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Renewal of the Austrian Gravimeter Calibration Line HCL

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Abstract

The Hochkar Calibration Line (HCL) was established 1982 between Goestling/Ybbs to Hochkar and has been used yearly for calibrating relative gravimeters in Austria. The gravity difference of 198.3 mGal (1.983 μm/s²) at this line with only 20 km distance is based mostly on the height dependence of gravity. In 1988 and 1995 the HCL was checked and fixed by absolute gravity measurements using the free fall gravimeter JILAg6. Due to changes (constructions) at the top station Hochkar in 2013 it was necessary to define a new end-point combined with some new secondary points. In 2014 at the still existing absolute stations in Goestling and Hochkar absolute observations were repeated with an absolute gravimeter FG5. The long time observations by several relative gravimeters since 1982 are analysed and combined with the absolute gravity results. The new results show a small gravity change at the top station of approximately –20 μGal in comparison to 1995. The BEV now provides for the users of the HCL an updated and high accurate calibration facility for relative gravimeters.

Keywords: Relative gravimetry, Absolute gravimetry, Calibration, metrology, FG5, Scintrex

Kurzfassung

Die “Hochkar-Eichlinie” – Hochkar Calibration Line (HCL) wurde 1982 zwischen Göstling/Ybbs und dem Hochkar eingerichtet und wird seither jährlich zur Kalibrierung der Relativgravimeter in Österreich verwendet. Die Schweredifferenz von 198.3 mGal (= 1.983 μm/s²) dieser Linie mit bloß 20 km Länge wird hauptsächlich durch die Höhenabhängigkeit der Schwere verursacht. Infolge von Veränderungen (Umbauten) an der oberen Station Hochkar im Jahr 2013 wurde es nötig, den Endpunkt mit einigen neuen Versicherungspunkten neu festzulegen. An den noch vorhandenen Absolutstationen in Göstling und Hochkar wurden die Absolutschweremessungen mit einem Absolutgravimeter FG5 wiederholt. Die über lange Zeit erfolgten Relativmessungen seit 1982 wurden mit den Absolutschweremessungen kombiniert und analysiert. Die neuen Messungen zeigen eine kleine Schwereänderung von etwa –20 μGal an der oberen Station gegenüber 1995. Durch die Aktualisierung steht den Nutzern der HCL weiterhin eine hochgenaue Einrichtung zur Kalibration von Relativgravimetern zur Verfügung.

Schlüsselwörter: Relativgravimeter, Absolutgravimeter, Kalibrieren, Metrologie, FG5, Scintrex

1. Introduction

Austrians gravimeter calibration line was installed 1982 between Goestling/Ybbs and Hochkar in Lower Austria [1]. It's easily reachable from Vienna in about two hours in a driving distance of 160 km (Figure 1). The top station Hochkar gave the name: “Hochkar Calibration Line – HCL”. Since that time the HCL was frequently used for checking and calibrating relative gravimeters. The total gravity difference of about 200 mGal between the end points is mostly based on the height dependence of gravity. This gravity difference covers the measuring range of the two LCR[1)]-D relative gravimeters which were mostly used at the IMG-UW[2)] and the BEV[3)] for a very high number of gravity observations in Austria. Moreover the HCL is used for all other used relative gravimeters. The calibration line consists of four main stations. That enables to check also the non linearity of gravimeter factors which strongly occurs by LCR meters [2]. The time needed to access these sites successive by car is less than 30 minutes at a distance of 20 km. Therefore a fast and economic procedure for calibrating improves the quality of drift determinations. Nevertheless the total height difference of about 950 m of the HCL affects the measurement uncertainty of the results due to air pressure effects and consequential a hysteresis behaviour of the LCR meters.

