ANALYSIS OF MEASUREMENTS COLLECTED IN GRAVITY LABORATORY IN JÓZEFOSŁAW OBSERVATORY DURING 2007-2010 PERIOD

Marcin Barlik, Marcin Rajner, Tomasz Olszak
Warsaw University of Technology, Department of Geodesy and Geodetic Astronomy
pl. Politechniki 1, 00-661 Warszawa, Poland
`mbarlik@gik.pw.edu.pl, mrajner@gik.pw.edu.pl, t.olszak@gik.pw.edu.pl`

Abstract

Keywords: absolute gravimetry, tides, environmental impact on gravity

Astro-Geodetic Observatory in Józefosław (near Warszawa) is equipped with two gravimeters for different purposes. Continuously recording LCR ET-26 spring gravimeter (since 2002) serves for determination of accurate local tidal coefficients and investigation of environmental effects such as atmospheric and ocean influence on gravity. FG5 no. 230 ballistic gravimeter is operated periodically - once a month. Frequently measurements allows us for study non-tidal gravity changes caused mainly by local and continental hydrology. In this paper we present some advantages of using two types of gravity measurements. During calibration process the gravity records from ballistic gravimeter are used for determination of scale factor of spring gravimeter. On the other hand ballistic gravimeter utilizes local tidal model determined from spring gravimeter for obtaining non-tidal series. Long series of synchronous measurements were used for determination of background noise, atmospheric (admittance factor), ocean and hydrological effect on gravity changes. Results from both gravimeters are presented and discussed.

Introduction

In Józefosław Observatory various geodetic and geophysical researches are conducted. In these studies gravity observations plays important role and have long tradition (Rogowski and others, 2010). Nowadays we observe continuous gravity changes with LCR-ET no. 26 spring gravimeter (Bogusz, 2002) and periodically absolute gravity values using FG5 no. 230 ballistic gravimeter (Barlik, 2009). This paper gives short overview of main investigations in gravity field and its changes on the basis of measurements collected in last 40 months.

Observations

The data discussed here were measured at 1 min samples. Before performing analysis bad points were replaced by interpolation, the data was digitally filtered and decimated to hourly samples using Tsoft (Van Camp and Vauterin, 2005). The absolute measurements were of different length. Typically one session consisted 24 sets (each of 100 drops) taken during one day. Raw observations of LCR are presented in Fig. 1 along with FG5 periodically taken measurements.

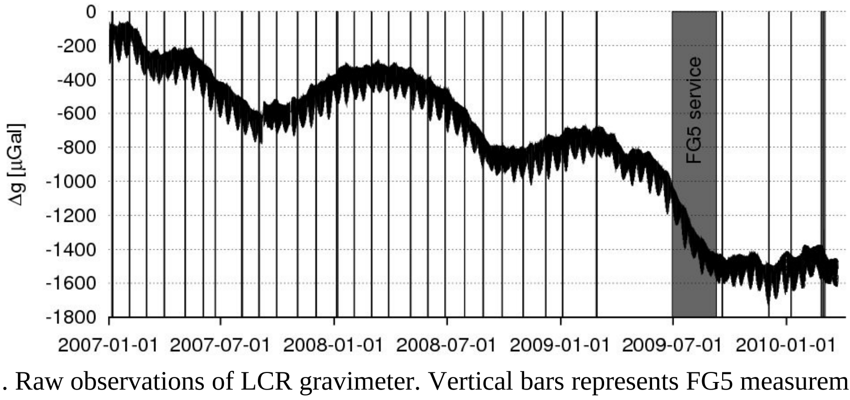

Fig. 1. Raw observations of LCR gravimeter. Vertical bars represents FG5 measurements.

Spring gravimeter average drift rate is 1.5 μ*Gal* per day, but one could see strong yearly variation of drift curve with amplitude of about 100 μ*Gal*. This behaviour is probably caused by humidity variation which is typical for LCR gravimeter and was noted before by some authors (el Wahabi and others, 2000; Pálinkáš, 2006). This will require further investigation and will be undertaken through installation humidity sensor in gravimeter chamber.

Calibration of spring gravimeter using AG measurements

Comparison of gravimeters relative to absolute measurements is frequently used method for determination of gravimeters scale factors. This technique as completely non-invasive is especially important in periodic control of continuously recording gravimeters. For determining of scale factor we used mean set FG5 values and filtered LCR data. Assuming that impact of environmental disturbances (atmospheric, hydrological) and tides (body tide,ocean loading) is exact for both gravimeters we used uncorrected, centred data for further analysis. Simple equation ($g_{FG}=kg_{ET}+s$), was applied for computing LCR scale factor (*k*) using Least Square Adjustment. Weights for measurements were proportional to inverse of square of set uncertainty.

