Present State of Absolute Gravity Measurements in Brussels and Comparison with the Superconducting Gravimeter Drift

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Abstract: Since 1987, seven absolute gravity measurements have been performed at Brussels with JILAG-3 and JILAG-5 instruments. During the same period the superconducting gravimeter GWR-T003 has been continuously operating. Between 1989 and 1993, the absolute gravity measurements present a drift of about 5 microgal per year similar to the drift of the superconducting gravimeter. This drift is well correlated with the water table variations. The annual variation of about 5 microgal detected in the superconducting data cannot be confirmed by the absolute measurements because the absolute measurements unfortunately sample the same phase of the annual variation corresponding to the maximum gravity effect. Further investigations seem to be restricted by the lack of absolute gravity measurements and by the precision of both instruments limited to about 3 microgal which is partly due to site noise.

Keywords: Absolute gravimeters, Supercondcuting gravimeters, non tidal gravity variations.

Introduction

In 1976, an absolute determination of the gravity was performed by the Istituto di Metrologia G. Colonnetti (IMGC) at the Royal Observatory of Belgium (ROB) in Uccle (Brussels). The observed value served as a reference for the first order gravimetric network of Belgium achieved in 1978.

Since 1987, an absolute gravimeter (Jilag-3 or Jilag-5) visited almost each year a point close to the superconducting gravimeter GWR-T003 installed at the ROB in 1982. The goals of such periodically repeated measurements are the calibration of the superconducting gravimeter and the monitoring of its long-term stability. The first attempt to calibrate the superconducting gravimeter is published elsewhere (Ducarme et al., 1993). This paper deals with the control of the long-term stability.

In a previous paper of Ducarme et al. (1991), it was found by intercomparison between absolute gravimeters Jilag-3 and Jilag-5 in Brussels and Clausthal that there is an offset of 10 microgal between the two instruments. Besides, the data of the superconducting gravimeter corrected for the polar motion showed an annual wave with an amplitude of the order of 5 microgal (extreme in March and September). When correcting the Jilag-5 data for the annual term, the standard deviation of the absolute measurements in Brussels and Clausthal was decreasing. This weak evidence of an annual variation is not confirmed by the new observations made since 1990.

The Absolute Gravity Observations

The details of measurements performed by the Jilag-3 of the Institut für Erdemessung (Hannover) and the Jilag-5 of the Geodeettinen Laitos (Helsinki) are given in Table 1. This is the intercomparison of the data in Paris, Clausthal and Brussels which allowed to determine the offset between the two instruments. Since 1990, there is no more Jilag-3 data. Measurements were carried out at the comparison station Clausthal and also at Brussels and Strasbourg at the superconducting gravimeter site. Since 1991, measurements were also performed at Membach where we intend to install the superconducting gravimeter CT-021 in April 1995. In Figure 1, we can observe a slight increase of the gravity in Membach and Strasbourg and a slight decrease of the gravity in Brussels and Clausthal.

The superconducting data

The GWR-T003 is recording at Brussels since April 1982. The data set can be divided into two sets. The first one covers four and a half years and it is characterised by instrumental problems bringing difficulties in modelling the long-term drift. The instrumental problems were due to a leak in the Dewar and they have been solved by putting a permanent getter (a ceramic crystal) inside the Dewar. The second set starts at the end of 1986 (15/11/1986) after an instrumental failure. It has a better signal-to-noise ratio. Almost all the absolute gravity measurements (except two) were done after the beginning of the second set of superconducting data.

For a complete description of the analysis procedure of the superconducting data of the Brussels instrument we refer to the work of De Meyer and Ducarme (1994) which will be published soon. A synthetic tide is computed from the observed amplitude and phase factors of 35 tidal waves in the diurnal, semi-diurnal and ter-diurnal band determined with the Venedikov method analysis. This synthetic tide including theoretical amplitude factor for the long period tides waves is subtracted from the hourly readings of the superconducting gravimeter. The residuals are then averaged over 1 day giving the so-called 'daily means'. These are corrected for the air pressure effect, for the polar motion and for the variation of the length of the day. The daily mean residuals are plotted in Figure 2. Their spectrum shows one main line frequency corresponding to an annual term with an amplitude of about 5 microgal (extreme in March and September).

