ROLE OF ENVIRONMENTAL SIGNALS IN THE EARTH TIDES OBSERVATIONS: EXPERIMENTS AT JOZEFOSLAW OBSERVATORY

Janusz Bogusz

Institute of Geodesy and Geodetic Astronomy, Warsaw University of Technology

1. INTRODUCTION

This paper presents the results of the project aimed at the investigation of the role of the environmental effects in gravimetric Earth tides observations which was held at the Jozefoslaw Observatory. The Observatory belongs to the Warsaw University of Technology and is placed at the suburbs of Warsaw. The importance of maintaining fundamental stations with multi-parameter observations is beyond every doubt. At Jozefoslaw Observatory satellite (GPS and GLONASS) observations are run in parallel to absolute (using FG-5) and tidal (with LC&R ET-meter) gravity measurements. The knowledge of the local tidal gravity parameters is required for correction of the absolute gravity measurements and for the interpretation of local ground displacement as well. The correlation between local gravity changes and the environmental signal (local meteorological model, rainfalls, water table changes and soil moisture) was investigated. The project was supported by the grant of the Polish Ministry of Science and Computerisation No 4 T12E 003 27.

1. GRAVIMETRIC DATA

Tidal gravimetric observations in the Observatory started in 1993 using LaCoste&Romberg model G gravimeter. Since 2001 the Observatory has been equipped with the ET-26 model dedicated to the stationary gravimetric measurements. The tidal research program also encompasses environmental studies to make the results more reliable. This study presents the analyses of the data collected from 2002 to 2005. The ET-26 gravimeter is placed in the Astrogeodetic Observatory in Jozefoslaw on the pillar located 5.5 m deep to reduce microseisms, into a thermally stabilized chamber. The temperature in the room is stable up to 0.2°C. Computer's clock is synchronized once every 1 hour using internet and time signal from Borowiec Astrogeodynamic Observatory (vega.cbk.poznan.pl). The stability of the pillar is monitored by the electronic levels built-in the gravimeter, but the instrument has no automatic tilt compensation.

This research concerns the observations collected from 2002 to 2005 (fig. 1). The data is stored on the computer with 1 minute sampling interval using software provided by LaCoste&Romberg. Spikes, gaps and steps were removed using TSoft software (Van Camp and Vauterin, 2005), downloaded from International Centre for Earth Tides web page - http://www.orb.be/ICET/home.html.

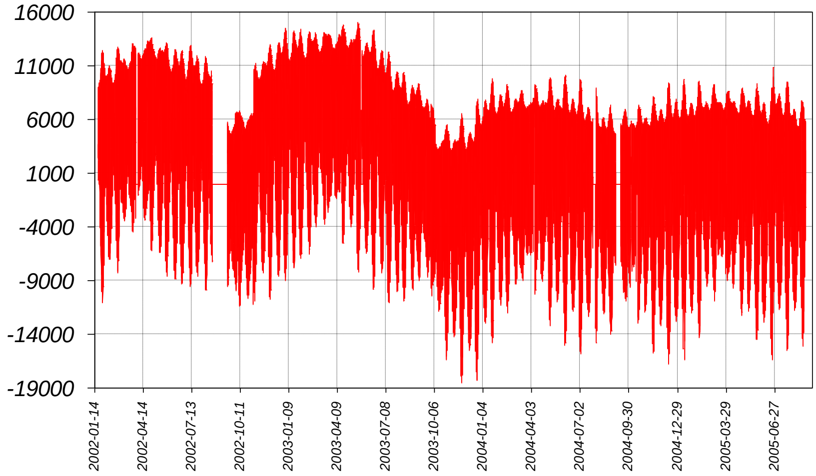

Fig. 1. Tidal data [nm/s^2]

3. ENVIRONMENTAL EFFECTS

In gravimetric tidal observations special attention to environmental effects has to be paid. These effects affect gravity in the tidal frequencies and hence are not possible to be removed using statistical methods (Melchior, 1983). The main of them are:

1. **ocean loading;**
2. **atmospheric mass variations;**
3. **hydrological influences (ground water table, rainfalls, soil moisture, etc.).**

The observational programme of the environmental effects encompasses four kinds of observations:

1. **ambient pressure, temperature and humidity;**
2. **ground water level;**
3. **soil moisture;**
4. **rainfalls.**

In figure 2 particular sensor's locations are presented.

