INVESTIGATION IN TIDAL GRAVITY RESULTS IN JÓZEFOSŁAW OBSERVATORY

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Abstract

In this paper we used 40 months (2007-2010) of continuous gravity measurements to study different tidal phenomena. The records are taken from the Observatory in Józefosław equipped with LaCoste&Romberg Earth Tide Gravimeter.

Tidal gravity parameters in diurnal and semi-diurnal bands are computed using international standard data processing techniques. Accuracy assessment, as well variation in time of those parameters are given. Long series of consistent data allows to investigate in small signals such as gravity changes due to ocean loading. Subtracting body tides from results yields a differences up to 1 µGal which are in good agreement with computed indirect ocean effect using most recent models. It clearly explains main source of disagreement between results from measurements and tidal models, despite of long distance to nearest ocean. Paper deals also with barometric pressure influence on gravity measurements. Importance of reducing pressure variation in tidal analysis is discussed and admittance factor is computed.

1 INTRODUCTION

Fig. 1. LaCoste&Romberg Earth Tide gravimeter.

Tidal laboratory in Józefosław (Warsaw suburb area) is equipped with *LC&R ET-26* gravimeter with electrostatic feedback since 2001 (Bogusz, 2002). It is located on the pillar about 6 m under ground level in thermal stabilized chamber. After serious repair in summer 2006 gravimeter operates continuously. Since end of 2005 scale factor is controlled through periodically synchronous measurements with FG5 gravimeter (Rajner and Olszak, 2010).

Nowadays the most precise continuous gravity measurements are obtaining using superconducting gravimeters (Hinderer et al., 2004) but spring gravimeters with electrostatic feedback can challenge them under favorable condition and carefulness in maintenance (Zürn et al., 1991, Ducarme et al., 2002). Some results and explanations concerning tidal and non-tidal gravity changes are presented below.

2 OBSERVATIONS

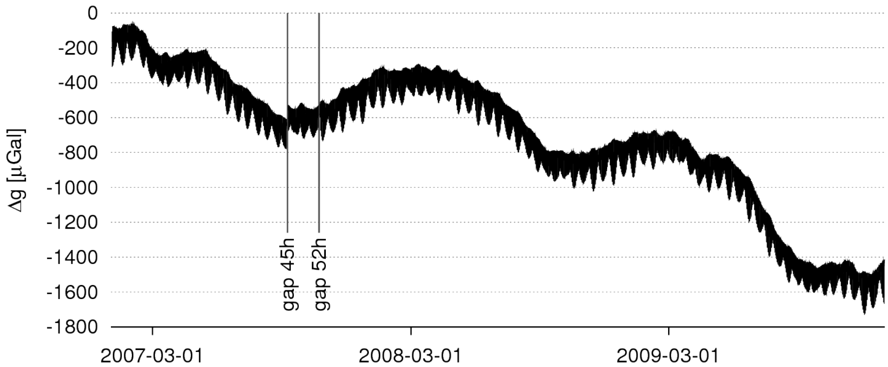

Fig. 2. Raw records of gravimeter.

Raw measurements are shown in Fig. 2. The average drift rate is 1.5 µGal per day, but one could see strong yearly variation of drift curve with amplitude of about 100 µGal. This behavior is probably caused by humidity variation which is typical for LCR gravimeter and was noted before by some authors (el Wahabi et al., 2000, Palinkaš et al., 2006). This will require further investigation and will be undertaken through installation of additional humidity sensor and air-dryer in gravimeter chamber.

The main source of decreased quality of observations are strong Earthquakes (Fig. 3). This is clearly seen in daily RMS graph, which was plotted using series where tides and 9th degree polynomial were subtracted. Increased value of this factor is strongly correlated with Earthquakes occurrences.

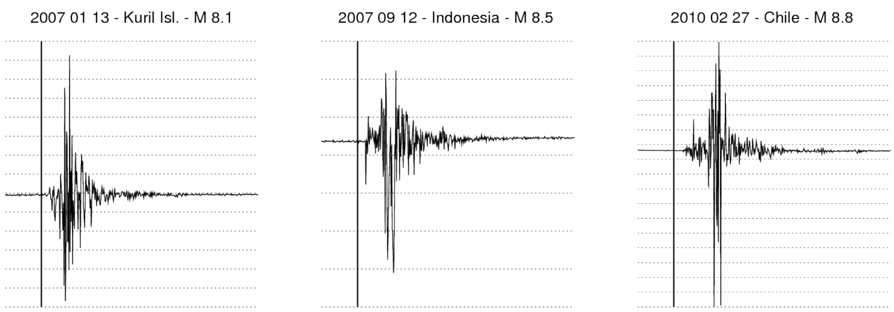

Fig. 3. Earthquakes in observations (every window is 7 *h* width, y grid is 1 *Gal*, vertical bar represents start of the Earthquake).

