Quality Control Metrics for Airborne Gravity Data

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Summary

Some traditional QC procedures for gravity acquisition projects are evaluated, as well as newer procedures that have proven helpful for the determination of noise levels in Sander Geophysics' (SGL's) AIRGrav data. Static test and test line data are primarily useful for determining system functionality. Intersection statistics are affected by the length of the line filters on the gravity data. The value of comparison with ground survey data depends on the quality and regularity of the sampling interval of the ground data. Procedures developed for QC of AIRGrav data include comparisons of line data to filtered grid data, monitoring of GPS acquisition conditions and the 'even-odd grid comparison' method, which involves comparison of two different grids, each one processed using every second line of the survey data.

Introduction

Current quality control (QC) procedures for airborne gravity data acquisition are based on experiences from projects using older L&R gravimeters, sometimes even from ship-borne acquisition. Recent projects have been flown using gravimeters based on inertial navigation accelerometers mounted on Shuler-tuned platforms, such as SGL's AIRGrav system, for which a revised set of quality control procedures would be more appropriate. QC procedures should check for errors and or conditions that are known to cause deterioration in data quality. They must be geared towards a specific genre of instrumentation, in order to identify suspect data from that particular type of instrument and data processing stream.

Many traditional QC methods for gravity data are geared towards calculating low frequency drift over time. This is not a behaviour that is normally exhibited by the AIRGrav system. A larger contributor to noise in AIRGrav data are GPS errors which cause localized errors in the gravity data. The new QC procedures are geared to monitoring these types of errors.

Traditional QC techniques

Static Test – pre and post flight: Historically repeat gravity measurements have been recorded in a set location several times over the duration of the survey. For airborne gravity projects, this translates to recording data for a number of minutes at the beginning and end of each flight while the aircraft is parked as close to the same location as possible. The purpose of this test is usually to determine the instrument drift. AIRGrav is not a spring-based gravimeter and the AIRGrav data has not proven to exhibit a measurable low order drift over time. However, static tests can still serve a useful purpose for AIRGrav projects. They can be used to easily identify data offsets that may be due to the change in some system control parameter. This may have occurred either in error, or a refined parameter may have been determined. A static test will also determine system functionality before the flight begins.

Test Line - pre and post flight: This is more or less the same test as a static test, except the data is acquired over a fixed test line. Test line data would be expected to contain a larger error component than static test data due to navigation errors and the larger errors in calculating differential GPS positional data for a moving object than for a stationary object. The benefit as a system functionality test would be the same, but the disadvantage of using a test line over a static test for system functionality is that any potential problems would be identified in the air during the flight rather than on the ground before the flight.

Intersection statistics: A common QC technique for airborne surveys is the statistical analysis of the differences between control and traverse lines at their intersections. Since each intersection has two measurements - one from the control line and one from the traverse line - the difference between the two is a test of internal consistency. Calculating the standard deviation of all the intersection differences for a survey gives a reasonably accurate picture of the error level. This type of QC is standard for airborne magnetic surveys and has been transferred to airborne gravity surveying.

If the intersection errors are calculated for a range of line filter lengths the analysis can be expanded to calculate the error level as a function of system resolution. Line intersection differences allow for a meaningful comparison between surveys by avoiding complications introduced when they are flown with different line spacing or when different gridding methods are used. Figure 1 shows the standard deviation of intersection errors over a range of wavelengths for several surveys. The lower series of curves are from surveys flown using Sander Geophysics' AIRGrav system; the shorter upper curve is from a survey flown in the Northern Territory of Australia using a Canadian Micro Gravity (CMG) GT1-A airborne gravimeter.