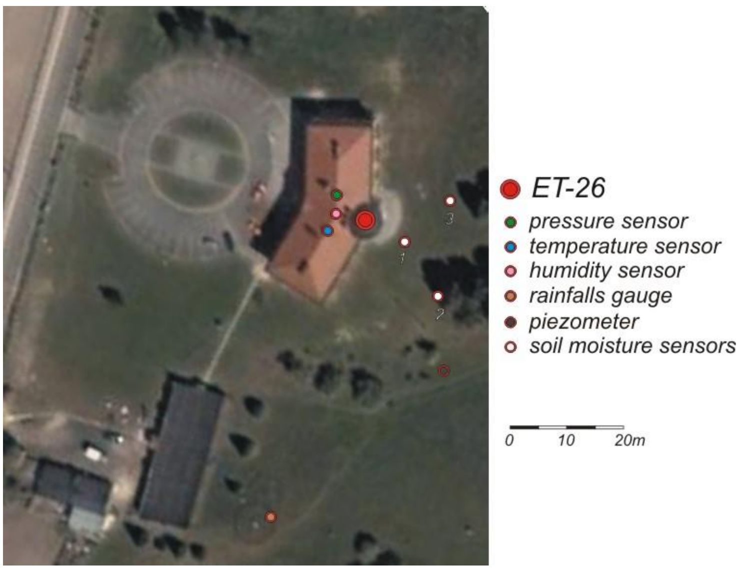

Fig. 2. Location of the sensors

Figures 3 to 4 present tidal changes of the gravity due to ocean and atmosphere, figures 5 to 7 changes of the gravity due to water table, soil moisture and rainfalls respectively. In these changes tidal oscillations were not found. Details of the computation could be found in (Bogusz, 2007).

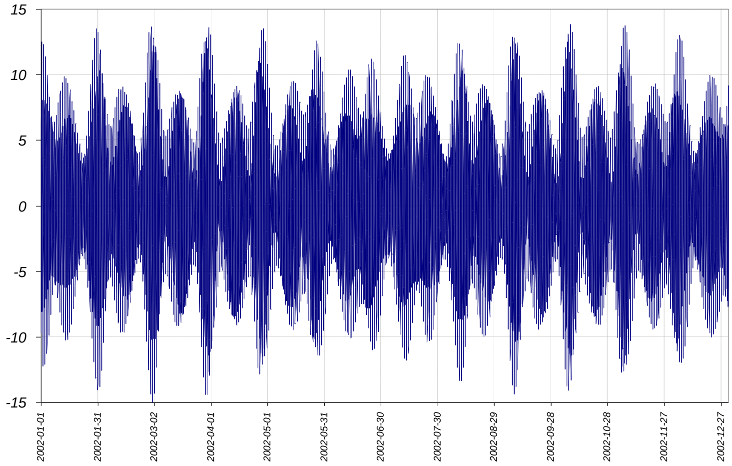

Fig. 3. Ocean indirect effect [nm/s^2] for Jozefoslaw Observatory (GOT00 model - Ray, 1999)