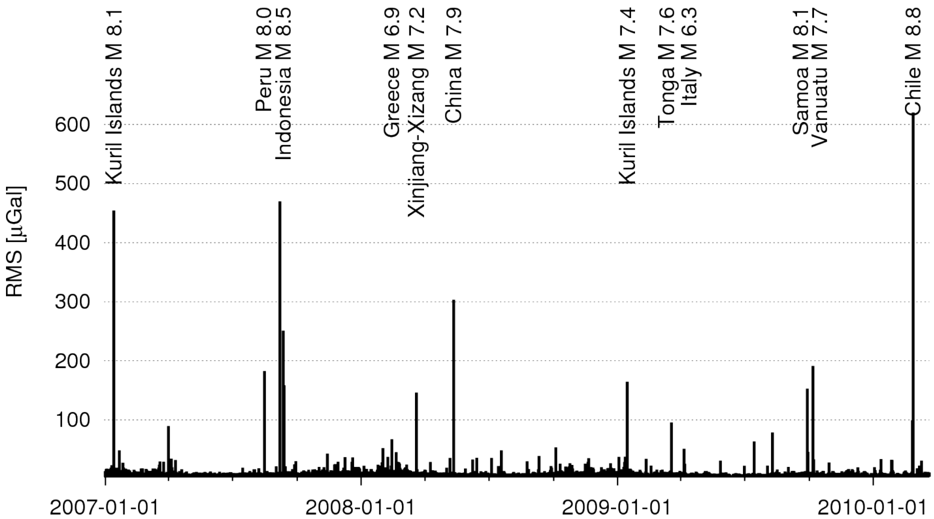

Fig. 4. Daily RMS and dates of strong Earthquakes occurrences.

The data discussed here were measured at 1 min samples. Before performing tidal analysis bad points were replaced by interpolation, the data was digitally filtered and decimated to hourly samples using Tsoft (VanCamp and Vauterin, 2005).

3 ANALYSIS

Firstly we examined power spectrum density of signal using Fourier's transform. In Fig. 5 one could see that results are with a good agreement with prediction. The main power persists in diurnal and sub-diurnal bands. The noise level is somehow larger in diurnal band but nevertheless signal to noise ratio is high. Long-period frequencies are not shown as they were cut-off during preprocessing to avoid dealing with drift.

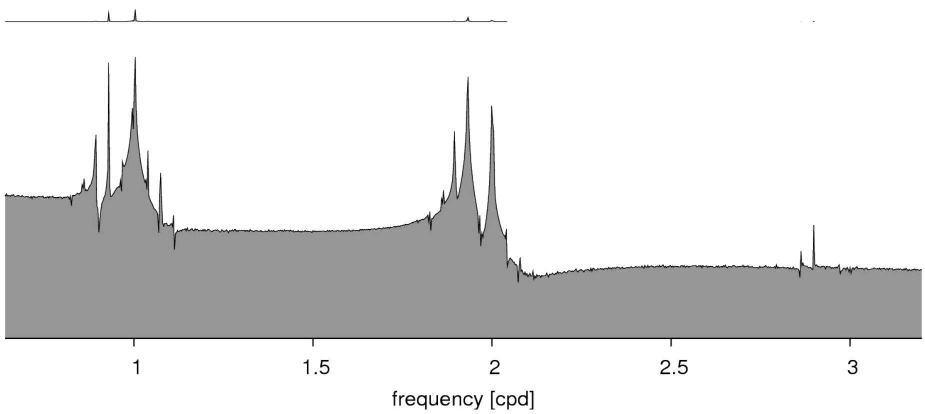

Fig. 5. Power Spectrum Density. Upper graph linear and bottom graph logarithmic scale respectively.

Tidal parameters were computed using ETERNA (Wenzel, 1996) twice: without and with barometric pressure as auxiliary series for investigation in atmosphere importance. The results are presented in Tab. 1 and Fig. 6. They are compared to Wahr-Dehant tidal model (Wahr, 1981, Dehant, 1987).

