Comparison study between airborne and ship-borne full tensor gravity gradiometry (FTG) data

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Summary

Four separate surveys have been acquired over the same 25 block area in Mississippi Canyon to test the repeatability of full tensor gravity gradiometry acquisition. Three surveys were acquired using marine vessels, and one survey was acquired using a fixed wing airplane. Comparing these data both qualitatively and quantitatively indicates that the vertical gradient measured from marine surveys is repeatable to within 0.9 Eotvos. Although the airborne data appeared to contain slightly greater noise, it produced reasonably good quality data once high frequency noise from within the water column was removed.

Introduction

For over ten years full tensor gravity gradiometry (FTG) has been acquired offshore using marine vessels and onshore using fixed wing aircraft. Jorgensen et al. (2001) provides an overview of the application of FTG has been applied for oilfield applications. Up to this point, no one has made a true comparison between data acquired using these two different platforms. Should the airborne data be comparable to the marine data, mobilization and logistics would be much easier, and surveys that cover both onshore and offshore would be possible without any loss of data quality in the offshore areas. Otherwise, should marine data quality provide a substantially superior signal quality, it would remain the preferred platform for offshore acquisition.

For any airborne or marine gravity survey, recorded accelerations caused by vessel motion induce noise that needs to be removed. For a gradiometer system, each accelerometer measures exactly the same first order motion from vessel accelerations, and when the signals are subtracted to calculate the gradient, the first order vessel motion is removed. The gradiometer is still susceptible to noise from higher order vessel accelerations. Thus a more stable platform should provide higher quality data. One therefore might expect that data acquired on a slow moving, large ship might be significantly higher quality than data acquired at higher speed on a fixed wing airplane. Alternatively, it might be possible that for the frequencies of interest, the intrinsic noise removal of the gradiometer might compensate for the airplane begin being less stable.

Test location and background

The survey was acquired over approximately 25 OCS blocks (715 square kilometers) in Mississippi Canyon with a water depth of approximately 1-2 km (Figure 1). The series of repeat marine surveys that had previously been acquired over these blocks provided an opportunity to test overall repeatability of marine FTG data as well as an appropriate baseline for comparing airborne and marine FTG data.

The three ship-borne surveys were acquired in April 1999, June 1999, and August 1999 on the Naval Vessel NAWC-38. It is 57.5 meters long and has a beam of 12.1 meters. The data was acquired continuously at a speed of approximately 18.5 kilometers/hour. The survey line separation for the marine data was 1 kilometer with 2 kilometer tie lines.

The airborne data was acquired in July 2008 onboard a Basler BT-67 (turbo DC-3) at a speed of approximately 215 kilometers/hour and an altitude of 152 meters above sea level. Survey lines for the airborne survey were 500 meters apart with 5 kilometer tie lines.

Methodology and Data Preparation

Each survey was fully processed independently using identical methods. After the initial corrections and compensations each survey was leveled and bathymetry corrected using a density of 2.0 gm/cc. Final compensations that take advantage of the full tensor matrix were applied using 2.5 km and 4 km cut-off filters.

The data were compared qualitatively by displaying maps and plotting the survey amplitudes along a cross-section that intersects the largest features in the free air maps. The data were quantitatively compared by calculating the standard deviation of the difference plots of the surveys.

