Results from SGL's AIRGrav airborne gravity system over the R.J. Smith test range at Kauring

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1. INTRODUCTION

Accurate information about the performance of different airborne gravity (AG) and airborne gravity gradiometer (AGG) systems is needed to make sound decisions when choosing an appropriate technology to meet the objectives of a given survey. A broad generalization, that AGG systems are best suited to shorter wavelength, shallower, point-source features, while AG systems hold an advantage at longer wavelengths and deeper targets, is of limited use since there is a wide range of perceptions about what 'shorter' and 'longer' means. In addition, generalizations obscure significant variations in the characteristics of individual AG and AGG systems. System performance tests can provide some clarity.

- **Side-by-side testing in the same aircraft** provides the most direct comparison of instruments, eliminating variability created by different survey design and flying conditions. For example, a side-by-side independent test of a Sander Geophysics AIRGrav and Canadian Micro Gravity GT-1A gravimeter was conducted which demonstrated the AIRGrav system was able to acquire more accurate data and was able to do so in a wider range of flight conditions (Studinger et al., 2008). The practical difficulties in arranging these kinds of tests make them rare.

- **Repeatability tests** are more commonly used as they are relatively easy to perform. The noise characteristics of the AIRGrav system were examined using 100 passes of a test line acquired over 10 years in Elieff and Ferguson (2008) and compared with noise estimates from survey data. Both the repeat lines and survey data consistently show accuracies in the 0.1 - 0.3 mGal range for spatial resolutions of 1.4 - 4.5 km, depending on survey design.

- **Ground gravity test areas** allow comparisons to be made to the ground data and between different instruments flown over the area. The R.J. Smith gravity test site at Kauring in Western Australia is an excellent tool for the analysis of airborne gravity and gradiometer systems because of the publicly available, high quality, independently acquired ground gravity data at the site (Howard et al., 2010).

2. KAURING SURVEY AND RESULTS

- An AIRGrav airborne gravity system was flown over Geoscience Australia's Kauring airborne gravity test site with the following specifications:
  - Kauring site: Detailed ground data sampled in the inner-most 5x5 km region (the "AGG area"), 500 m stations in a wider 20x20 km region (the "AG area").
  - AIRGrav survey design: AGG area flown with 50 m line spacing, AG area flown with 200 m line spacing.
  - AIRGrav acquired using a fixed wing aircraft flying 180 km/h, using a terrain-following drape flying surface, minimum ground clearance of 80 m, and in normal daytime turbulence conditions.
  - 600 m (AGG area) and 1000 m (AG area) half-wavelength low pass filters were chosen for the AIRGrav data. The low pass filter sets the resolution limit of the data.

