Absolute Gravity Requirements in Canada

(Update of Internal Report 74-1)

R.K. McConnell

April, 1979

Explains Project 4.2.2.2 1979/80 milestones

This document was produced by scanning the original publication.

Ce document est le produit d'une numérisation par balayage de la publication originale.

Introduction

The gravity and Geodynamics Division internal report 74-1 entitled "The Need for an Absolute Gravity Apparatus in the Gravity Division" outlined a number of potential applications for absolute gravity measurements in Canada and reviewed the state-of-the-art in absolute gravity instrumentation. Since no major technological or theoretical breakthroughs have occurred in the past five years the substance of the 1974 report remains valid today. During this period, however, there has been considerable activity in many countries (Boulanger, 1978) directed toward the investigation of what is termed "non-tidal variations of gravity". A review of these studies simply confirms what we have known for some time i.e. that relative gravimeter measurements, no matter how high their internal consistency, have fundamental limitations in the investigation of temporal changes in the gravity field. As a result, there has been a growing recognition in the geophysical community of the need for precise absolute measurements for direct monitoring of changes in the gravity field and to provide absolute calibration standards for relative gravimeters. This need has been reflected in resolutions passed at the IAC meeting in IAG ? 1974 and the IGC meeting in 1978.

The purpose of the present report is to provide an update of the 1974 outlook based on developments over the past few years.

Recent Theoretical Developments

Mather (1977), using simulated data from a hypothetical network of 25 absolute stations around the world, has shown that measurements with a noise level of ±10μGal would likely yield significant information on earth expansion, motion of the geocentre and changes in flattening of the earth's meridians and equator. His data are derived on the basis of assumed rates of change of these geodynamic parameters which are somewhat speculative and, in the case of earth expansion, probably on the high side. Nevertheless, it is interesting to note that, for a station in Vancouver, the maximum predicted rate of change of gravity due to any one of the above phenomena is only 0.64 μGal per year. It is worthy of note that Mather's models assume that absolute measurements and carried out over periods in excess of 10 years to average out the seasonal effects due to groundwater and atmospheric pressure variations.

Recent Instrumental Developments

a) Italian Apparatus

This transportable free-fall apparatus based on Sakuma's design has been developed by the Istituto di Metrologia in Turin and is the only currently available instrument which operates in the production mode. Between 1976 and 1978, this apparatus occupied seventeen stations in Europe and reoccupied a number of U.S. stations established some years ago with the Faller/Hammond apparatus. A measurement at Ottawa was only partially successful due to instrument malfunction. The results of the European measurements (Canizzo et al, 1978) indicate that this instrument has a precision of ±10μGal. The results of the U.S. comparisons have not yet been published possibly due to the occurence of instrumental and other problems.

A major shortcoming of the Italian apparatus lies in its size (two 125 cu.ft. packing crates) and weight (3800 lbs.). The Instituto di Metrologia will establish absolute stations to a guaranteed precision at a cost of approximately $3000 per station plus transportation costs for the instrument and two operators. The apparatus is also commercially available through a French company at a purchase price of approximately $400,000.

b) AFGL (Hammond) apparatus

This instrument is a redesigned and re-engineered version of the original Faller/Hammond apparatus. As far as can be determined through personal communication with Hammond the main design changes lie in the addition of an automatic dropping mechanism and modern electronics. Although field tests of this instrument were planned for 1978 it seems to have been plagued with various problems which are, as far as we know, still unresolved. In any case, the estimated precision of this apparatus (±20μGal) would limit its value to us.

c) Faller "Super-Spring" apparatus

This instrument is presently being developed (Faller, 1977) at the University of Colorado. Its high precision (±3μGal) and small size result from the development of:

i) a servo controlled, electronically terminated, "super spring" which isolates the reference corner cube in the interferometer from vibration.

ii) a system whereby the dropped corner cube falls inside a chamber which is itself falling. This greatly reduces air drag and removes the requirement to operate the drop chamber at high vacuum.