The instrumental drift subsequent to the instrumental failure is modelled by an exponential function (the bold curve in Figure 2) which is interpreted as the response of the gravimeter after relevitating the ball. The linear part of the drift after the relaxation of the gravimeter may be of instrumental origin or reflect a real decrease of the gravity at the Brussels station.

Intercomparison between absolute and superconducting data

The absolute gravity measurements and the superconducting data are plotted on the same Figure 2. As the superconducting gravimeter is a relative instrument, we adjust the linear part of the superconducting drift with the straight line fitted on the absolute measurements. There is a fairly good agreement between the linear part of the drift in the superconducting data and the absolute data. Both show a drift of -5 microgal per year.

The absolute measurements confirm the decrease of the gravity in Brussels. This observed long-term variation of gravity seems to have its origin in the water table whose the level shows the same long-term trend as the gravity (Figure 3). Delcourt et al. (this issue) have calculated the theoretical gravity effect of the water table and found that the water table variations can explain 50% of the observed gravity variations. This result is in good agreement with the admittance coefficient of 0.17 microgal/cm found by De Meyer and Ducarme (1994) which is twice the theoretical value. This disagreement between an empirical determination and the theoretical prediction of the water table effect will be considered to improve the model. On the other hand, we must mention that the first absolute measurements in Figure 2 does not credit the correlation between the gravity and water tables variations. But, its reliability is questionable since this value already corrected for an offset was obtained with an old Jilag-3.

Concerning the annual wave detected in the superconducting data, it is not possible to confirm its existence in the absolute measurements because we dispose practically of only one value per year. Moreover, the measurements were performed either in March or in September near the amplitude maxima of the annual wave so that always the same phase (positive and negative) has been sampled. We also corrected the absolute measurements for the annual waves : the scatter of the data as well as the correlation with the long-term drift of the superconducting data are not affected. We think that the annual term is more probably of instrumental origin because the annual variation of the gravity is highly correlated with the room temperature where the electronic of the superconducting gravimeter is installed (for more detail, see De Meyer and Ducarme, 1994). In the future, the electronic of our instruments will be thermostatized allowing to answer whether or not the annual term is due to the temperature variation of the electronics.

Conclusion

The superconducting data and the absolute gravity measurements in Brussels show a similar long-term drift of about -5 microgal per year between 1989 and 1993. The calculated gravity effect of the water table variations can partly explain the observed drift. There is no evidence of an annual variation in the absolute gravity measurements in Brussels. One reason is that the sampling (1 data per year) of the absolute measurements is insufficient to find out an annual term. The other is that the annual wave in the superconducting data is probably due to the variation of the temperature in the electronics.

Further investigations require to refine the model used to calculate the gravity effect of the water table but also to consider other environmental effects (precipitation, moisture, ...). The reality of the annual wave will be checked by a better thermostatization of the electronics of the superconducting gravimeter and also by increasing the number of absolute gravity determinations in Brussels and Membach.

Acknowledgements

We are very indebted to Prof. Kakkuri, director of the Geodeettinen Laitos (Helsinki) and to Prof. W. Torge, director of the Institut für Erdmessung (Hannover) who allowed the use of the absolute gravimeters. Thanks to M. Hendrickx who read the manuscript. The expenses for the measurements were mainly covered by a Research Grant of the National Fund for Scientific Research (Belgium) and by a financial support of the European Center of Geodynamics and Seismology (Luxembourg).

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Table 1: Intercomparison of absolute measurements.

Epoch	*Brussels* 981 116.***			*Clausthal* 981 115.***		*Strasbourg* 980 877.***	*Paris* 980 925.***		*Membach* 981 046.***
	IMGC	J3	J5	J3	J5	J5	J3	J5	J5
1976 06	*662*								
1986 03				*745*					
1987 05				*729*					
06		*680*							
1989 02				*740*					
1989 04			*662.6*		*734.9*				
1989 05						*771. 2*			
1989 09				*738*					
1989 12		*668*	*656.4*	*735*	*724.5*	*771.5*	*977.2*	*968.4*	
1990 09			*646.8*			*758.4*			*688.9*
1990 10					*722.5*				
1991 04			*644.3*			*762.7*			
1991 05					*726.6*				*697.4*
1992 08			*643.8*		*722.6*	*767.4*			*703.0*