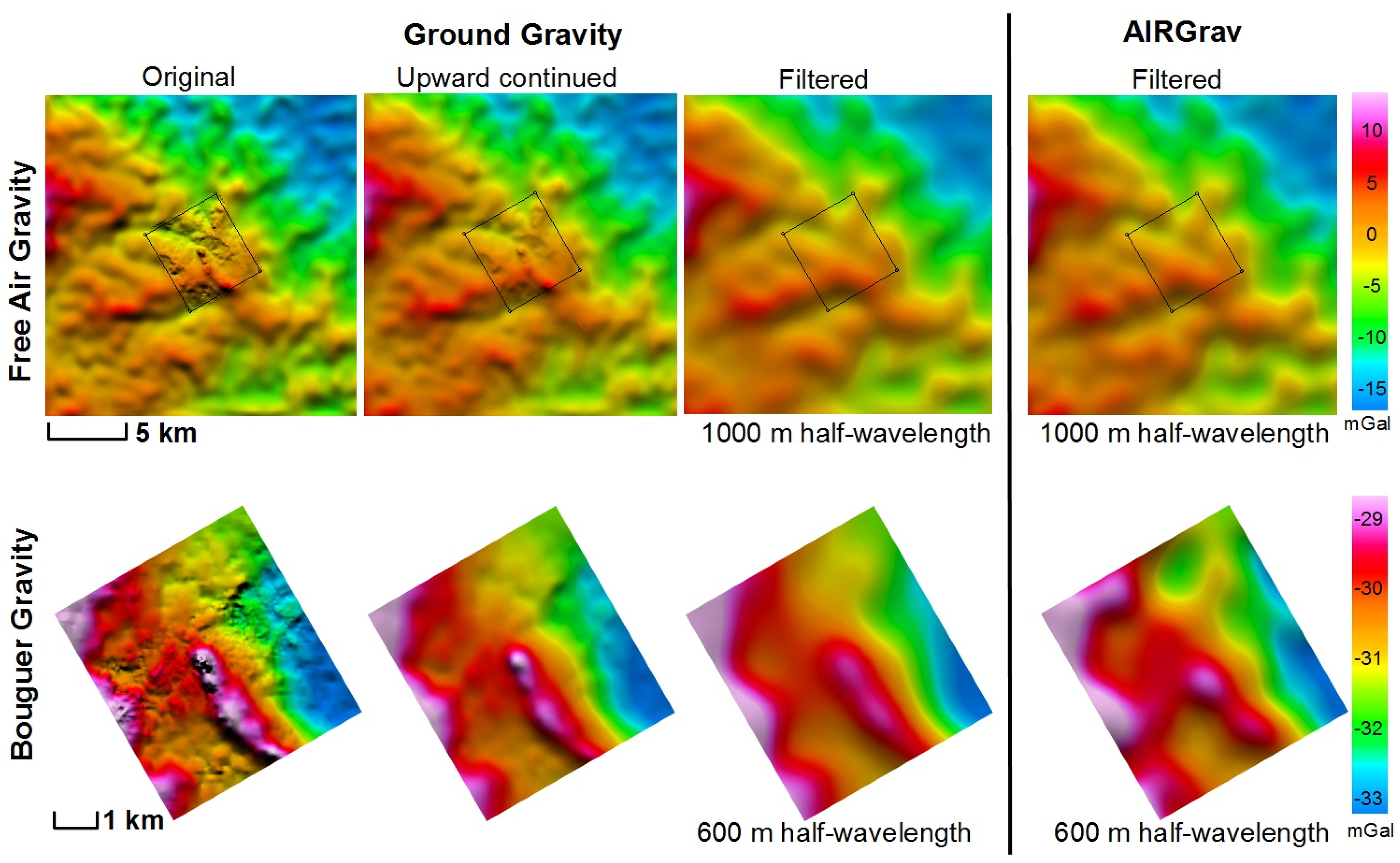
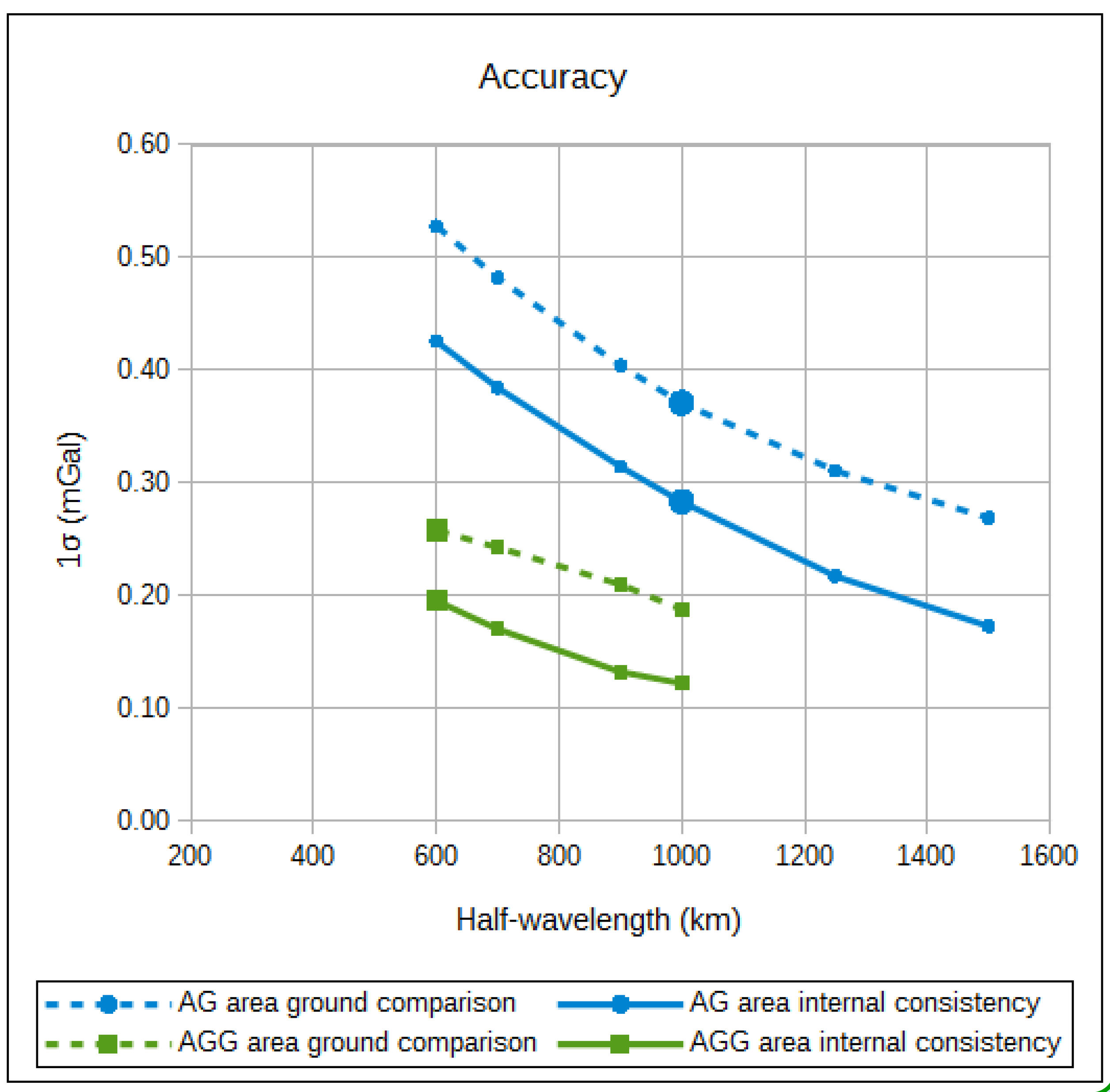