Since this apparatus holds the greatest promise for future use in Canada, Faller has been invited to give a seminar at the Branch on May 24, 1979 in order to bring us up to date on his work. He will remain in Ottawa for a day for detailed discussions with various members of the Gravity and Geodynamics Division.

Current Role of Absolute g in the Calibration of Relative Gravimeters

The feasibility of using 14 of the European absolute stations as a calibration line for Lacoste Romberg geodetic (model G) gravimeters was examined by McConnell and Marson in August 1978. This analysis involved readjusting some 4000 existing gravimeter measurements along the European Calibration Line and comparing the derived gravity values at the 14 absolute stations with the measured values. The mean gravimeter response showed a non-linearity with amplitude of 50μGal. Individual gravimeters showed considerably larger non-linearities. As a result of this analysis a proposal was presented to the World Gravity Standards Working Group in September, 1978 recommending the use of the European absolute line as a standard for determining gravimeter non-linearities. The proposal was adopted as a resolution of the IGC at its September meeting.

In collaboration with IMG (Morelli) and OGS, Trieste and DMA, Cheyenne (Wyoming) the first ? field experiment to evaluate gravimeter non-linearities will take place in June, 1979. Eleven gravimeters including our four best meters will be transported over the line by land vehicles specially outfitted to minimize vibration effects and power losses.

Based on the analysis of existing European gravimeter measurements we expect to achieve a calibration precision of about 1 part in 10^5 on the European line. The amplitude of the non-linearity correction can probably be determined to a precision better than ±10μGal. By using our four meters to reobserve the primary stations in the National Gravity Net we should be able to reduce our non-linearity errors, which may be as high as 100μGal, to the 10μGal level. Reobservation of the Ottawa-Resolute calibration line will reduce any non-linearity errors therein to the same level and permit us to calibrate other geodetic gravimeters over this line with a precision only marginally less than the European absolute calibration. The four linearity

corrected meters will also be used to establish a D-meter calibration line in the vicinity of Ottawa. This line should enable us to determine D-meter scale to about 5 parts in 10^5 at the time the line is established. Periodic scale transfers from some absolute standard or direct absolute measurements will still be required to monitor non-seasonal variations in the length of the line.

Conclusions

1. The cost of establishing even a minimal network (say 5) absolute stations in Canada using available instrumentation (Italian apparatus) to measure regional variations of gravity with time would be difficult to justify.
2. The most reasonable alternative for the present lies in the use of geodetic gravimeters calibrated against existing absolute stations in Europe to transfer absolute scale for the network and calibration lines in Canada. The cost of such calibrations is $2500 per meter. These calibrations might have to be repeated at approximately three year intervals.
3. Recognizing the limitations and the complexities of using relative meters to measure temporal variations in gravity we should follow closely and indeed encourage the development of the Faller drag-free apparatus since it appears to be the only potentially viable device on the horizon to provide an absolute datum control for a variety of gravity studies in Canada.

References

Boulanger, J.D., 1978. Brief Review of Research on Non-Tidal Gravity Variations. Report of IAG Special Study Group 3.40.

Canizzo, L., Cerutti, G., and Marson, I., 1978. Absolute Gravity Measurements in Europe. Il Nuovo Cimento, Vol. IC, No.1.

Faller, J.E., Rinker, R.L., and Zumberge, M.A., 1977. Plans for the Development of a Portable Absolute Gravimeter with a few parts in 10^9 accuracy

Lambert, A., and McConnell, R.K., 1974. The Need for an Absolute Gravity Apparatus in the Gravity Division. Gravity and Geodynamics Division Internal Report 74-1.

Mather, R.S., Masters, E.G., Coleman, R., 1977. The Role of Non-Tidal Gravity Variations in the Maintenance of Reference Systems for Secular Geodynamics. Publication of the Department of Geodesy, University of New South Wales, Sydney.