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

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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.

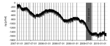

Fig. 1. Raw observations of LCR gravimeter. Vertical bars represents FG5 measurements.

Spring gravimeter average drift rate is 1.5 μGal per day, but one could see strong yearly variation of drift curve with amplitude of about 100 μGal. 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 ($g_{LCR}=k g_{FG5}+n$), 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).

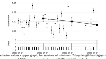

Fig 2. Scale factor values - upper graph, for sessions of minimum 2 days length has bigger marks. Number of FG5 measurements days and RMS of LCR residuals.

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/s² range.

Tidal parameters determination

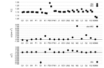

Fig 3. Amplitude factors, differences in amplitude factors relative to Wahr-Dehant tidal model and phases for main tidal constituent (pressure correction applied).

Nowadays the most precise continuous gravity measurements are obtaining using superconducting gravimeters but spring gravimeters with electrostatic feedback can challenge with them under favourable conditions 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 μGal. The standard deviation of least-square technique reached 1 nm/s².

Atmosphere influence on gravity

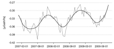

Fig 4. Seasonal variation of atmospheric pressure admittance factor (smoothed).

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 μGal 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).

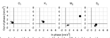

Fig. 5. Phase plots for residual values (subtracted body tides, filled circle) and residua corrected for ocean loading using most recent models (other marks, we do not differentiate models here, as they give similar results).

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.

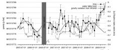

Fig. 6. AG measurements compared to gravity change due continental water storage and local water table level variation.

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.

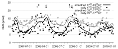

Fig. 7. Daily and smoothed (Beziér curve) RMS for day and night.

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.

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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


ARTIFICIAL SATELLITES, Vol. 45, No. 4 – 2010
DOI: 10.2478/v10018-011-0006-2
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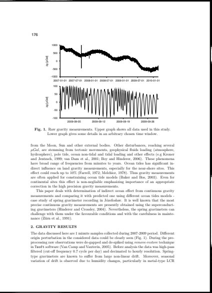
ABSTRACT.
1. INTRODUCTION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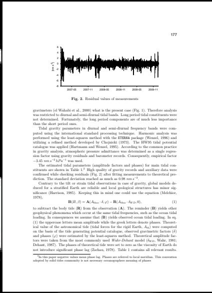
2. GRAVITY RESULTS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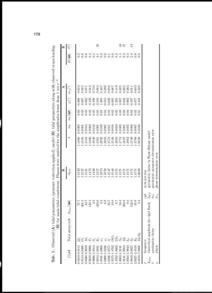
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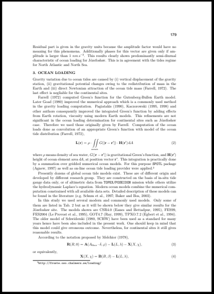
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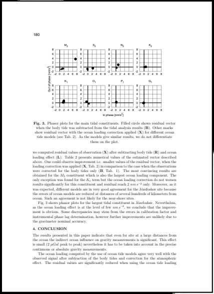
3. OCEAN LOADING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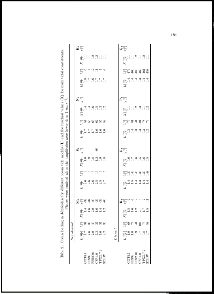
4. CONCLUSION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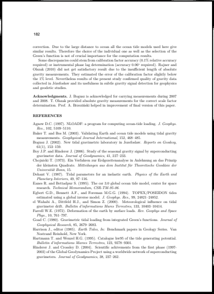
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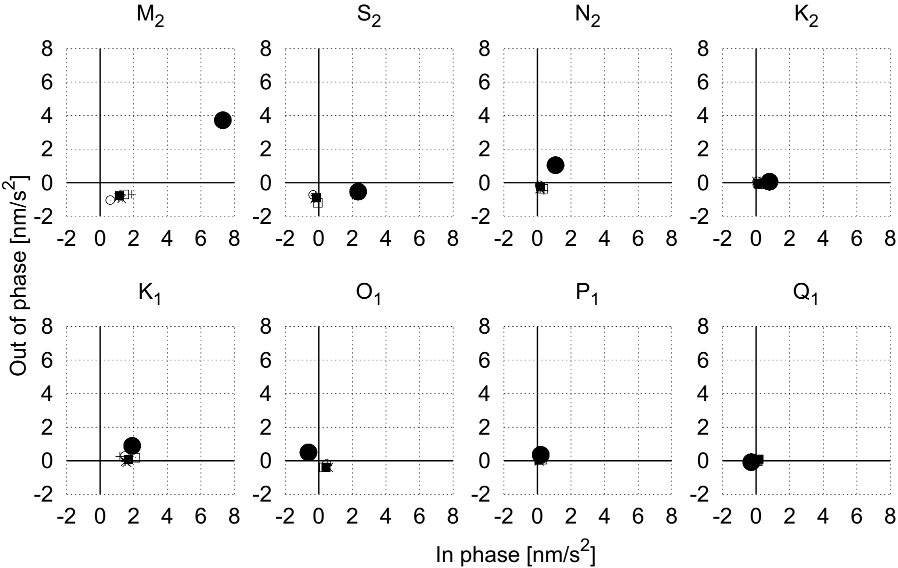

Phasor plots for the main tidal constituents. Filled circle shows residual vector

EARTH FREE OSCILLATION MEASUREMENTS WITH LCR-ET 26 SPRING GRAVIMETER

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Abstract

After strong earthquakes the Earth oscillates with spheroidal and toroidal modes. The former cause gravity changes which can be detected with sensitive instruments. For this purpose we used continuous gravity measurements with LaCoste&Romberg Earth Tide spring gravimeter from Józefosław Observatory. Spectral analyses of records show significant peaks in normal mode frequencies. This peaks are above noise level and their eigenfrequencies are in good agreement with seismic theories. We show here some examples of free oscillations registration after particular earthquakes and stacking method as well. Some remarks concerning noise level in gravity measurements and data treatment are also given.

