The measuring offset between the Hannover absolute gravimeters JILAG-3 and FG5-220

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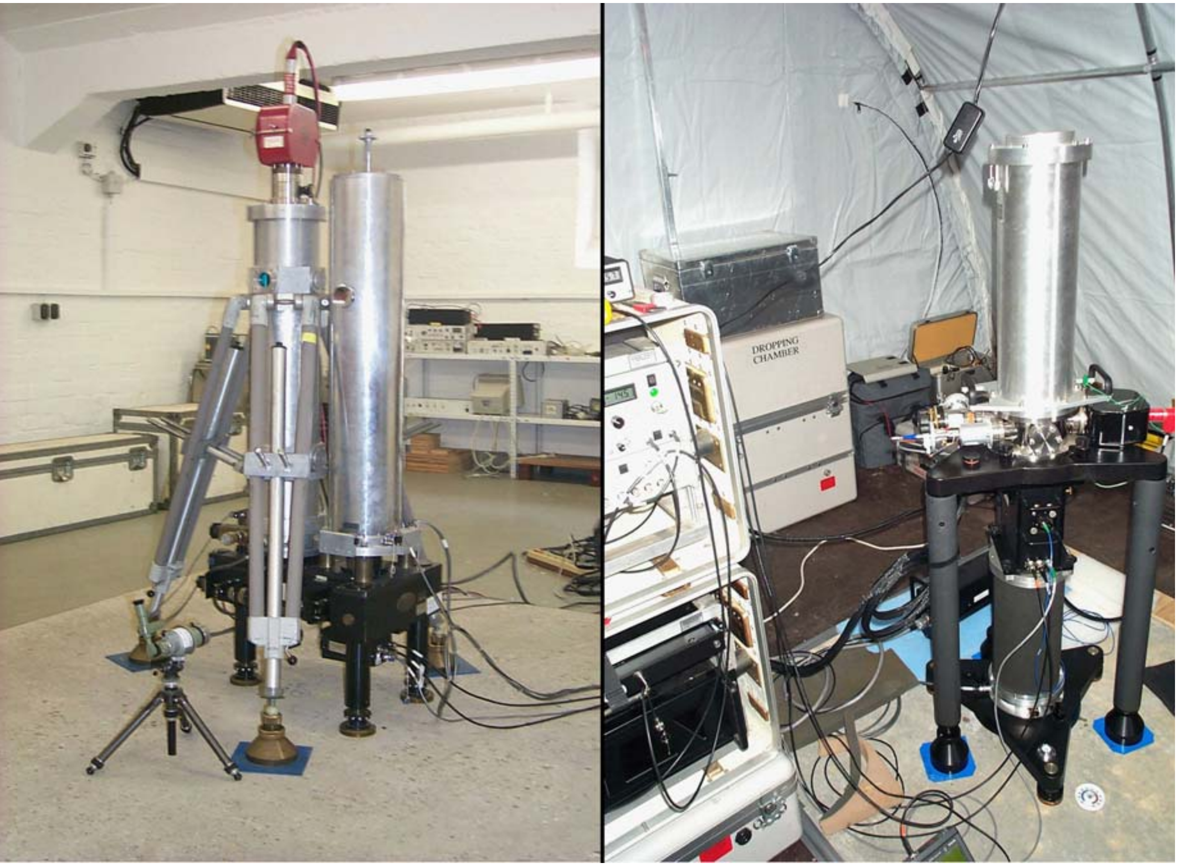
L. Timmen, O. Gitlein
&
R. Falk, H. Wilmes



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Motivation: Cooperation IfE with GI/KMS/DNSC