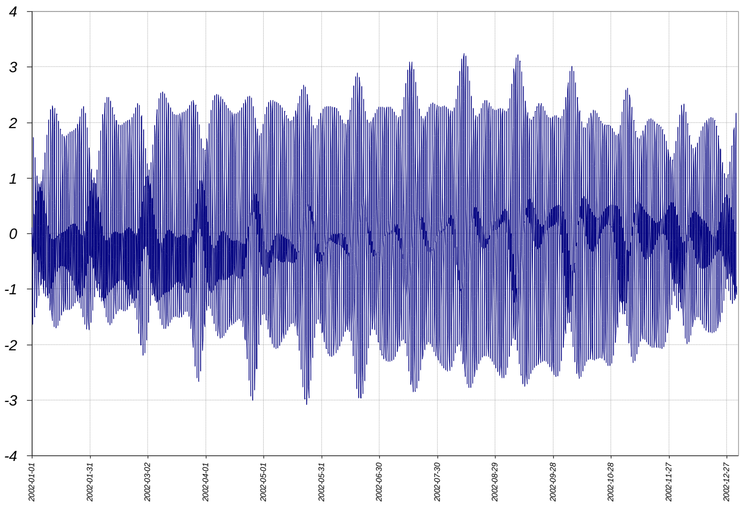

Fig. 4. Atmospheric tidal indirect effect [nm/s^2]

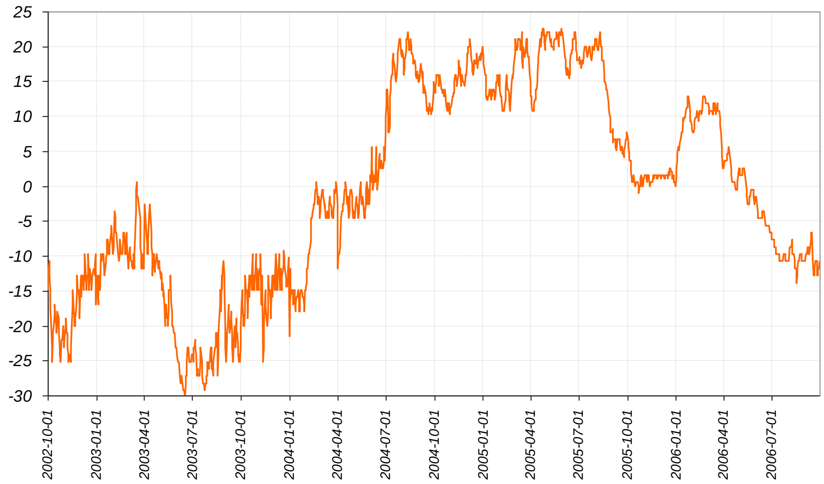

Fig. 5. Changes in gravity [nm/s^2] due to the water level changes

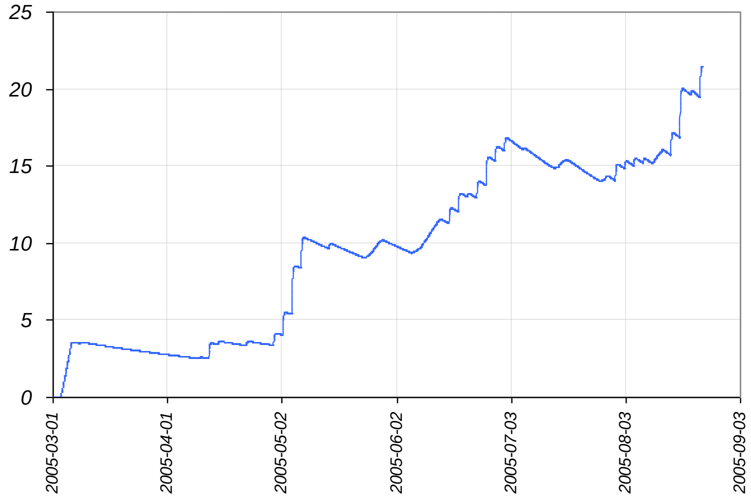

Fig. 6. Changes of the gravity [nm/s^2] in Jozefoslaw in 2005 due to the rainfalls