1) LCR gravimeters manufactured by LaCoste&Romberg
2) Institute of Meteorology and Geophysics, University of Vienna; http://img.univie.ac.at/
3) Bundesamt für Eich und Vermessungswesen (Federal Office of Metrology and Surveying); www.bev.gv.at

2. Reference frame / datum

In the beginning the gravity stations were determined by 3 LCR gravimeters which were calibrated by using the results of the Austrian

Site	Station nb.	φ	λ	Height [m]	geology
Goestling	S1-071-00	47°48.49’	14°56.16’	528,9	Alluvial gravel
Lassing	S1-101-10	47°44.82’	14°54.06’	684,8	Alluvial gravel
Aiblboden	S1-101-20	47°44.10’	14°54.56’	1115,9	Limestone
Hochkar	S1-101-37	47°43.14’	14°55.04’	1489,8	Limestone, dolomite

Tab. 1: Main gravity stations at the Hochkar Calibration Line – HCL

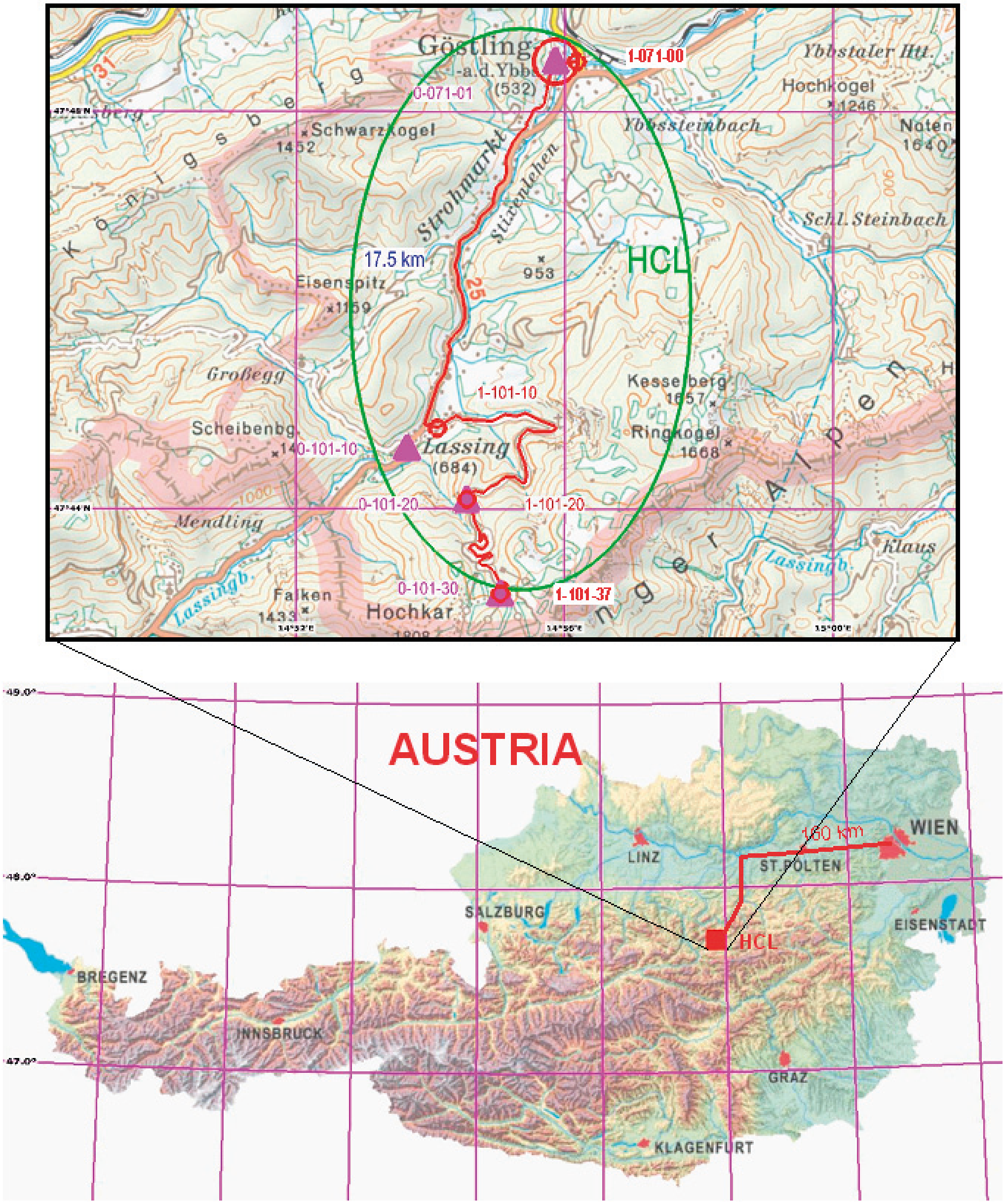

Fig. 1: Situation of HCL in Austria

Fig. 2: Lower station Goestling – Nepomuk S1-071-00

Gravity Base Network that was adjusted by six absolute gravity stations [1].

