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Calibration of a superconducting gravimeter: a comparison between the mass attraction method and the use of FG5 absolute gravity measurements

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Abstract. The Superconducting Gravimeter GWR T015 is recording continuously in a laboratory of ENEA (Italian National Institute for Energy Development) at Brasimone site, in the Apennines between Bologna and and Florence (Italy). The gravimeter is routinely calibrated by means of a moving mass system with a precision of about 0,3%.

In October 1997 a comparison campaign between the absolute gravimeter FG5-206 of EOST (Ecole et Observatoire des Sciences de la Terre) of Strasbourg and the Superconducting Gravimeter (SC) itself has been performed, in oder to verify and to improve the precision of the calbration factor of the SC gravimeter.

The seismic noise due to the Umbria-Marche swarm earthquakes didn't effect the measurements, and the result of the comparison campaign agrees with the mass system at a level of 0.06%. The calibration constant of the SC gravimeter has been improved by a factor 2.5.

The Superconducting Gravimeter GWR T015 has been working continuously at a laboratory of the Research Centre of ENEA (Italian National Institute for Energy Development) since 1995, in the frame of the *Global Geodynamics Project* (see Crossley and Hinderer, 1995). The gravimeter is regularly calibrated using the mass calibration method described below:

- a stainless steel annular mass (a circular ring with a square cross-section) weighing 273 kg, suspended from a light support sliding into vertical rails, is moved vertically by an engine controlled by a personal computer and a wireless digitiser, producing a gravity perturbation of 6.731 μGal (Fig. 1). The design of the apparatus is simple and can be easily modelled to evaluate of the expected gravity signal; possible systematic errors due to the estimation of

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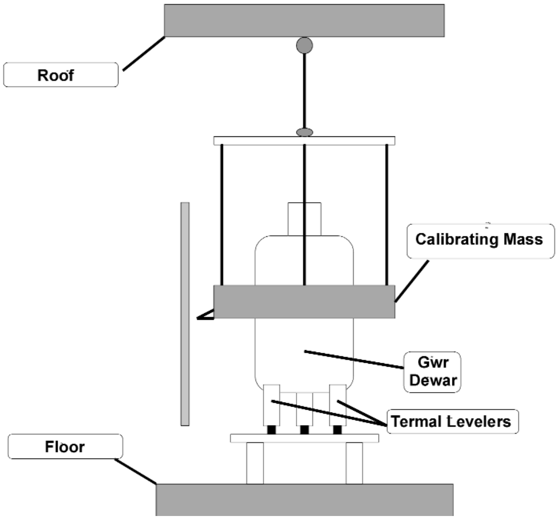

Fig. 1 - Scheme of the mass attraction calibration system.