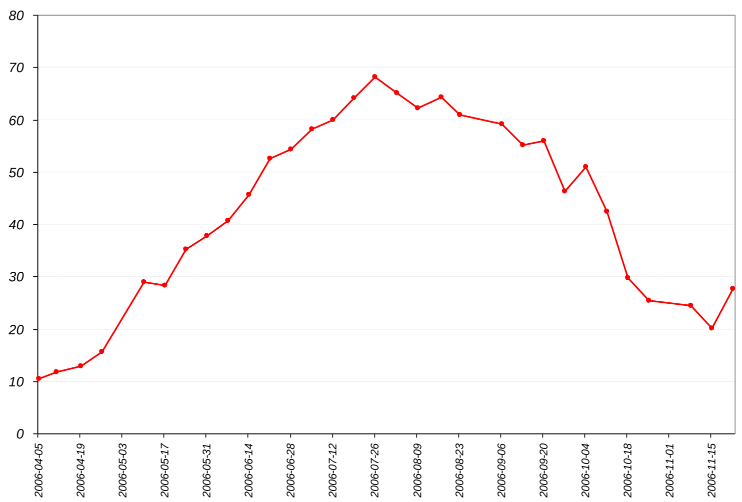

Fig. 7. Gravity changes [nm/s^2] due to the soil moisture in 2006

4. RESULTS

Environmental effects have to be very carefully removed from the observations using the following scheme (Melchior, 1983):

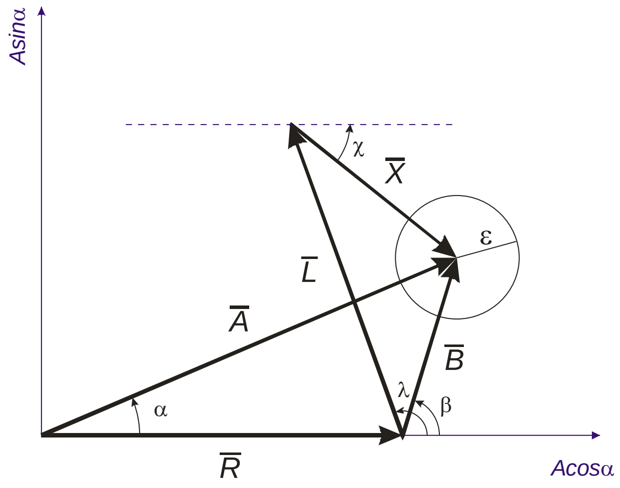

Fig. 8. Method of indirect effects correcting

In this figure:
R – the theoretical vector referred to the rigid and oceanless Earth model,
A – amplitude vector,
α – its phase,
L – vector of the environmental influences,
λ – its phase.
Finally we are able to obtain residual vector X and χ (phase).

The data (time span of 44 months) was analyzed using ETERNA 3.4 Earth tides processing package (Wenzel, 1996). Software is based on the classical manner which utilizes least squares method (Chojnicki, 1977). Environmental reductions were applied beforehand. No hydrological reductions were applied since we have no detected tidal signal within.

