Accuracy Estimation of the IfE Gravimeters Micro-g LaCoste gPhone-98 and ZLS Burris Gravity Meter B-64

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Relative Gravimeters

Micro-g LaCoste gPhone-98

- rubidium clock
- 1Hz/7Hz data
- level correction

ZLS Burris Gravity Meter B-64

- Gravity Consult ET recording software on laptop
- GPS time syncronisation
- 10s data (10 minute filter)
- B-64: non-calibrated model

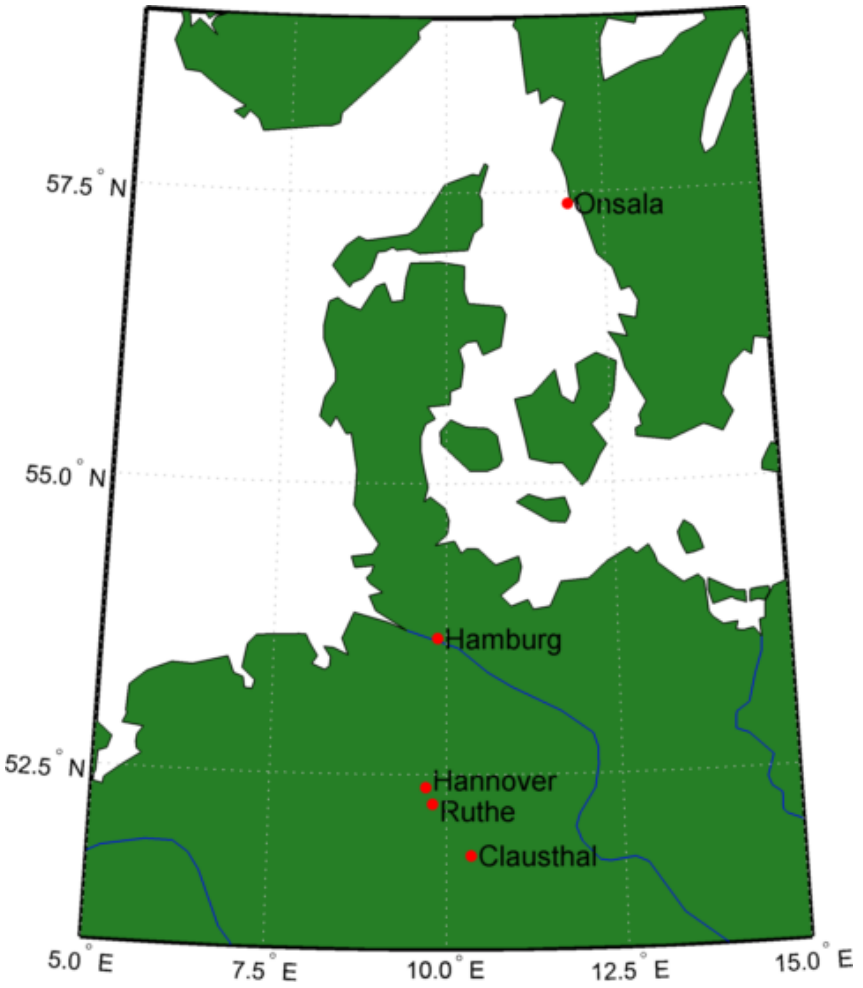
Overview of Gravity Stations

gPhone

Location	Duration (days)
Hannover	55
Hamburg	84
Clausthal	98
Ruthe	152

Burris

Location	Duration (days)
Onsala	48 49
Hannover	45
Ruthe	45 21



- **Calibration, drift and accuracy of instruments**
- **Comparison of stations and instruments**
- **Tidal analysis**
- **Micro-gravimetric measurements with Burris**

Calibration of Instruments

gPhone

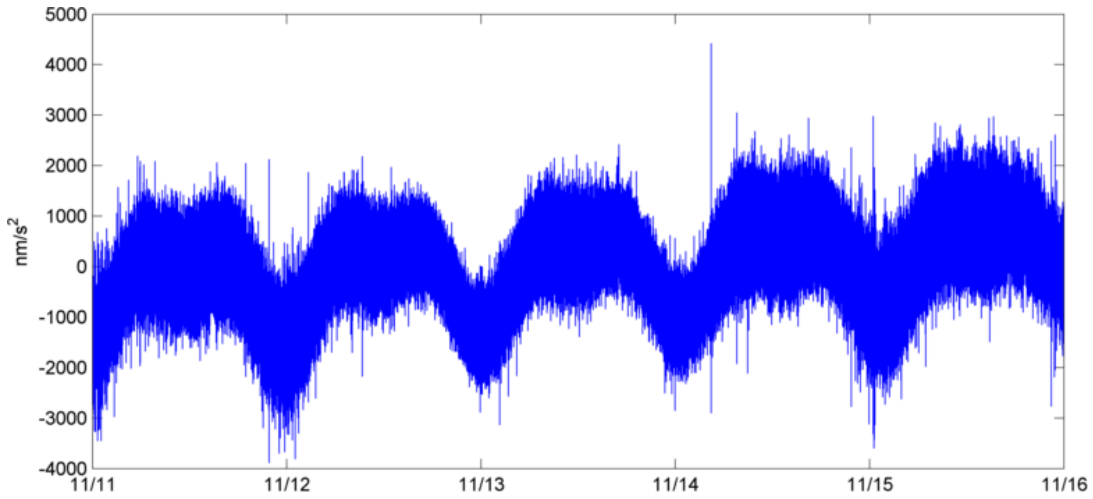
Date	lin. fac.	Δ e-3
12/2011	1.00240	0.015
04/2012	1.00206	0.366
08/2012	1.00247	-0.122
02/2013	1.00268	-0.259
mean	**1.00242±0.00027**	