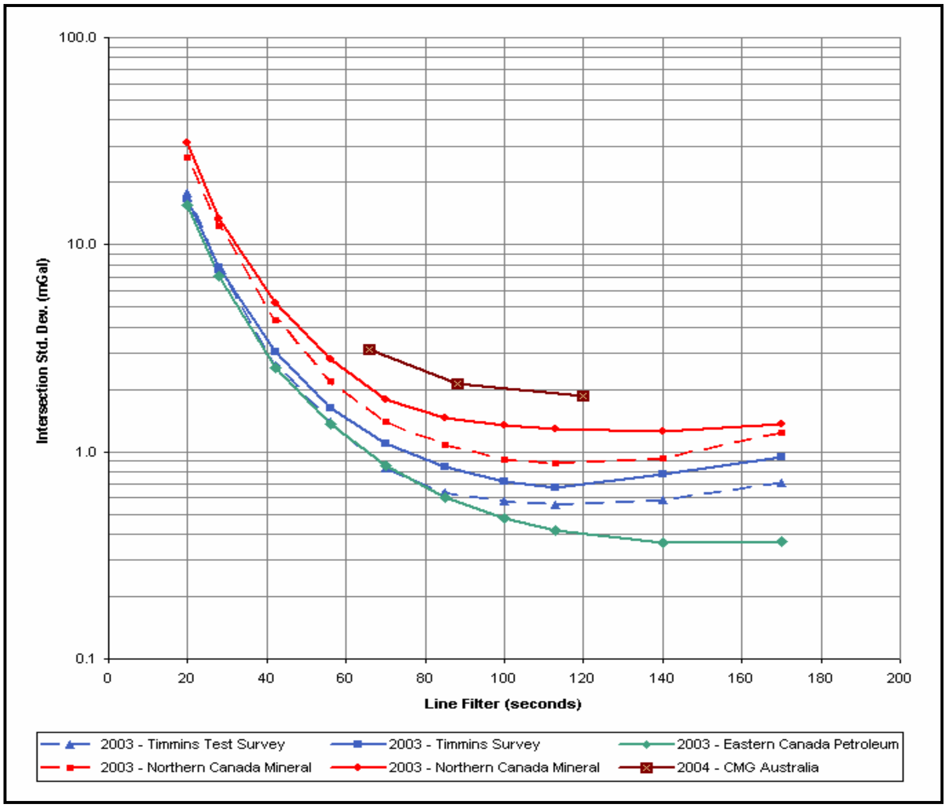

Figure 1: Standard deviation of intersection errors for different lengths of line filters from several different AIRGrav surveys and from a survey flown using a Canadian Micro Gravity GT1-A airborne gravimeter.

A drawback of using filtered line data to quantify noise is the effect real geological signal has on intersection differences. A north-south oriented anomaly will be spread out by a filter applied to an east-west line. North-south lines adjacent to the anomaly will not be similarly affected, resulting in higher intersection errors. The effect becomes more pronounced as the length of the filter increases, and manifests itself as an upturn in the noise level at long wavelengths, especially in mineral surveys where the geological signal is strong. It also means that two surveys flown in different locations with identical instruments will have curves that differ based on the geological signal present. The pairs of red and blue lines are examples of this: each pair is from essentially identical surveys flown in slightly different locations. Since there was overlap in the two Timmins surveys, it was possible to repeat the analysis using only the area common to both surveys. When this is done, the curves match closely, indicating that the system's accuracy is constant and the differences are indeed geological.

While the geological signal is the primary reason for the "noise" increase at longer wavelengths when comparing the petroleum survey to the two Timmins surveys, the poorer results from northern Canada reflect a true increase in noise. The northern Canada surveys were flown above the Arctic Circle, where the GPS signal is degraded by heavy ionospheric activity and poor satellite geometry.

The CMG gravimeter results were derived from publicly available digital data from the Geoscience Australia government website (Geoscience Australia, March 2004). The full details of the line filters used were not provided in their report so the line filter lengths were evaluated by power spectrum analysis and filtering with various frequency domain filters. The filters described by CMG as 60s, 80s, and 107s were found to approximate 66s, 88s, and 120s equivalent SGL frequency domain filters. Note that although the filter lengths are specified and compared in time, the average flying speed for the two systems differed. Flying speed was 69m/s for the CMG survey and 55m/s for the SGL surveys, which directly affects the spatial resolution of the given filter length specified in time (seconds).

