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Faculty of Civil Engineering
Department of Theoretical Geodesy

Research Institute of Geodesy, Cartography and Topography
Geodetic Observatory Pecný
Ondřejov

Monitoring the Gravity Changes in an Urban Area Using gPhoneX 108 Relative Gravimeter

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- The main characteristics of the relative gravimeter gPhoneX 108
- Data preprocessing strategy from 1 s to 1 min sampling interval
- Off-level effect on gravity and level correction
- Modelling the instrumental drift
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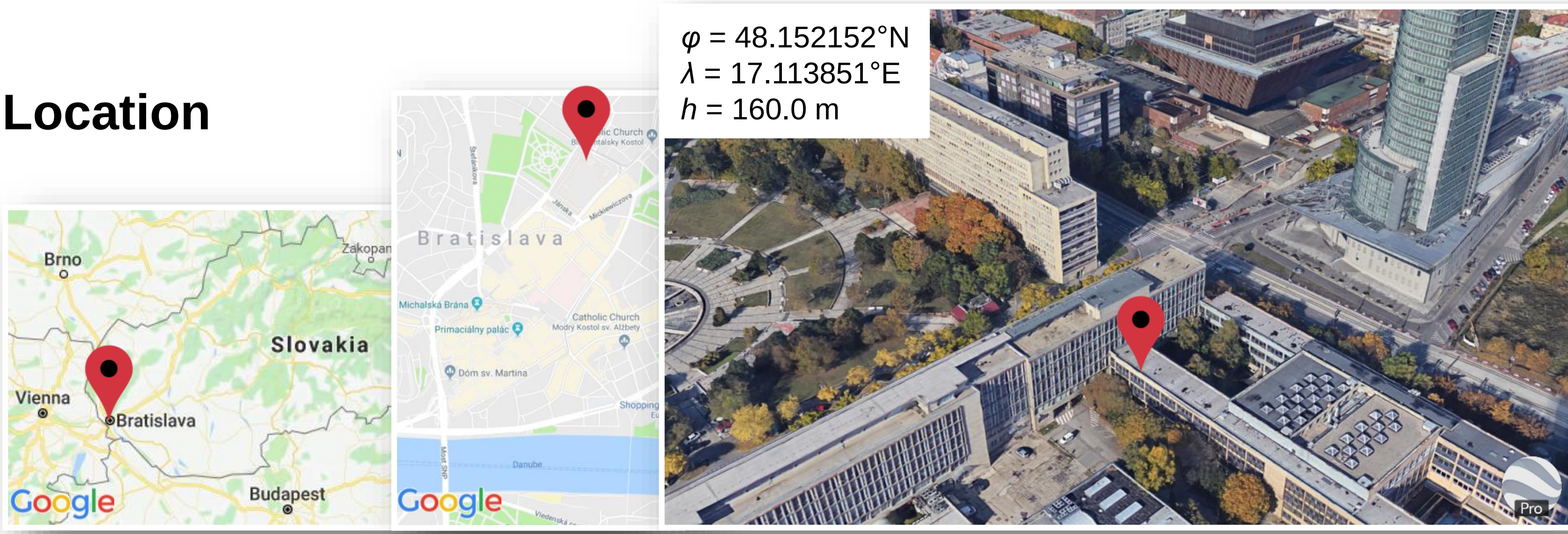
- Tidal analysis results
- Conclusions

Introduction

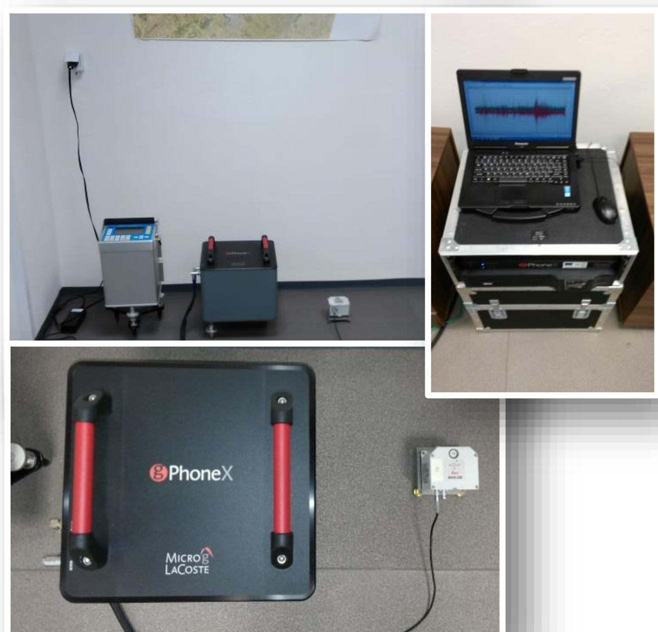
- Laboratory for Modeling Geospatial Objects and Phenomena as a part of the University Science Park of Slovak University of Technology in Bratislava (Slovakia).
- Focused on the monitoring of changes in the spatial position of buildings using satellite and terrestrial geodetic methods.

Location



Micro-g LaCoste gPhoneX 108

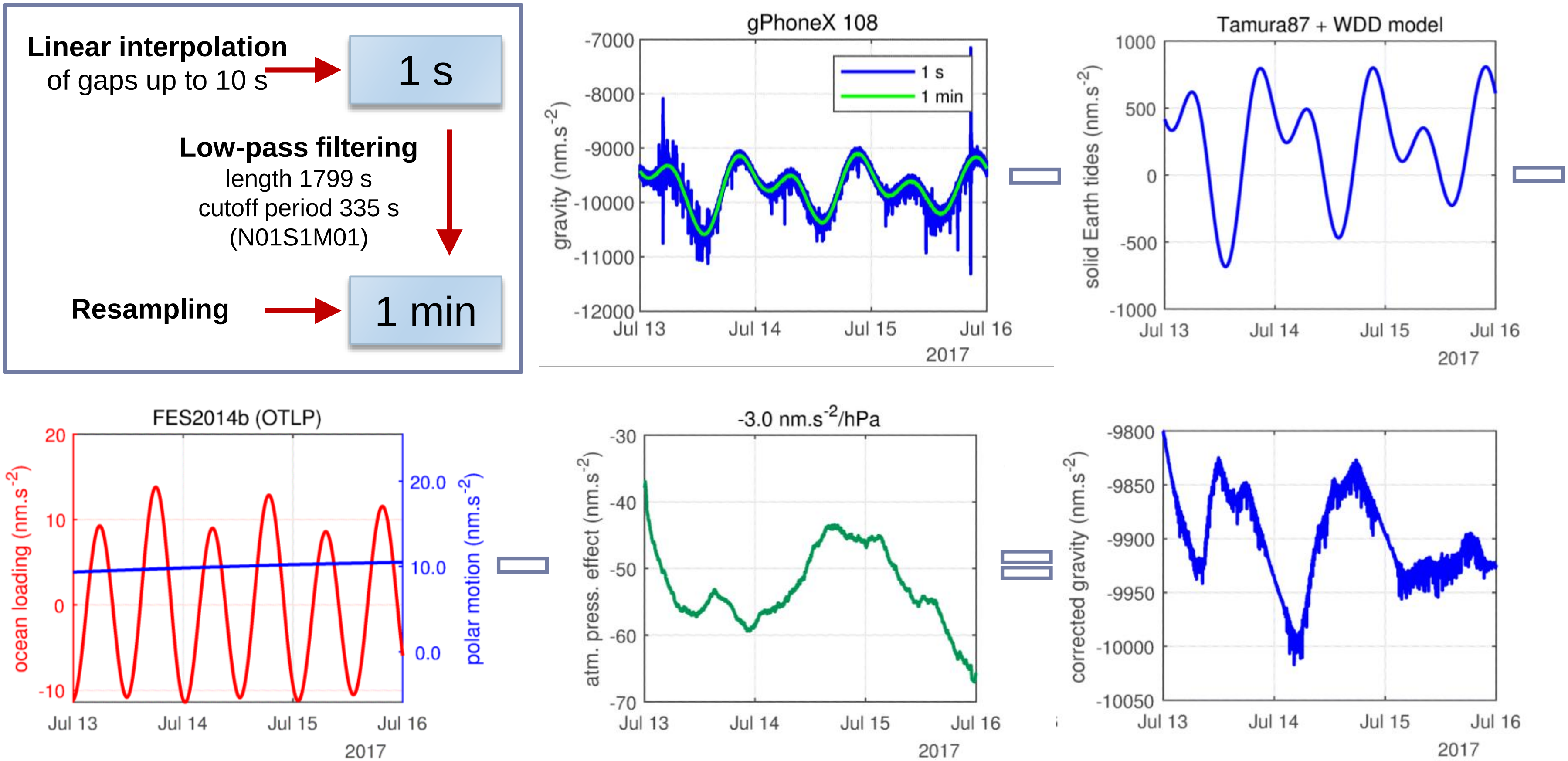
- Installed in the building of Faculty of Civil Engineering in January 2016.
- Its specific location also enables observing the other phenomena related to the structural movements of the building together with its inside activity, and environmental noise.