1 Introduction

It is well known that studying of free oscillation provides information and constraints of Earth's interior (Gilbert and Dziewoński, 1975; Resovsky and Ritzwoller, 1998; Park et al., 2005). In this works not only seismometers can be applied. The gravimeters are also used and are superior in the low-frequency band.

In this study we used tidal gravity measurements collected with *LC&R Earth Tide no. 26* spring gravimeter at Józefosław Observatory (Bogusz, 2002). This gravimeter serves in tidal and geodynamical studies (Rajner, 2010). In this paper we discuss sub-seismic and normal mode band where Earth free oscillations have their eigenfrequencies. Analysis of records after strong earthquakes shows that whole spectrum of spheroidal fundamental modes is exited and and their frequencies are in very good agreement with theoretical ones computed on the basis of Earth models.

It should be pointed out that nowadays the superconducting gravimeters are far superior than spring type instruments especially in low frequency band where the gravest modes are observed (Widmer-Schnidrig, 2003). Nevertheless spring gravimeters still can challenge them in subseismic band (Richer et al., 1995).

2 Data treatment

Classical tidal gravity analysis treats earthquake data as a serious disturbance which has to be corrected or removed in preprocessing stage. Moreover after removing outliers the data is usually decimated to hourly samples which is common procedure as there are no any significant tidal components with periods shorter then few hours. Consecutive we dispose all information in periods shorter than few hours.

In order to investigate in frequency band with periods from several minutes to hour we took raw data which are recorded every one minute. This data is 400s window length moving averaged. Consecutively we refer to this data as filtered data. Before spectral analysis we subtracted solid Earth tides from data. This was done with the previously determined gravimetric factors and phases for main tidal constituents (Rajner, 2010). This procedure removes also ocean tidal loading. For the pressure correction single admittance factor from tidal analysis (-3.45 $nm\cdot s^{-2}\cdot hPa^{-1}$) was used along with local barometric records.

2.1 Noise level

The Józefosław is located in Warsaw suburb area, near the fast growing settlement. This fact is well observed in quality of our records in terms of environmental noise. One could see in the spectrogram of gravity residuals (Fig. 1) long-term increase of noise with seasonal fluctuation. Barlik et al. (2010) gave some insight in noise level in Józefosław. They analysed detided and depressured gravity measurements in time-domain. This approach showed significant variation of noise in seasonal and daily time scale. The former is probably of geophysical origin (pelagic storms) and the latter is caused by intensive urbanization. More qualitative evaluation of the noise level is shown as power spectral densities (PSD) of whole multi-year data set in comparison to New Low Noise Model (NLNM) introduced by Peterson (1993). This model reflects the lowest noise from whole network of seismometers and is frequently used as reference level in instrument and site dependent noise evaluation. Fig. 2 shows very high noise level in data. We do not see any significant improvements in residuals after subtracting synthetic tides and pressure effect (diminishing of diurnal and semidiurnal tidal peaks is the only distinct change). This indicate that dominant source of noise in short-period spectrum is not connected with atmosphere. On the right graph we show PSD in normal mode band from long data set with PSD of one of the quiets day. This huge difference proves that this increased noise is due to anthropogenic origin. From comparison of PSD with NLNM one can conclude that Józefosław is very noisy site. We should mention that gravimeters, when located in quiet sites, are slightly above or even below NLNM, especially in low-frequency normal mode band (Banka and Crossley, 1999; Rosat et al., 2004).

The large noise is the most important delimitation when studying phenomena in subseismic frequency band. Anyway we show in subsequent paragraphs the despite of this disadvantages free oscillation still can be observed above noise floor.

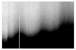

Fig. 1. Spectrogram of residuals of gravity measurements. Horizontal axis is time-span of 3.5 years (2006-2010) and vertical axis is frequency: 0-8 mHz.

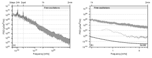

Fig. 2. (a) PSD of filtered gravity results (black) and residuals (de-tided and de-pressured time series, gray). (b) Blow-up of left figure with PSD of one very quiet day along NLNM. The free oscillation band is marked with horizontal bar.