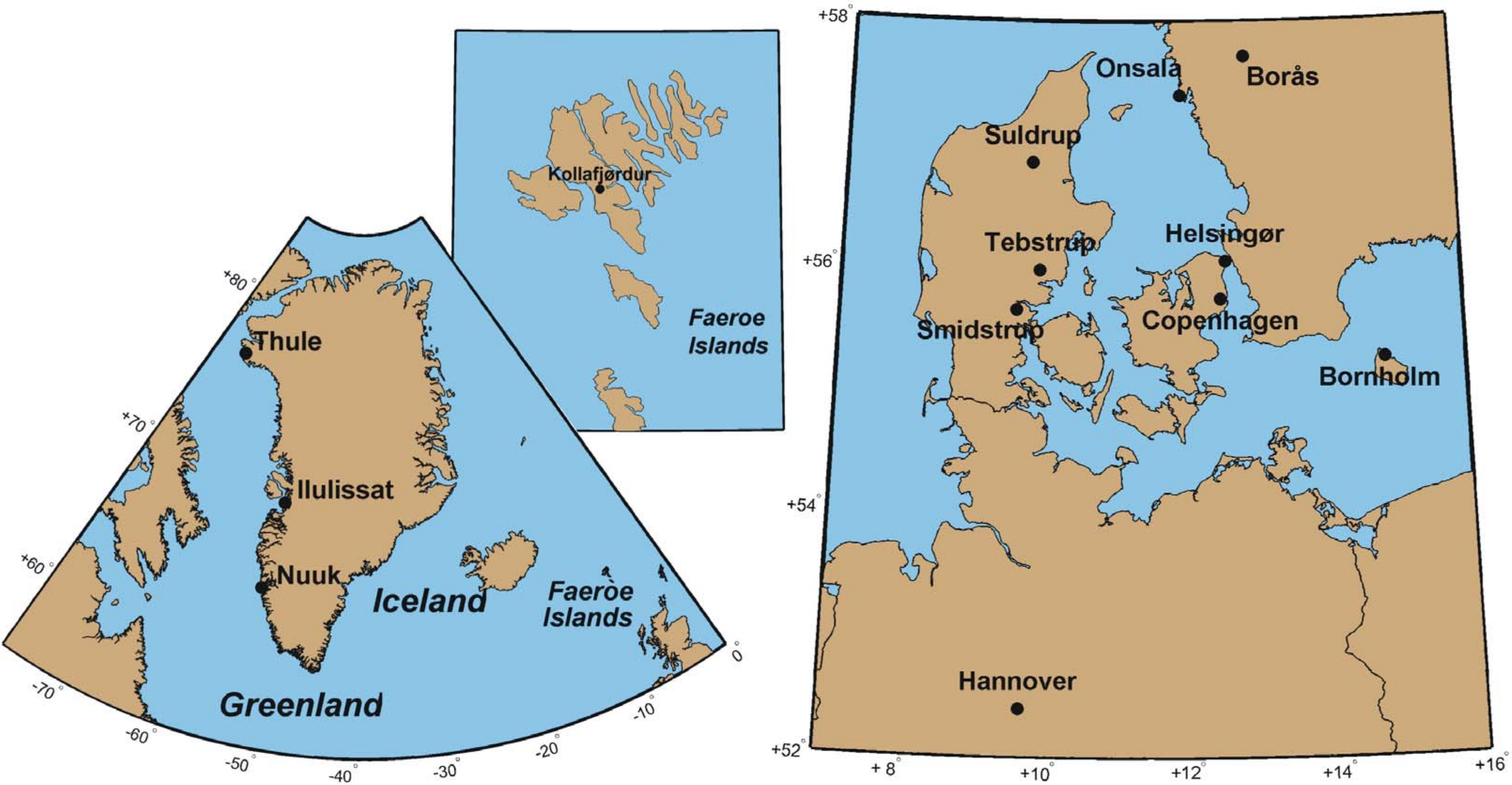


Fig. 7: The absolute gravity sites occupied by JILAg-3 and FG5-220 within the Danish-German cooperation since 1986