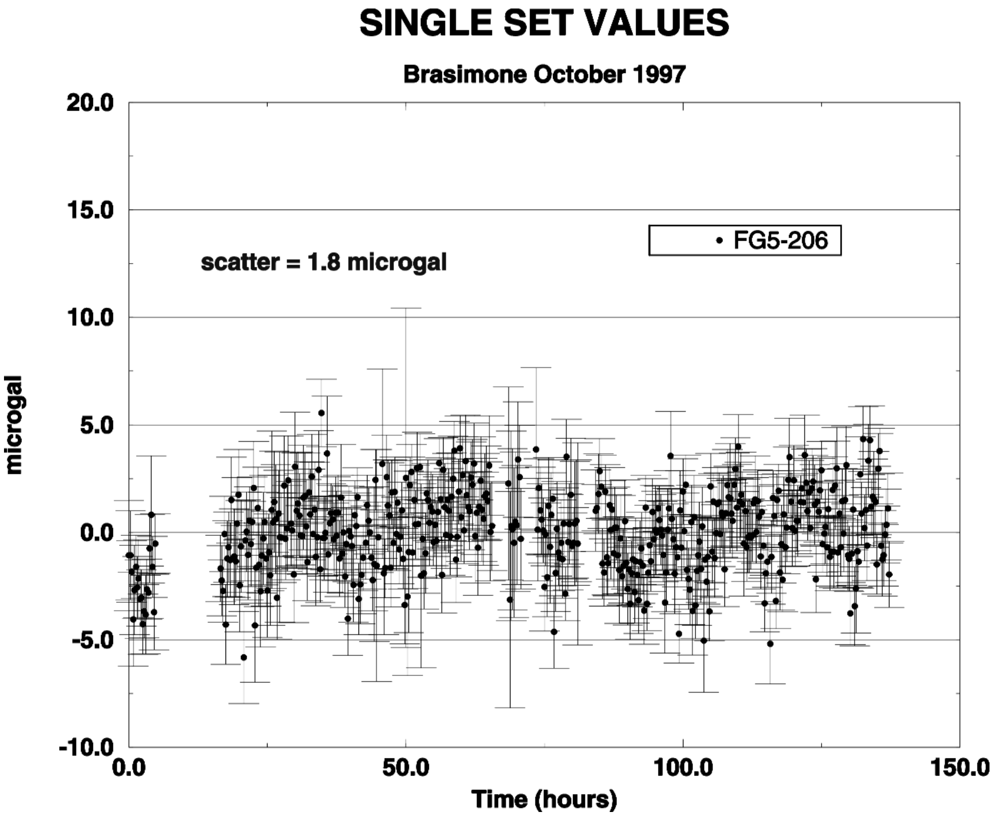

Fig. 2 - Values of absolute gravity expressed in microgals with respect the mean are shown as a function of time; each single set value is the mean of 25 drops.

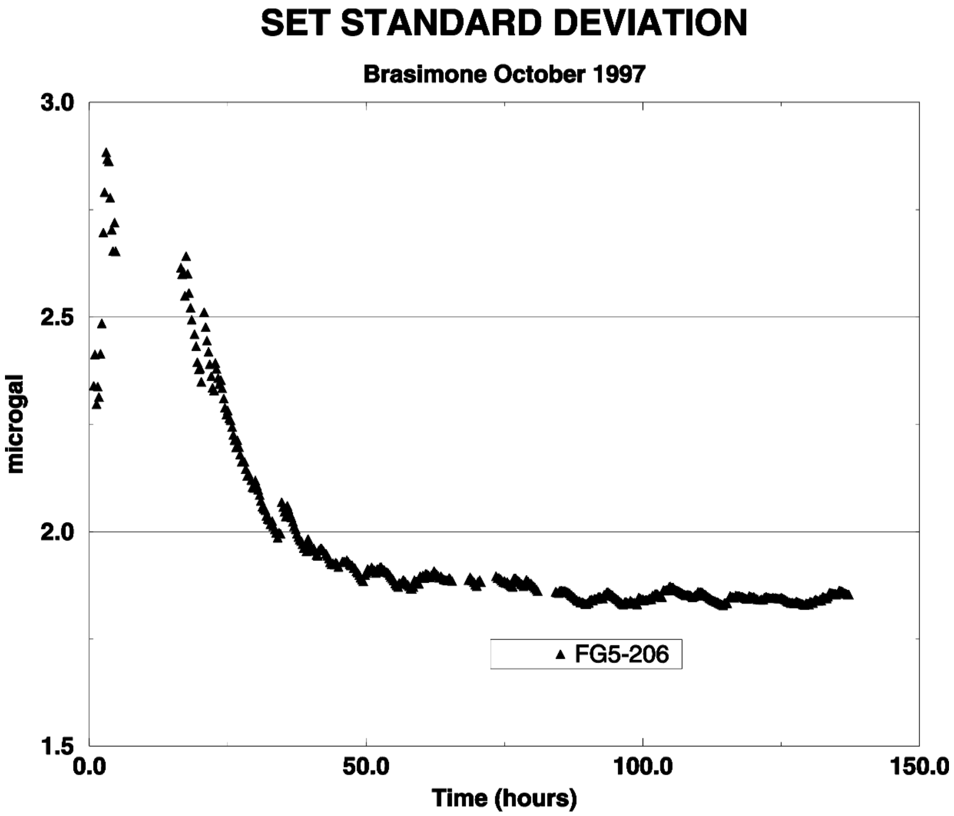

Fig. 3 - Cumulative standard deviation of the set values of absolute gravity.