3 Free oscillations

The main source of excitation of the Earth free oscillation are the strong earthquakes. A few examples are given in Fig. 3. During this event we see large amplitude of gravity variation. The motion of the Earth can be written as a sum of decaying harmonic (Masters and Widmer, 1995),

$$u(t)=\sum_k A_k\cos(\omega_k t+\phi_k)\cdot e^{-\frac{\omega_k t}{2Q_k}},$$

where A,ω,ϕ is amplitude, frequency and phase respectively and Q_k is "quality factor" of k-th constituent. This oscillation can be observed with horizontal and vertical seismometers as well as with gravimeters. The latter is restricted only to spheroidal modes, however toroidal ones also can appear in spectral analysis as a consequence of coupling with spheroidal ones, especially through Coriolis force. This oscillation can be observed for long time. In very quiet sites it is even possible to observe this modes during silent days when there was no source of excitation in solid Earth (Suda et al., 1998). This continuous vibration is believed to be of atmospheric or oceanic origin. Unfortunately we are unable to observe this so-called "hum" as this amplitudes are at nanogal level, much lower that our noise content.

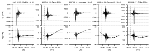

Fig. 3. Raw (top) and filtered (bottom) records of LCR ET26 gravimeter from great earthquakes. Vertical bars indicate start of the event. Note different scale on vertical axis.

The quick look at the spectrogram of residuals (see supplementary figures and enhanced on line text) shows that earthquakes are easily recognizable in the records.

Figure 4 shows an example of normal mode registration. The amplitude spectra are computed on the basis of almost 40 hours window a few hours after Chilean earthquake in 2010. All fundamental spheroidal modes are well resolved. We can see even fine structure of $_0S_2$ mode which is due coupling with nearby modes. We can easily connect every significant peak with theoretical prediction. The vertical bars in figures depict frequencies for spheroidal modes which were taken from Masters and Widmer (1995) for the PREM model (Dziewoński and Anderson, 1981). Due to high noise level we are not able to investigate in deviations in terms of lateral heterogeneity in mantle or splitting and coupling due to earth flattening and rotation (Zürn et al., 2000; Rosat et al., 2007). This example shows even the gravest modes like „breathing" and „football" mode ($_0S_0$ and $_0S_2$ respectively).

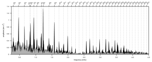

Fig. 4. Amplitude spectra from about 5h to 43h after Chilean (2010) earthquake (black). For comparison there is shown a spectra from window of similar length before earthquake which estimate noise level in measurements (gray).

3.1 Stacking spectra

Here we present also stacked spectra from several great earthquakes (shown in Fig. 3). The following formula was used,

$$A(f)=\left(\prod_{i=1,\dots,n}A(f)_i\right)^{1/n},$$

which yields simple geometrical mean. The amplitude of spectra (A) for specific frequency (f) is computed on the basis of n amplitudes from different earthquakes. This method confirms that spheroidal modes can be retrieved from our data. Here we also note increased noise below 2 mHz which is due to atmosphere and background noise as well. The stacked spectra are shown in Figure 5.

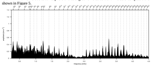

Fig. 5. Amplitude product spectra from selected great earthquakes

The increased noise in low frequencies is attributed to pressure induced gravity change. This effect is normally eliminated or reduced with single admittance atmospheric factor (Zürn and Widmer, 1995). Unfortunately this is not the case. We do not see any significant improvement in this band using atmospheric correction. We used admittance factor of -3.45 $nm\cdot s^{-2}\cdot hPa^{-1}$ which was obtained in previous tidal analysis (Rajner, 2010). Fig. 6 presents low frequency amplitude spectra with and without pressure correction. We do not found any significant change. Again we suspect the exceptionally high noise.

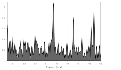

Fig. 6. Amplitude spectra from Chilean earthquake in low frequency normal mode band. The solid colors show results without pressure correction and the dark line shows results for records where atmospheric correction was applied. We used the factor -3.45 $nm\cdot s^{-2}\cdot hPa^{-1}$ from least square tidal analysis.

3.2 Quality factors

The quantitative evaluation of oscillations decaying is given here in terms of quality factor Q. We estimated spectra for single modes with moving window. Afterwards the exponential function was fitted and Q factor was estimated. Again this study is limited because modes are quickly lost in floor noise. Fig. 7 presents two examples of decaying amplitudes and fitted function for two modes. This examples are chosen arbitrarily. One should aware that for other modes we did not find such a good results.

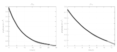

Fig. 7. Fitted exponential regression function for two modes. The estimated Q value for $_0S_{21}$ is 293 comparing to theoretical value of 259. For [illegible] we found 284 when the expected from Earth model is 325 respectively. Applying standard pressure correction do not affect results significantly.

4 Conclusion

We confirmed that free modes are evident in *LCR ET* record. This small gravity changes which has amplitudes at $nm\cdot s^{-2}$ level are very well resolved. The eigenfrequencies are in good agreement with theoretical ones computed on the basis of Earth models. Nevertheless one should aware that these single results cannot be fully exploited in terms of knowledge of Earth's interior structure. We shows also that the noise level in Józefosław is very high and is the main limitation in precise gravity measurements in normal mode frequency band.

On-line material

For supplementary text with additional colored figures in high resolution, please see the website: www.geo.republika.pl/pub

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EARTH FREE OSCILLATION MEASUREMENTS WITH LCR-ET 26 SPRING GRAVIMETER

Marcin Rajner, Jerzy B. Rogowski

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Abstract

After strong earthquakes the Earth oscillates with spheroidal and toroidal modes. The former cause gravity changes which can be detected with sensitive instruments. For this purpose we used continuous gravity measurements with LaCoste&Romberg Earth Tide spring

like „breathing” and „football” mode (${}_0S_0$ and ${}_0S_2$ respectively).

