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Airborne Geophysics – A Fast Track Approach in Petroleum Explorations

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Summary

Recent advances in mapping technologies coupled with the emerging needs of the exploration industry to precisely characterize the sub-surface systems, have led to the resurgence in interest for gravity and magnetic (so called potential field) methods in oil and natural gas exploration. The need for acquiring large potential field data sets at greater speed over highly prospective and frontier areas is increasing the demand for airborne measurement systems. In response to this need, UTS-Aeroquest offers the latest version of airborne gravity systems called TAGS (Turnkey Airborne Gravity System) on a fixed wing geophysical survey aircraft, which is already equipped with a magnetic acquisition system as well as radar and laser altimeters. Prior to offering the services of this new system, a pre-purchase test of the gravity meter was undertaken. The results provided a high level of confidence in offering this multi-system airborne geophysical approach to the petroleum industry.

Introduction

Traditionally the potential field measurements are time consuming. But the need for acquisition of large gravity and magnetic data sets at a greater speed has renewed the demands for precise airborne measurement system, which has unlimited accessibility over any terrain conditions such as coastal areas covering both land and shallow sea, over remote deserts, marshy lands, thick forests, icy lands or any transition zones. Significance of airborne geophysical approaches have increased with major advances in satellite positioning technology such as GPS and GLONASS, which enables the determination of 3-D position of the moving platform (aircraft) with greater accuracy.

Airborne gravity surveys are becoming increasingly popular in the mining and oil industry for exploration and geological mapping (e.g. Gumert, 1998, Joseph et al. 2003). Usually in airborne gravity surveys, magnetic data are also collected simultaneously. Although such magnetic data acquired generally have lower spectral and spatial resolution than the standard ultra high resolution aeromagnetic data, they add significant value to the interpretation of the acquired gravity data. In many cases the gravity and magnetic data are responding to the same geological source. This short paper describes the capabilities of the airborne geophysical service industry (with reference to UTS-Aeroquest) in carrying out such multi-system approaches, giving more emphasis to airborne gravity, the latest addition to airborne geophysical techniques.

Airborne Survey System

UTS-Aeroquest has acquired the Turnkey Airborne Gravity System (TAGS), which is based on the concept of LaCoste-Romberg Air-Sea Gravimeter (Nettleton et al., 1960; LaCoste, 1967). It consists of a highly damped, spring-type gravity sensor mounted on a gyro-stabilized platform with auto feedback setup to keep the spring tension tending to zero. An improved spring tension tracking loop & stabilized platform control loop as well as GPS time synchronization to 1.0 millisecond accuracy are some of the new features of the new system. It has a measuring range of ±150,000 mGal world wide with a resolution of 0.01 mGal; a static repeatability of 0.05 mGal and has an operating temperature range of 0 - 40^{o}C. Geodetic quality GPS receivers are installed & operated both on the aircraft and at the ground base station especially for determining the three dimensional (3-D) positions and velocities of the moving platform/aircraft with high precision. A ground based CG-5 gravity meter is used for base line ties with known/established IGSN-71 gravity station in the close vicinity of the survey area. A high resolution cesium vapour magnetometer sensor with an ambient range of 15,000 – 100,000 nT interfaced with a signal processor and

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compensator instrumentation are installed on the aircraft for simultaneous collection of magnetic data. Ground based magnetometer stations are operated to measure diurnal variations of the magnetic field and to provide adequate warning about magnetic storms. Apart from the above mentioned items, high precision radar and laser altimeters are installed on the aircraft to provide the ground clearance of the survey flights, which is essential in applying various correction factors to the potential field data collected from an airborne platform.

Data collection and processing

Prior to offering the services of this new airborne gravity meter system, a test over the Polk Country region of Florida, US, was undertaken. This area was selected mainly because of the relatively flat terrain and availability of dense ground gravity data, as well as the favorable weather conditions especially in winter months of the Northern hemisphere. Due to the close proximity to busy airports in that region, we had to restrict ourselves to an area of 3800 sq. km north of Tampa International Airport as shown in Figure 1. We opted for survey transects at 1 km spacing. Flights were operated at an altitude of 300m with a speed of ~120 knots. The selection of the survey flight altitude and speed has been chosen after a few trail flights at different altitudes and at different speeds to assess the air turbulence and system noise levels. The airborne gravity and GPS data were collected at 1 sec sampling while the magnetic data were collected at 0.1 sec interval.