Table 1. The results of tidal analysis with Eterna 3.4 of 1311 days of hourly data.

```
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	1.20876	0.11507	0.2551	5.4528
0.842148	0.860293	2Q1	7.6350	1.15713	0.03411	-2.7633	1.6886
0.860294	0.878674	SGM1	9.2069	1.16867	0.02648	-0.0527	1.2986
0.878675	0.896968	Q1	57.6960	1.15013	0.00401	-0.4084	0.1999

0.896969	0.911390	RO1	10.9513	1.14514	0.02018	-0.4756	1.0098
0.911391	0.931206	O1	301.3400	1.15140	0.00071	-0.1375	0.0356
0.931207	0.949286	TAU1	3.9278	1.20534	0.06683	-2.7087	3.1778
0.949287	0.967660	M1	23.6870	1.15500	0.00797	0.0436	0.3955
0.967661	0.981854	CHI1	4.5326	1.11731	0.04695	-0.0939	2.4073
0.981855	0.996055	PI1	8.1943	1.10690	0.03029	-3.2865	1.5677
0.996056	0.998631	P1	140.1888	1.14976	0.00179	0.0690	0.0894
0.998632	1.001369	S1	3.3137	0.84182	0.10867	-60.4033	7.3962
1.001370	1.004107	K1	423.6256	1.13654	0.00055	-0.0465	0.0278
1.004108	1.006845	PSI1	3.3153	1.45061	0.07423	-3.4797	2.9329
1.006846	1.023622	PHI1	6.0322	1.15103	0.04277	-3.3553	2.1294
1.023623	1.035250	TET1	4.5312	1.19458	0.04991	1.3389	2.3937
1.035251	1.054820	J1	23.6955	1.14832	0.01035	0.2314	0.5167
1.054821	1.071833	SO1	3.9299	1.21257	0.05946	-1.3890	2.8094
1.071834	1.090052	OO1	12.9608	1.17778	0.01360	0.0292	0.6617
1.090053	1.470243	NU1	2.4820	1.11483	0.07190	0.7188	3.6953
1.470244	1.845944	EPS2	2.0966	1.13395	0.07721	3.1643	3.9016
1.845945	1.863026	2N2	7.1896	1.17639	0.02640	3.4348	1.2857
1.863027	1.880264	MU2	8.6772	1.16144	0.01987	2.9365	0.9802
1.880265	1.897351	N2	54.3304	1.18470	0.00328	0.4421	0.1588
1.897352	1.915114	NU2	10.3204	1.16829	0.01631	0.3770	0.7996
1.915115	1.950493	M2	283.7601	1.18054	0.00059	0.2267	0.0285
1.950493	1.970390	L2	8.0213	1.15365	0.01248	-0.1875	0.6201
1.970391	1.998996	T2	7.7159	1.13446	0.02081	-0.8045	1.0507
1.998997	2.001678	S2	132.0081	1.17950	0.00122	-0.3138	0.0592
2.001679	2.468043	K2	35.8682	1.18557	0.00372	0.1369	0.1797
2.468044	7.000000	M3M6	3.4287	1.07943	0.01069	-1.4262	0.5676