In 1988 close to the two end points of the HCL absolute gravity stations were founded and observed with the JILAg-6 free fall absolute gravimeter of Austria. In 1995 the absolute gravity measurements were repeated at the end points and supplemented by observations close to the waypoints (intermediate sites) Lassing and Aiblboden [3]. In Goestling the former station in the church-tower was no longer suitable for sensible free fall absolute observations, therefore

Fig. 3: Upper station Hochkar S1-101-37

a new station was founded near by in the cellar of the school building and tied to the former site by relative gravimeters. The comparisons of the results of the two observations epochs do not show significant differences at the repeated sites (Table 2). The given difference of 429 µGal is the result of the network adjustment using about 40 ties.

Additionally during the 1995 campaign vertical gradient measurements were performed at all stations (absolute and relative sites) and a microgravity network was established including all the sites of the HCL (Table 3).

3. Relative gravity observations

Since 1982 a very high number of gravity measurements (132) were taken for calibrating the relative gravimeters. Nevertheless the results in Figure 4 show quite large differences between the instruments. The red line gives the average value respectively the nominal difference value. The nominal difference value corresponds to the directly measured connections from the HCL end points to the absolute stations. The average value is calculated using all relative gravity measurements between the end points of the HCL. Both values fit to 0.8 µGal. The maximum scatter of the measured differences between the main points

Goestling-Nepumuk and Hochkar amounts 97 µGal which is 0.05 % of the total difference. The big scatter of the relative gravimeter results may be caused by not exactly compensated pressure influence of the LCR-meters which also show quite large hysteresis effects at the two waypoints dependent from the direction of driving whether you come down or up [2]. This graph gives also an impression of measurement uncertainties of the relative gravimeters which may occur during normal field observations. Using Scintrex CG5 relative gravimeters since 2007 show an improvement of the results. A very high attention has to be paid to the vertical gradients of gravity at the different stations. This is necessary, if the sensors of the different used relative gravimeters are in different positions above the benchmarks. Particularly the sensors of Scintrex gravimeters are located ~20 cm higher than those of the LCR gravimeters. Table 3 shows the different gradients at the stations. The scatter amounts 175 µGal/m. Negating the effect of gradients

Site	Station	1988	1995	2014
Goestling church-tower absolute station	0-071-00	980 681 839 ± 5	980 681 843 ± 4 (relative deduction)	980 681 844 ± 8 (relative deduction)
Relative tie (school – tower)			429 ± 3	429 ± 3
Goestling school (absolute)	0-071-01	—	980 682 272 ± 3	980 682 273 ± 7
Hochkar absolute station	0-101-00	980 484 648 ± 5	980 484 647 ± 5	980 484 626 ± 5

Tab. 2: Comparison of repeated absolute gravity observations at the HCL (1988/1995) values in µGal (=10 nm/s²)

Site	Station	Order	VG [µGal/m]
Goestling church-tower	0-071-00	Absolute I	235 ± 4
Goestling school	0-071-01	Absolute II	183 ± 5
Goestling Nepomuk	1-071-00	Main HCL point	282 ± 6
Goestling church	1-071-01	Secondary HCL point	250 ± 6
Lassing Maut	1-101-10	Main HCL waypoint	258 ± 7
Aiblboden	1-101-20	Main HCL waypoint	333 ± 7
Hochkar JUFA outside	1-101-37	Main HCL point	357 ± 7
Hochkar JUFA inside	0-101-30	Absolute	356 ± 4