Figure 1: Ground and airborne free air gravity for the wider AG area (first row) and Bouguer gravity for the inner AGG area (second row). The effect of upward continuing and filtering the ground data to match the airborne data is illustrated by the first three panels (left to right) in each row. The fourth panel shows the AIRGrav data.

Area	Line Spacing	Resolution	AIRGrav Accuracy Estimate	Standard Deviation (1 σ) g_z	Standard Deviation (1 σ) G_{zz}
AGG Area	50 m	600 m	Ground comparison	0.26 mGal	8.1 Eö
			Internal consistency	0.20 mGal	7.2 Eö
AG Area	200 m	1000 m	Ground comparison	0.37 mGal	7.5 Eö
			Internal consistency	0.28 mGal	6.0 Eö

Table 1: AIRGrav accuracy estimates from both comparisons to filtered ground data and internal consistency checks. The airborne-ground differences are larger than the repeatability estimates. This is expected since ground comparisons include errors in both the ground and airborne data, which is not an issue for a repeatability estimate based only on airborne data, as well as differences in spatial sampling between the ground and airborne data.

Figure 2: Accuracy estimates for a wider range of resolutions (filters). The enlarged points on each curve represent the values given in Table 1. These curves illustrate the relationship between line spacing, accuracy, and resolution. Since the highest resolution of the AIRGrav data is set by the low pass filter being used, choosing an appropriate low pass filter requires balancing resolution and accuracy. A shorter filter can be used, but as the upward trend on the curve when moving to shorter wavelengths indicates, this trades away accuracy. Flying tighter line spacing, such as going from 200 m line spacing in the AG area to 50 m line spacing in the AGG area, improves overall accuracy and shifts the entire accuracy-resolution curve down (blue → green).



- Vertical gravity gradients are shown in Figures 3 and 4. Falcon airborne gravity gradiometer data, shown in the middle column, were acquired by CGG using 50 m line spacing (Christensen, 2013). Ground and AIRGrav gradients are computed from the measured vertical gravity.
- The central anomaly of the AGG area represents an ideal target for an AGG system; the Falcon gradiometer reproduces these point sources well. The smallest anomalies are removed by the low pass filter employed by AIRGrav (Figure 3), but a 500 - 1000 m band pass filter (Figure 4) shows similar features in all three data sets in this relatively short wavelength band.