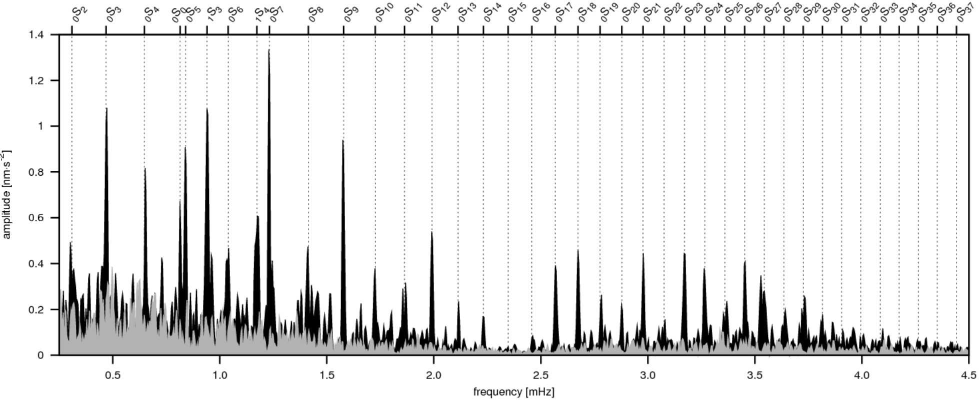
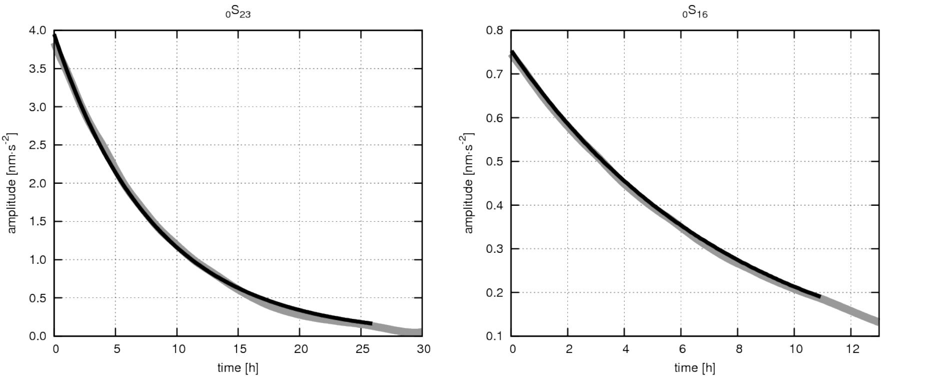


Fig. 4. Amplitude spectra from about 5h to 43h after Chilean (2010) earthquake (black). For comparison there is shown a spectra from window of similar length before earthquake which estimate noise level in measurements (gray).

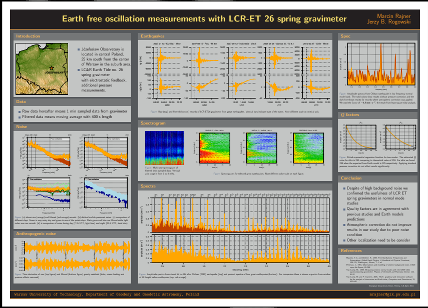
3.1 Stacking spectra

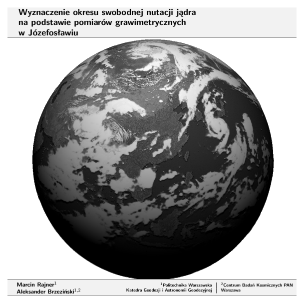
Here we present also stacked spectra from several great earthquakes (shown in Fig. 3). The following formula was used, y lost in floor noise. Fig. 7 presents two examples of decaying amplitudes and fitted n for two modes. This examples are chosen arbitrarily. One should aware that for other we did not find such a good results.

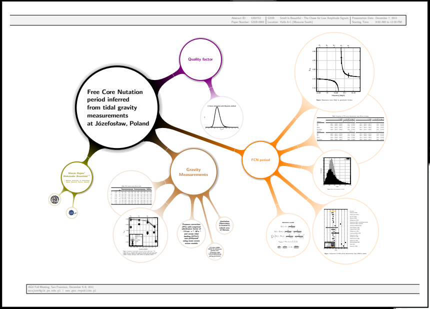


itted exponential regression function for two modes. The estimated Q value for $_0S_{23}$ is 293 comparing to al value of 259. For $_0S_{16}$ we found 284 when the expected from Earth model is 325 respectively. Apply-dard pressure correction do not affect results significantly.