Tab. 3: Different vertical gravity gradients at different stations

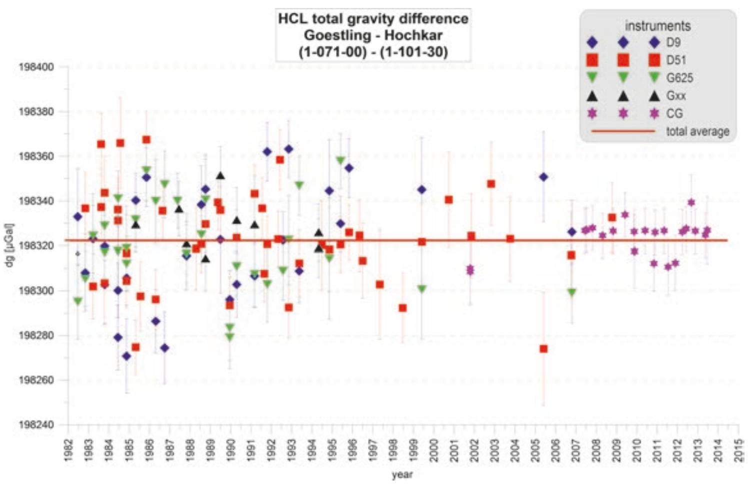

Fig. 4: Relative gravimeter measurement scatter at the HCL before calibration

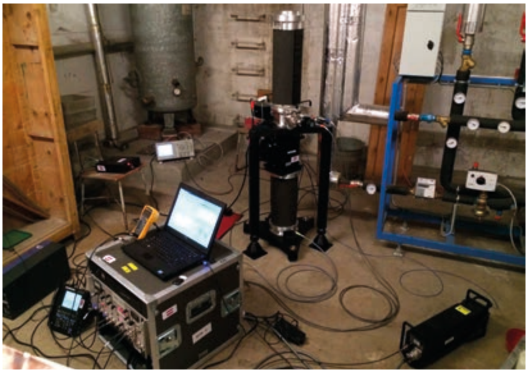

Fig. 5: *FG5 absolute gravimeter at the absolute gravity station Goestling*

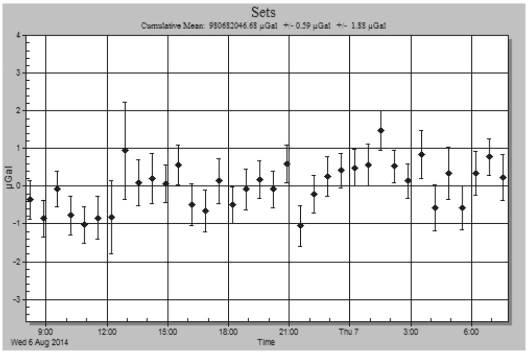

Fig. 6: *Set results of FG5-242 at Goestling 2014*

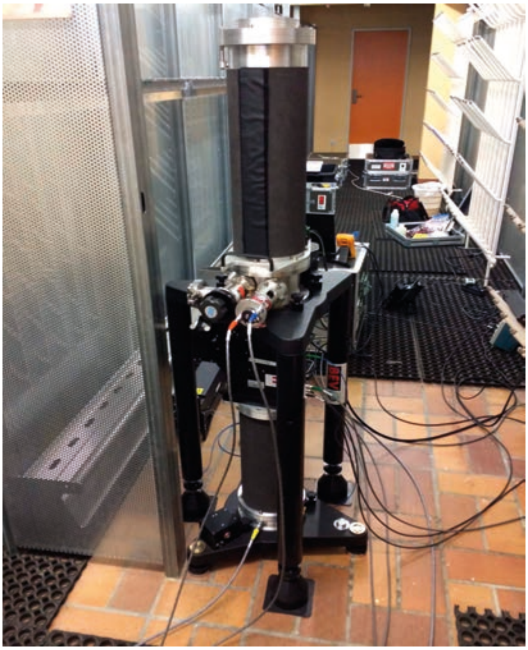

Fig. 7: *Absolute station Hochkar 2014*

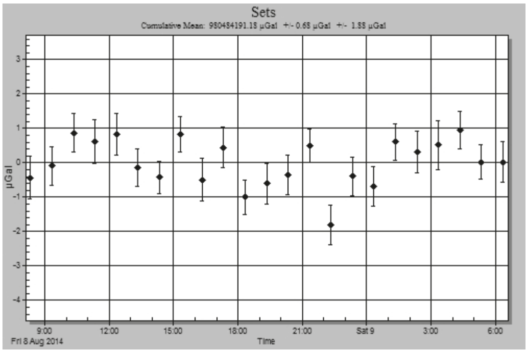

Fig. 8: *Set results at Hochkar 2014*

may cause errors in the results in order of more than 30 μGal for the gravity differences between certain stations.