Table 1. Least square adjustment results.

					without pressure correction				with pressure correction			
		Name	A_{theo} [nm/s^2]	δ_{WD}	δ	m_δ	φ [°]	m_φ [°]	δ	m_δ	φ [°]	m_φ [°]
0.5014	0.9114	Q_1	57.7	1.1480	1.1476	0.0013	-0.135	0.066	1.1480	0.0005	-0.069	0.024
0.9114	0.9480	O_1	301.3	1.1505	1.1505	0.0003	0.041	0.013	1.1505	0.0001	0.087	0.005
0.9480	0.9819	M_1	23.7	1.1518	1.1479	0.0040	0.000	0.197	1.1518	0.0014	0.062	0.071
0.9819	0.9986	P_1	140.2	1.1486	1.1488	0.0007	0.263	0.033	1.1486	0.0002	0.129	0.012
0.9986	1.0014	S_1	3.3	1.1949	1.0515	0.0416	-16.6	2.268	1.1949	0.0152	-6.199	0.734
1.0014	1.0041	K_1	423.6	1.1361	1.1361	0.0002	0.136	0.010	1.1361	0.0001	0.103	0.004
1.0041	1.0068	ψ_1	3.3	1.2892	1.3098	0.0277	-0.371	1.210	1.2892	0.0100	1.805	0.447
1.0068	1.0236	φ_1	6.0	1.1663	1.1798	0.0167	1.402	0.810	1.1663	0.0061	-0.015	0.298
1.0236	1.0575	J_1	23.7	1.1572	1.1578	0.0031	0.087	0.153	1.1572	0.0011	0.038	0.056
1.0575	1.4702	OO_1	13.0	1.1530	1.1551	0.0048	-0.248	0.239	1.1530	0.0018	-0.005	0.087
1.4702	1.8803	$2N_2$	8.7	1.1683	1.1697	0.0032	1.068	0.154	1.1683	0.0024	1.216	0.119
1.8803	1.9141	N_2	54.3	1.1774	1.1779	0.0007	0.937	0.033	1.1774	0.0005	0.957	0.025
1.9141	1.9504	M_2	283.8	1.1827	1.1829	0.0001	0.636	0.007	1.1827	0.0001	0.642	0.005
1.9504	1.9843	L_2	8.0	1.1964	1.1947	0.0072	0.246	0.344	1.1964	0.0055	0.063	0.265
1.9843	2.0027	S_2	132.0	1.1749	1.1795	0.0003	0.091	0.014	1.1749	0.0002	-0.197	0.011
2.0027	2.4519	K_2	35.9	1.1788	1.1811	0.0009	0.117	0.043	1.1788	0.0007	0.077	0.033
2.4519	7.0000	M_3M_6	3.4	1.0826	1.0840	0.0056	0.338	0.294	1.0826	0.0042	0.104	0.220

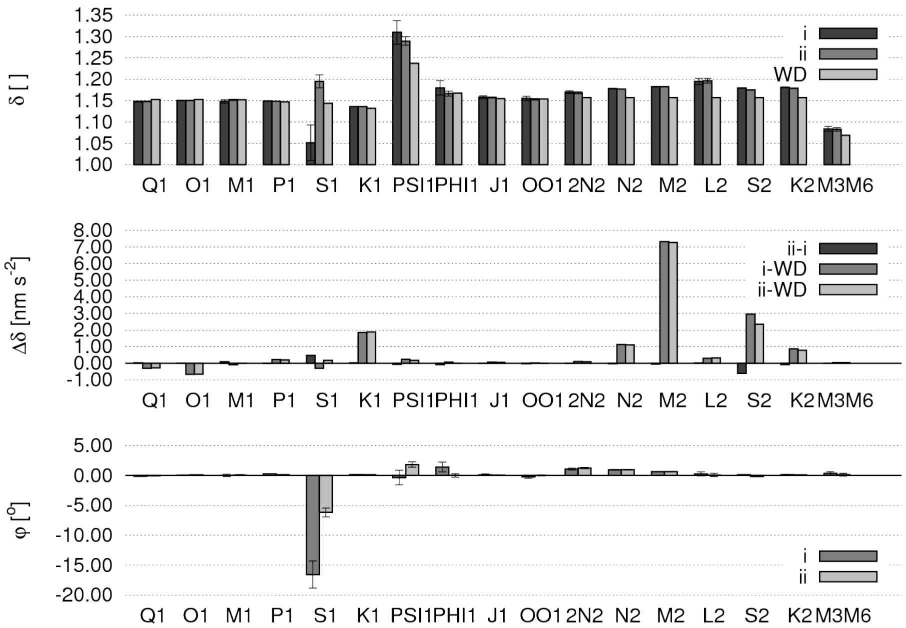

Fig. 6. Amplitude factors, difference in amplitude factors and phases for main tidal constituent estimated without (i) and with pressure correction (ii), compared to Wahr-Dehant model.