Burris

Date	lin. fac.	Δ e-3
04/2012	0.99974	-0.354
04/2012	0.99953	-0.138
05/2012	0.99944	-0.059
09/2012	0.99895	0.441
11/2012	0.99937	0.042
01/2013	0.99961	-0.222
02/2013	0.99963	-0.237
05/2013	0.99946	-0.169
07/2013	0.99870	0.692
mean	**0.99939±0.00033**	

- calibration before and after recordings
- vertical calibration line Hannover
- Burris: quadratic factor <0.5e-9

Example of Gravity Recordings in Hannover

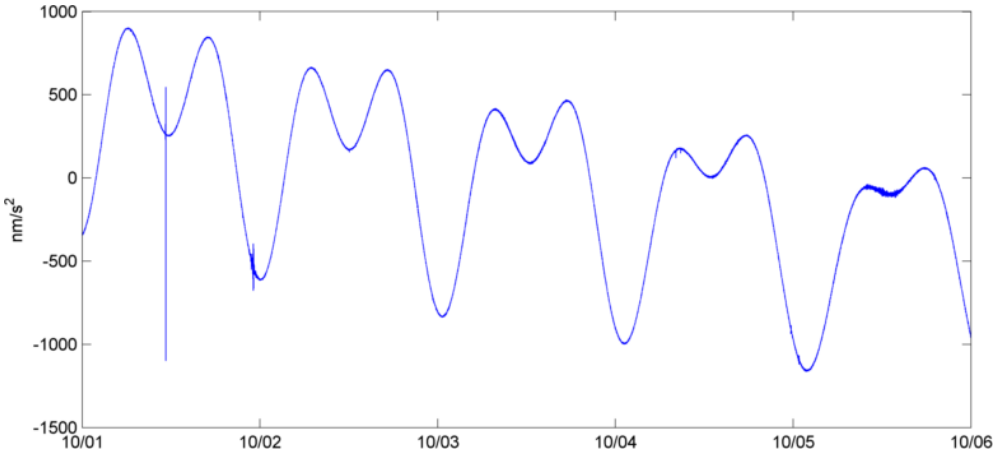


gPhone raw data 11/2011

- 1 Hz recording
- σ = ±730.9 nm/s²

Burris raw data 10/2012

- 0.1 Hz recording
- σ = ±3.7 nm/s²



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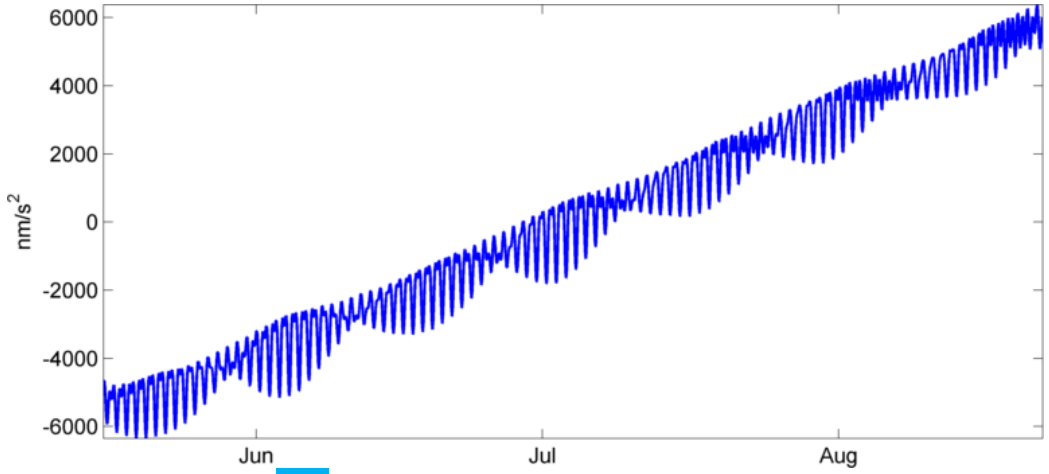