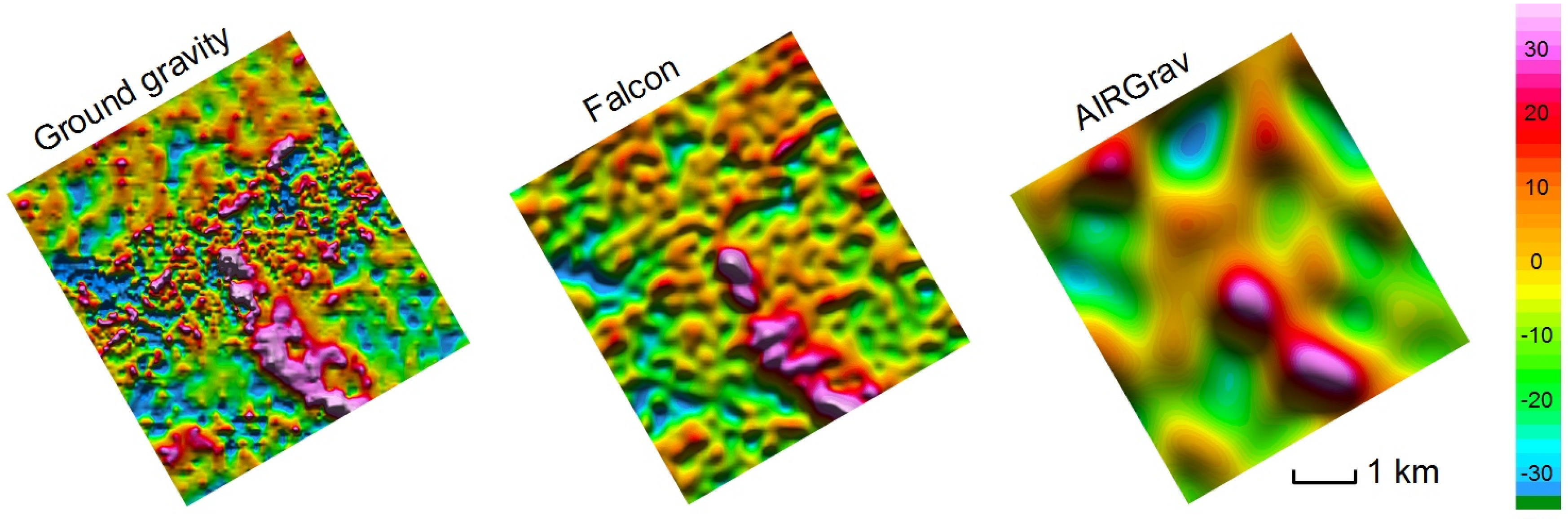


Figure 3: Bouguer vertical gravity gradient (G_{zz}).

