TIDAL OBSERVATIONS IN ASTRO-GEODETIC OBSERVATORY IN JOZEFOSLAW

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1. INTRODUCTION

Tidal gravimetric observations in Astro-Geodetic Observatory in Jozefoslaw started in 1993 using LaCoste&Romberg model G gravimeter. Since 2001 Observatory has been equipped with the ET-26 model dedicated to the stationary gravimetric measurements. Tidal research program also encompasses environmental studies to make the results more reliable. This elaboration presents the analyses of the data collected until 2008 and the comparison with the previous obtained results as well.

2. THE OBSERVATORY

The Astro-Geodetic Observatory at Jozefoslaw was founded in 1949. In 1958 the Observatory was designated for the national programme conducted within the frame of the International Geophysical Year, namely in the Longitudinal Operation of the IGY. From these times several geodetic observations were carried out. One of them are gravity permanent observations. Along with the development of research into the Earth's crust deformations, more laboratories were opened in the Observatory in 1993, including a laboratory for absolute gravimetric measurements equipped with a ballistic gravimeter designed and constructed at the Institute of Geodesy and Geodetic Astronomy; a tidal laboratory conducting day-to-day observations with the help of LC&R gravimeter, model G-986, then model D-196. Until the end of 2001 the Observatory was equipped with modern instruments, financed by the State Committee for Scientific Research. Gravimetric laboratory was equipped with the most precise spring static instrument, used to measure gravimetric Earth tides - the gravimeter LC&R model ET- 26.

3. DATA

The data contains observations collected from 2006 to 2008 by LaCoste&Romberg model ET-26 meter in Astrogeodetic Observatory at Jozefoslaw. The observations are 1-minute sampled and stored to the computer together with some additional data including ambient pressure and temperature, inner gravimeter temperature as well as the electronic levels indications. The following chart presents the raw gravimetric data after the first "repair" (steps, spikes and gaps remove) using Tsoft software (Van Camp, M., and Vauterin, P., 2005):

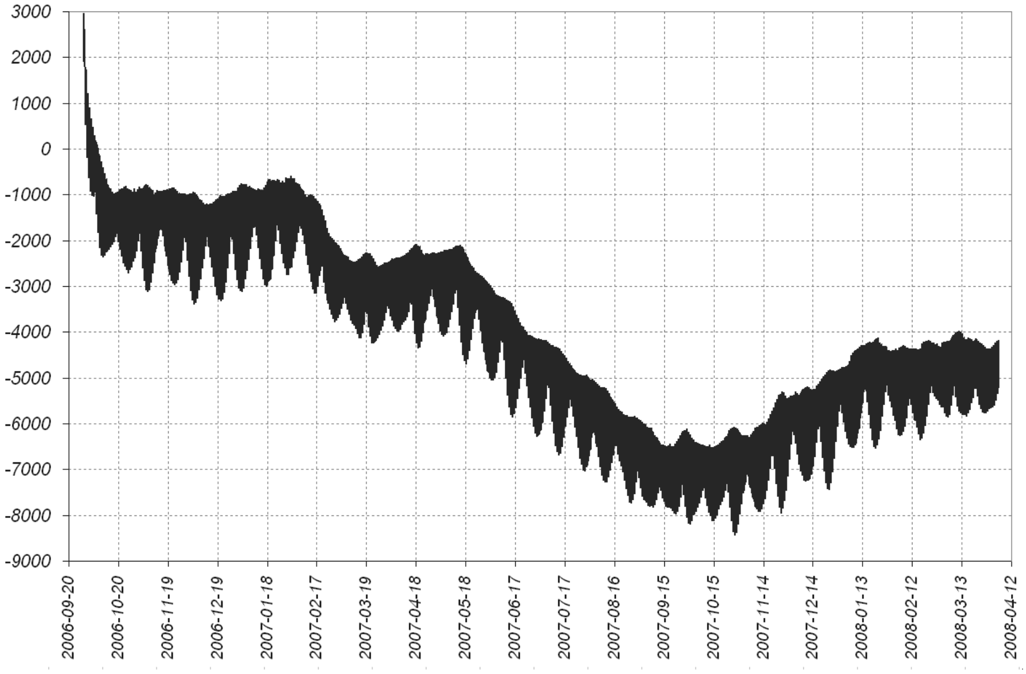

Fig. 1. Tidal data [nm/s^2].

