviation of the difference map is 5.6 Eo.

A map of the FALCON vertical gravity, g_D, is shown in Figure 3. The central anomaly in the AGG Test Site corresponds to a vertical gravity anomaly exceeding 1.6 mGal. For comparison Figure 3 also shows a map of the corresponding vertical ground gravity variably upward continued to the aircraft drape surface, again by equivalent source methods. For comparison both data sets have been low-pass filtered with a 2nd order Butterworth filter with a cut-off wavelength of 300m, and both data sets have had any first order trend removed.

Again there is good correspondence between the FALCON vertical gravity, g_D, and the corresponding variably upward continued vertical ground gravity. This general correspondence is also reflected in the final map in Figure 3 showing the difference between the FALCON vertical gravity, g_D, and the corresponding upward continued vertical ground gravity. The range of the difference map is [-0.52mGal, 0.58mGal], the mean is 0.0 mGal and the standard deviation of the difference map is 0.18 mGal.

COMPARISON OF DIGITAL ELEVATION MODELS

In addition to the extensive ground gravity coverage, a 1m-cell DEM over the Kauring AGG Test Site is provided by Fugro Spatial Solutions from an airborne laser scanning (LiDAR) survey flown in October 2009. The point elevations have an estimated horizontal accuracy of 0.16 m and an estimated vertical accuracy of 0.05 m (Howard et al., 2010). This DEM was used terrain correcting the Kauring FALCON AGG survey data.

The FALCON AGG system also has on-board laser scanner and differential GPS capability to record and construct DEM for terrain correction of the FALCON AGG data, when no other DEM is available. The access to an independent, third party, high resolution DEM allows me to assess the accuracy of the FALCON DEM.

Figure 4 shows the comparison between the FALCON derived DEM and the DEM derived from the dedicated LIDAR survey flown by Fugro Spatial Solutions in 2009. The difference map indicates that the error in the vertical position of the FALCON DEM is less than 0.5m. A vertical error of less than 0.5m at 60m terrain clearance will result in an error in AGG terrain correction of less than 2 Eo (Dransfield and Zeng, 2009), which is below the Kauring AGG Test Site FALCON survey noise of 5.6 Eo.