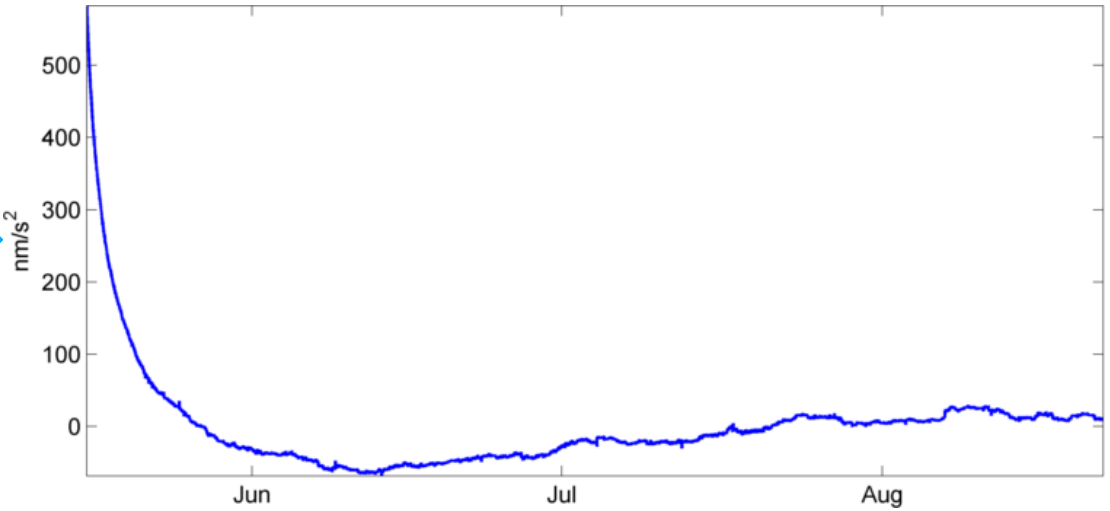
Drift of gPhone-98



gPhone raw data (3 months) resampled to 5 minute interval

corrected for

- time variable gravity
- trend 116.8 nm/s² per day

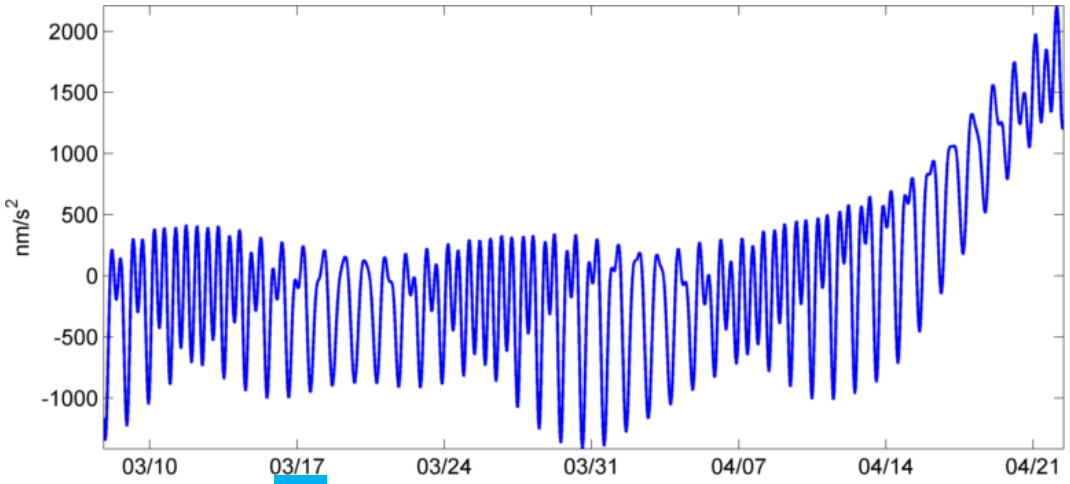


gPhone-98 Accuracy

Location	Date	Drift (nm/s² per day)	Standard deviation	
			1s (nm/s²)	300s (nm/s²)
Hannover	10/2011 - 12/2011	191.2 ±12.5	730.9	13.1
Hamburg	01/2012 - 04/2012	126.2 ±4.6	528.2	11.1
Clausthal	05/2012 - 08/2012	117.1 ±2.6	150.6	0.9
Ruthe	02/2013 - 08/2013	93.9 ±1.8	446.8	2.4

- linear drift estimated from 7 day linear fit
- 1s/300s standard deviation estimated of 1. derivative