4. TEMPERATURE STABILITY

The temperature in the thermal chamber should be stable up to 0.5°C. Fig. 2 presents stability during considered period. It shows some problems with outer gravimeter temperature between July and August 2007.

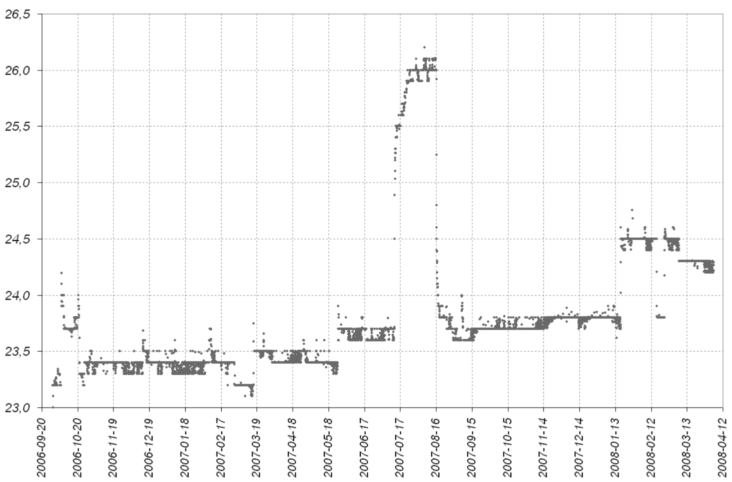

Fig. 2. Changes of the chamber's inner temperature [°C].

5. PILLAR'S STABILITY

Fig. 3 presents changes of the pillar's tilt registered by two in-built electronic levels (so-called Cross and Long). It shows some periodical changes in the pillar's movement (1-year) and weak correlation between level's indications and the shape of the instrumental drift. No correction for the tilt is implemented to the gravimetric data.

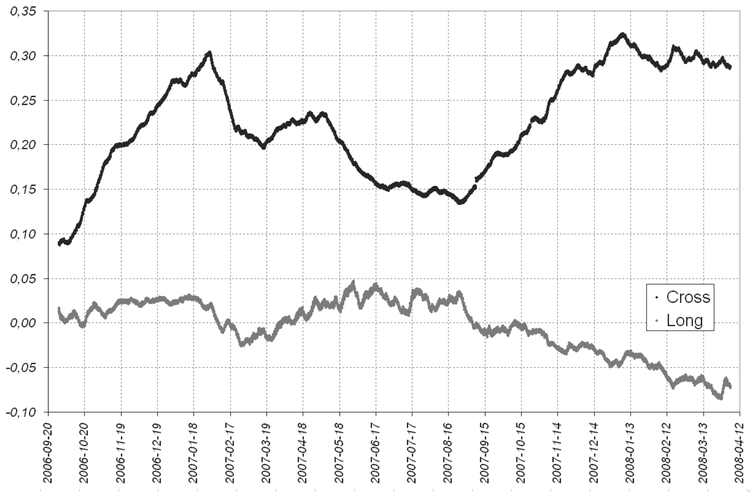

Fig. 3. Indications of the electronic levels [level's units].

6. OCEAN LOADING

This effect is caused by the ocean's tides and its "indirect" influence to the Earth's tides. The distribution of the oceanic waters varying with the tides is represented by the cotidal charts. This denomination is given to special maps of the ocean bearing a superposition of equal-height lines (co-amplitudes lines) and equal phase lines (cotidal lines) describing for every tidal constituent the periodic movement of the oceanic water under the influence of the tidal potential and the Coriolis force due to the rotation of the Earth (Melchior, 1983).
Calculation of the ocean indirect effect depends on the convolution sum between ocean tides distribution in particular frequencies and gravity Green's functions calculated for considered Earth's model (PREM in this study). Special service of ocean loading effect was established. It is available on web page http://www.oso.chalmers.se/~loading/.
Several models for Jozefoslaw Observatory were tested. They were: FES95, FES02, CSR3, CSR4, ORI96 and GOT00. These test gave very similar results (maximum difference of 0.3 nm/s^2 for M2 wave) as far as this effect at the Observatory is very weak when we compare it to the coastal sites. Figures 5 to 7 present amplitudes, phases and total ocean indirect effect respectively, calculated using GOT00 model (Ray, 1999).