4. Absolute gravity measurements 2014

In August 2014 new absolute gravity measurements were performed at the HCL with the absolute gravimeter FG5-242 which is also used as the Austrian national metrological standard for the earth acceleration. The use of the FG5 absolute gravimeter improves the measurement uncertainty greatly compared with the former used JILAg instrument. The measurement uncertainty now varies around 2.5 μGal (1 μGal $= 10^{-8} m/s^2$). Both used absolute gravimeters were validated regularly by international absolute gravimeter comparisons every 4 years at least [4, 5, 6].

Due to the changes caused by construction at the top station Hochkar it was necessary to repeat the absolute gravity observations there. So it was also opportune to repeat the observation at the bottom station Goestling-school. Because of the unfavorable locations of the absolute stations of the waypoints their re-measurements were waived.

Usually in practice the relative gravimeter observations for calibrations are made at the main HCL stations (Goestling-Nepomuk, Lassing-Maut, Aiblboden, Hochkar-JUFA) and not at the absolute points. The reason is primary the more complicated accessibility of the inside stations which would cause much more time. The relative gravity connections between the absolute stations and the HCL calibration points were repeated several times over the years.

4.1 Absolute station Goestling

The absolute measurements at Goestling were performed in the cellar of the primary school

			differences [µGal]			
Site	*station*	*g [µGal]*	*1-071-01*	*1-101-10*	*1-101-20*	*1-101-37*
Goestling Nepomuk	1-071-00	980683147	1228	41152	126880	198356
Goestling church	1-071-01	980681919	0	39924	125652	197128
Lassing Maut	1-101-10	980641995		0	85728	157204
Aiblboden	1-101-20	980556267			0	71476
Hochkar JUFA	1-101-37	980484791				0

Tab. 4: *New gravity values of the HCL at the benchmarks main stations for relative gravimeters*

(Figure 5) and lasted 24 hours (Figure 6). Around 3500 free fall drops were used for the final gravity value. The result at the reference benchmark coincides with the former measurements in the level of about 2 µGal (Table 1). The measurement uncertainty of the observation 2014 amounts 2.4 µGal. The set gravity values are shown in Figure 6. Their scatter is clearly below 2 µGal.

4.2 Absolute station Hochkar

The absolute measurements at Hochkar were performed in the JUFA Hotel in the ski storage room (Figure 7). The measurements lasted over two days. About 3500 drops were used for calculating the absolute gravity value. The new result differs about 21 µGal from the former measurement results. That means that the value at the absolute gravity station at Hochkar is 21 µGal less than the old values of 1988 and 1995. The reason of this gravity decrease could be explained by earthmoving through renovation of the buildings respective the near surrounding.

5. HCL results

The new values of the HCL for relative gravimeter positions are calculated using all suitable gravity differences and absolute observations by network adjustment (Table 4). The measurement uncertainty of the results is 3 µGal at one sigma level due to this adjustment. Detailed descriptions of the stations are available at the BEV in Vienna.

6. Conclusion

The Hochkar Gravimeter Calibration Line HCL is a very important facility in Austria for checking and calibrating relative gravimeters. This Line is used since 1982 periodically by domestic gravimeters as well as by foreign gravimeters. The HCL itself is checked by absolute gravity observations on the one hand; on the other hand it can be checked recursively using the results of the relative gravity measurements. The results of the relative measurements show unfortunately a large scatter. Nevertheless the combination of absolute and a high number of relative measurements give quite good gravity values at the main stations. It is also necessary to observe the surrounding of the stations if there may be an influence on the gravity value caused by constructions and mass movements. Therefore absolute observations have to be repeated from time to time.

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