Comparison to existing ground survey: This is an excellent QC procedure if the location of the ground survey data points is known and the ground survey is of sufficiently high quality. Experience with AIRGrav data has shown good agreement with closely spaced ground data and generally less agreement where the ground data has been interpolated between unevenly sampled data points.

Newer QC Procedures developed for AIRGrav surveys

GPS conditions: It is most important to minimize noise in the GPS data. Prior to flying, the expected number of satellites in view with varied elevation masks should be checked to make sure that the flight will be flown during optimal GPS conditions. This is most important for projects in the northern-most and southern-most regions of the planet where there are often fewer satellites in view.

Figure 2 shows an example of a plot of number of satellites in view, for Ottawa, Canada in February, 2005.

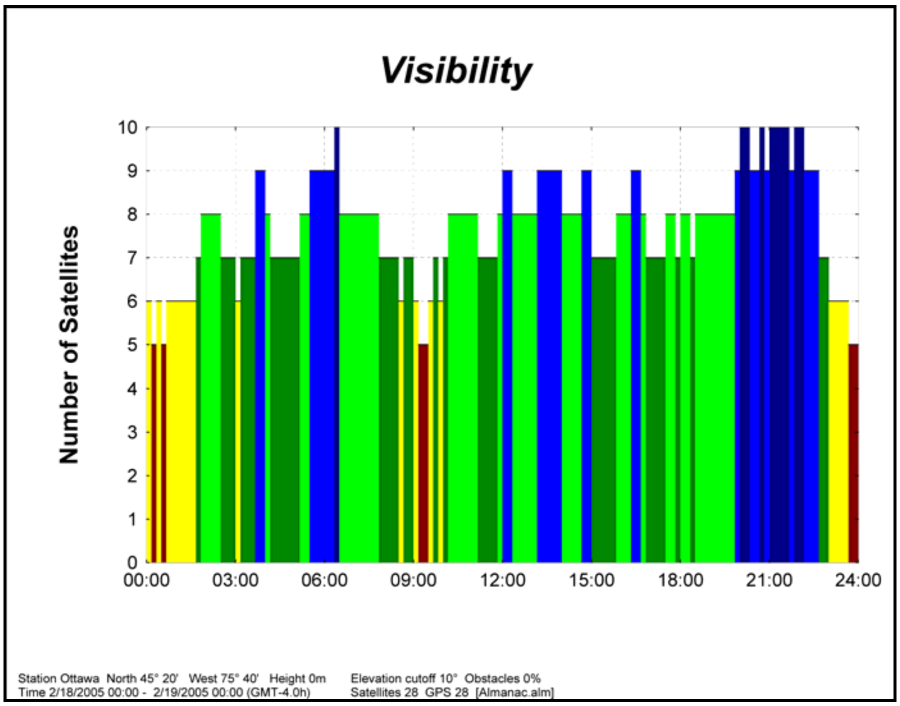

Figure2: Satellites in View, Ottawa, February 2005

Comparison of filtered line data to filtered grid data: For AIRGrav projects, GPS data is acquired using two GPS antennae on the aircraft and two in different locations on the ground. Several different methods are used to calculate the final differential GPS (DGPS) data using all combinations of data from different antennae. This can result in up to fifty different DGPS solutions for each flight line. An iterative procedure is used to choose the best solution by comparing gravity computed using each solution to processed gravity grids. The filtered grid data contains less noise than filtered line data due to 2D filtering which improves accuracy from the inclusion of several adjacent lines of data.