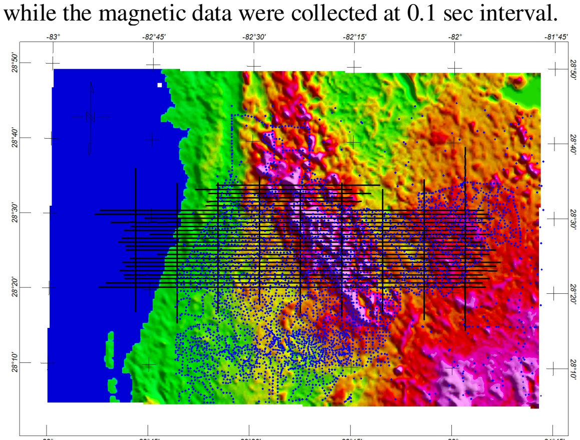

Figure 1: The survey lines are shown in black colour on the digital terrain model (SRTM data). Blue dots represent the ground gravity data points.

Gravity Corrections: While processing the airborne gravity data, the primary aim is to correct for the motions of the gravimeter. Gravity signals are calculated from the Gravity meter spring and beam data along with cross-coupling data derived from accelerometers, which is achieved using AeroGrav software developed at Micro-g Lacoste Inc. The precise position and velocities of the aircraft are obtained from the post-processing of GPS data using Waypoint's GrafNav v 8.10. As a next step in data processing, GPS time synchronization with 10 millisecond accuracy is enforced and the GPS derived corrections are computed and applied to the gravity data. Apart from the above steps, we also need to account for the normal gravity correction factors such as latitude correction, Eötvös effect, free air correction, Earth-tide effect, as well as complete Bouguer correction (which include simple slab, terrain and Earth's curvature corrections). A finite impulse response (FIR) filter is applied on the processed gravity data. Here in this filtering process, the filter weights are computed by (a) calculating the ideal impulse response of a filter with perfect cutoff and then (b) windowing the filter impulse response with a Blackman-Harris window function, which smoothly tapers the impulse response to zero outside the window width. As a last step in the data processing, the leveling correction is applied according to the average cross over errors/shift seen between survey transects and tie lines.

Magnetic Corrections: The magnetic data from the aircraft undergoes various corrections. Initially the data are corrected/compensated for aircraft maneuver. Then the raw data are visually inspected for spikes, gaps and instrument noises. Then parallax correction is applied to synchronize the magnetic and navigation data. The base station magnetic data are then used to correct for diurnal variations, followed by removal of the International Geomagnetic Reference Field (IGRF) using the latest IGRF data applicable to the survey region. The total magnetic intensity (TMI) data thus obtained are then leveled for cross over errors. Once it is done, the data are ready for further qualitative and quantitative processing, analysis, as well as modeling.

Results and discussions

To test the repeatability of the airborne gravity system we conducted several repeat flights along a pre-defined line. Figure 2 shows the repeat statistics of this test data while applying a 100 sec filter. The obtained repeat statistics (Standard Deviation = 0.48 mGal) is quite promising. It is less than half of the same claimed by the system manufactures as mentioned in system specification (personal communications with Micro-*g* LaCoste Inc).

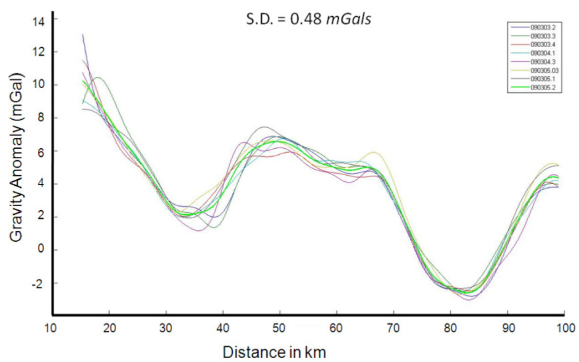

Figure 3, Repeatability of the observed free air gravity anomaly along a pre-defined flight line flown 8 times. The Standard Deviation (S.D) is calculated as 0.48 mGal.