Station	Remarks/Purpose
Tebstrup	geodynamics: Fennoscandian land uplift line (east-west, 56°N); national grav. reference; destroyed since 2005
Helsingør	geodynamics: Fennoscandian land uplift line (east-west, 56° N); nat. grav. reference
Copenhagen, Gamlehave	national grav. reference; former Danish Geodetic Institute; destroyed
Copenhagen, Buddinge	national grav. reference; not any more accessible
Copenhagen, University	national gravity reference
Copenhagen, Vestvolden	geodynamics: Fennoscandian land uplift net; national gravity reference
Smidstrup GPS	national grav. reference; outside station (tent)
Suldrup GPS	national grav. reference; outside station (tent)
Bornholm, Tejn	geodynamics: Fennoscandian land uplift net; nat. grav. reference; city hall
Nuuk, Godthåb (Greenland)	geodynamics: crustal deformation; absol. control: deglaciation due to climate change; nat. grav. ref; IAGBN
Ilulissat, Jakobshavn (Greenland)	geodynamics: crustal def.; absol. control: deglaciation; nat. grav. ref.
Thule/air base (Greenland)	geodynamics: crustal deformation; absol. control: deglaciation; nat. grav. ref.
Kollafjørdur (the Faeroe Islands)	geodynamics: crustal deformation; absol. control: tide gauge stability; nat. grav. ref.; agriculture station: old point destroyed, new point in same building

Station	Instr.	Date
Tebstrup	JILAg-3	22.08.1986
	FG5-220	10.-11.06.2003
Helsingør	JILAg-3	23.08.1986
	FG5-220	07.-08.06.2003
	FG5-220	18.-20.06.2005
Copenhagen, Gamlehave	JILAg-3	20.08.1986
Copenhagen, Buddinge	FG5-220	03.-04.06.2003
Copenhagen, University	FG5-220	17.-18.10.2005
Copenhagen, Vestvolden	FG5-220	05.-06.06.2003
	FG5-220	17.-19.10.2004
	FG5-220	15.-16.10.2005
	FG5-220	03.-05.05.2007
	FG5-220	09.-11.10.2007
Smidstrup GPS	FG5-220	10.-11.06.2005
Suldrup GPS	FG5-220	15.-17.06.2005
Bornholm, Tejn	FG5-220	20.-22.10.2004
Nuuk, Godthåb	JILAg-3	14.-15.05.1988
Ilulissat, Jakobshavn	JILAg-3	17.-18.05.1988
Thule, air base	JILAg-3	20.-22.05.1988
Kollafjørdur old	JILAg-3	29.-30.06.1987
new	FG5-220	01.-04.11.2004

Measuring Offset between JILAg-3 and FG5-101

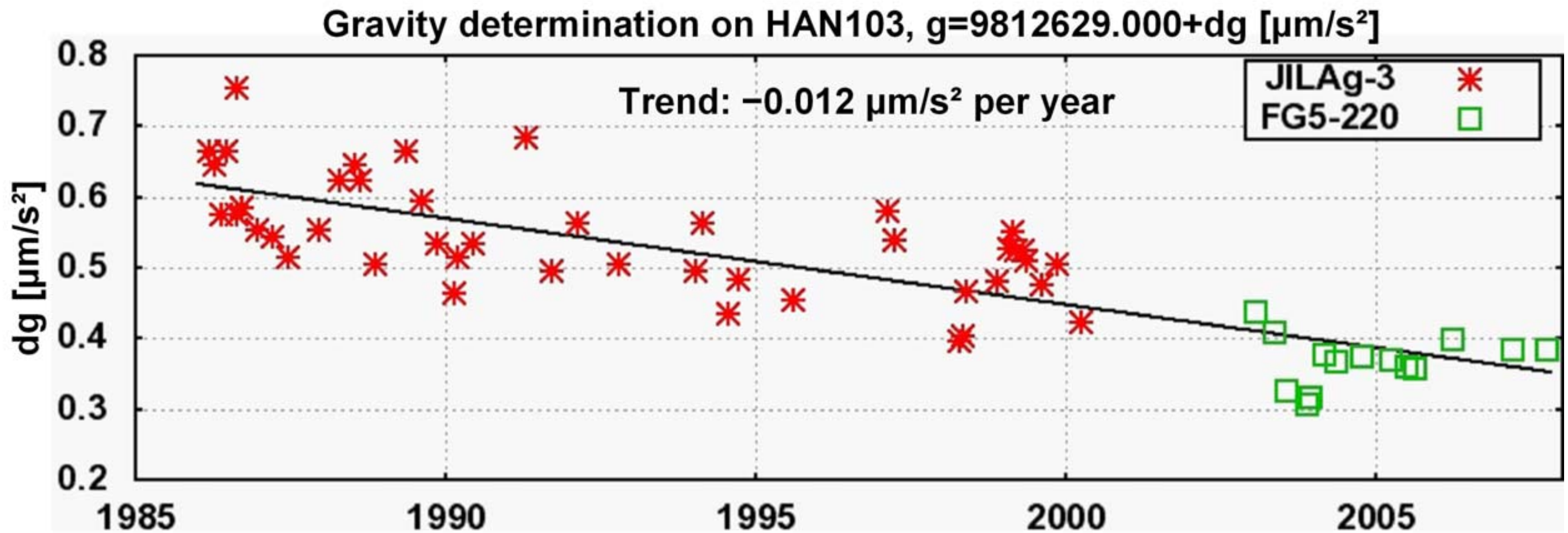
Das Deutsche Schweregrundnetz 1994 (DSGN94):
W. Torge, R. Falk, A. Franke, E. Reinhart, B. Richter, M. Sommer, H. Wilmes 1999