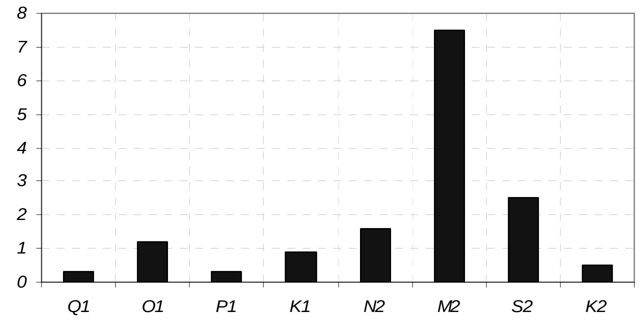

Fig. 4. Amplitudes [nm/s^2] of ocean indirect effect

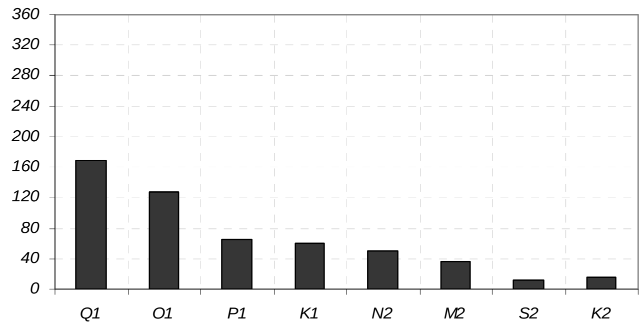

Fig. 5. Local phase [°] of ocean indirect effect

7. ATMOSPHERIC MASS VARIATIONS

This effect is caused by the variation of the atmospheric masses in the vicinity of the instrument. It is divided into two different effects: Newtonian and loading. In this study the effect is calculated using single regression coefficient determined for the Observatory (Bogusz, 2000).

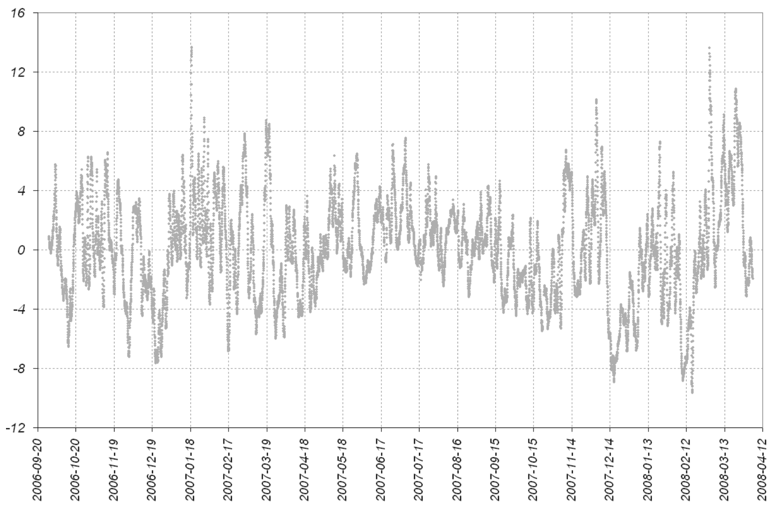

Fig. 6. Atmospheric indirect effect [nm/s^2] for Jozefoslaw Observatory.

8. HYDROLOGICAL OBSERVATIONS

Full hydrological cycle contains several phenomena such as: rainfalls, infiltration and changes of the ground water level, percolation, evaporation etc. Their causes a slight changes of the gravity in the vicinity of the instrument.
Taking this into account the meteorological (ambient pressure, temperature and humidity) and hydrological (changes of the ground water level, changes of soil moisture and rainfalls) observations are made. The figure below presents distribution of the particular sensors and the gravimeter itself.