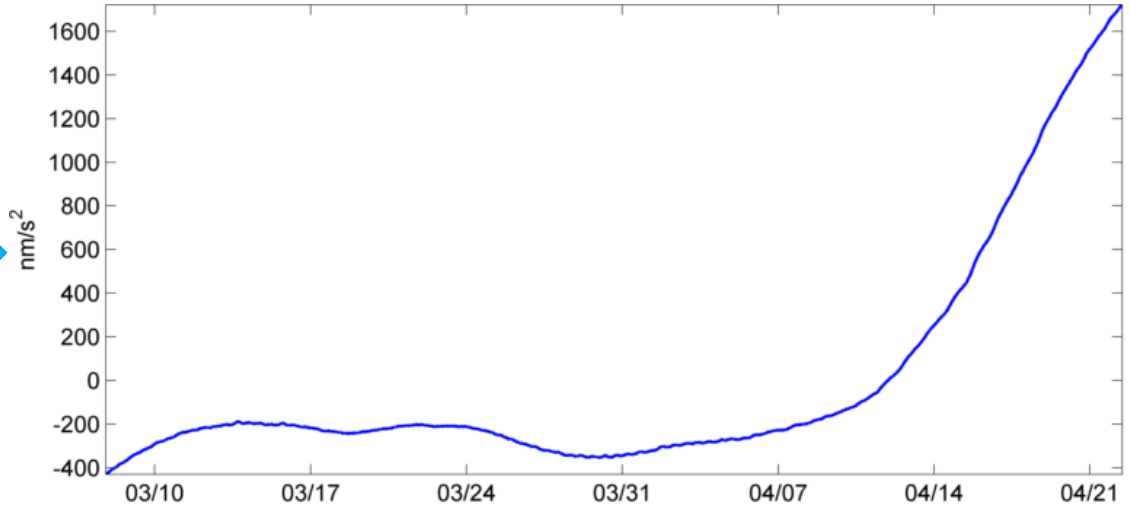
Drift of Burris B-64



Burris raw data (7 weeks) resampled to 5 minute interval

corrected for

- time variable gravity



Burris B-64 Accuracy

Location	Date	Drift (nm/s^2 per day)	Standard deviation	
			10s (nm/s^2)	300s (nm/s^2)
Onsala	06/2012 - 07/2012	-209.4 ±61.2	3.1	0.7
	07/2012 - 09/2012	-155.4 ±39.2	4.0	0.8
Hannover	09/2012 - 11/2012	-177.4 ±15.0	3.7	0.8
Ruthe	03/2013 - 04/2013	-186.7 ±76.3	3.6	0.8
	05/2013	-10.4 ±44.5	3.7	1.0

- linear drift estimated from 7 day linear fit
- recordings with ET software not affected by station quality
- non-linear drift

- Calibration, drift and accuracy of instruments
- **Comparison of stations and instruments**
- Tidal analysis
- Micro-gravimetric measurements with Burris

Earth Tide Recordings

Dataprocessing

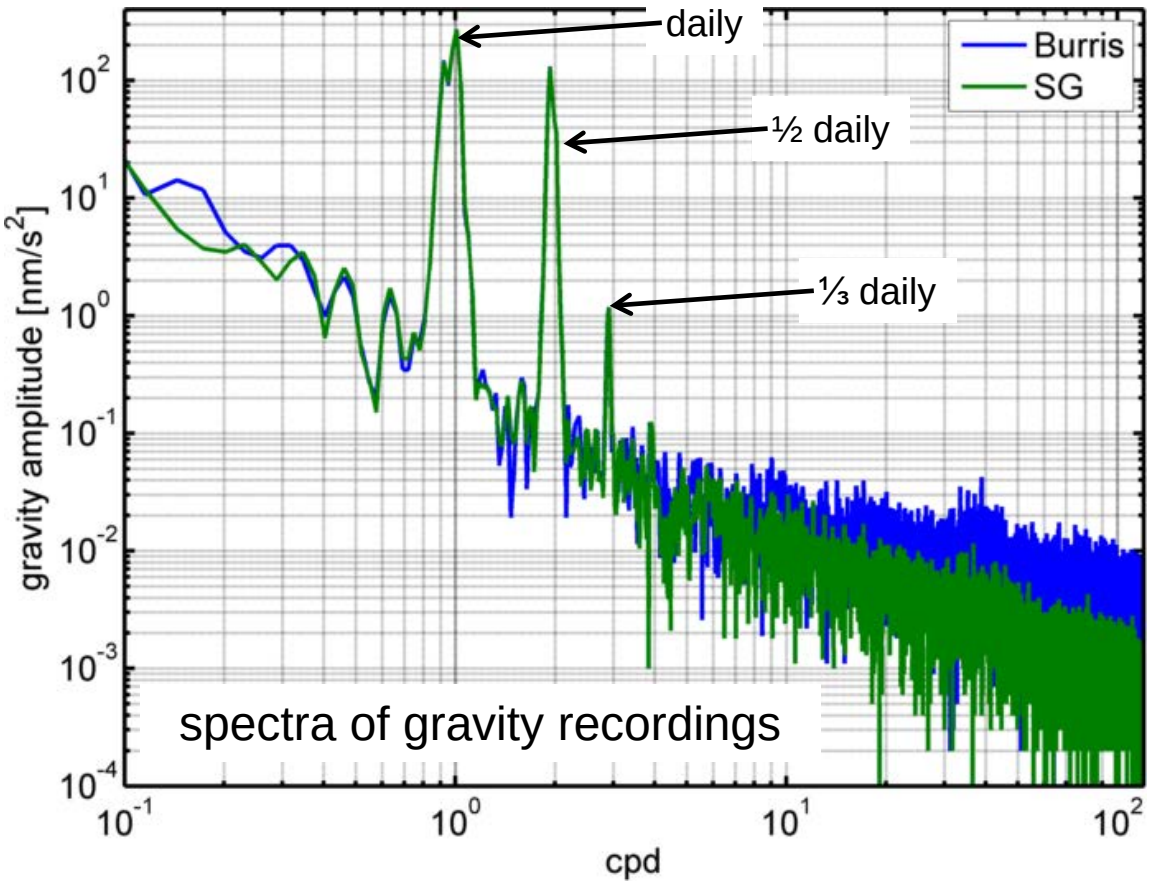
- reductions due to
  - atmospheric masses
  - synthetic gravity tides including ocean loading[1]
  - polar motion
- earthquakes, spikes, steps, drift removed
- resampling to five minute time interval