Instrument	Sèvres 1994 (Pfeiler A0) [μm s^{-2}]	Sèvres 1997 (Pfeiler A) [μm s^{-2}]	DSGN94 5 Stationen [μm s^{-2}]	Clausthal [μm s^{-2}]
JILAG 3	9 809 257.13	9 809 257.132		9 811 157.338
FG5-101	9 809 257.04 *	9 809 257.051		9 811 157.244
Differenz JILAG-3 – FG5-101				
	0.090	0.081	0.082	0.094
Differenz zum Mittelwert in Sèvres				
JILAG 3	- 0.028	- 0.052		
FG5-101	+ 0.062	+ 0.030		

Measuring Offset between JILAg-3 and FG5-220

Tab. 1: Mean gravity values for station Clausthal (Germany) derived with JILAg-3 (n=29 occupations, 1986-2000) and FG5-220 (n=4 in 2003). The given s_i are standard deviations for a single gravity determination.

JILAg-3/FG5-220 Comparison	Remarks	Gravimeter	Period	Mean g-Result [µm/s²]
Clausthal (Harz Mountains)	IfE reference station for JILAg-3, ref.height 0.000m	JILAg-3	1986 to 2000	9811157.345 $s_i=\pm0.049$, n=29
		FG5-220	Jan. to Oct. 2003	9811157.251 $s_i=\pm0.023$, n=4
				$\Delta g = +$**0.094**