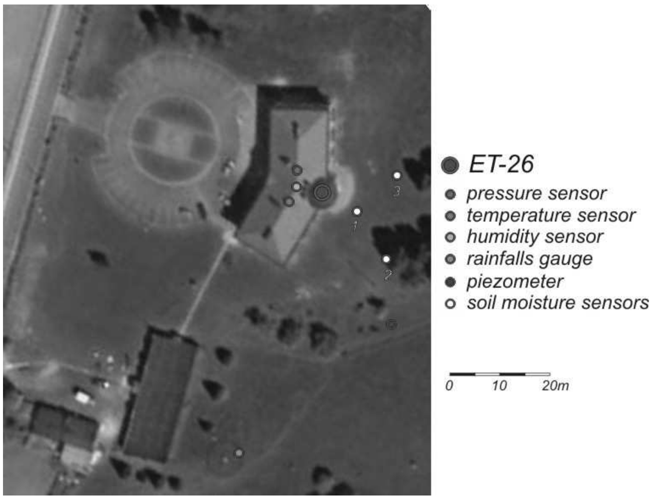

Fig. 7. Location of the sensors.

The ground level changes are recalculated to the gravity using the formula that contains single regression coefficient determined for the Observatory's conditions (porosity, density, etc.). To monitor precipitation events special gauge was installed. The procedure of the determination of the gravity changes due to the rainfalls is based on two parameters dependent on many physical, hydrological and biological parameters. Two sensors investigated changes of the soil moisture were installed since the geological researches showed differences in the soil structure (sand and clay). The gravity changes are calculated using Bouguer's plate using the density of about 999 kg/m^3 for water and thickness of 1 m.
The detailed descriptions of particular procedures were presented at the EGU General Assembly in 2007 (Bogusz, 2007).
The tidal oscillations in these observations almost don't exists, but it make sense to reduce these effects from gravity as it leads to a better signal-to-noise ration in the gravity data and thus improves the results of the tidal analyses.

9. RESULTS

Tidal analyses were made using Eterna 3.4 software (Wenzel, 1996) which utilised classical manner based on the least squares method (Chojnicki, 1977).

Table 1. The results of tidal analysis.

Gravimetric Earth Tide Station Jozefoslaw no. 909 Poland.
Institute of Geodesy and Geodetic Astronomy,
Warsaw University of Technology, Poland.
52.0973N 21.0316E H141M Gravity.
Gravimeter LaCoste-Romberg no. ET26 electrostatic feedback.
Digital recording with 1 min. interval.
Supervisor J. Bogusz, IGGA.
206.5 s instrumental time lag corrected during preprocessing.