As a next step we compared the above data with upward continued ground data to the flight altitude. Figure 3 shows the comparison of airborne and ground free air gravity anomaly data. The standard deviation (S.D.) is calculated as 0.51 mGal. While comparing these results one may keep in mind that the station spacing of ground gravity measurements varies 1-2 km, while the airborne observation samples approximately at every 60 m. This result has provided us the confidence to carry out further data collection over the area indicated in Fig 1.

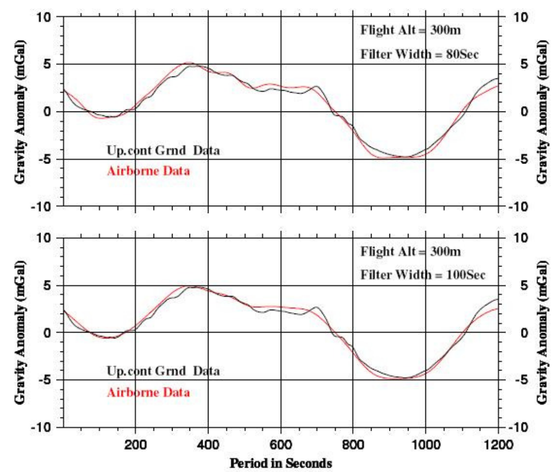

Figure 3, A comparison between airborne (blue) and ground (red) free air gravity anomalies along the pre-defined survey line. The red colour represents the airborne data and the black colour represents the ground data upward continued to flight altitude (300m)

As mentioned earlier, a detailed survey with a line spacing of 1 km, covering about 3800 sq.km was conducted over 4 consecutive days (3 - 7 March 2009). To avoid severe air turbulence, the survey flights were operated in the early hours of each day. The data were processed as discussed in the previous section.

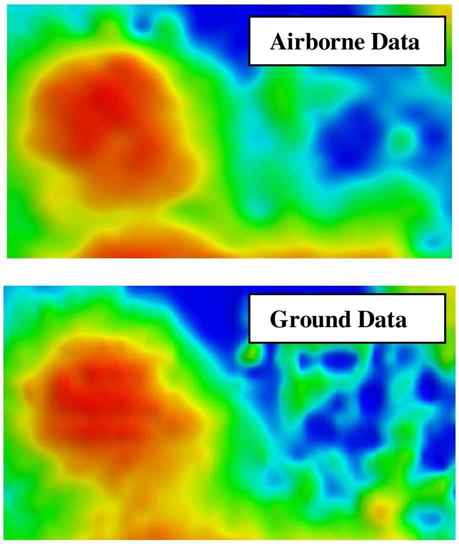

Figure 4, A comparison of airborne (top) and ground (bottom) free air gravity anomalies from the test survey area.

Figure 4 shows the airborne and ground free air gravity anomaly maps. You may notice that the airborne survey result has reproduced most the gravity anomalies observed on the ground data. Moreover the airborne survey has systematically covered the survey area, where as the ground gravity stations are randomly positioned mainly due to lack of accessibility due marshy land and thick forests.

Conclusion

The performance of the airborne geophysical survey system tested successfully. The gravity anomaly data obtained from the new airborne gravity meter agrees well with the ground gravity anomaly data. For conducting a detailed ground gravity over an area similar to that of the test area described in this paper (~ 3800 sq.km), would take a few weeks to a few months, while the airborne survey covered the area in just four days, without compromising on data quality. Aeromagnetic and radar altimeter data were also simultaneously collected and analyzed. The test survey thus indicates that the multi-system survey approach using an airborne platform/aircraft is successful, quicker and cost effective.

In the near future we may see additional geophysical methods (e.g. Airborne EM, Radiometrics etc) being added to the multi-system aircraft.

References

Gummert, W.R., 1998, An HHistorical review of airborne gravity, The Leading Edge v. 17;1; p. 113-116

Joseph, J, J. Segawa, S. Kusumoto, E. Nakayama, T. Ishihara, M. Komazawa and S. Sakuma, 2003, Airborne gravimetry - a new gravimeter system and test results, Exploration Geophysics, 34, 82–86.

LaCoste, L. J. B., 1967, Measurements of gravity at sea and in the air: Reviews of Geophysics, 5, 477-526.

Nettleton, L. L., L. J. B. LaCoste, and J. C. Harrison., 1960, Tests of an airborne gravity meter, Geophysics, 25, 1, 181-202.

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