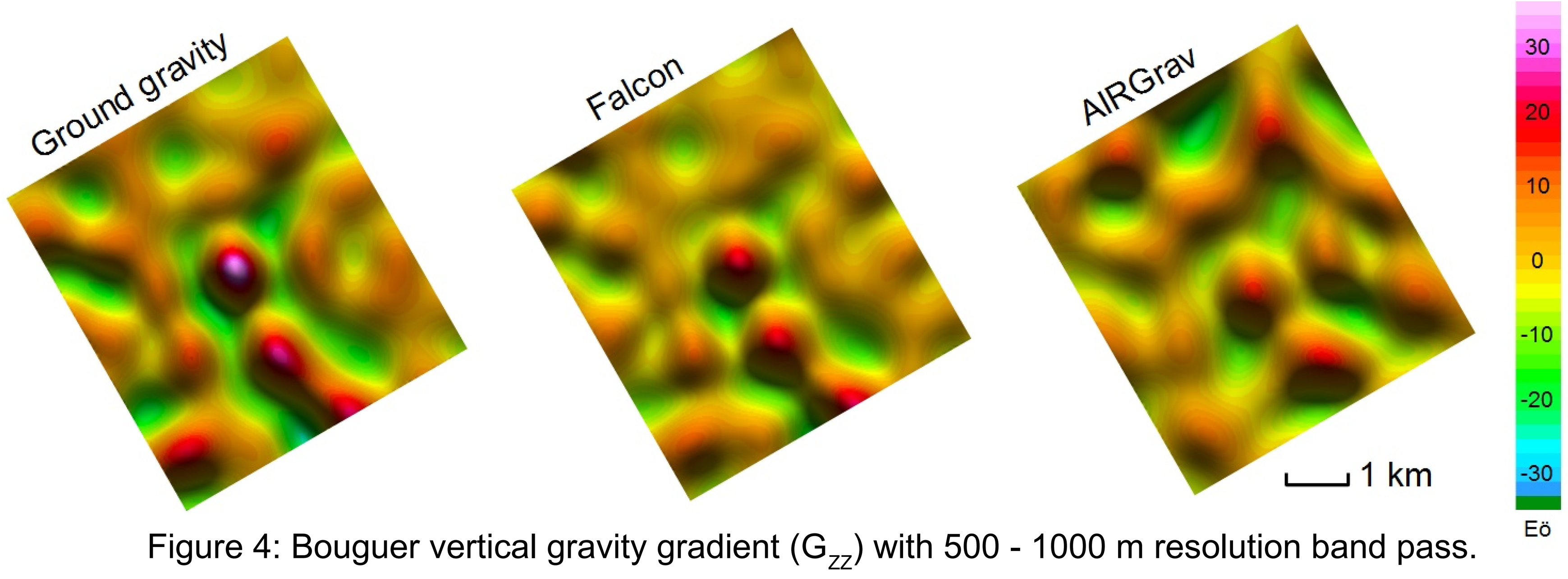
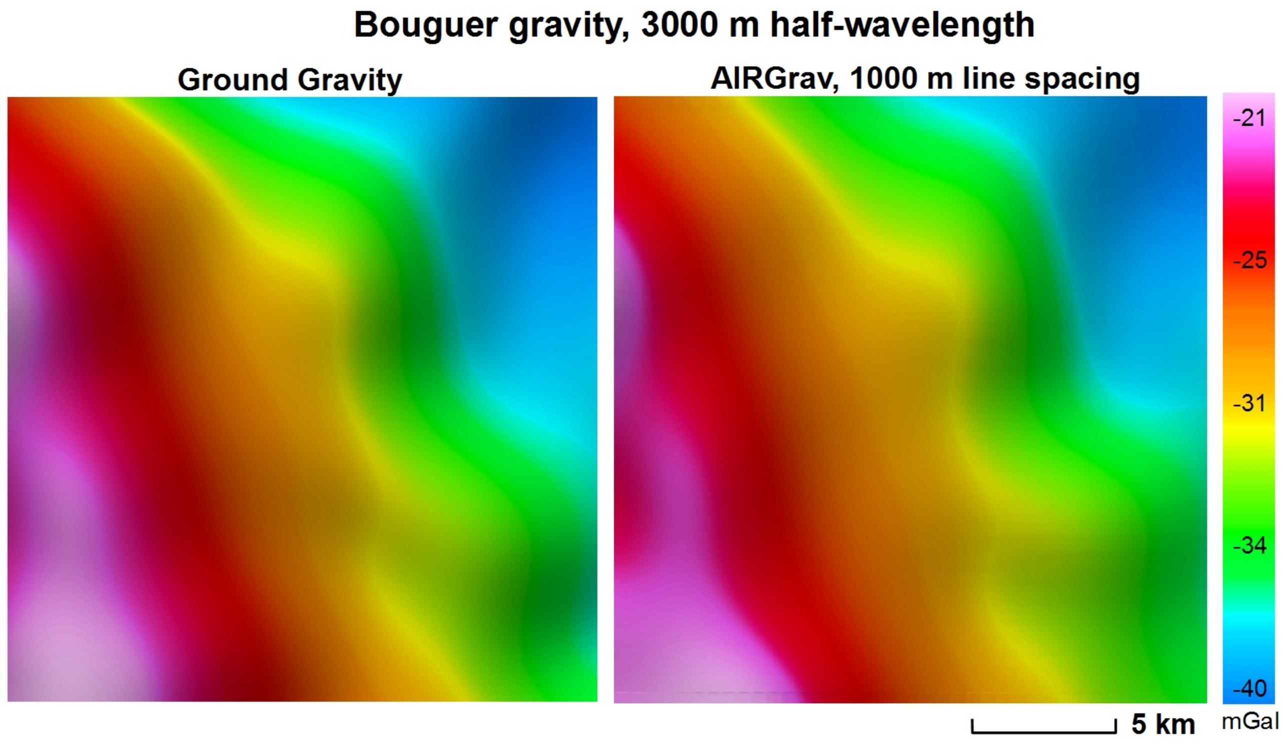


Figure 4: Bouguer vertical gravity gradient (G_{zz}) with 500 - 1000 m resolution band pass.

- At longer wavelengths it is more appropriate to use the entire AG area due to the small size of the AGG area relative to these wavelengths. This is displayed using Bouguer vertical gravity and 3000 m half-wavelength in Figure 5. AIRGrav data shown in this figure use 1000 m line spacing (every 5[th] survey line from the AG area).
- Falcon data are not available for the entire AG area, nor would it make sense to include it here since Falcon relies on external data sources for longer wavelengths (Dransfield, 2010), where the long wavelength limit is a function of the size of the survey area.