weight, geometry, vertical and horizontal positions of the moving masses with respect to the levitating sphere of the superconducting gravimeter, are estimated to be less than 0.001 µGal (Achilli et al., 1995). The very stable basement in which the laboratory lies (a dismissed nuclear plant with thick walls in reinforced concrete) prevents any instability effects during the movement of the mass.

The calibration may be performed by slowly moving the mass, recording time, position and gravimeter signal, and then comparing the theoretically predicted effect (in a least square sense) with a correction to the gravity for tide and instrumental drift; a second approach consists in moving the mass from the position of maximum to the position of minimum effect.

With this method one can obtain, in just a few hours, a set of data that can estimate the calibration factor with a standard deviation of 1÷2 nm $\cdot$ s^{-2} $volt^{-1}$, corresponding to a precision of about 0.3% (Casula et al., 1998).

Two other methods may be used to calibrate relative gravimeters: the first consists in submitting the instrument to a periodical acceleration using a moving platform, while the second, relies on the simultaneous measurement of the variation of gravity due to solid earth tides with an absolute gravimeter. In both cases, one can obtain a calibration factor with an accuracy of 0.1% or better (Richter et al., 1995; Hinderer et al., 1998; Francis et al. 1998).

In order to compare the *absolute* and *mass* methods, the absolute gravimeter FG5 of EOST

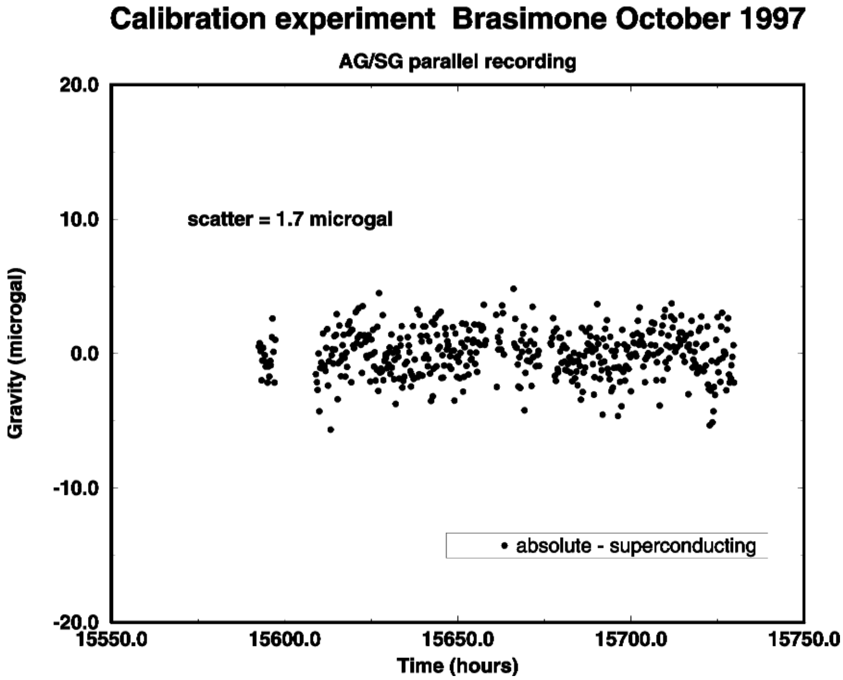

Fig. 4 - Comparison between absolute and relative gravity values after calibration of the superconducting gravimeter.