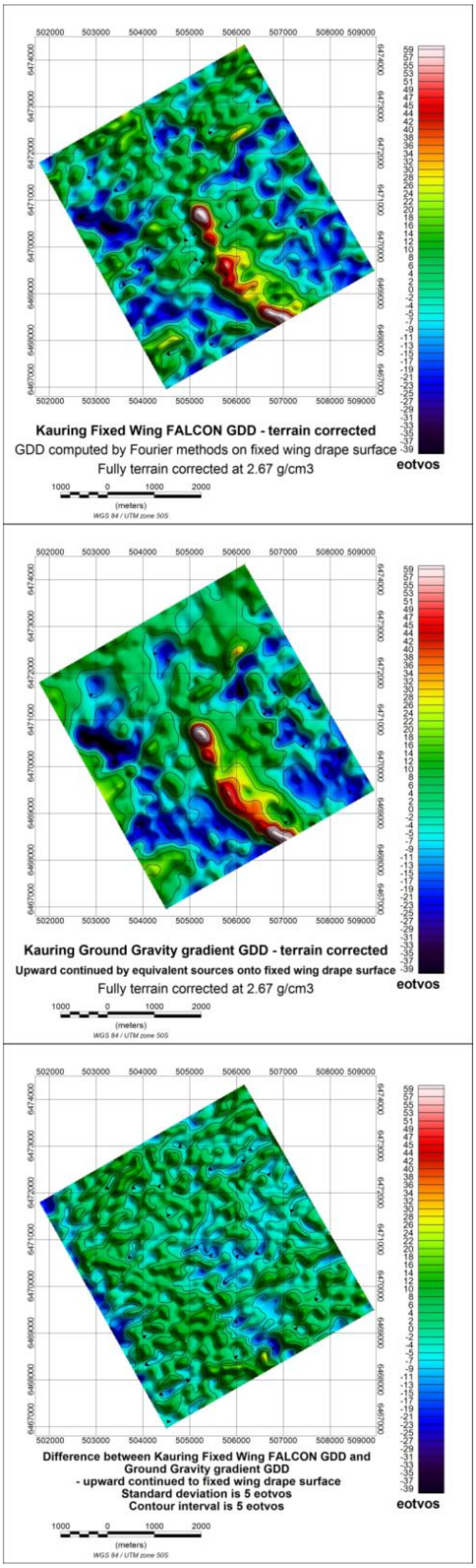

Figure 2. (*Top*) Map of FALCON G_{DD} vertical gravity gradient. Contour interval is 10 Eo. (*Centre*) Map of the vertical gradient of the vertical ground gravity, variably upward continued to the aircraft drape surface, derived by equivalent source methods. Contour interval is 10 Eo. (*Bottom*) Map of the difference between the FALCON G_{DD} vertical gravity gradient and the upward continued vertical gradient of the vertical ground gravity. The standard deviation of the difference is 5.6 Eo.

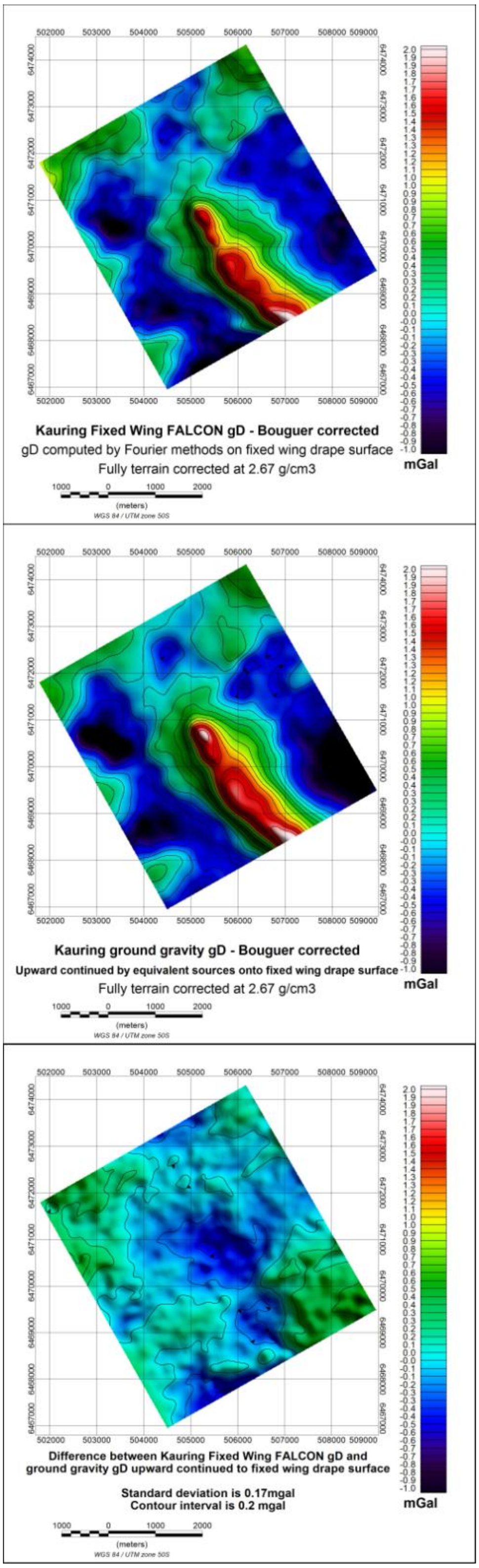

Figure 3. (*Top*) Map of FALCON g_D vertical gravity. Contour interval is 0.2 mGal. (*Centre*) Map of the vertical ground gravity, variably upward continued to the aircraft drape surface, derived by equivalent source methods. Contour interval is 0.2 mGal. (*Bottom*) Map of the difference between the FALCON g_D vertical gravity and the upward continued vertical ground gravity. The standard deviation of the difference is 0.18 mGal.