1st underground floor

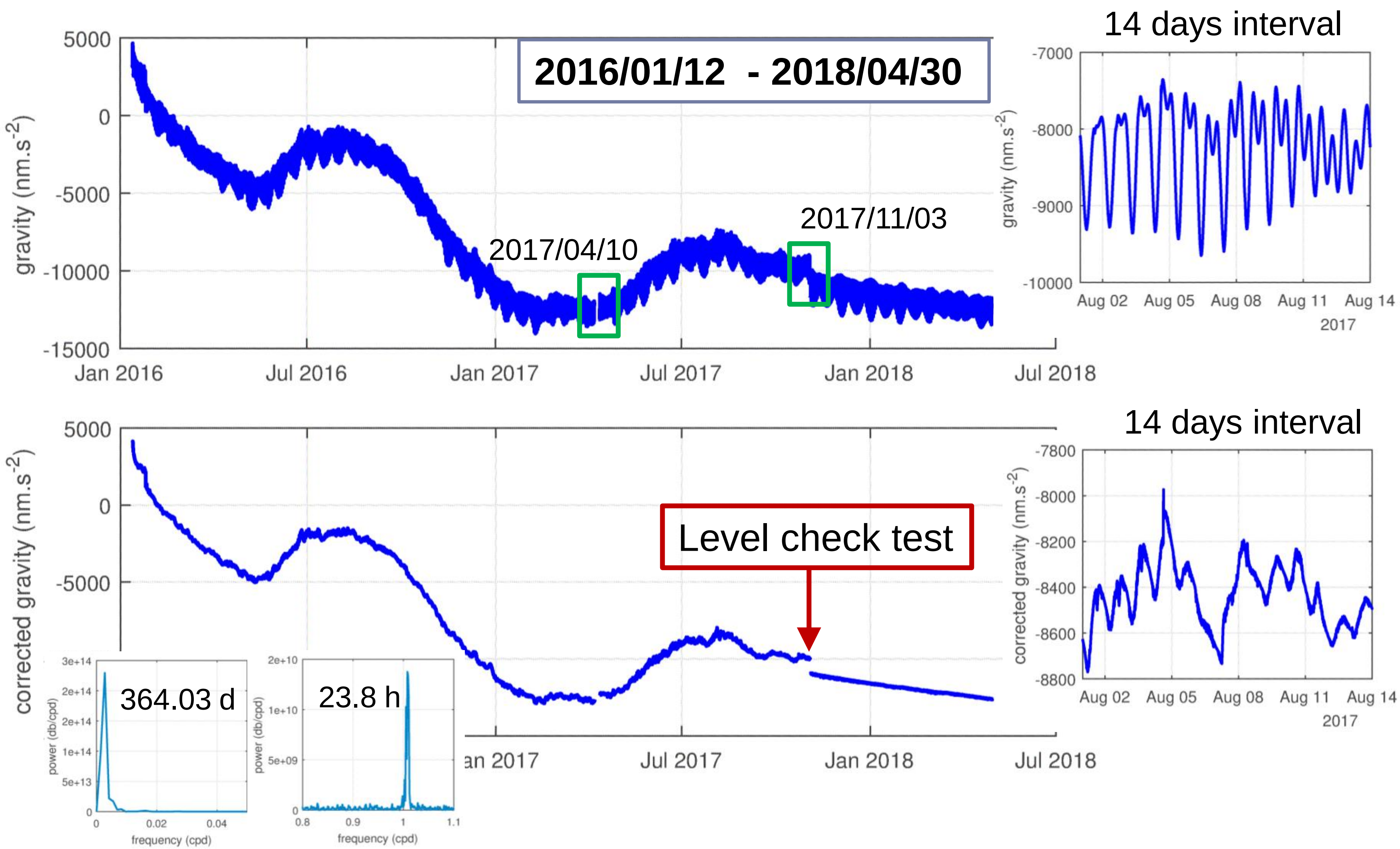
- Supporting techniques:
  - FG5X 247 absolute gravimeter,
  - Leica Nivel 220 inclination sensor,
  - MWS 9-5 local weather station,
  - Permanent GNSS station.