[1] Timmen and Wenzel (1995): IAG Symp. Vol. 113

Comparison at the same station Burris and SG in Onsala

simultaneous measurement with instrument of higher accuracy

- Superconducting Gravimeter (SG) at OSO
- low noise environment
- climate controlled



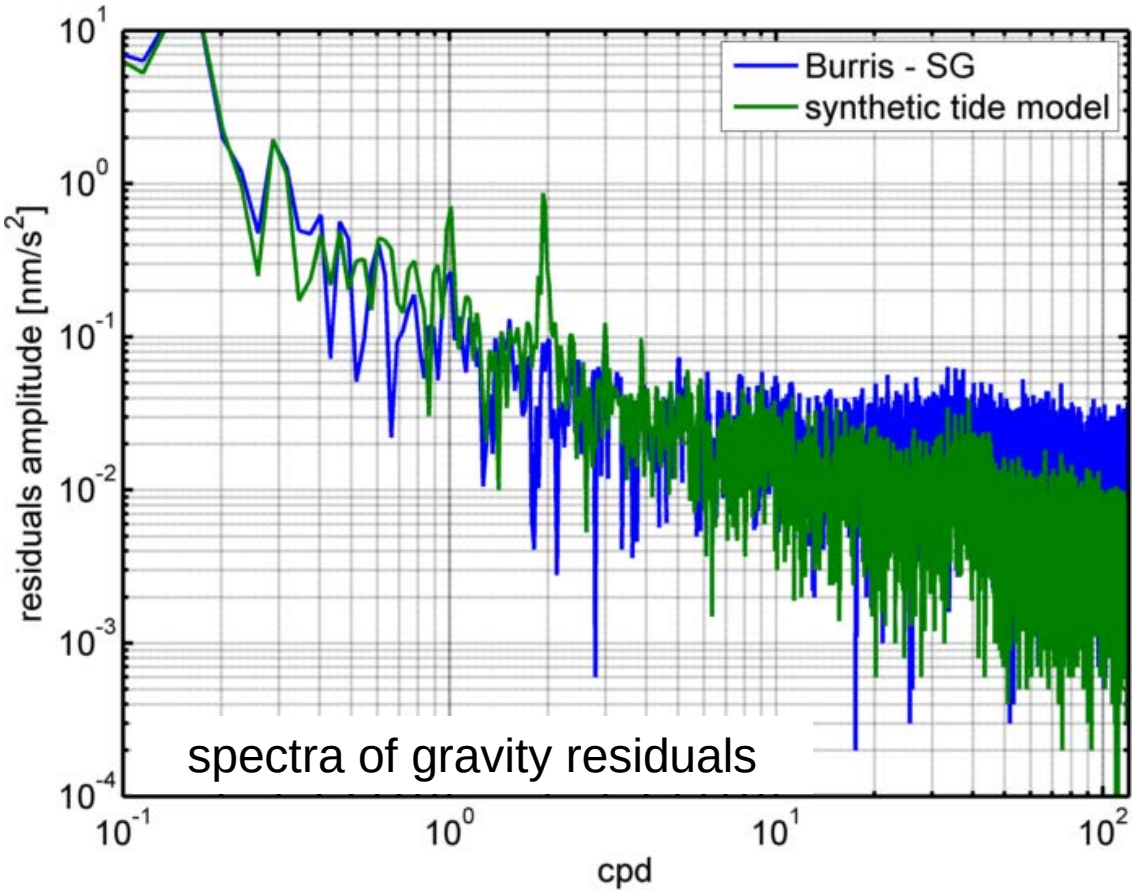
Comparison at the same station Burris and SG in Onsala