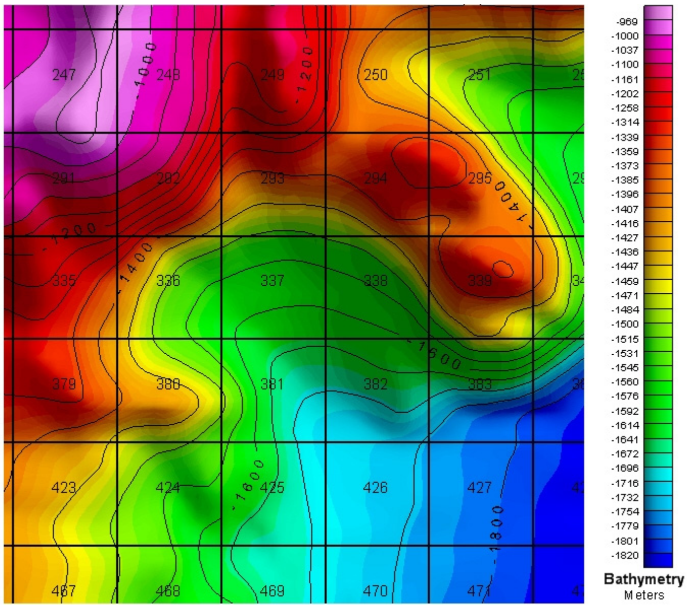
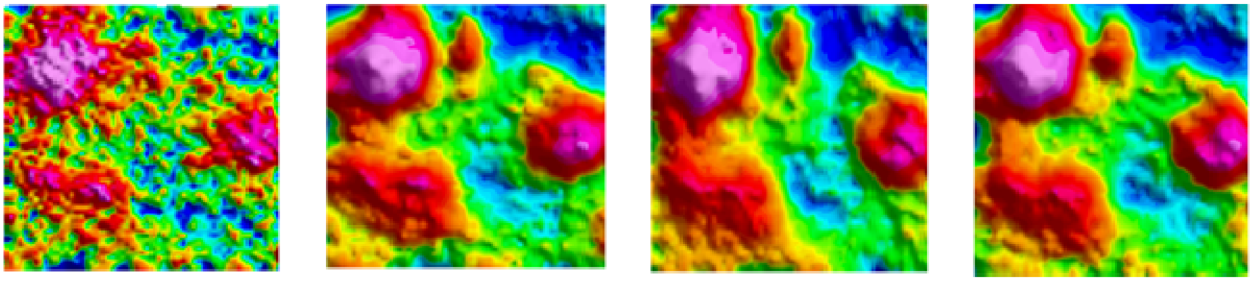
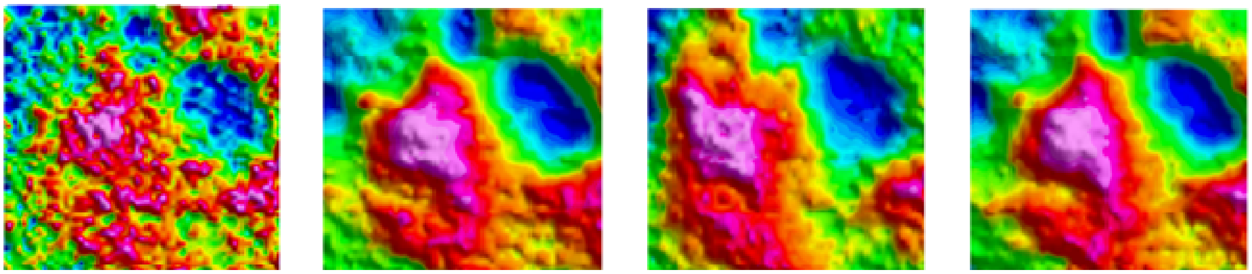


Figure 1. Outline and bathymetry of test area in Mississippi Canyon Area of the Gulf of Mexico.



Airborne Free Air Tzz | Marine #1 Free Air Tzz | Marine #2 Free Air Tzz | Marine #3 Free Air Tzz

(a) Free air vertical gradient after leveling



Airborne BC Tzz | Marine #1 BC Tzz | Marine #2 BC Tzz | Marine #3 BC Tzz

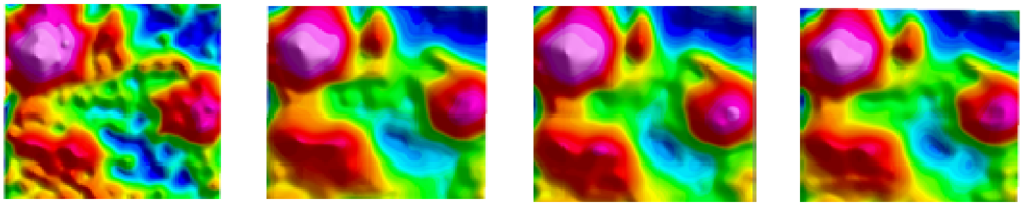
(b) Bathymetry corrected vertical gradient after leveling

Figure 2. (a) Vertical gradient of free air data from four repeat surveys after leveling. (b) Bathymetry corrected (BC) vertical gradient of four repeat surveys after leveling.

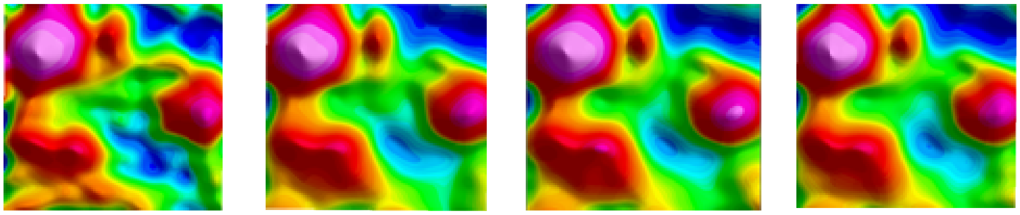
Discussion of Results

Figure 2a shows the vertical gradient (Tzz) after leveling but before the full tensor noise reduction. As one would expect, major features in the bathymetry are imaged in all of the surveys. Although each of the marine surveys compare well, the airborne data appears to contain high frequency noise that distorts the details. The noise in the airborne data is just as apparent after correcting for the contribution of the bathymetry to the data (Figure 2b).