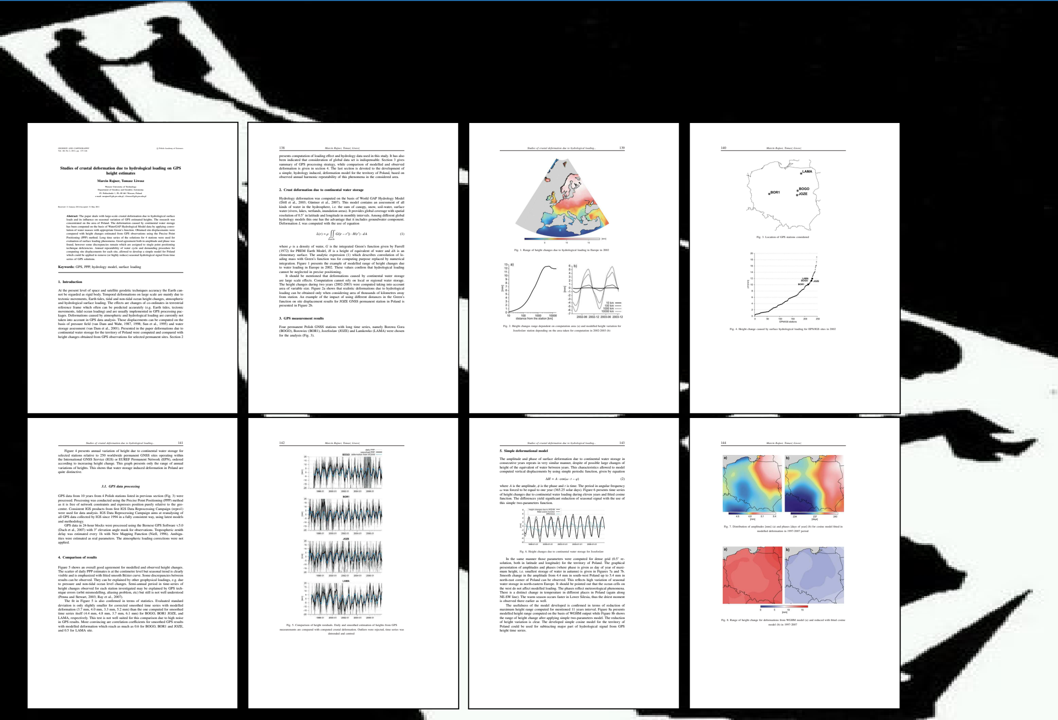
clusion


Earth free oscillation measurements with LCR-ET 26 spring gravimeter
Marcin Rajner
Jerzy B. Rogowski
Introduction
Józefosław Observatory is located in central Poland, 25 km south from the center of Warsaw in the suburb area.
LC&R Earth Tide no. 26 spring gravimeter with electrostatic feedback, additional pressure measurements.
Data
Raw data hereafter means 1 min sampled data from gravimeter
Filtered data means moving average with 400 s length
Noise
Anthropogenic noise
Earthquakes
Spectrogram
Spectra
Spec
Q factors
Conclusion
Despite of high background noise we confirmed the usefulness of LCR ET spring gravimeters in normal mode studies
Quality factors are in agreement with previous studies and Earth models predictions
Atmospheric correction do not improve results in our study due to poor noise condition
Other localization need to be consider
References
Warsaw University of Technology, Department of Geodesy and Geodetic Astronomy, Poland
mrajner@gik.pw.edu.pl


Wyznaczenie okresu swobodnej nutacji jądra
na podstawie pomiarów grawimetrycznych
w Józefosławiu
Marcin Rajner[1]
Aleksander Brzeziński[1,2]
[1]Politechnika Warszawska
Katedra Geodezji i Astronomii Geodezyjnej
[2]Centrum Badań Kosmicznych PAN
Warszawa


Free Core Nutation
period inferred
from tidal gravity
measurements
at Józefosław, Poland
Quality factor
FCN period
Gravity
Measurements
AGU Fall Meeting, San Francisco, December 5-9, 2011


Jakie informacje zawierają ciągłe
pomiary grawimetryczne?
Pomiary
Wpływ atmosfery
Sejsmologia też?
Wpływ oceanów
Współczynniki
grawimetryczne
Ciekłe jądro?
Aktywność ludzka
i urbanizacja
Więcej?
KATEDRA GEODEZJI I ASTRONOMII GEODEZYJNEJ


Studies of crustal deformation due to hydrological loading on GPS height estimates
Marcin Rajner, Tomasz Liwosz

GEODESY AND CARTOGRAPHY
Vol. 60, No 2, 2011, pp. 137-146

Studies of crustal deformation due to hydrological loading on GPS height estimates

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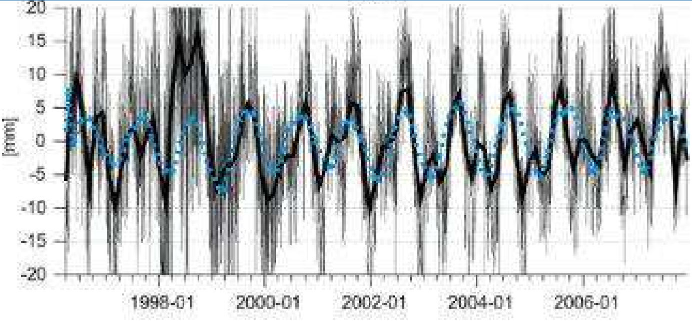
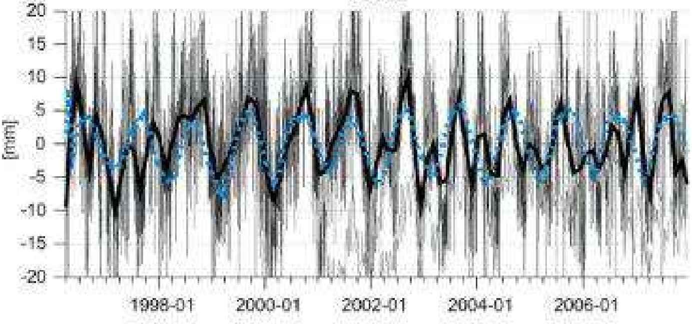
Received: 11 January 2011/Accepted: 31 May 2011