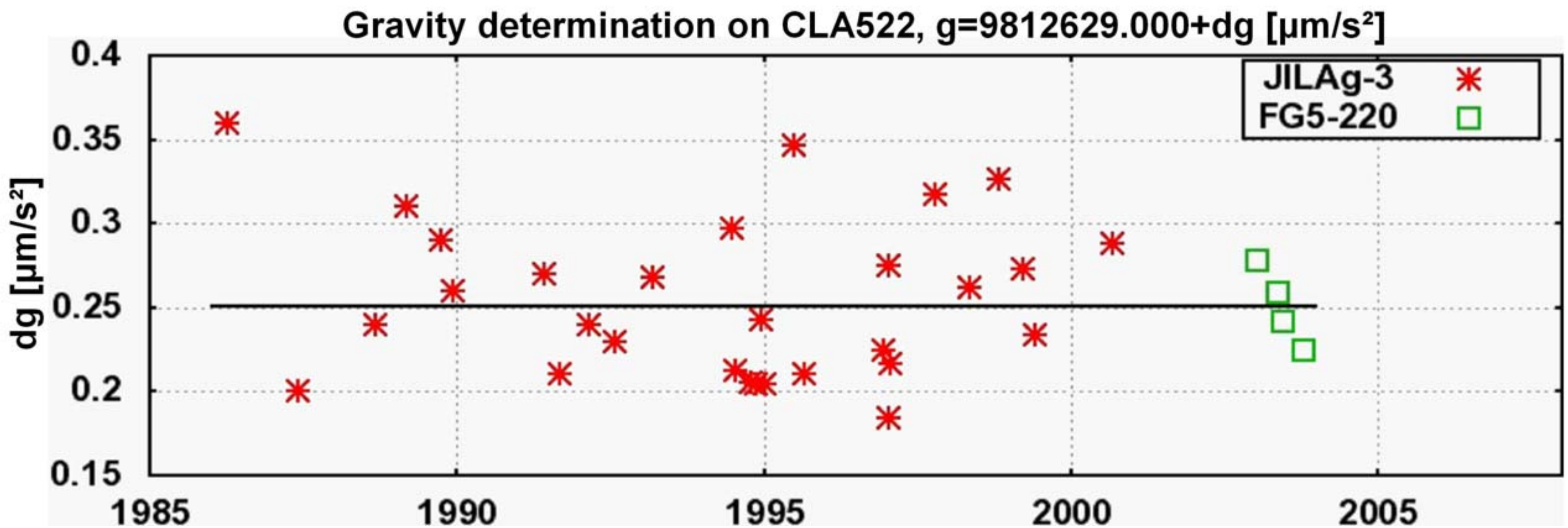


Fig. 5: Absolute gravity determinations with JILAg-3 and FG5-220 at stations Hannover (HAN103, trend -0.012 ±0.001 µm/s² per year) and Clausthal (CLA522, trend -0.001 ±0.002 µm/s² per year). An instrumental offset of −0.09 µm/s² (±0.01 µm/s²) was applied to the JILAg-3 results.