The high quality of data could be seen if one look in residuals after fitting tidal constituents (Fig. 7). With use of auxiliary pressure data we reduced environmental noise significantly. Two periods with time synchronization problems are marked with grey bars (those periods are marked on others figures respectively).
The standard deviation of least-square technique reached 2.21 nm/s^2 (without pressure correction) and 0.98 nm/s^2 (with pressure correction).

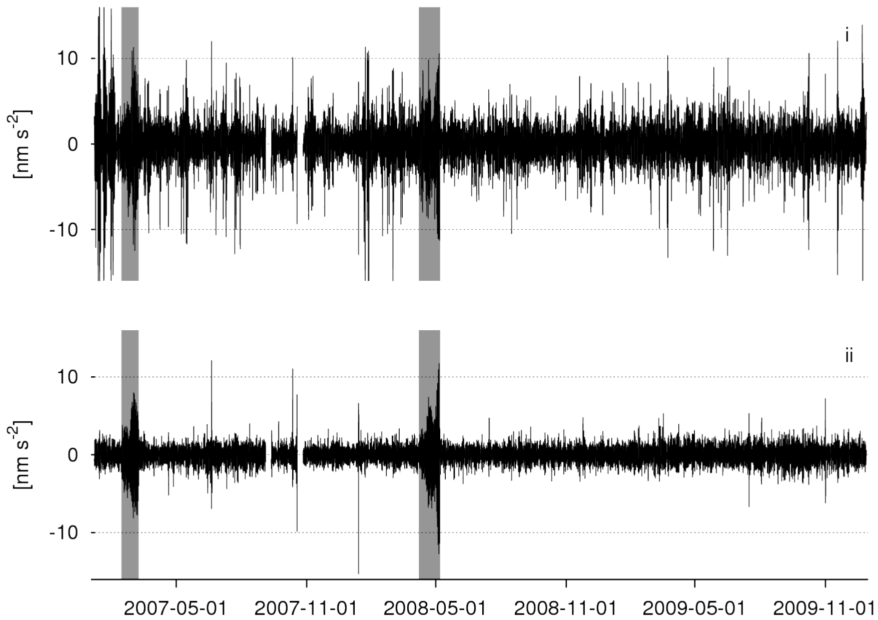

Fig. 7. Gravity residuals without (i) and with pressure correction (ii).

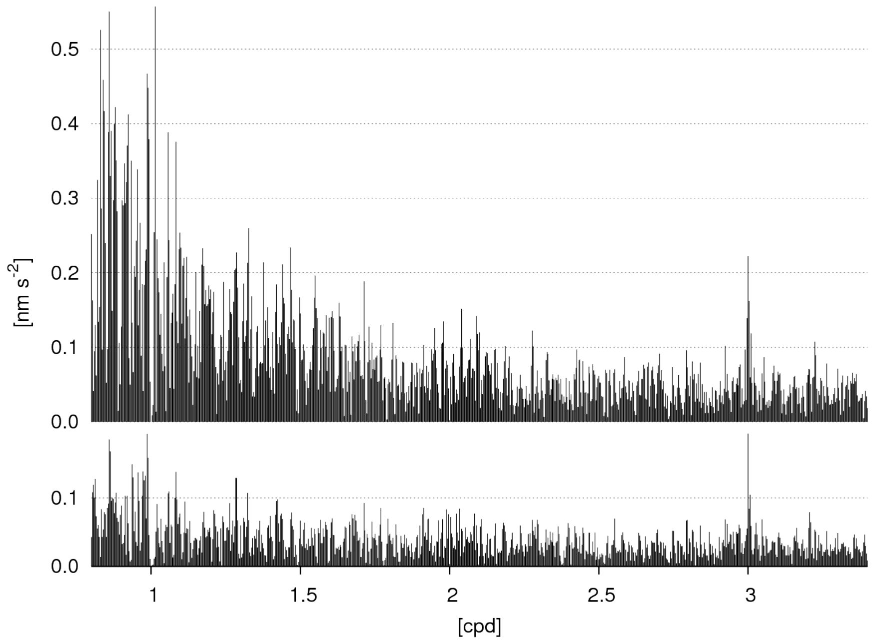

Fig. 8. Fourier's spectrum of residuals. Upper graph without and lower graph with pressure correction.