Abstract: The paper deals with large-scale crustal deformation due to hydrological surface loads and its influence on seasonal variation of GPS estimated heights. The research was concentrated on the area of Poland. The deformation caused by continental water storage has been computed on the basis of WaterGAP Hydrological Model data by applying convolution of water masses with appropriate Green's function. Obtained site displacements were compared with height changes estimated from GPS observations using the Precise Point Positioning (PPP) method. Long time series of the solutions for 4 stations were used for


[mm]
1998-01
2000-01
2002-01
2004-01
2006-01

JOZE


[mm]
1998-01
2000-01
2002-01
2004-01
2006-01

LAMA

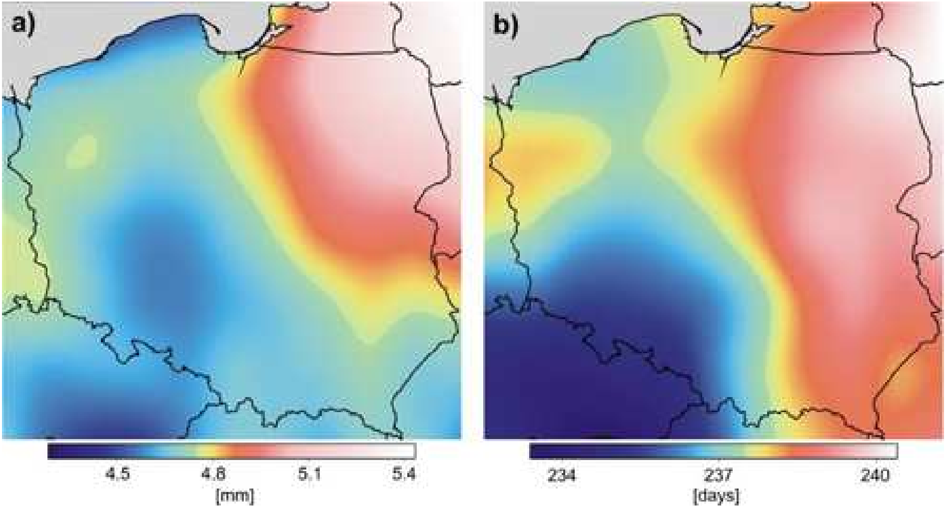


Fig. 7. Distribution of amplitudes [mm] (a) and phases [days of year] (b) for cosine model fitted in modelled deformation in 1997-2007 period

Comparison of GRACE Derived Seasonal Deformation with Hydrology Model and GNSS Measurements in Poland

Global vs Regional GNSS solution

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Warsaw University of Technology

Abstract. We evaluate usefulness of regional solution in terms of studies of large scale geodynamic phenomena. For this purpose a few GNSS sites in Poland with long history of measurements were selected. Co-ordinate time series were taken from homogeneously reprocessed global network within International Global Navigation Satellite Systems (GNSS) Service (IGS) "repro1" project and from our own regional processing – Warsaw University of Technology (WUT) Local Analysis Center (LAC) contribution to European Permanent Network (EPN) "repro1". This results were compared with modelled crustal deformation due to continental hydrology loading. The hydrology mass variation were taken from Gravity Recovery and Climate Experiment (GRACE) satellite data assessment and WaterGAP Hydrology Model (WGHM) output. For completeness of comparison we took Atmospheric Loading (ATML) into account to give an illustration of importance of this phenomena on seasonal signal for considered sites.

We found good agreement of observed and modelled variation for vertical component. The hydrology loading explain main source of seasonal height variation of GNSS sites in Poland which can reach as much as 1 cm peak to peak. The interpretation for horizontal component variation is ambiguous.

The regional and global solution show good agreement for site co-ordinate time series if homogeneous global products were taken in regional network processing. Some discrepancies shown here favor global solution as a source of more reliable information when global scale effects are considered. Nevertheless our solution are rather consistent with IGS results indicating great potential of regional networks in terms of global geodynamic effects investigation.

Keywords. GNSS time series, Regional Solution, WUT LAC, GRACE, WGHM

1 Introduction

With Global Navigation Satellite Systems (GNSS) measurements we are able to observe subtle geodynamic processes. Among different phenomena loading effects are subject of ongoing discussion whether the conventional models should be included in routine processing scheme (Petit and Luzum, 2010). The most pronounced loading effects are those of atmospheric (van Dam et al., 1994; Dong et al., 2002; Petrov and Boy, 2004; Dach et al., 2011) and hydrologic origin (van Dam et al., 2001; Fritsche et al., 2011; Rajner et al., 2011). We give here a comparison of modelled seasonal crustal deformation due to continental hydrology loading computed on the basis of Gravity Recovery and Climate Experiment (GRACE) (Tapley et al., 2004) satellite data and WaterGAP Hydrology Model (WGHM) (Döll et al., 2003; Güntner et al., 2007) output. To get a proper conclusion the Atmospheric Loading (ATML) was considered as well.