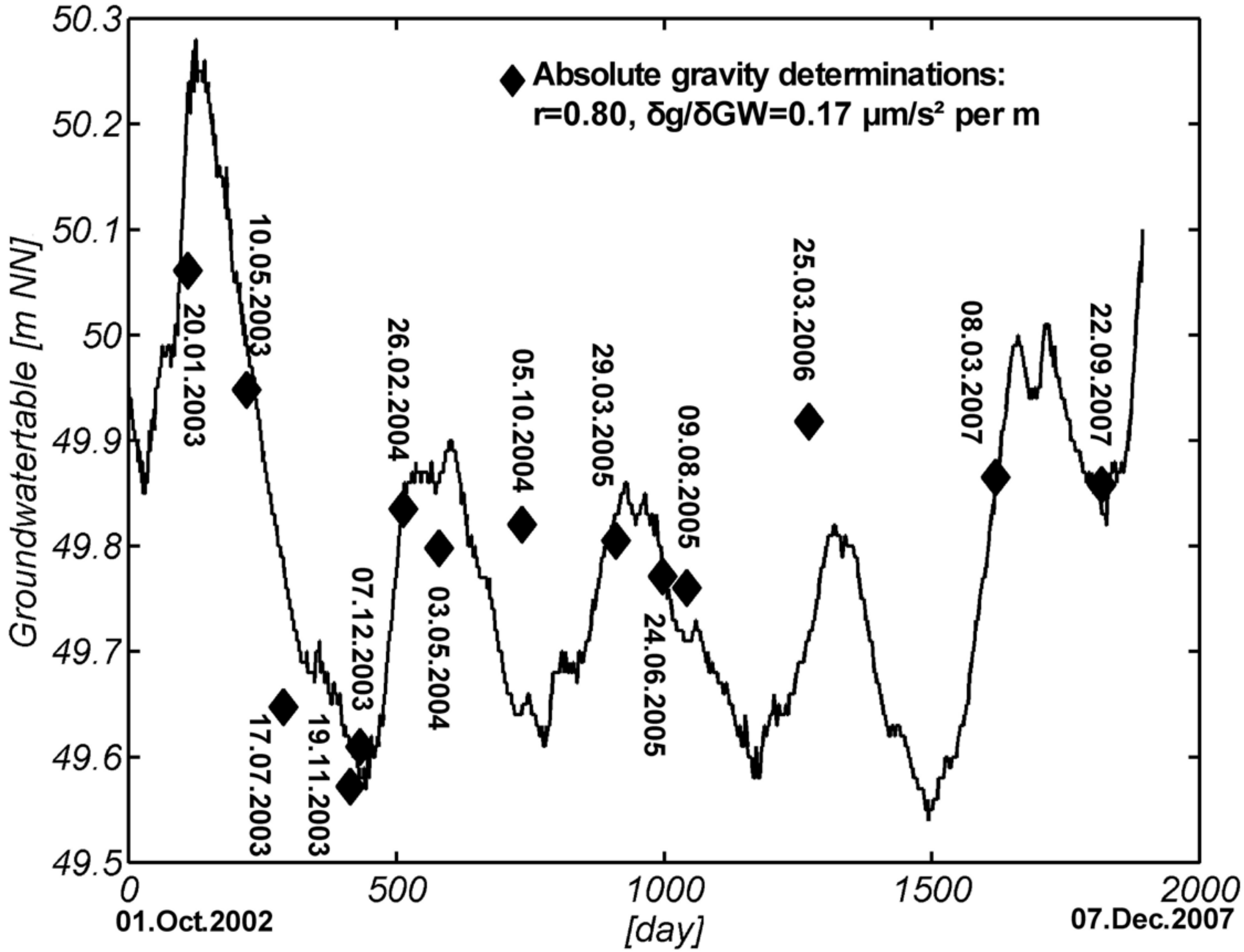


Fig. 6: Groundwater table at the gravimetry laboratory in Hannover and absolute gravity determinations with FG5-220 since 2003. The transfer function from gravity to groundwater change, with the linear coefficient 0.17 µm/s² per m, has been applied to the absolute gravity determinations to convert the *g*-values to groundwater readings.

JILAg-3 in the International Gravimetry Comparisons

Tab. 2: JILAg-3 absolute gravity meter controlled by external (international) and internal (repetition) comparisons to ensure consistent long-term measurement accuracy (n = number of observations)

JILAg-3 External Comparisons	Remarks	Gravimeter Group	Mean g-Result [μm/s²]	Std. Dev. of a Single Observ. [μm/s²]	Δg [μm/s²] (JILAg-3 minus Mean)
ICAG89, BIPM (Boulanger et al. 1991, Tab. 7)	referred to site A, ref. height 0.050 m, 19 station determinations with 10 absolute gravimeters	5 JILA	9809259.754	±0.062, n = 11	+0.018
		GABL, BIPM, IMGC, NIM, NAO	9.739	±0.092, n = 8	+0.033
		all 10 meters	9.748	±0.074, n = 19	**+0.024**
		only JILAg-3	9.772	n = 2	
ICAG94, BIPM (Marson et al. 1995, Tab. 4)	referred to site A0, ref. height 0.900 m, 12 observations with 11 absolute gravimeters	4 JILA	9809257.103	±0.049, n = 4	+0.027
		6 FG5	7.104	±0.028, n = 7	+0.026
		1 IMGC	7.090	n = 1	+0.040
		all 11 meters	7.102	±0.033, n = 12	**+0.028**
		only JILAg-3	7.130	n = 1	
ICAG97, BIPM (Robertsson et al. 2001, Tab. 5)	occupied site A with 12 instruments, ref. height 0.900 m	4 JILA	9809257.081	±0.055, n = 4	+0.056
		7 FG5	7.070	±0.037, n = 7	+0.066
		1 GABL-E	7.144	n = 1	–0.008
		all 12 meters	7.081	±0.045, n = 12	**+0.055**
		only JILAg-3	7.136	n = 1	
ICAG97, BIPM (Robertsson et al. 2001, Tab. 5)	occupied site A2 with 13 instruments, ref. height 0.900 m	4 JILA	9809257.166	±0.035, n = 4	+0.035
		6 FG5	7.137	±0.029, n = 6	+0.064
		IMGC, NIM-2a, ZZB	7.139	±0.101, n = 3	+0.062
		all 13 meters	7.146	±0.050, n = 13	**+0.055**
		only JILAg-3	7.201	n = 1	