Amplitudes are in microgal

IMGC: Istituto di Metrologia G. Colonnetti, Torino
J3: Institut für Erdemessung, Hannover
J5: Geodeettinen Laitos (Helsinki)

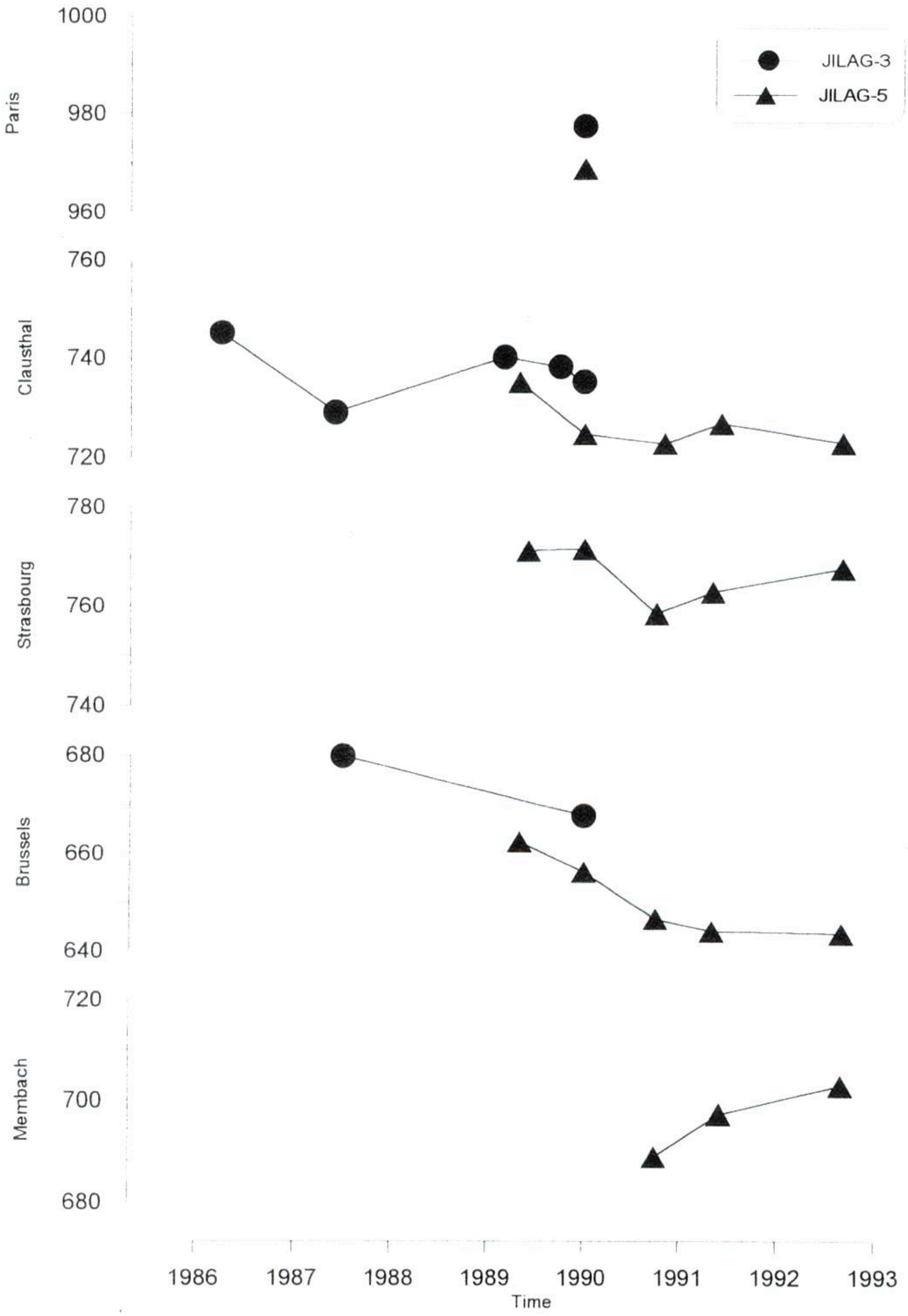

Fig. 1. Plot of the absolute measurements of the Jilag-3 and Jilag-5 gravimeters listed in table 1. Only the three digits at the microgal level are given.