In order to investigate in such small signal and get correct interpretation it is common to use global solution. In this work we compared regional network time series with global ones and obtained comparable results. The exceptional discrepancies on the other hand can be crucial. This problem still need for more comprehensive elaboration.

2 Data

2.1 GNSS

We consider here International GNSS Service (IGS) "repro1" weekly solution (Dow et al., 2009)(herein referred as global solution) and the results of Warsaw University of Technology (WUT) Local Analysis Center (LAC) reprocessed regional European Permanent Network (EPN) (Bruyninx, 2004) subnetwork of 60 sites within "repro1" project (Volksen, 2009)(referred as regional solution). The Bernese GNSS software was used along with IGS "repro1" products. The processing details can be found in Liwosz et al. (2010).

Fig. 1. Selected GNSS sites

We selected five permanent GNSS stations in Poland (Fig. 1) according to their long observation period and availability of results within IGS "repro1" and WUT LAC "repro1" projects. Site co-ordinates were transformed to topocentric reference frame, outliers were removed and trend was subtracted. For better comparison the smoothing procedure was applied using simple smoothing window with length of 60 days.

2.2 Loading

Hydrological loading was computed using Green's function formalism (Farrell, 1972). The continental water masses distribution were taken from Groupe de Recherche en Géodésie Spatiale (GRGS) solution (Lemoine et al., 2007) and WGHM. This computation follows scheme given in Rajner et al. (2011).

The Petrov and Boy (2004) model of ATML was used in this study to show its importance for site position in seasonal time scale. Note that ATML is removed in processing of GRACE data to avoid aliasing effects (Lemoine et al., 2007). Therefore GRACE observes mainly hydrology mass transport when a few years time scale is considered and removed ATML from GNSS time series seems to be proper way when such comparison is performed.

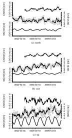

Fig. 2. North, east and vertical component of GNSS solution (from IGS, gray dots) and smoothed time series (gray line, see text) along with modelled deformation from GRACE and WGHM for Lamkówko site (LAMA). The black solid line indicate smooth GNSS solution with ATML subtracted. Note different scale for horizontal and vertical components.

3 GNSS results vs modelled hydrology loading

The one example of comparison of GNSS time series with modelled hydrology deformations for north, east and vertical component are presented in Fig. 2.

The seasonal variation of height is well explained by hydrology loading (with some obvious exceptions due to local effects or processing imperfection). The WGHM gives slightly overestimated results. The good agreement in phase shows typical behaviour of maximum load in spring and the rebound during late summer and early autumn. For horizontal component the interpretation is ambiguous. Moreover we observe different pattern of deformation from GRACE and WGHM model. The periods with reasonable agreement of GNSS results with modelled deformation as well as disagreement period (even with opposite phase) can be recognized. This problem was already reported before (Tregoning et al., 2009) but remains unexplained. The example of LAMA shown in Fig. 2 is representative for other considered sites. We refer to Rajner et al. (2011) for the quantitative evaluation of similar comparison using more sites.

Table 1. Correlation of GNSS results between IGS and WUT solutions for north (n), east (e) and vertical (u) component

BOR1			JOZ2		
n	e	u	n	e	u
0.20	0.69	0.73	0.18	0.40	0.73
JOZE			**LAMA**		
n	e	u	n	e	u
0.41	0.63	0.68	0.53	0.83	0.62

4 Comparison of regional with global time series

In this section we look into similarities of time series between regional and global signals. The regional solution is belived to be not suitable for geodynamic studies. GNSS time series are usually slightly different for global and regional networks.

Fig. 3 shows an example of IGS and WUT LAC results for Borowiec (BOR1) site (the modelled deformation are shown for completeness). Quick look give an impression that this time series are similar but detailed inspection reveal some crucial differences.

In Table 1 we present the correlation coefficients of IGS and WUT solution for topocentric component for different sites (Borowa Góra was excluded due to problematic results in both solution). These results lead to conclusion that investigating in global scale geodynamic process is possible with regional solution but possible misinterpretation should be kept in mind. This problem still need to be carried out more comprehensively in future.

5 Conclusion

In the previous section we showed that the hydrology loading is the main source of seasonal height variation. Modelled deformation on the basis of water mass distribution and crust properties explain well GNSS results. Discrepancies for horizontal components still wait for reasonable explanation, however this ones are of much smaller amplitudes. Presented regional time series for Polish sites possess comparable geophysical signal in height component as global IGS results.

Acknowledgments. The data and product from IGS were indispensable. A. Güntner is acknowledged for sharing WGHM model.

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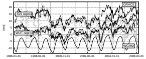

Fig. 3. Comparison of global IGS and regional WUT LAC solution for Borowiec (BOR1) for vertical component along with modelled deformation using GRACE and WGHM. Time series were shifted for clarity.

