Review of Canadian Experience in Precise Gravimetry

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Abstract. Results of gravity observations made in Canada from 1974 to 1978 have been reviewed, in order to estimate the true accuracy of present-day gravimetry and thereby assess the potential capability of the method for detecting crustal movements. The standard error of the mean of ties is 15-20 nm/s^2. Inter-instrument comparisons and other tests show, however, that a more realistic estimate of D meter accuracy is 30-40 nm/s^2. This accuracy can only be maintained over the long term where uncertainties in gravimeter calibration curves are minimized by resetting to the same dial reading on the resurveys. A further deterioration in accuracy to 40-50 nm/s^2 occurs where reliance is placed on presently available D meter calibration curves. Despite the present accuracy limitations significant time variations in gravity of 100-150 nm/s^2 are seen over spatial scales of 10-100 kilometers in Canada over a period of several months.

Accuracy of Gravity Measurements

A distinction must be made between short-term and long-term accuracy of gravimeters, in order to make a realistic evaluation of gravimeter performance. The standard error of the mean of a set of ten consecutive gravity ties with a LaCoste and Romberg model D gravimeter under average transport conditions is 15-20 nm/s^2. In the hand-carried mode this value reduces to about 10 nm/s^2. When hand-carried measurements of near-zero gravity differences are made, gravimeter calibration is not important and, for practical purposes, 10 nm/s^2 can be taken as an estimate of the accuracy of the gravity difference determination. The reliability of this short-term accuracy estimate for three model D gravimeters was tested by making hand-carried measurements of sixteen small (<400 nm/s^2) gravity differences between adjacent (<1 m) stations. Means of measurements of these small gravity differences over a period of two years exhibited a standard deviation of 30-40 nm/s^2, not 10 nm/s^2 as expected. Since the gravity difference between such closely spaced stations should remain constant, the presence of significant systematic instrumental effects is indicated.

In typical gravity networks where larger gravity differences are measured, uncertainties in gravity calibration could be important in estimating gravimeter accuracy. In Canadian networks the effect of the unknown structure of the gravimeter dial factor curves is minimized by always resetting to within 1000 nm/s^2 of the same dial readings in the resurveys. In addition, the overall scale factor for the gravimeter is controlled by one or more independent calibration ranges. Therefore, 30-40 nm/s^2 is a realistic estimate of gravimeter accuracy in practical networks.

This estimate of the long-term accuracy based on the measurement of near-zero differences is borne out by comparisons of time changes seen by different gravimeters throughout various precise gravity networks in Canada. European tests (Kiviniemi, 1974; Brein et al., 1977) on LaCoste and Romberg model G gravimeters also show similar inter-instrument discrepancies. Thus, the repeatability of gravity ties in the short-term tends to give an over-optimistic estimate of the long-term accuracy of spring gravimeters. The contribution of temperature, pressure, magnetic effects, mechanical "sets" and levelling errors to the long-term uncertainties in gravimetry are being investigated by many groups but, so far, no consensus on the causes has emerged.

Gravimeter Dial Factor Curves

Dial-factor curves for LaCoste and Romberg model D gravimeters can be determined in the laboratory by a method devised by the manufacturer involving the addition and removal of a small calibrated weight equivalent to a 200 μm/s^2 change in gravity. Significant (>0.1%) variations in calibration factor across the instrument range are revealed by these tests (Lambert et al., 1978). These variations are probably due to nonlinearities in the lever system that is activated by the dial screw to null the gravimeter (Harrison, personal communication). Although application of such calibration curves to the instrument readings is obviously important, it has been found that significant and repeatable inter-instrument discrepancies remain. The amplitude of these discrepancies suggests the presence of further uncertainty in gravimeter calibration equivalent to ±40-50 nm/s^2. These results require that at least two instruments be operated simultaneously in a network to ensure that time-changes in gravity be monitored continuously at the 30-40 nm/s^2 level of accuracy in the event of the demise of one instrument.

Stability of the Gravity Field

In spite of the more-conservative estimates of accuracy, there is indisputable evidence of significant relative variations of gravity with periods of a year or less. Semi-annual resurveys of local-scale (<100 km) precise gravity networks in both eastern and western Canada show variations of up to 150 nm/s^2 (Dragert, Liard and Lambert, 5th annual meeting, Canadian Geophysical Union, London, Ontario, 1978). These changes appear to be a combination of seasonal effects of the type discussed by Lambert and Beaumont (1977), as well as possible superimposed tectonic effects, presently under investigation. Significant effects due to ocean-tide attraction at coastal stations have also been observed (Lambert and

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Bower, 1978). It is obviously important to understand these short period variations, if longer term trends due to crustal movements are to be delineated.

Conclusion

There is a discrepancy between short-term precision determined from repeated gravity ties and long-term accuracy revealed by inter-instrument comparisons and other tests. An isolated gravity difference can be determined in reality with a standard error of 30-40 nm/s^2. In practice, the uncertainties in measured gravity differences in a network are reduced somewhat by the network structure. Useful investigations into the time variations of the gravity field and their causes can be accomplished with presently available instrumentation.

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