4 TIDAL PARAMETERS VARIATION

We performed tidal analysis using BAYTAP08 (Tamura and Agnew, 2008) with moving window 40 days span and 10 days shift. In Fig. 9 we see that amplitude for M_2 is stable within 1 nm/s^2 range. The change in phase is significant only during registration problem confirming its origin and stability of calibration factor (Rajner and Olszak 2010).

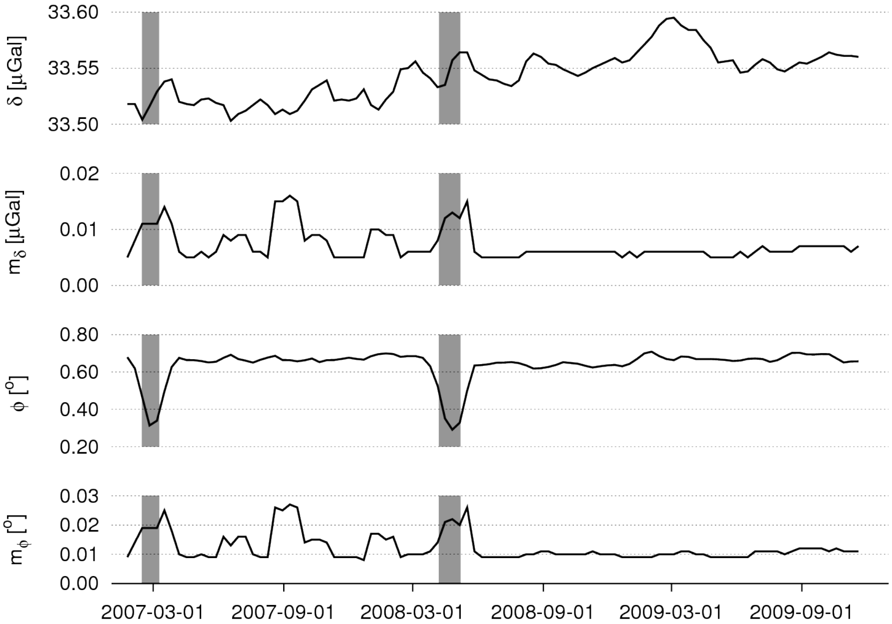

Fig. 9. Tidal parameters for M2 constituent.

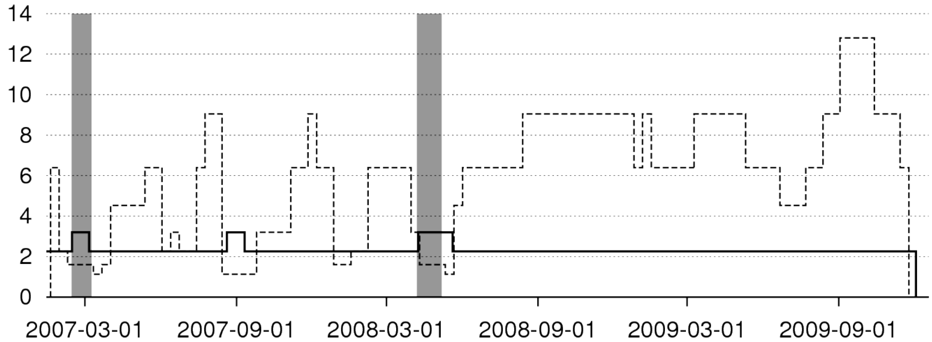

Fig. 10. D-hyperparameter variation using moving window (intermittent line, span - 40 days, shift - 10 days, higher value means better fit to model) and „excluding data" window (solid line, span - 20 days, shift - 20 days).

It was found that factor determining „goodness" of fitting model using Bayesian approach clearly indicates periods with instrumental problems or environmental influences especially when using „excluding data" moving window.