Preprocessing strategy

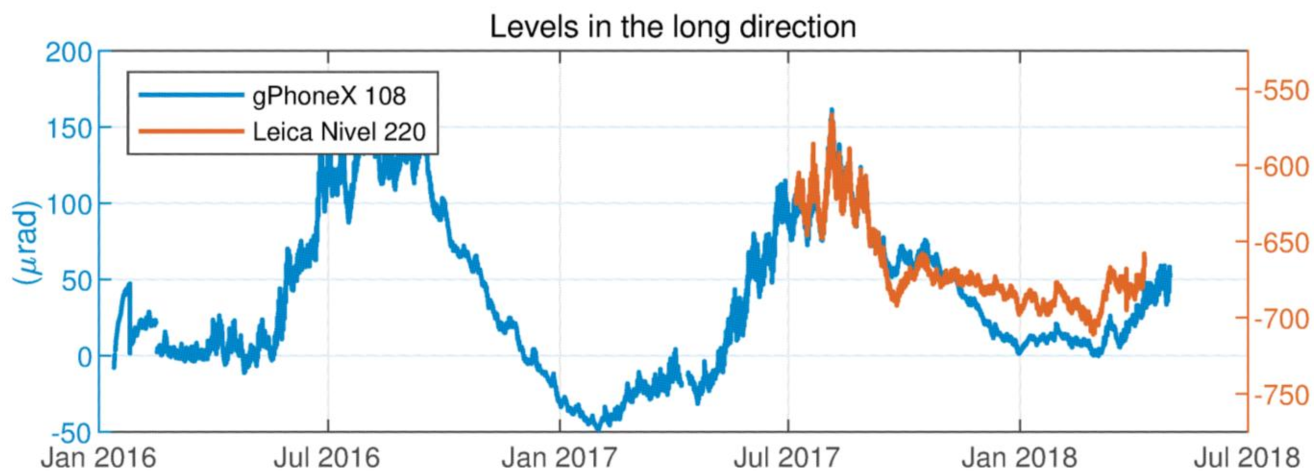


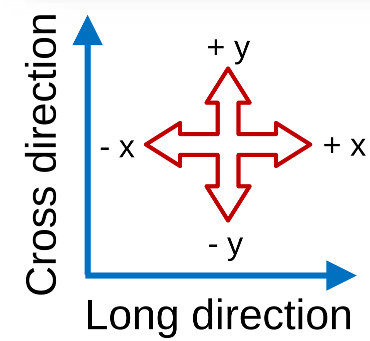
- Effects on the gravity calculated in Tsoft (*Van Camp and Vauterin, 2005*) and outliers rejected in Matlab software (*Mathworks, 2018*).