The final processing step for full tensor gradiometry discussed by Jorgensen et al (2001) and Murphy et al. (2006) takes advantage of the six acquired channels (five independent tensor components and gravity) of the same potential field to identify and remove noise. This process can include a low pass filter to remove high frequencies. The filter can be selected based upon line spacing or based upon the geological objectives. For example, in this case, a series of filters may be applied to the calculated bathymetry response to show the frequencies that begin to have any affect below the water column. By using such techniques, 2.5 km and 4 km low pass filters were chosen and applied to the data (Figure 3). For the 2.5 km low pass filter the marine data compare exceptionally well. The airborne data, however, remains somewhat noisy. Using a 4 km filter, all data sets compare much better which indicates that the noise in the airborne survey appears to be higher frequencies.



(a) 2.5 km cut-off frequency



(b) 4 km cut-off frequency

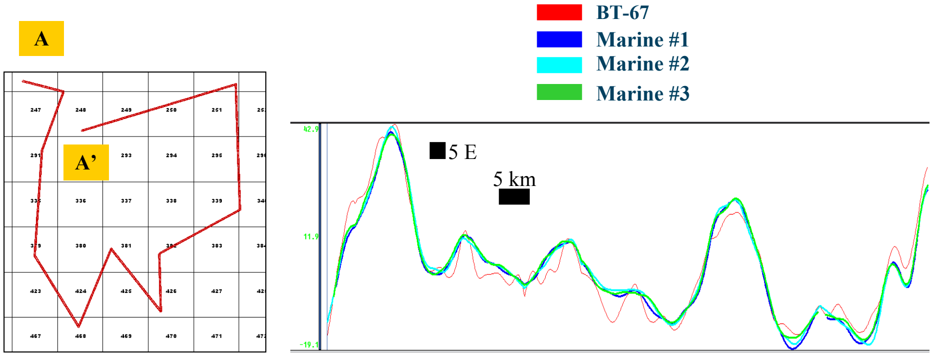
Figure 3. (a) Free air vertical gradient of four surveys after application of full tensor noise reduction using a 2.5 km low-pass cut-off. (b) Free air vertical gradient of four surveys after application of full tensor noise reduction using a 4 km low-pass cut-off.

Figure 4 shows a cross section that cuts through the major free air features. The response from each of the four surveys for both the 2.5 km low pass data and the 4 km low pass data along this profile are plotted to see how well the data match. After applying the 2.5 km filter, the marine profiles match within 1-2 Eotvos total deviation. The airborne profile contains somewhat greater noise, with deviations up to 5 Eotvos from the marine data. Using a 4 km filter, the marine data repeats extremely well, with a maximum deviation of approximately 1 Eotvos. Using the 4 km filter, the airborne data compares significantly better.

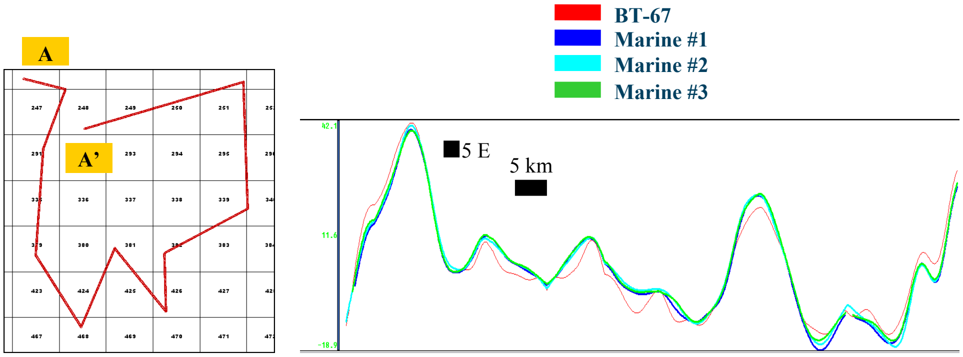
Table 1 shows a more quantitative estimate of the noise levels by looking at the standard deviation of the difference plots. These results indicate that the average noise level for the repeat marine surveys is below 0.8 Eotvos using a 2.5 km low pass filter and 0.9 Eotvos using a 4 km low-pass filter. The airborne data appears to have a standard deviation from the marine surveys of 2.6 and 2.9 using 2.5 km and 4 km low-pass filters, respectively.

Table 1. Standard deviation of the difference between repeat surveys

Compared Surveys	2.5 km filter SD (E)	4 km filter SD (E)
Marine #1 vs. Marine #2	0.87	0.78
Marine #1 vs. Marine #3	0.87	0.77
Marine #2 vs. Marine #3	0.87	0.76
Airborne Survey vs. Marine #1	2.8	2.6
Airborne Survey vs. Marine #2	2.9	2.7
Airborne Survey vs. Marine #3	2.8	2.6



(a) 2.5 km cut-off



(b) 4 km cut-off

Figure 4. Cross section showing amplitude response from each of the four surveys. a. After applying a 2.5 km filter. b. After applying a 4 km filter.

Conclusions

This study confirms that a ship is a more stable platform for acquisition of FTG data verses an airplane. An additional and significant finding is that, the airborne data compares quite well once higher frequencies that include the water column response have been removed. This suggests that offshore airborne acquisition of gravity gradient data is a viable alternative for many applications.

EDITED REFERENCES

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