Long series of repeated measurements allows us for comprehensive study on utility of calibration with this procedure. Different computational approaches was performed. Below are shown results for particular series along with AG measurements length (Fig. 2).

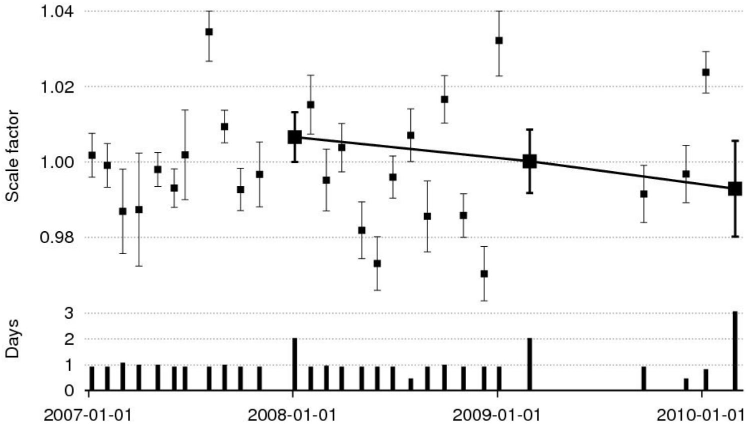

Fig 2. Scale factor values - upper graph, for sessions of minimum 2 days length has bigger marks. Number of FG5 measurements days and RMS of LCR residuals.

Unfortunately lengths of measurements allows for confirming manufacturer scale factor at 1% level only.

Stability of scale factor was confirmed performing tidal analysis using baytap08 (Tamura and Agnew, 2008) with moving window. Amplitude factor variation for constituent was within 1 nm/s^2 range.

Tidal parameters determination

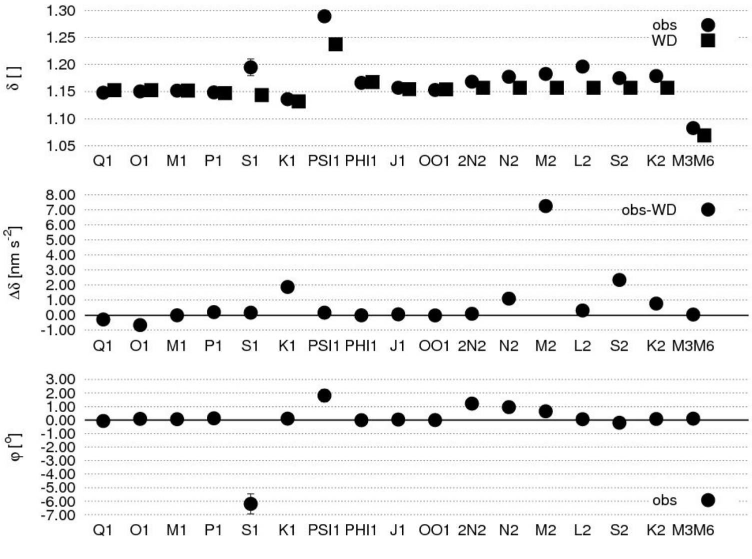

Fig 3. Amplitude factors, differences in amplitude factors relative to Wahr-Dehant tidal model and phases for main tidal constituent (pressure correction applied).

Nowadays the most precise continuous gravity measurements are obtaining using superconducting gravimeters but spring gravimeters with electrostatic feedback can challenge with them under favourable condition and carefulness in maintenance (Ducarme and others, 2002). Tidal parameters in diurnal and semi-diurnal bands were computed using `ETERNA` (Wenzel, 1996) The results are presented in Fig. 3. Comparison with theoretical amplitudes for Wahr-Dehant tidal model yields discrepancies up to 1 µ*Gal*. The standard deviation of least-square technique reached 1 nm/s^2.

Atmosphere influence on gravity

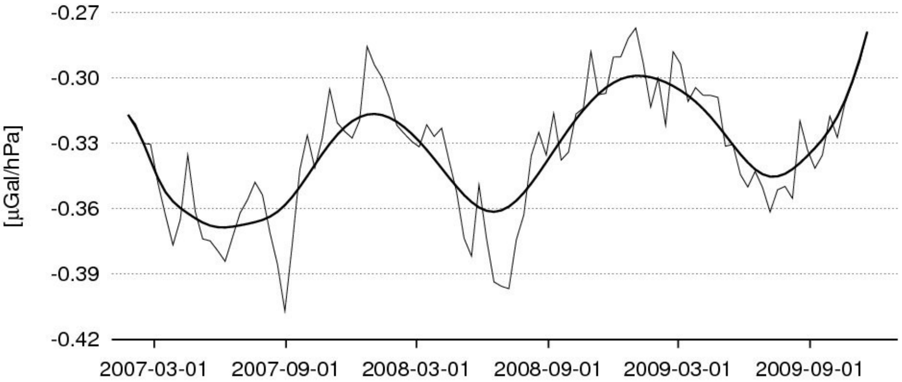

Fig 4. Seasonal variation of atmospheric pressure admittance factor (smoothed).