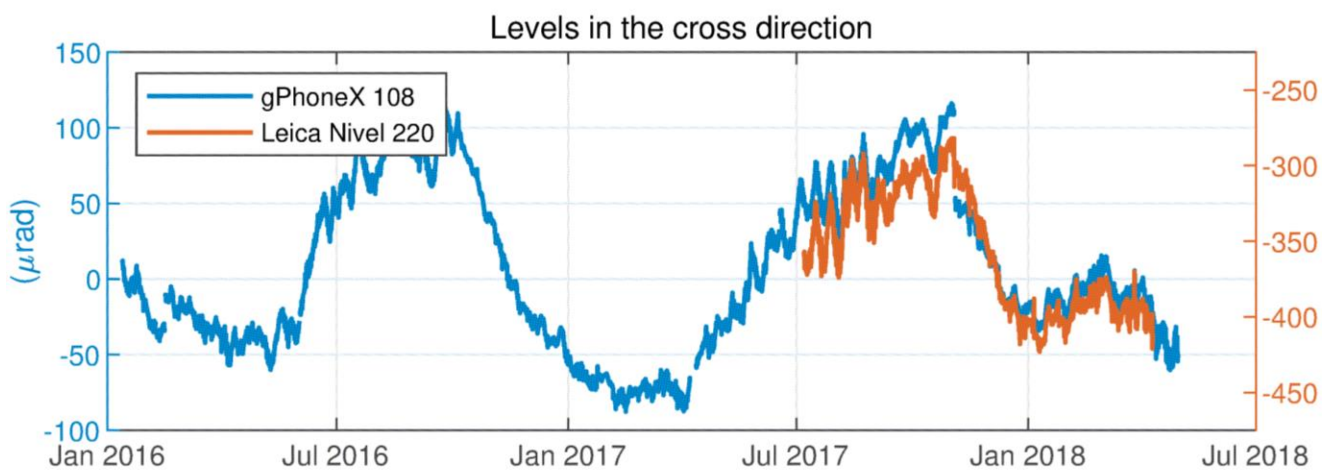
1 min corrected gravity

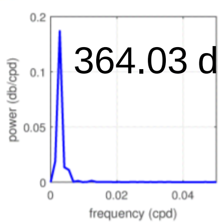


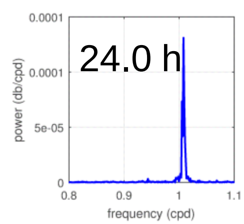
Level correction



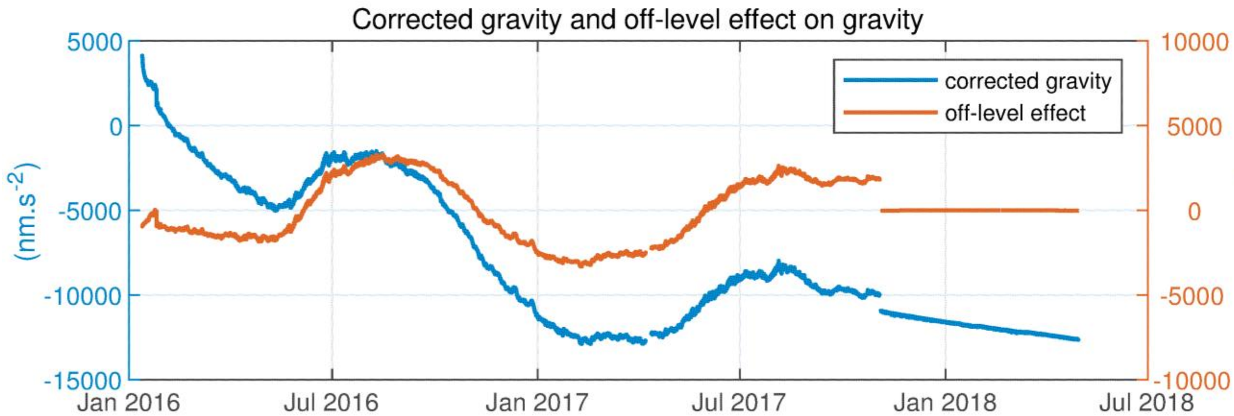


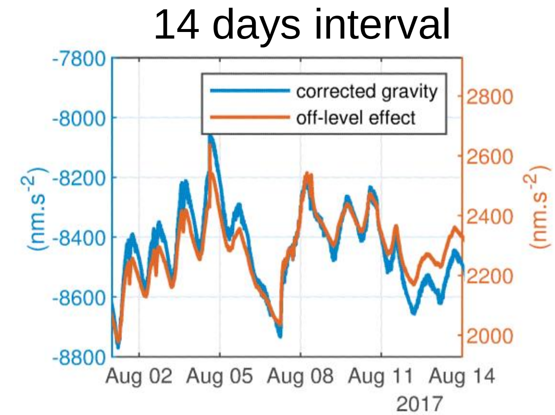


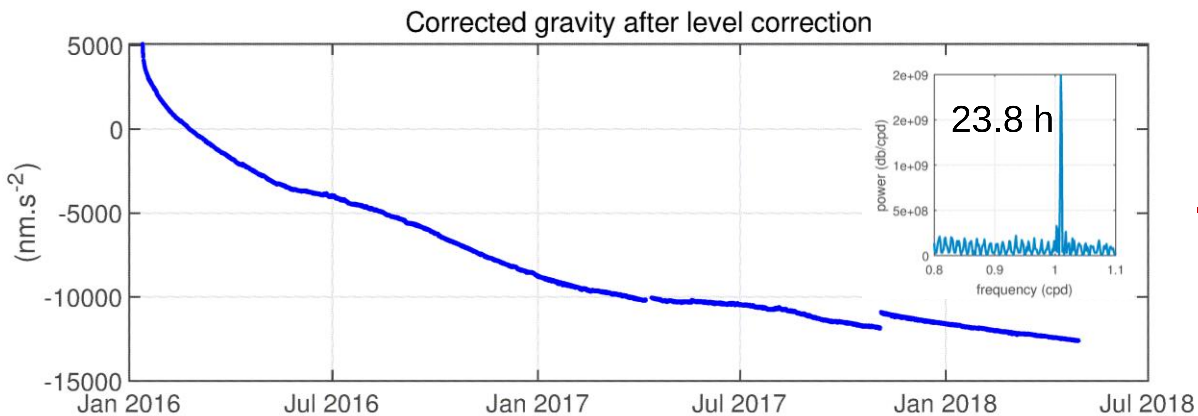


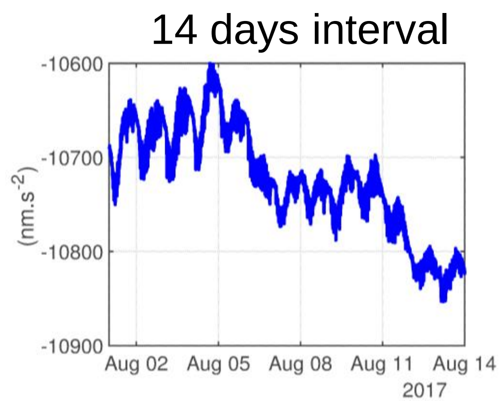


Level correction



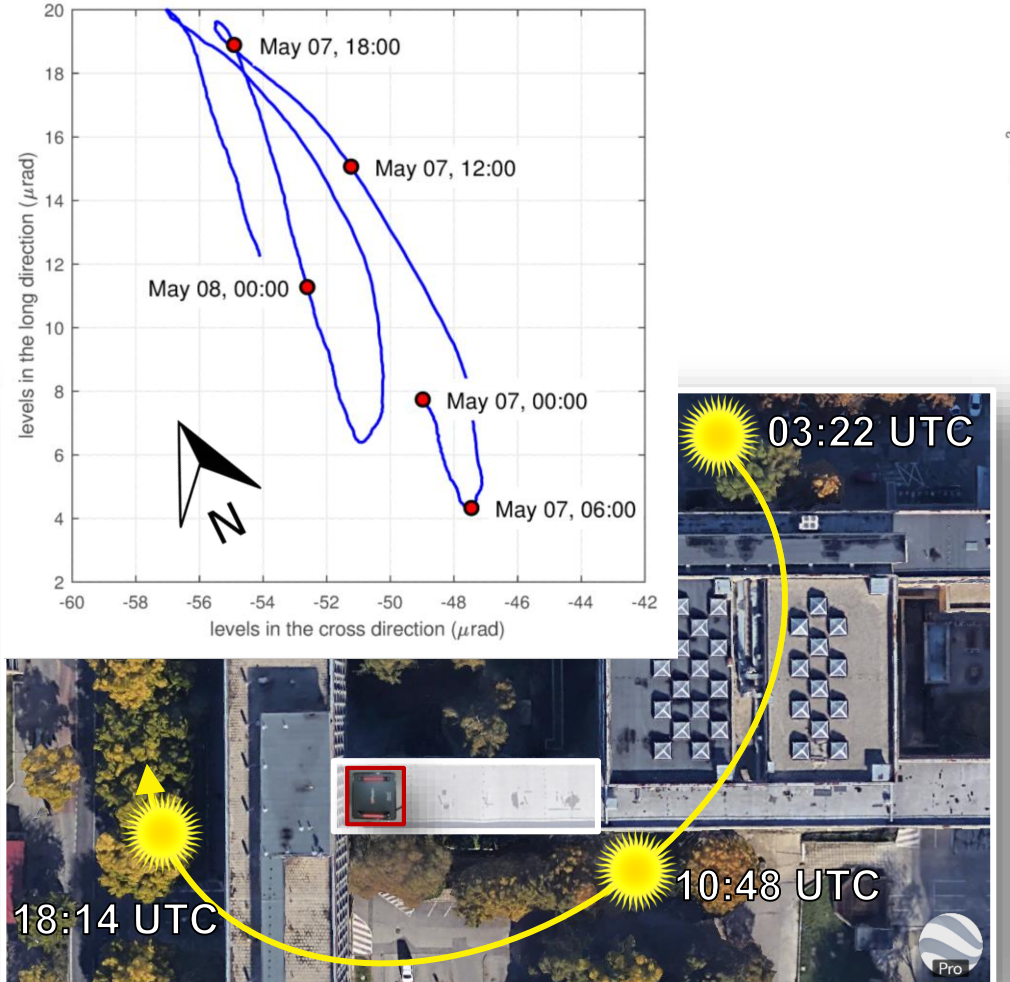




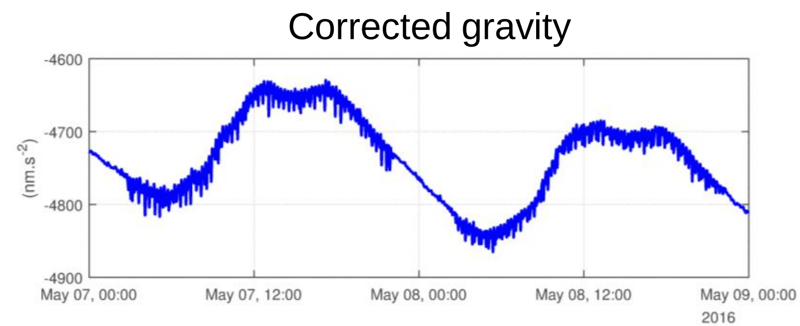


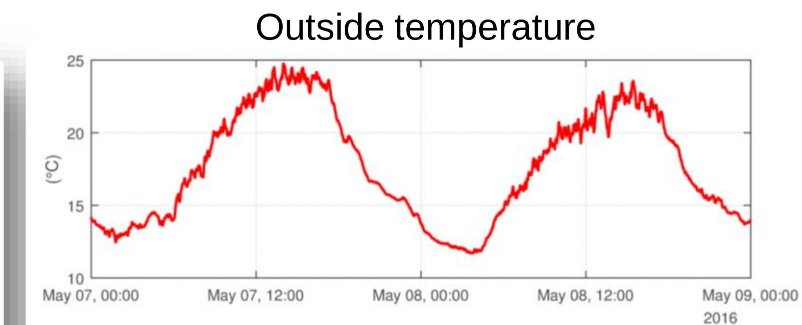
- The standard deviation characterized the level check test was 63 nm.s^{-2}.