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Comparison of GRACE Derived Seasonal Deformation with Hydrology Model and GNSS Measurements in Poland

Global vs Regional GNSS solution

M. Rajner, T. Liwosz, J.B. Rogowski
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Abstract. We evaluate usefulness of regional solution in terms of studies of large scale geodynamic phenomena. For this purpose a few GNSS sites in Poland with long history of measurements were selected. Co-ordinate time series were taken from homogeneously reprocessed global network within International Global Navigation Satellite Systems (GNSS) Service (IGS) "repro1" project and from our own regional processing – Warsaw University

1 Introduction

With Global Navigation Satellite Systems (
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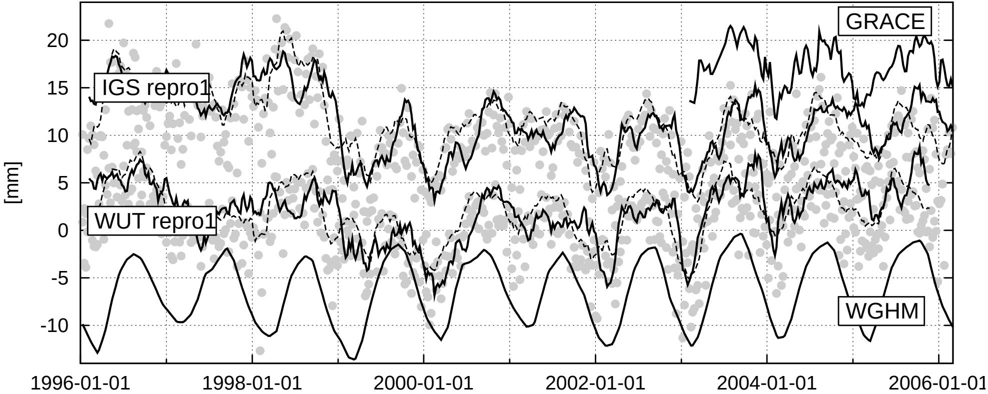

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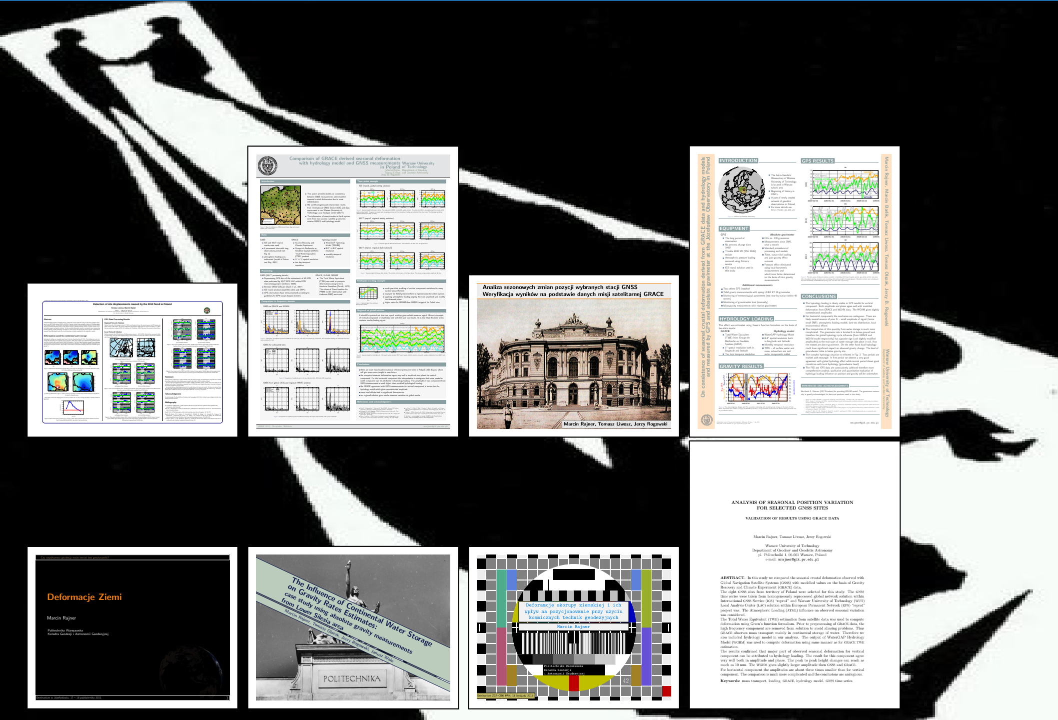
Detection of site displacements caused by the 2010 flood in Poland
Comparison of GRACE derived seasonal deformation with hydrology model and GNSS measurements in Poland
Warsaw University of Technology
Analiza sezonowych zmian pozycji wybranych stacji GNSS
Weryfikacja wyników na podstawie danych misji satelitarnej GRACE
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On consistence of seasonal crustal deformation derived from GRACE data and hydrology models and measured by GPS and absolute gravimeter at the Józefosław Observatory in Poland
Marcin Rajner, Marcin Barlik, Tomasz Liwosz, Tomasz Olszak, Jerzy B. Rogowski
INTRODUCTION
GPS RESULTS
EQUIPMENT
HYDROLOGY LOADING
GRAVITY RESULTS
CONCLUSIONS
Deformacje Ziemi
Marcin Rajner
Politechnika Warszawska
Katedra Geodezji i Astronomii Geodezyjnej
The Influence of Continental Water Storage on Gravity Rates Estimates: case study using absolute gravity measurements from Lower Silesia area
POLITECHNIKA
Deformacje skorupy ziemskiej i ich wpływ na pozycjonowanie przy użyciu kosmicznych technik geodezyjnych
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ANALYSIS OF SEASONAL POSITION VARIATION FOR SELECTED GNSS SITES
VALIDATION OF RESULTS USING GRACE DATA
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Dziękuje

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