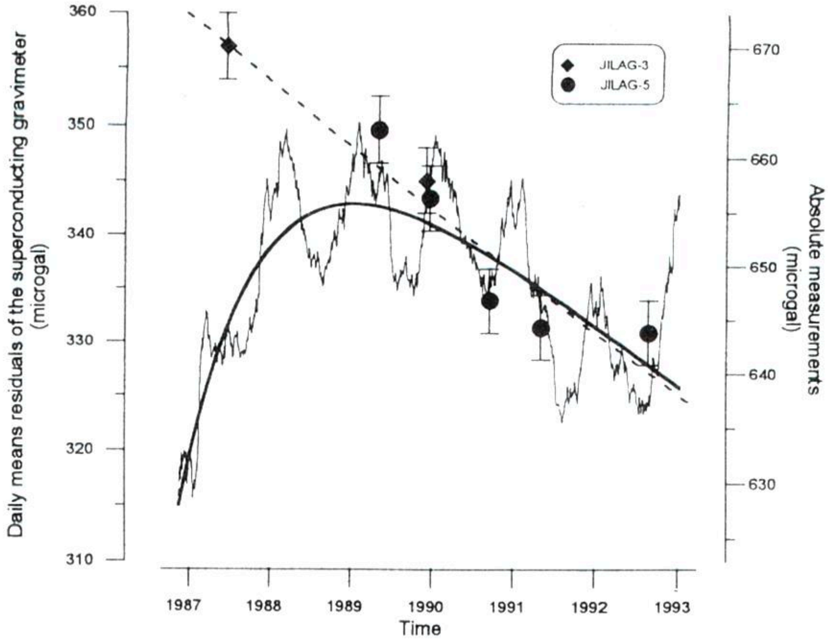

Fig. 2. Intercomparison between the superconducting and the absolute gravimeter data in Brussels. The full line is the daily mean residuals of the superconducting gravimeter data, the bold line the modelled instrumental drift, the dots are the absolute gravity measurements (the Jilag-3 measurements are correct for an offset of -10 microgal) and the dashed line is the associated regression line. An arbitrary and reasonable error bar of 3 microgal have been assigned to the absolute measurements in order to give a better view of the scale.

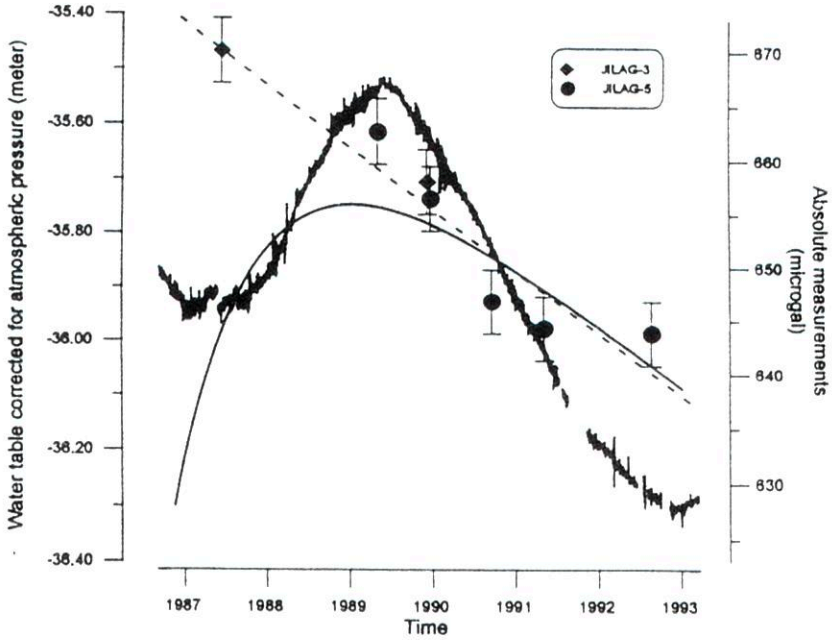

Fig. 3. Intercomparison between the superconducting drift (bold line), the absolute gravimeter data (dots) and the water table level (full line) in Brussels. The Jilag-3 measurements are correct for an offset of -10 microgal and the dashed line is the straight line fitted on the absolute measurements. An arbitrary and reasonable error bar of 3 microgal have been assigned to the absolute measurements in order to give a better view of the scale.