```
Standard deviation:                4.2  nm/s**2
Degree of freedom:                       7189
Maximum residual:                  46.311  nm/s**2
Maximum correlation:               -0.140 Y-wave-PSI with X-wave-K1
Condition number of normal equ.    1.916
```

Results in the table 1 are given here for information purposes and to give the idea of quality of measurements. After the adjustment the maximum residuum is about 46 nm/s^2 (fig. 9) which is relatively high. I still have no explanation for that but it could be explained by clay on which the pillar is placed. In particular days we observe strong correlation between rainfalls and enlarged short-term oscillations of the instrument's measuring system. Besides in the next research I intend to check calibration of the ET gravimeter. It was already calibrated on the vertical base in Austin, USA, but it will be also compared to the absolute gravity measurements which are carried out in Jozefoslaw using FG-5 No 231. Still the noise levels in tidal bands are relatively large. The mean square error of 4.2 nm/s^2 and the drift of -4.5 nm/s^2 per month are acceptable for this type of equipment.

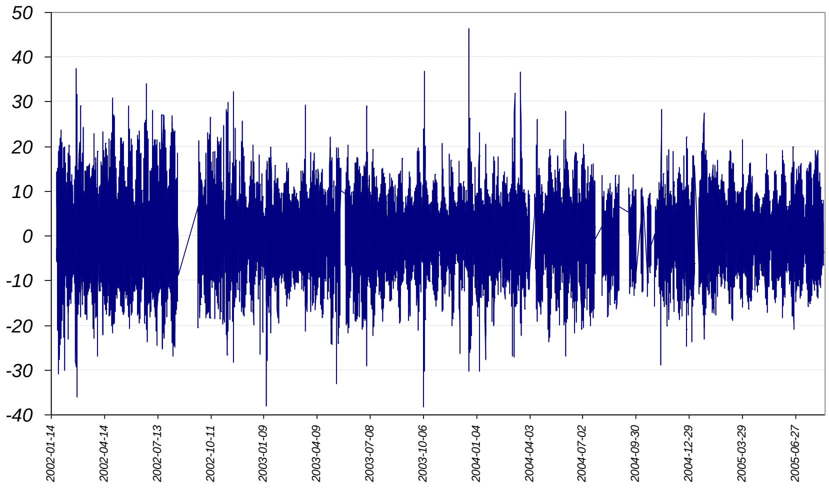

Fig. 9. Gravity residua [nm/s^2]

Amplitude spectrum of gravity residua (fig. 10) still show some oscillations in tidal bands, but its existence could be rather explained by the imperfectness of the method of data adjustment.

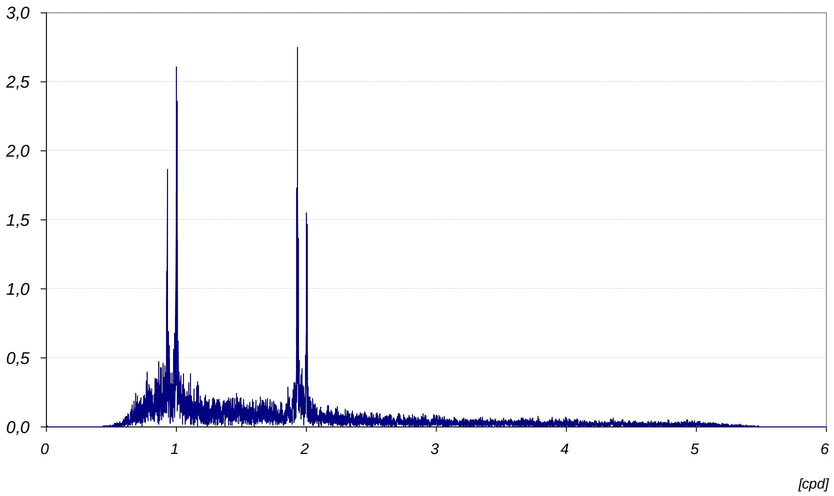

Fig. 10. Amplitude spectrum of gravity residua [nm/s^2]

5. CONCLUSIONS

The data treatment is not yet finished and the corrections applied still have to be improved. The research presented showed how the elimination of environmental influences is an important element of tidal observations. It is equally indispensable as precise instrument or its errors delimitation. The precise tidal model which is the result of analysis should contain all elements connected with environmental effects. But new equipment for hydrological changes monitoring is necessary to be installed in the Observatory. The model determined for Jozefoslaw was sent to International Centre for Earth Tides, where it figures as official one.

Acknowledgements.

Dr Magdalena Kłęk for her supporting in data adjustment is gratefully acknowledged. This research was supported by the Polish Ministry of Science, grant no. 4 T12E 003 27.

REFERENCES

1. Bogusz J. (2007): "Environmental influences on gravimetric Earth tides observations". Submitted to Artificial Satellites.
2. Chojnicki T. (1977): „Sur l'analyse des observations de marees terrestres". Ann. Geophys., 33, 1/2, Edition du CNRS, Paris, pp. 157-160.
3. Melchior P. (1983): "The Tides of the Planet Earth". Pergamon Press.
4. Ray R. (1999): "A global ocean tide model from Topex/Poseidon altimetry: GOT99.2". NASA Technical Memorandum 209478, 58 pages, Sept. 1999.
5. Van Camp, M., and Vauterin, P. (2005): "Tsoft: graphical and interactive software for the analysis of time series and Earth tides", Computers & Geosciences, 31(5), pp. 631-640.
6. Wenzel H.-G. (1996): "The nanogal software: Earth tide processing package ETERNA 3.30". Bulletin d'Information des Marées Terrestres (BIM), No. 124, pp. 9425-9439, Bruxelles, 1996.