5 PRESSURE ADMITTANCE FACTOR

Pressure reduction cannot be neglected in high precision analysis. Usually the pressure admittance factor is computed as simple regression coefficient using gravity residuals with pressure changes (Warburton and Goodking, 1977). Using same manner as in previous section (moving data windowing) we examined seasonal behavior of pressure admittance factor which is presented in Fig. 11. It shows its seasonal variation caused by fact that single value cannot represent pressure field accurately (van Dam and Francis, 1998).

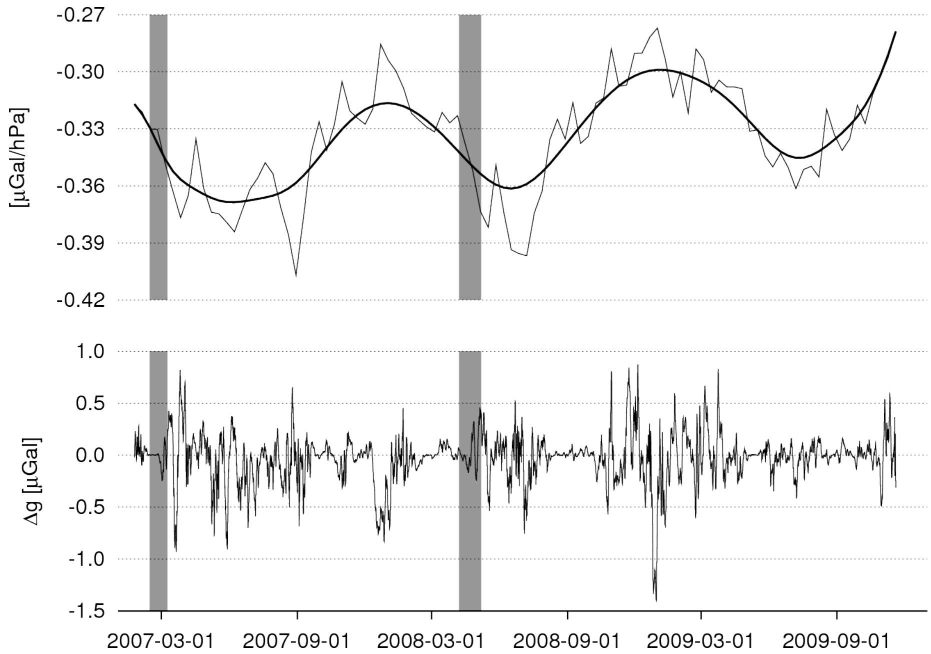

Fig. 11. Seasonal variation of atmospheric pressure admittance factor and differences between using mean and time-dependent values for gravity correction.

6 OCEAN INDIRECT EFFECT

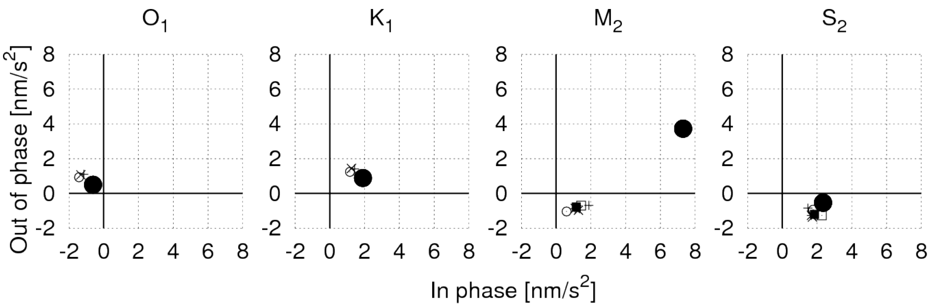

Fig. 12. Phasor plots for residual values (subtracted body tides, filled circle) and residua corrected for ocean loading using most recent models (other marks).

Józefosław is far from nearest ocean and the nearest sea (Bałtyk) is almost tideless. In Fig. 12 one can see significant discrepancies between determined and predicted from model body tide especially for M_2 constituent. Using ocean loading correction computed on basis on ocean tide models (www.oso.chalmers.se/~sherneck, we do not differentiate them as they give similar values for station far from shore) greatly reduces these differences.

7 CONCLUSIONS

Gravity measurements with LCR-ET gravimeter provide high quality tidal parameters (despite of relative high background noise). Carefulness in processing and long time series allows for investigation in weak environmental signals - pressure and ocean loading. Combining these results with records from different instruments (meteorological station, absolute gravimetry, GNSS observations, piezometr and others)

in Józefosław Observatory makes it unique place for geodetic, geodynamic and geophysics studies.

8 ACKNOWLEDGEMENTS

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