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. We computed pressure admittance as simple regression coefficient on basis of LCR measurements. Using moving data windowing we examined its seasonal behaviour which is presented in Fig. 5. This variation confirms known fact that single value cannot represent pressure field accurately. For highest precision one should use two dimensional pressure field (Merriam, 1992) or three dimensional operational weather model (Neumeyer and others, 2004).

Ocean loading

Long series of consistent data allows to investigate in small signals such as gravity changes due to ocean loading. Subtracting body tides from tidal analysis results yields a differences up to 1 µ*Gal* which are in good common with computed indirect effect of ocean using most recent models for this site (Rajner, 2010). For this purpose we used `SPOTL` package (Agnew, 1996). Ocean loading effect clearly explains main source of disagreement between results from measurements and tidal models, despite of long distance to nearest ocean (Fig 5).

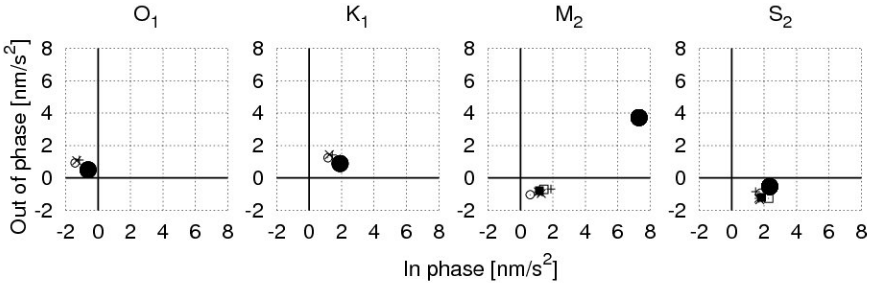

Fig. 5. Phase plots for residual values (subtracted body tides, filled circle) and residua corrected for ocean loading using most recent models (other marks, we do not differentiate models here, as they give similar results).

Hydrological effects

Continental water masses also have considerable influence on gravity. AG measurements show seasonal variation of gravity values. Part of seasonal signal can be explained by local water table and global water storage (Fig. 6), however we do not see such obvious correlation as was noticed before (Wziontek and others, 2009; Rosat and others, 2009). It is quite strange as topography around site is not very complicated so those unknowns could stem from unrecognized soil properties. Better agreement is expected using more sophisticated modelling of atmospheric effect. In this paper WGHM model (Döll, 2003) was used.

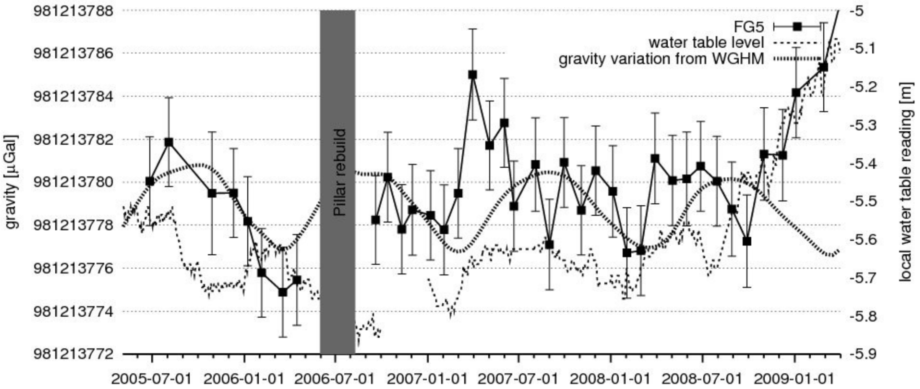

Fig. 6. AG measurements compared to gravity change due continental water storage and local water table level variation.

Background noise

Last section is devoted to local traffic induced noise. We investigated in background noise (containing instrumental noise) on basis of raw LCR observation (1 min sampling). Here we present daily standard deviation from records where tides using H-W potential catalogue (Hartmann and Wenzel, 1995) and polynomial of 9th degree were subtracted. We see that during day noise is significantly higher then during the night. This is consequence of rapidly developing of Józefosław which is in Warsaw suburb area. Seasonal dependence of noise is expected and is observed with use of seismometers. Here very strong variation could have some other origins not explained yet.