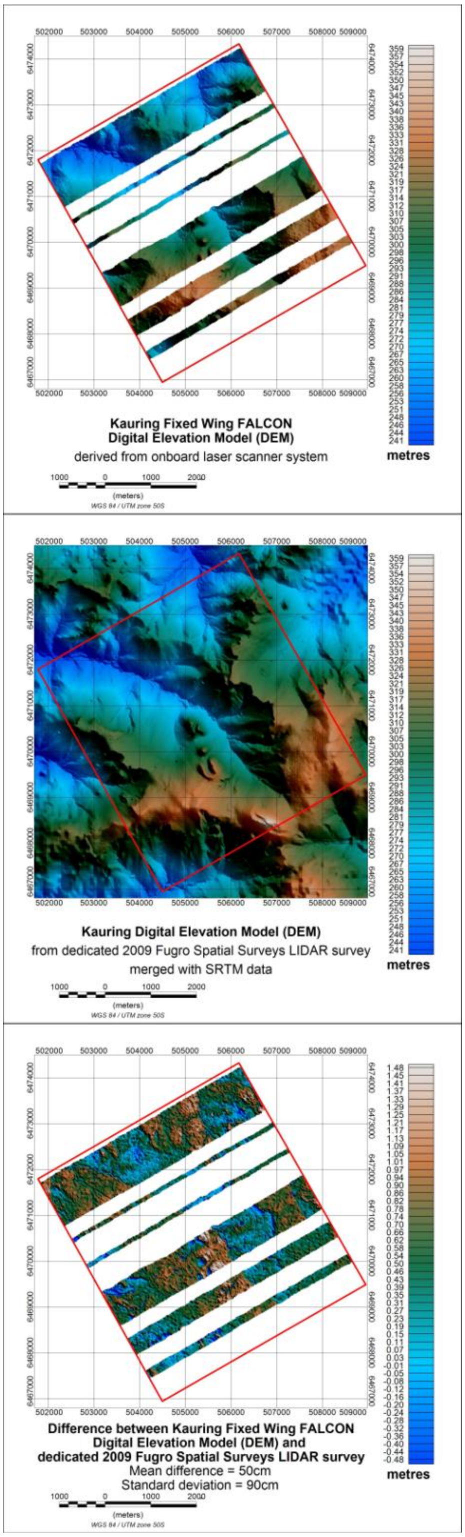

Figure 4. (*Top*) Map of the FALCON DEM derived from on-board laser scanner and differential GPS readings. Laser scanner data was only acquired for part of the test survey. (*Centre*) Map of DEM derived from a dedicated LIDAR survey flown by Fugro Spatial Solutions in 2009 and merged with lower resolution SRTM data. (*Bottom*) Difference map between the FALCON DEM and the high resolution DEM from the dedicated LIDAR survey. The error in the vertical position of the FALCON DEM is less than 0.5m.

CONCLUSIONS

Comparison between the FALCON AGG survey data and the high resolution ground gravity data over the Kauring AGG Test site indicates that the FALCON vertical gravity, g_D, has an error of $^+$/- 0.18 mGal, and that the FALCON vertical gravity gradient G_{DD} has an error of $^+$/- 5.6 eotvos. Comparison between the FALCON derived DEM and a third party LIDAR DEM indicates that the error of the vertical position of the FALCON differential GPS is better than 0.5m. At 60m terrain clearance this corresponds to a subsequent error in AGG terrain correction of less than 2 eotvos. This terrain correction error is well within the Kauring AGG Test Site FALCON survey noise envelope of 5.6 eotvos.

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