Even and Odd Grids: AIRGrav surveys are generally flown at a line spacing that is less than the length of the filter applied to the acquired data. Thus the survey area is oversampled to take advantage of the increased accuracy that results from 2D filtering including adjacent lines. SGL has instituted a quality control procedure which we call "even-odd grid comparison" that has proven very effective. Two completely separate data sets are processed – one using all the even numbered flight lines and the second using the odd numbered flight lines. All processing including terrain corrections is performed separately for each data set. As the data sets cover the same area, the geological signal will cancel, leaving only the noise of the two data sets. The RMS noise measured on the difference grids will be twice the noise level of the combined grid

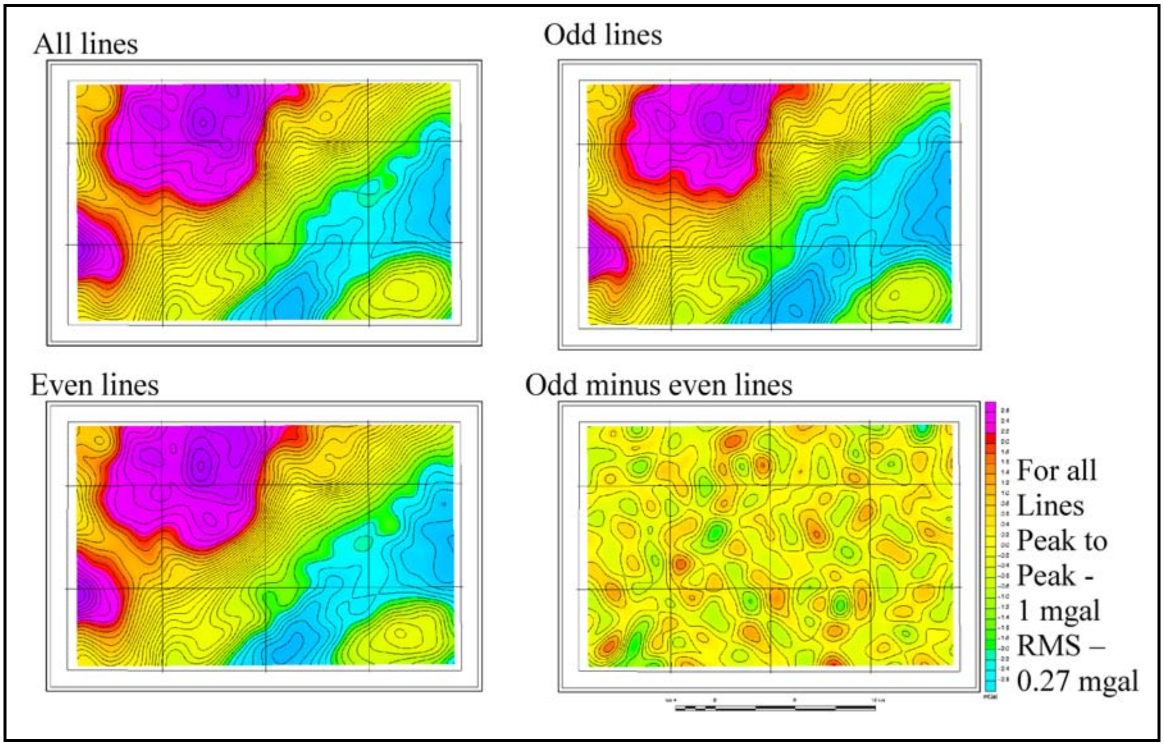

Figure 3: Even-Odd Grid Comparison

Conclusions

Many traditional QC methods for gravity data are geared towards calculating low frequency drift over time. This is not a behaviour normally exhibited by the AIRGrav system. Consequently, tests such as static tests and the compilation of test line data are useful mainly to verify system functionality. Filtered grid data is an important tool for evaluating the accuracy of AIRGrav gravity data. The filtered grid data contains less noise than filtered line data due to 2D filtering which includes several adjacent lines of data. The most effective means of evaluating AIRGrav data involves comparing line data to filtered grids, or comparing two grids each made using half the data.

References

Geoscience Australia website, Airborne Gravity Survey West Arnhem Land, NT Release of Point Located Data , http://www.ga.gov.au/rural/projects/w_arnhem_gravity.jsp., March 22 2004.