from cpd]	to [cpd]	wave	theor. ampl. [nm/s**2]	ampl.fac.	stdv.	ph. lead [deg]	stdv. [deg]
0.501370	0.842147	SGQ1	2.2244	1.24149	0.06434	-5.5878	2.9688
0.842148	0.860293	2Q1	7.6350	1.15587	0.01766	-1.4788	0.8756
0.860294	0.878674	SGM1	9.2069	1.13457	0.01493	-2.3785	0.7543
0.878675	0.896968	Q1	57.6960	1.14557	0.00220	-0.9266	0.1101
0.896969	0.911390	RO1	10.9513	1.14413	0.01193	-1.7553	0.5974
0.911391	0.931206	O1	301.3400	1.15002	0.00041	-0.7413	0.0205
0.931207	0.949286	TAU1	3.9278	1.17329	0.04203	-2.9347	2.0519
0.949287	0.967660	M1	23.6870	1.14770	0.00460	-0.6112	0.2294
0.967661	0.981854	CHI1	4.5326	1.18540	0.02695	-2.7773	1.3026
0.981855	0.996055	PI1	8.1943	1.11655	0.01824	0.4861	0.9359
0.996056	0.998631	P1	140.1888	1.14887	0.00111	-0.6752	0.0552
0.998632	1.001369	S1	3.3137	1.05390	0.06839	-11.9133	3.7175
1.001370	1.004107	K1	423.6256	1.13508	0.00033	-0.7496	0.0166
1.004108	1.006845	PSI1	3.3153	1.35565	0.04513	3.4933	1.9075
1.006846	1.023622	PHI1	6.0322	1.17159	0.02582	-2.4211	1.2627
1.023623	1.035250	TET1	4.5312	1.14953	0.02909	1.3418	1.4501
1.035251	1.054820	J1	23.6955	1.15848	0.00525	-1.1710	0.2597
1.054821	1.071833	SO1	3.9299	1.17307	0.03245	-0.6435	1.5852
1.071834	1.090052	OO1	12.9608	1.14597	0.00689	-1.5569	0.3445
1.090053	1.470243	NU1	2.4820	1.14651	0.03510	-3.5021	1.7541
1.470244	1.845944	EPS2	2.0966	1.15730	0.02774	-2.2452	1.3735
1.845945	1.863026	2N2	7.1896	1.17417	0.00848	-0.8830	0.4136
1.863027	1.880264	MU2	8.6772	1.17684	0.00771	-0.2421	0.3752
1.880265	1.897351	N2	54.3304	1.18002	0.00119	-0.7220	0.0579
1.897352	1.915114	NU2	10.3204	1.18510	0.00656	-0.6393	0.3172
1.915115	1.950493	M2	283.7601	1.18192	0.00024	-1.0077	0.0115
1.950493	1.970390	L2	8.0213	1.19677	0.01272	-3.4454	0.6088
1.970391	1.998996	T2	7.7159	1.18633	0.00841	-1.6917	0.4063
1.998997	2.001678	S2	132.0081	1.17827	0.00050	-1.6268	0.0241
2.001679	2.468043	K2	35.8682	1.18207	0.00137	-1.6125	0.0665
2.468044	7.000000	M3M6	3.4287	1.06043	0.01077	-1.7118	0.5817

Standard deviation:	3.1 nm/s**2
Degree of freedom:	13077
Maximum residual:	20.153 nm/s**2
Maximum correlation:	-0.216 Y-wave-PSI with Y-wave-K1
Condition number of normal equ.	1.998

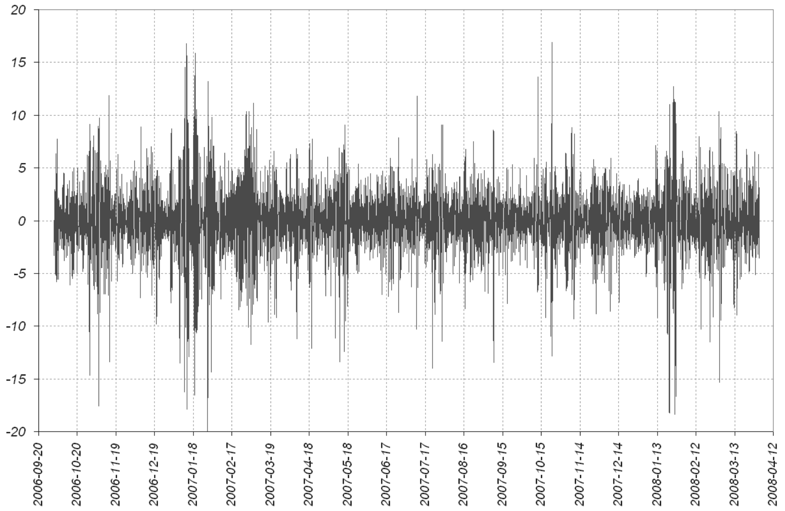

Fig. 8. Gravity residua [nm/s^2]

10.CONCLUSIONS

The data treatment has not been finished yet and the applied corrections still have to be improved. The presented research pointed out that the tidal model which is the result of the analyses should contain all elements related to the environmental effects. New equipment for hydrological changes monitoring is necessary to be installed in the Observatory to make the model more reliably. Still the Observatory is endeavoured to reach the founds for superconducting gravimeter to join GGP project.

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