Figure 5: AG area Bouguer vertical gravity. AIRGrav data shown in this figure are using only every 5th survey line for 1000 m line spacing. The improvement in accuracy at longer wavelengths means widely spaced lines – only a modest amount of oversampling – produces accurate data that matches the ground data very well.



3. DISCUSSION

Results from the Kauring test site demonstrate the AIRGrav system can obtain results with 0.2 - 0.3 mGal accuracy at and below 1 km resolution. This is possible because instrument errors in the gravimeter platform, such as those induced by flight dynamics, are small compared to the primary source of error, the GPS noise. Since the GPS noise is random it can be minimized through oversampling and grid filtering.

Relatively tight line spacing of 50 m (AGG area) and 200 m (AG area) was used for AIRGrav acquisition over the Kauring test site. For lower resolution data this is unnecessary. AIRGrav accuracy improves rapidly moving to longer wavelengths. Only a modest amount of oversampling will produce highly accurate data.

To demonstrate this, the AIRGrav data covering the AG area was divided into five subsets of 1000 m spaced lines. The accuracy was estimated using repeatability by comparing grids of each subset. When a 3000 m low pass filter is used in conjunction with 1000 m line spacing the AG area accuracy is 0.15 mGal. In general, an AIRGrav survey targeting 3 km resolution can use 1000 m line spacing and produce a final filtered grid with 0.1 - 0.2 mGal accuracy. The final accuracy of AIRGrav data is a function of both line spacing and the low pass filter which sets the maximum resolution.

As a final observation, it is worth noting that magnetic data were also acquired during the Kauring test survey (Figure 6). The small, central feature in the AGG area produced a 12,000 nT magnetic anomaly that was easily detected. Combined acquisition of magnetic with gravity data can enhance survey results.

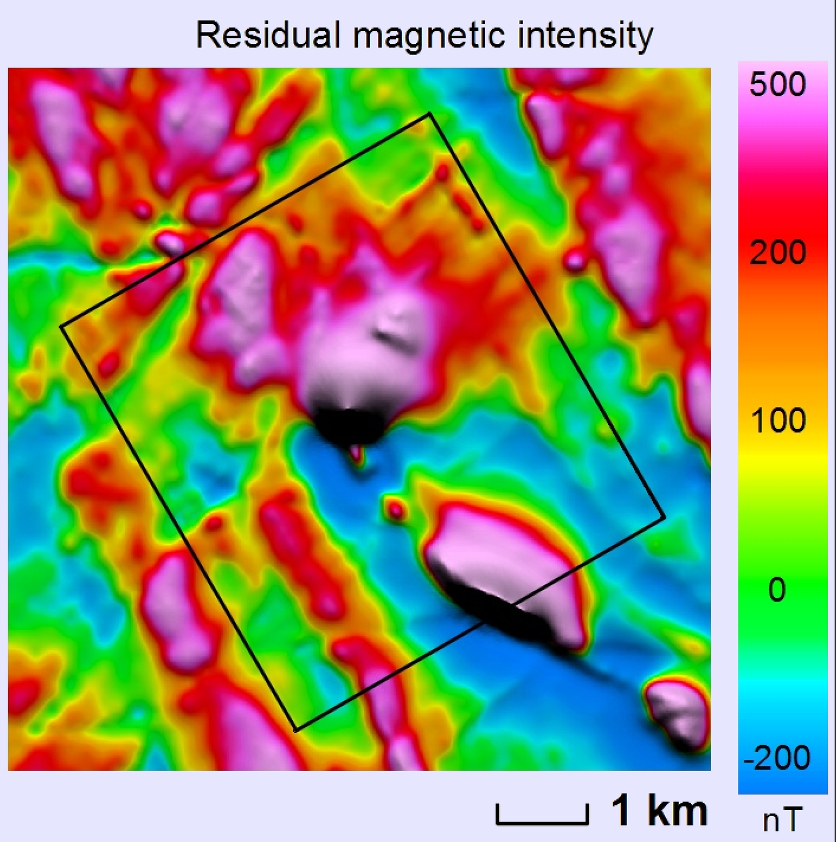


Figure 6: AGG area residual magnetic intensity. The small central anomaly is over 12,000 nT.

4. CONCLUSION

The AIRGrav system is capable of obtaining accurate gravity grids at three kilometre resolution using relatively wide 1 km line spacing. Tighter line spacing significantly extends AIRGrav's utility into shorter wavelengths through oversampling noise reduction, as is evident from the high resolution data acquired over the Kauring test site.

ACKNOWLEDGEMENTS

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Citations given on this poster are found in the reference list of the accompanying paper.