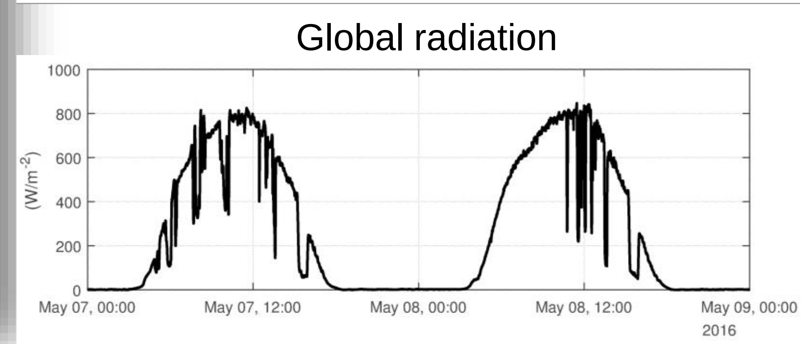
Tilts of building during 7-8 May 2016



Faculty of Civil Engineering SUT in Bratislava

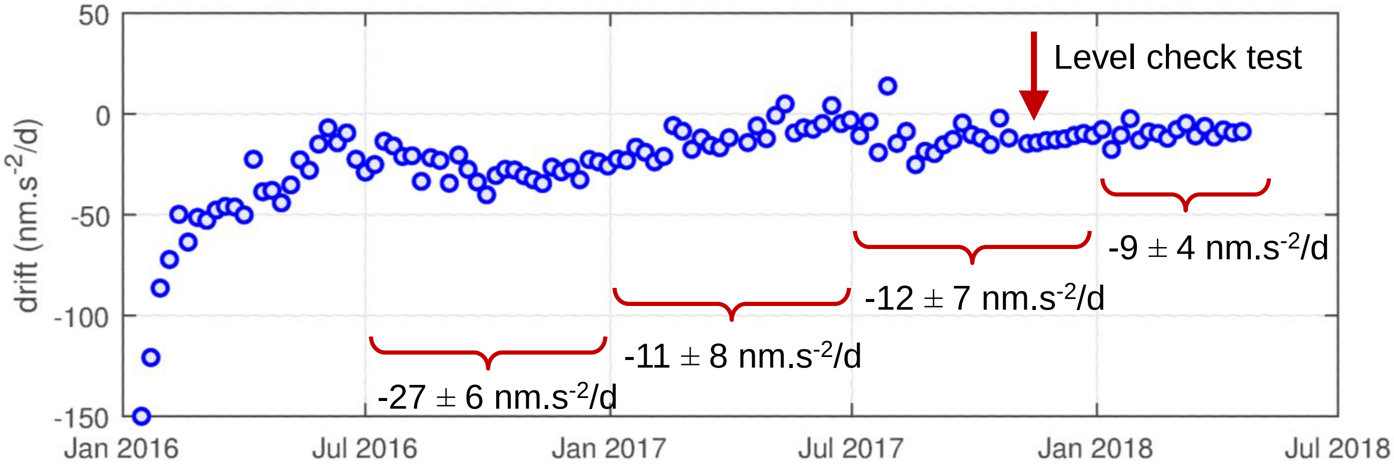


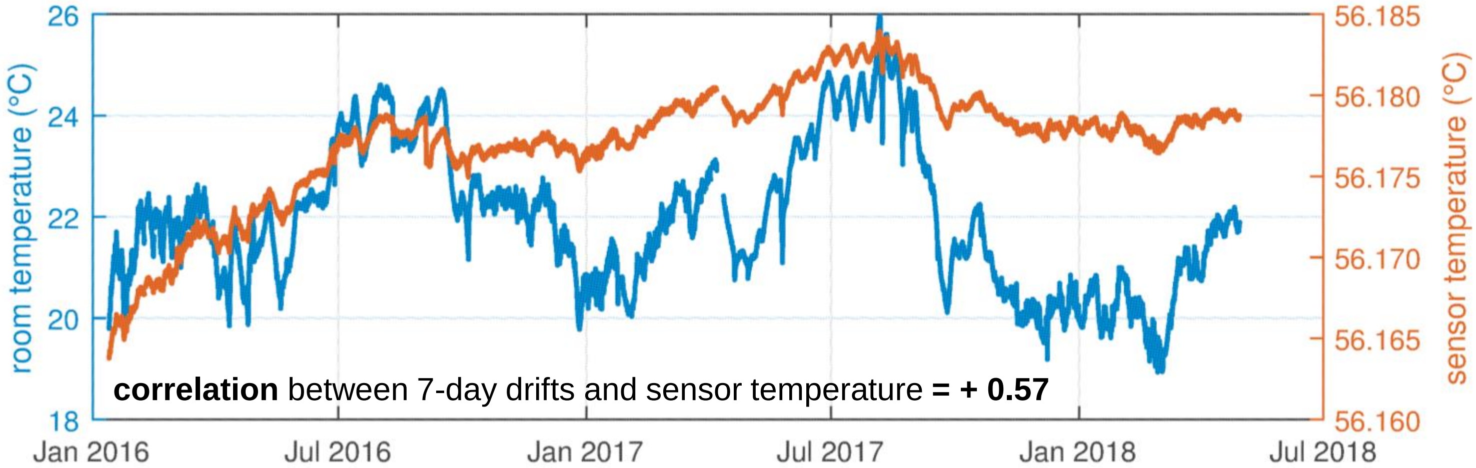




Instrumental drift

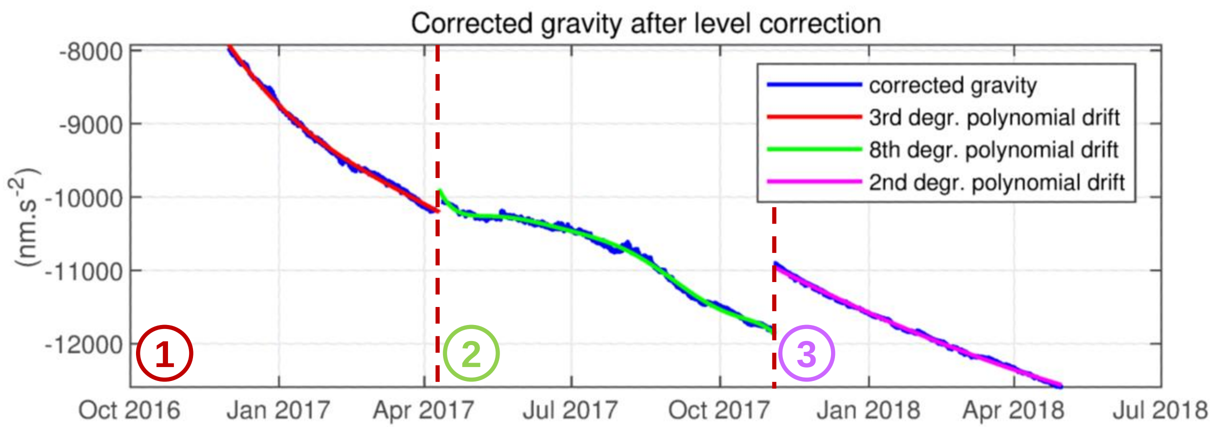
- 7-day estimates of linear instrumental drift:

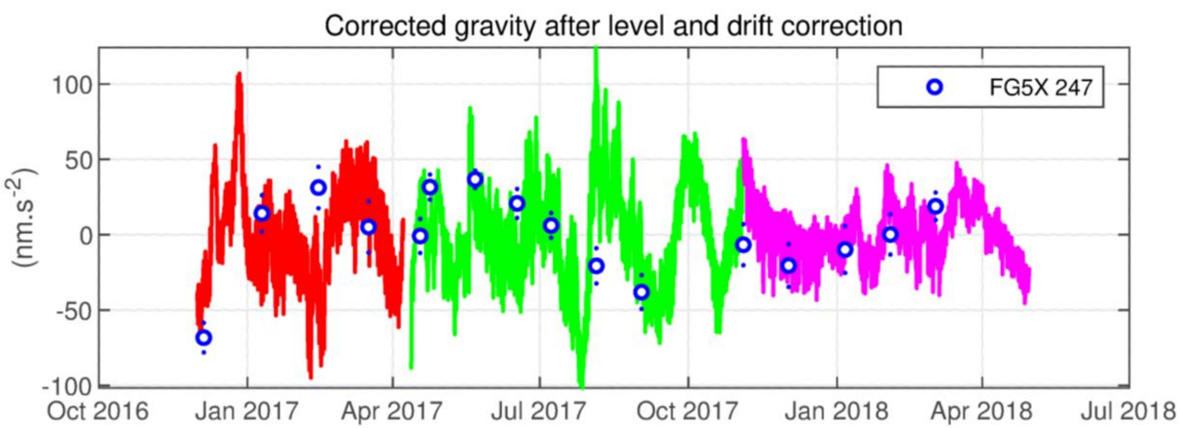




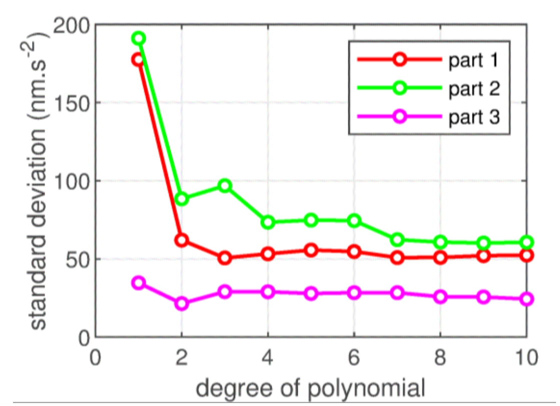
Instrumental drift – modelling using FG5X 247 AG

- Moving means of corrected gravity over a window with length 60 min.





Standard deviation of differences between drift-free gPhoneX 108 and FG5X 247 gravity

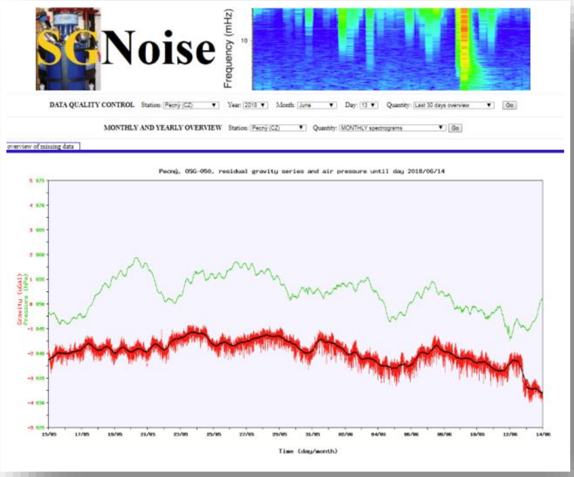


Noise level analysis

- Ambient noise is evaluated by spectrograms and probability density functions (PSD).
- Methodology is implemented in web tool SGNoise (*Vaľko and Pálinkáš, 2015*) available on *http://oko.pecny.cz/grav/*.

Data preprocessing

- Raw gravity data with sampling rate of 1 s corrected from:
  - Solid Earth tides,
  - Ocean loading,
  - Atmospheric pressure effect on gravity,
  - Polar motion effect on gravity,
  - Polynomial instrumental drift.