simultaneous measurement with instrument of higher accuracy

- Superconducting Gravimeter (SG) at OSO
- low noise environment
- climate controlled

gravity residuals

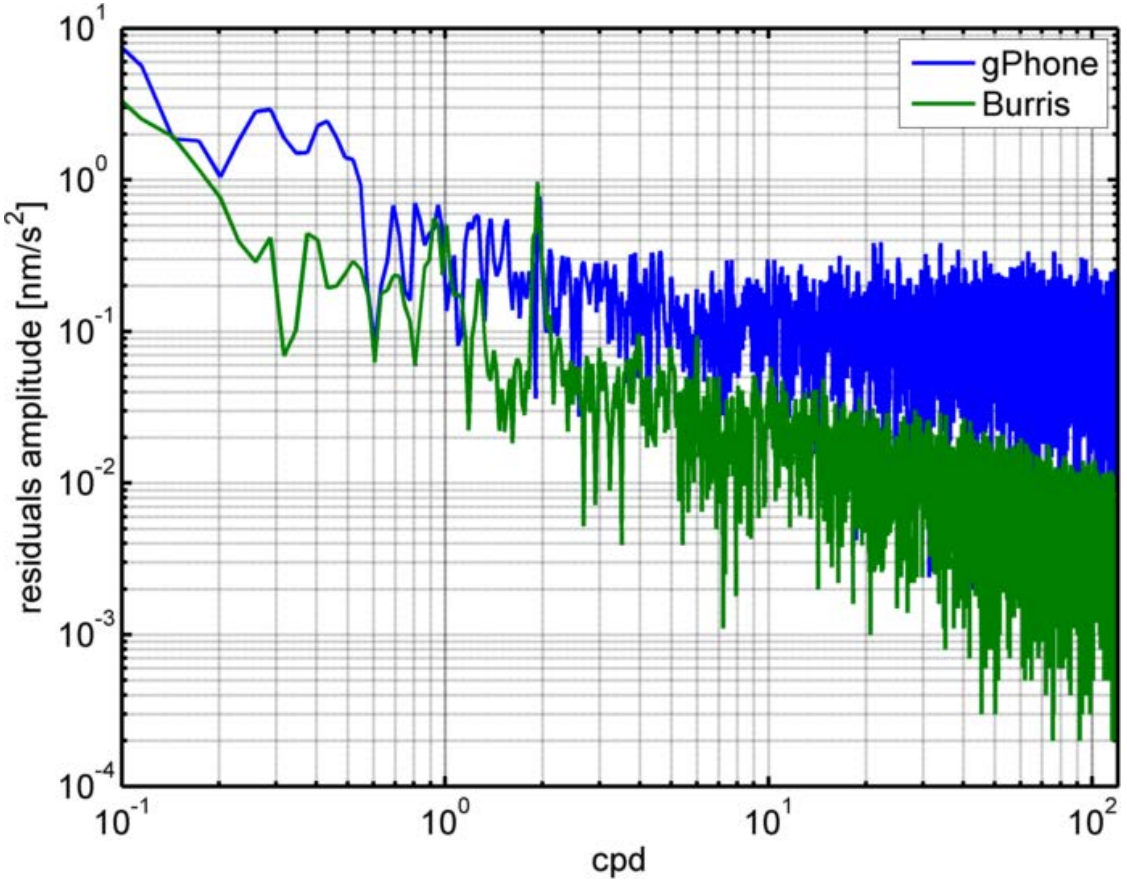
- distinct peaks when corrected with synthetic tides
- difference of both recordings shows no periodic effects



Comparison at the same station gPhone and Burris in Hannover

station Hannover located in city center (microseisms)

- amplitude difference at 2 cpd is 0.2 nm/s^2
- peak at 1 cpd not well determined from gPhone
- noise level at high cpd
  - 1×10^{-1} for gPhone
  - 1×10^{-2} for Burris