JILAg-3 Internal Comparisons	Remarks	Observation Periode	Mean g-Result [µm/s²]	Std. Dev. of a Single Observ.	Δg [µm/s²]
Clausthal/Harz	IfE ref. station for JILAg-3, 29 obs. over 15 years, floor level	period 1986 to 2000	9811157.345	±0.047, n=29	
		only 1986 to 1996	7.341	±0.048, n=20	**−0.004**
		only 1997 to 2000	7.354	±0.046, n= 9	**+0.009**
Yunnan Earthquake Area, China (Torge et al. 1999b, Tab. 3)	JILAg-3 observ. at 4 (1990/1992) and 5 (1992/1995) identical stations	epoch 1992 minus 1990	**−0.038**	±0.073, n= 4	
		epoch 1995 minus 1992	**−0.008**	±0.050, n= 5	

Conclusions:

- JILAg-3 was well embedded in the international absolute gravity definition.
- A larger discrepancy to other instrument groups did not really become obvious.
- But a bias to the international standard, here defined as the average of all participating gravimeters at BIPM, of up to +0.05 $\mu m/s^2$ can not be excluded.
- From the ICAG94 and ICAG97 comparisons, a measurement offset of +0.09 $\mu m/s^2$ becomes visible when just comparing JILAg-3 with FG5-101.
- The offset correction for JILAg-3 has mainly to be considered as a bias with respect to the FG5-220 and the FG5-101 gravimeters.
- Interpreting the results of the international comparisons in Sèvres with respect to the instrument groups, a systematic error, inherent in the instrumental design of the JILAg or FG5 gravimeters, does not exist or is within the 0.02 $\mu m/s^2$ level.

FG5-220 in the International Gravimetry Comparisons

Tab. 3: FG5-220 absolute gravimeter controlled by external (international) and internal (repetition) comparisons to ensure consistent long-term measurement accuracy

FG5-220 External Comparison	Remarks	Epoch	Δg [μm/s²] (FG5-220 – Mean g)
ICAG2003, ECGS (Francis et al. 2006, Tab. 16)	13 abs. meters, 14 points, 52 determinations	Nov. 2003	**–0.019** std. dev. (Mean of 13 meters) ±0.018
FG5-220 Internal Comparison	**Remarks**	**Epoch**	**Δg (FG5-220) [μm/s²] (Single – Mean g)**
Bad Homburg (gravimetry lab. of BKG, Wilmes and Falk 2006)	IfE reference station for FG5-220 since 2003	Feb. 2003	+0.017
		Nov. 2003	–0.014
		Apr. 2005	–0.002
		Apr. 2006	+0.003
		Nov. 2007	–0.004

Tab. 6: Gravity measurements performed by JILAg-3 compared with FG5-220 determinations within the Danish-German cooperation since 1986. The JILAg-3 offset correction of −0.09 µm/s² has been applied.

Station	Gravimeter/year	Comparison height [m]	δg/δh (mean) [µms⁻²/ m]	g [µm/s²]	Δg [µm/s²]
Helsingør	JILAg-3/1986	1.000	2.64	9815801.35	
	FG5-220/2003			9815801.26	−0.09
	FG5-220/2005			9815801.30	−0.05
Tebstrup	JILAg-3/1986	1.000	2.58	9815802.49	
	FG5-220/2003			9815802.36	−0.13
Copenhagen, Buddinge 102	JILAg-3/1986	0.000	(abs. points Gamlehave, Buddinge centred to base net point 102)	9815430.16	
	FG5-220/2003			9815430.14	−0.02
Kollafjørdur, Faeroes	JILAg-3/1987	0.000	(new centred to old +0.30 µm/s²)	9820866.82	
	FG5-220/2004			9820866.86	+0.04

- 3 Denmark stations: average gravity decrease of 0.07 µm/s² during 17 years.
- Interpreting this as a secular land uplift signal, the gravity rate of −0.004 µm/s² per year implies an possible uplift rate of 2 mm per year.
- The good agreement between the two determinations on the Faeroe Islands reveals a stable situation for that location for the period 1987 to 2004.

Conclusion :

The accuracy of long-term time series of absolute gravimetric measurements depends, among others, on possible instrumental offsets between present and future developments.

That should be controlled carefully by performing gravity determinations at common national and international reference stations with the available state-of-the-art gravimeters.

This creates time histories for the stations and might reveal biases caused by different instrumental designs and technological developments.

From the German point of view, especially the station Bad Homburg is an appropriate site. It is equipped with continuous GPS and superconducting gravimetry.