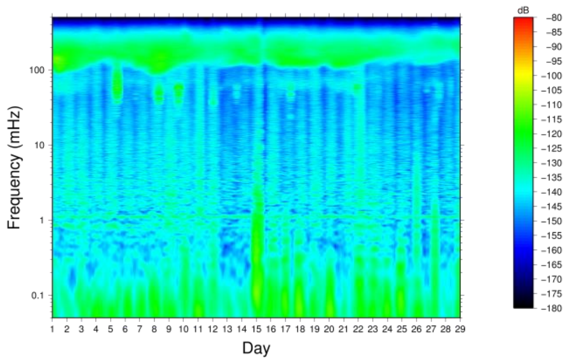


Noise level analysis

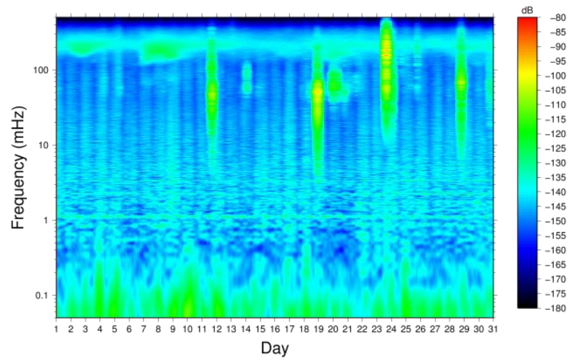
- **Spectrograms:**

ambient noise level up to 100 nm.s^{-2}

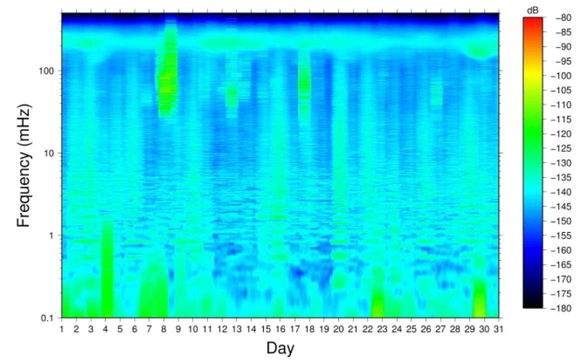
gPhoneX 108 – February 2016



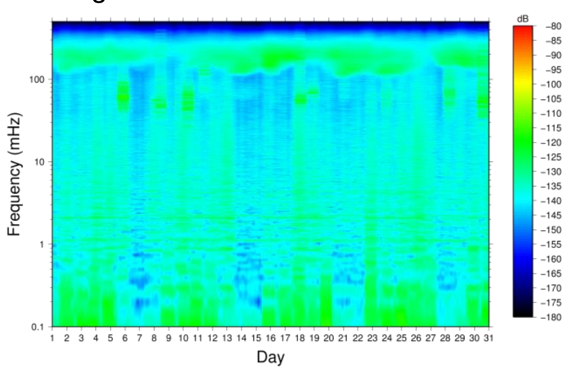
gPhoneX 108 – August 2016



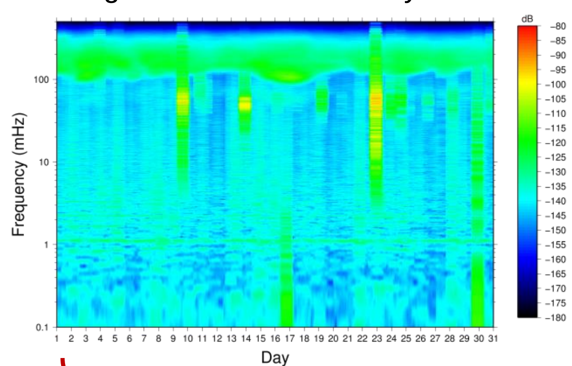
gPhoneX 108 – August 2017



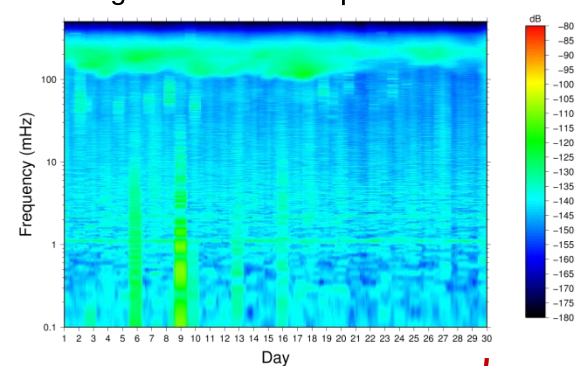
gPhoneX 108 – October 2017



gPhoneX 108 – January 2018



gPhoneX 108 – April 2018



-160 dB = 10 nm.s^{-2}

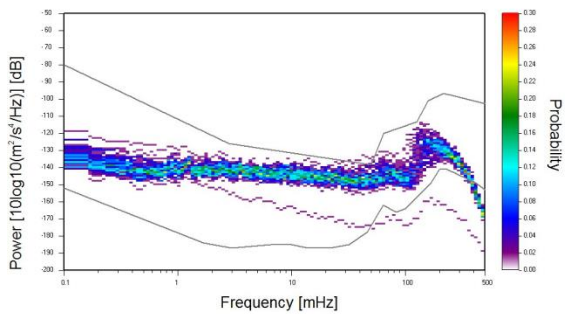
after level check test

Noise level analysis

- **Probability density functions:**

ambient noise level up to 100 $nm.s^{-2}$

gPhoneX 108 – February 2016



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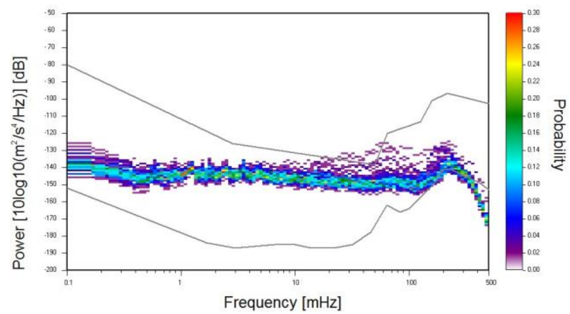

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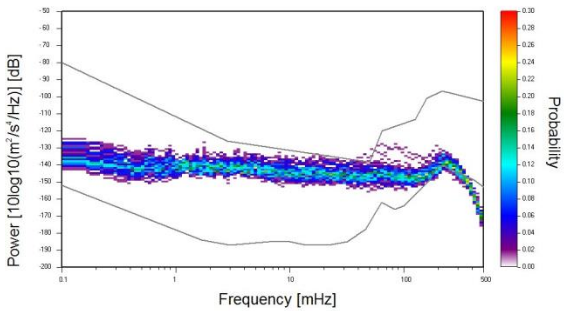

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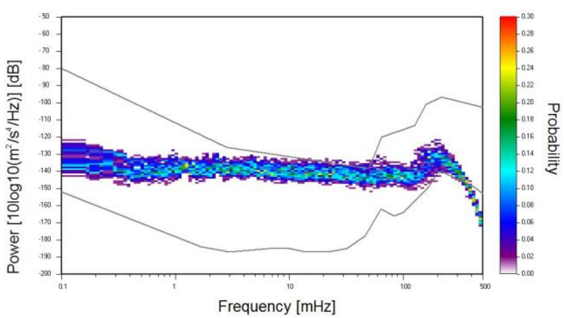

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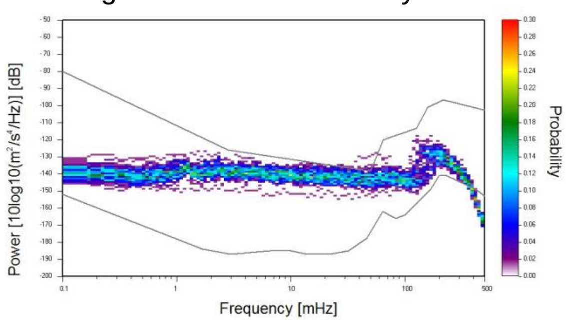

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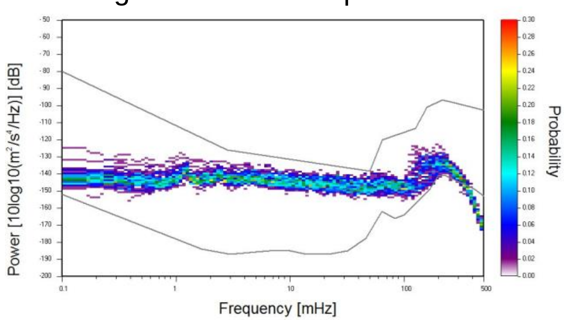
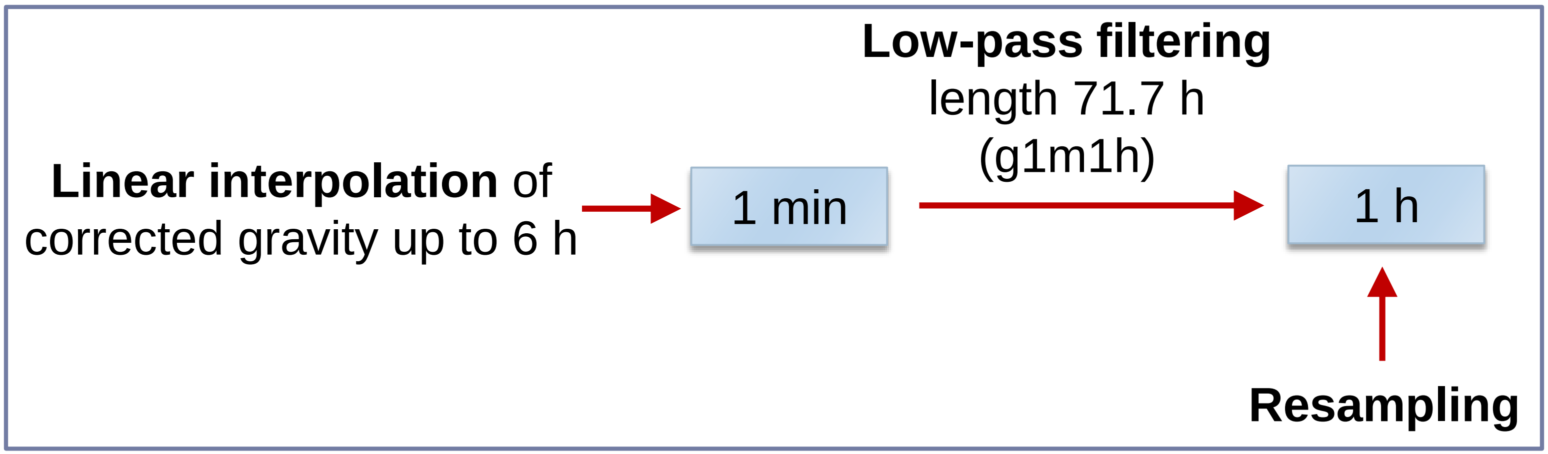