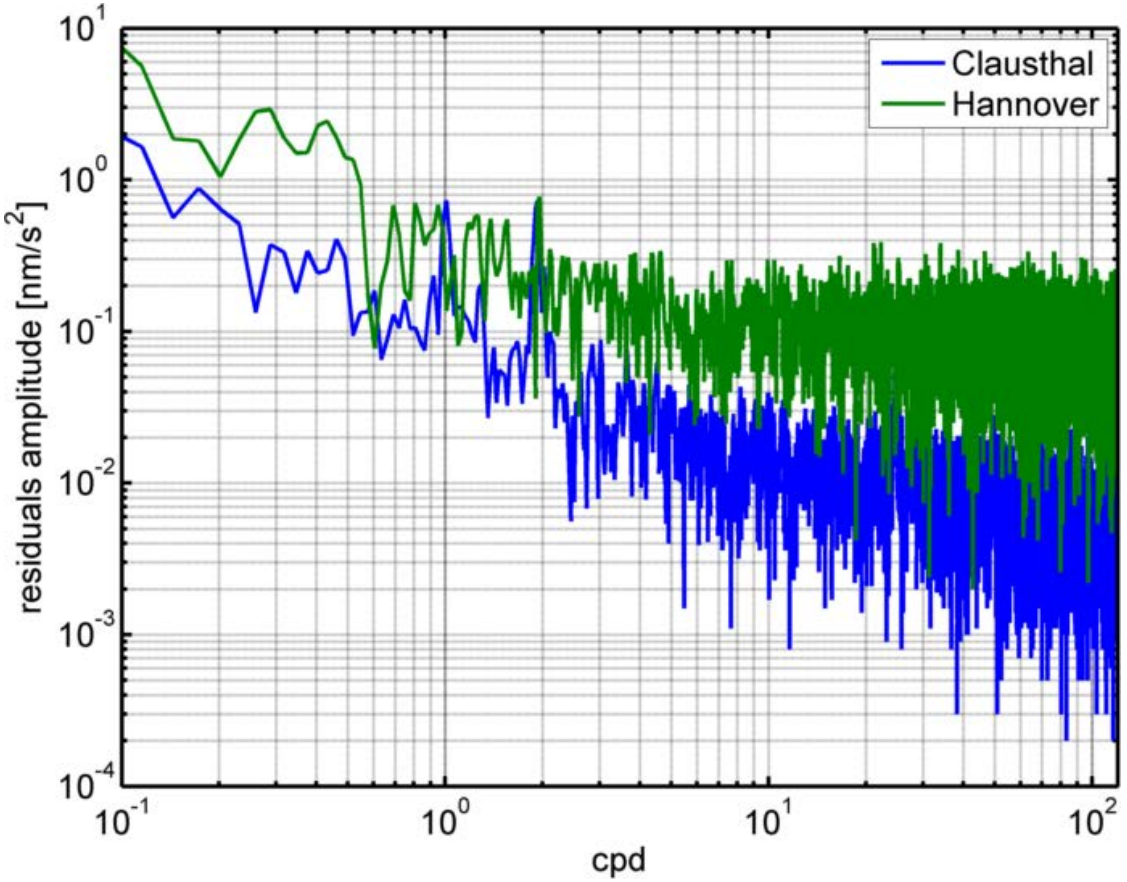
spectra of gravity residuals corrected with synthetic tides

Comparison of gPhone Recordings at different stations

different noise environments

- in Clausthal low noise
- noise at 2×10^{-2} nm/s^2 at high cpd, one order of magnitude below Hannover

Burris gravimeter using ET recording software is not affected by station quality to this extend