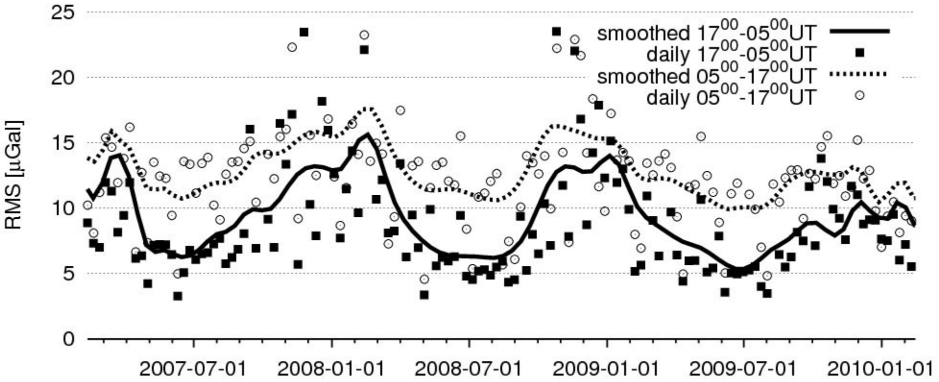

Fig. 7. Daily and smoothed (Beziér curve) RMS for day and night.

Conclusions

Measurements with *LCR-ET* and *FG5* provide high quality gravity values. Carefulness in processing and long series of collected data allows for investigation in weak environmental signals - pressure and ocean loading, hydrological signals. Combining those results with records from different instruments (meteo, GNSS, water table level and soil moisture observations) in Józefosław Observatory makes it unique place in Poland for geodetic, geodynamic and geophysics studies.

Acknowledgments

We greatly acknowledged our friends from department for help in carrying measurements. We are grateful to A. Güntner for sharing with us WGHM model. MR was supported by the European Union in the framework of European Social Fund through the Warsaw University of Technology Development Programme.

References

Agnew, D. C., 1996. SPOTL: Some programs for ocean-tide loading, *SIO Ref. Ser.*, 96-8, 35 pp.

Barlik, M., ed., 2009. Badanie długookresowych zmian absolutnego natężenia siły ciężkości na głównych jednostkach tektonicznych na terytorium Polski w okresie 2006–2009, Oficyna wydawnicza Politechniki Warszawskiej, monography in polish.

Bogusz, Janusz, 2002. New tidal gravimetric laboratory in Jozefoslaw, *Reports on Geodesy*, 61(1).

Döll, P., F. Kaspar and B. Lehner, 2003. A global hydrological model for deriving water availability indicators: model tuning and validation, Journal of Hydrology, 270, 105–134.

Ducarme, B., H.-P. Sun and J.-Q. Xu, 2002. New investigation of tidal gravity results from the GGP network, *Bulletin d'informations Mares Terrestres*, 136, 10761–10776.

Hartmann, T. and H.-G. Wenzel, 1995. Catalogue HW95 of the tide generating potential, *Bulletin d'informations Marees Terrestres*, 123.

Merriam, J. B., 1992. Atmospheric pressure and gravity, *Geophysical Journal International*, 109, 488–500.

Neumeyer, J., J. Hagedoorn, J. Leitloff and T. Schmidt, 2004. Gravity reduction with three-dimensional atmospheric pressure data for precise ground gravity measurements, *Journal of Geodynamics*, 38, 437–450.

Pálinkáš, V., 2006. Precise tidal measurements by spring gravitmeters at the station Pecný, *Journal of Geodynamics*, 41, 14–22.

Rajner, M., 2010. Investigation in Tidal Gravity Results in Józefosław Observatory, *Reports on Geodesy*, in press.

Rogowski, J., M. Barlik, T. Liwosz, M. Kruczyk, L. Kujawa, M. Rajner, T. Olszak and W. Kurka, 2010. Activities of Józefosław Astro-Geodetic Observatory in the last five decades, *Reports on Geodesy*, 89(2), 31–52.

Tamura, Y. and D. C. Agnew, 2008. Baytap08 User's Manual.

Van Camp, M. and P. Vauterin, 2005. TSoft: graphical and interactive software for the analysis of time series and Earth tides, *Computers and Geosciences*, 31(5).

el Wahabi, A., H.-J. Dittfeld and Z. Simon, 2000. Meteorological influence on tidal gravimeter drift, *Bulletin d'informations Mares Terrestres*, 133, 10403–10414.

Wenzel, H.-G., 1996. The nanogal software: Earth Tide Data processing package ETERNA 3.30, *Bulletin d'Informations Marees Terrestres*, 124.

Wziontek, H, H. Wilmes, P. Wolf, S. Werth and A Güntner, 2009. Time series of superconducting gravimeters and water storage variations from the global hydrology model WGHM, *Journal of Geodesy*, 48, 166–171.

Consent

Authors agree for publication of this paper in symposium proceedings.
09.08.2010.

Adress for sending proceedings: pl. Politechniki 1, 00-661 Warszawa, Poland