-160 dB = 10 $nm.s^{-2}$

Tidal analysis

- **Data preparation process:**



- **Tidal analysis setup:**
  - Program ANALYZE from ETERNA 3.40 package (*Wenzel, 1996*),
  - Only diurnal and semidiurnal tidal spectrum,
  - High-pass filtered observations before the analysis (> 0.8 cpd),
  - Tamura (1987) tidal potential catalog.

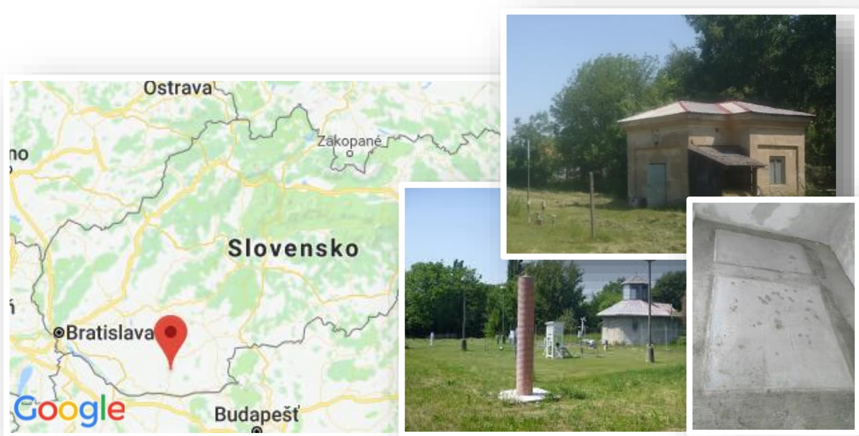
Comparison of observed tidal parameters

Solution		SG CT-025, Vienna *		gPhoneX 108, Bratislava					
		1995/08/02-2007/10/27 4284.583 days		2016/02/11-2017/11/03 626.292 days		2017/11/04-2018/04/29 176.958 days		2016/02/11-2018/04/29 803.250 days	
Tidal group	Theoretical amplitude	Amplitude factor	Phase lead	Amplitude factor	Phase lead	Amplitude factor	Phase lead	Amplitude factor	Phase lead
	($nm.s^{-2}$)	(-)	(°)	(-)	(°)	(-)	(°)	(-)	(°)
O1	308.7784	1.1497 ± *0.00003*	0.12 ± *0.001*	1.1548 ± *0.0013*	0.24 ± *0.06*	1.1491 ± *0.0010*	0.26 ± *0.05*	1.1532 ± *0.0011*	0.25 ± *0.05*
P1	143.6739	1.1487 ± *0.0001*	0.15 ± *0.003*	1.1252 ± *0.0024*	1.64 ± *0.13*	1.0731 ± *0.0330*	2.72 ± *1.75*	1.1280 ± *0.0020*	1.59 ± *0.10*
K1	434.2666	1.1357 ± *0.00002*	0.20 ± *0.001*	1.1426 ± *0.0009*	0.82 ± *0.05*	1.1377 ± *0.0190*	2.54 ± *0.96*	1.1407 ± *0.0008*	0.74 ± *0.04*
M2	334.4534	1.1834 ± *0.00001*	1.08 ± *0.001*	1.1873 ± *0.0004*	1.42 ± *0.02*	1.1831 ± *0.0007*	1.34 ± *0.03*	1.1864 ± *0.0003*	1.40 ± *0.02*
S2	155.6053	1.1806 ± *0.00003*	0.10 ± *0.002*	1.1701 ± *0.0008*	1.05 ± *0.04*	1.1676 ± *0.0021*	1.31 ± *0.10*	1.1699 ± *0.0008*	1.17 ± *0.04*
Air pressure admittance factor		-3.54 ± *0.002* $nm.s^{-2}/hPa$		-4.51 ± *0.08* $nm.s^{-2}/hPa$		-3.48 ± *0.08* $nm.s^{-2}/hPa$		-4.18 ± *0.06* $nm.s^{-2}/hPa$	
Average noise level		1.0 cpd: 0.010 $nm.s^{-2}$ 2.0 cpd: 0.006 $nm.s^{-2}$		1.0 cpd: 0.40 $nm.s^{-2}$ 2.0 cpd: 0.15 $nm.s^{-2}$		1.0 cpd: 0.32 $nm.s^{-2}$ 2.0 cpd: 0.29 $nm.s^{-2}$		1.0 cpd: 0.35 $nm.s^{-2}$ 2.0 cpd: 0.15 $nm.s^{-2}$	
STD of analysis		0.54 $nm.s^{-2}$		5.87$nm.s^{-2}$		3.94 $nm.s^{-2}$		5.78 $nm.s^{-2}$	

* Observed tidal parameters obtained from *Hábel and Meurers (2014)*

Future activities

- Establishing the new integrated geodetic and geophysical observatory in Hurbanovo (Slovakia).
- Instruments: relative gravimeter gPhoneX 108, absolute gravimeter FG5X 247, accelerometer, permanent GNSS station, local weather station, soil moisture sensors and ground water level sensor.
- Applications to geodynamics research, geophysics, tides and hydrology.
- Institutions: Earth Science Institute of the Slovak Academy of Sciences, Slovak University of Technology in Bratislava and Geodetic and Cartographic Institute Bratislava.



Conclusions

- Off-level of the gravimeter causes additional diurnal and annual variations of gravity (> 100 nm.s^{-2}). This requires to improve the determination of the level parameters and recalculation of the level correction.
- Instrumental drift is characterized by the non-linear behavior and is correlated with slight variation of the sensor temperature. Drift reaches about -10 nm.s^{-2}/d.
- Daily-varying ambient noise up to 100 nm.s^{-2} is related to both the strong peoples' activity in the building and the urban environment. This excludes the study of geodynamical phenomena with "small" amplitudes.
- The estimates of tidal parameters for diurnal tidal band are distorted by the daily variation of gravity due to the building tilts.
- In the near future, the gravimeter will be moved to a new location in Hurbanovo. After moving the instrument to new station we plan to become a contributor to IGETS service and database.

STU SvF

Thanks for your attention!