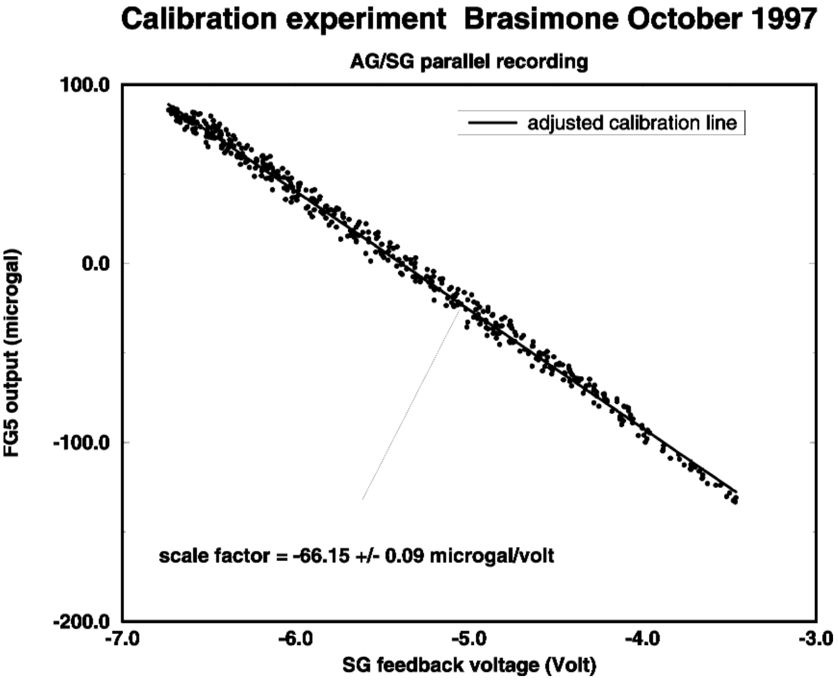

Fig. 5. Linear regression between absolute gravity and superconducting feedback voltage signals.

Table 1. Comparison between the calibration factors evaluated by means of the mass attraction method and the absolute gravity method.

Calibration method	**scale factor µgal/volt**	**accuracy µgal/volt**	**relative precision**
Mass attraction	-66.11	0.23	0.35 %
Absolute gravimetry	-66.15	0.09	0.14 %

(Ecole et Observatoire des Sciences de la Terre) in Strasbourg was installed in October 1997 in the Brasimone laboratory; continuous observations were carried out for about a week. In spite of some short-lasting interruptions in the recordings due to the noise produced by a seismic crisis which involved an area about 200 km away from the station, more than 13 5000 drops were measured and compared in time with the superconducting gravimeter feedback voltage.

Starting from a single drop every 15 sec, the mean value of 25 measurements was analysed and led to 4 values per hour. The scatter of these absolute gravity measurements is 1.8 µGal (Fig. 2); the cumulative standard deviation of the set values converges to the same value after 50 hours of measurements (Fig. 3).

The two data sets derived, respectively, from the absolute and the superconducting gravimeters were compared after the rejection of the values relative to short periods (generally shorter than one hour) after a seismic perturbation (Fig. 4). The linear regression between the two data sets leads to a value of the calibration factor of -66.15±0.09 µGal/volt (Fig. 5).

Just after the comparison with the absolute gravimeter, a calibration run with the mass method was performed on October 23, 1997 and provided a value which is in agreement with the previous one (see Table 1). The two calibration factors are in excellent agreement with a discrepancy well below the accuracy of the methods ($6 \cdot 10^{-4}$). Table 1 to be included also confirms the better precision (by a factor of 2.5) of the AG/SG method with respect to the mass method.

The previous agreement, as well as the increased precision available with the AG/SG calibration method, therefore provides an argument for redoing the geophysical experiment on Newton's inverse-square law which was performed at Brasimone (Achilli et al., 1997) and, as discussed by these authors, mainly limited by the calibration precision of the gravimeter.

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