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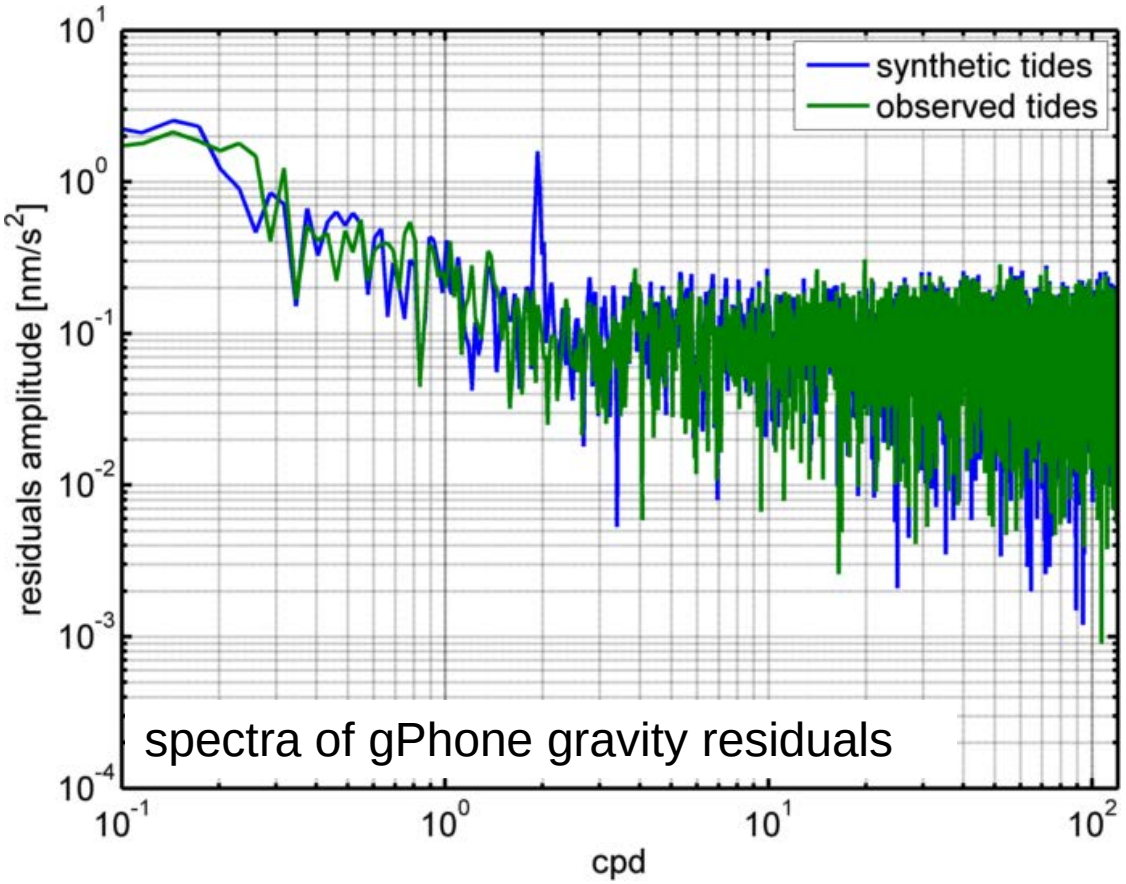
Observed and synthetic Tides in Hamburg

Station located 2.5 km from Elbe river

- ~4m tidal effect
- 1.6 nm/s^2 peak at 2 cpd when corrected with synthetic tides

→ effect is reduced by observed tides



Observed Tidal Parameters in Ruthe

gPhone (152 days)

wave	amplitude std.	phase [°] std.
O1	1.14835 ±0.00028	0.0897 ±0.0138
K1	1.13549 ±0.00021	0.2142 ±0.0107
M2	1.18444 ±0.00027	1.6233 ±0.0132
S2	1.18421 ±0.00065	0.3488 ±0.0319
M3	1.05571 ±0.00918	0.5014 ±0.4982

Burris (66 days)

wave	amplitude std.	phase [°] std.
O1	1.14934 ±0.00181	0.1768 ±0.0905
K1	1.13970 ±0.00168	0.2677 ±0.0838
M2	1.18642 ±0.00039	1.7052 ±0.0189
S2	1.18849 ±0.00116	0.4263 ±0.0569
M3	1.09183 ±0.02854	-1.5543 ±1.4977

in “gravity terms” these parameters differ by ±2 nm/s^2

Observed and synthetic Tides

relation factor of amplitude spectra between gravity residuals (synthetic to observed tides) at 1 and 2 cpd

	cpd	Ruthe		Hamburg	Clausthal	Onsala
		g-98	B-64			
gPhone	1	3.3	2.3	1.6	3.6	
	2	4	1.8	8.2	3.8	
Burris	1	1.7	1.7			3
	2	1.7	5.9			4.3

Amplitude of gravity residuals with synthetic tides are at the level of

- 0.5…0.7 nm/s^2 at 1 cpd
- 0.7…1 nm/s^2 at 2 cpd

at most stations examined

Observed tidal parameters by SG and Burris differ by 0.2 nm/s^2 at 1 cpd

- Calibration, drift and accuracy of instruments
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Micro-gravimetry

Network for determination of water mass changes

- 13 points
- short distances, max. 10 minutes between measurements
- hand transport
- 3.5 days duration

	Burris B-64	Scintrex CG3-4492
no. of connections	160	125
std. Instrument	20 nm/s²	40 nm/s²
mean std. adj. gravity	10 nm/s²	20 nm/s²

Summary

- linear calibration stability: $3x10^{-4}$ for both instruments
- gPhone:
  - linear drift decreases with age (currently 93 nm/s² per day)
  - noise level changes by fac. 5 for low and fac.10 for high cpd depending on station
- Burris:
  - non linear drift
  - noise level (ET Software) not affected by station
  - small network measurements at 10 nm/s² level
- tidal parameters from gPhone and Burris observations at same station differ by 1…3 ‰ (≈ ±2 nm/s² in predicted tides)

Timmen, L. and Wenzel, H.-G. (1995): Worldwide synthetic gravity tide parameters, IAG Symposia Vol. 113: Gravity and Geoid, 92-101, Springer Berlin