National Report of Poland to EUREF 2012

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1. Introduction

Since 2009 the main geodetic activities at the national level in Poland concentrated on maintenance of gravity control, gravity survey for geodynamic research, continuing operational work of permanent IGS/EPN GNSS stations, GNSS data processing on the regular basis at the WUT and MUT Local Analysis Centres, activity within the EUREF-IP Project, works towards monitoring troposphere, monitoring and modelling ionosphere, status of the ASG-EUPOS network in Poland, the use of data from satellite gravity missions, monitoring of Earth tides, activity in satellite laser ranging and in geodynamics.

2. Maintenance of gravity control and gravity survey for geodynamic research

Absolute gravity measurements were carried out on regular basis with the use of FG5-230 gravimeter in the Astrogeodetic Observatory in Jozefoslaw of the Warsaw University of Technology (WUT) since 2005 (Olszak, 2011) (Fig. 1).

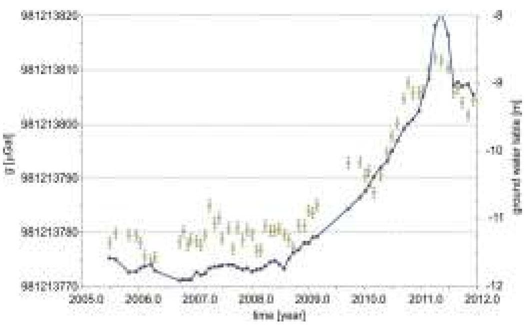

Fig. 1. Results of absolute gravity measurements with FG5-230 at Jozefoslaw (100 cm height)

Since September 2008 the Institute of Geodesy and Cartography (IGiK) uses its absolute ballistic A10-020 portable gravimeter. A series of absolute gravity measurements at the gravimetric laboratory of the Borowa Gora Geodetic-Geophysical Observatory (Fig. 2) shows high quality of A10 data. Accuracy and reliability of the A10 (Sękowski et al., 2011a), the effect of laser and clock stability and meteorological conditions on gravity surveyed with the A10 (Sękowski et al., 2011b) as well as performance and stability of metrological parameters of the A10 were investigated (Dykowski et al., 2012).

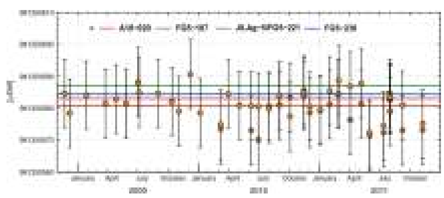

Fig. 2. Results of absolute gravity measurements with A10-020 at Borowa Gora

First results of gravity change in Finland 1962-2010 from the comparison of legacy relative measurements with new measurements made with the A10-020 were obtained (Mäkinen et al., 2011).

The A10-020 has further been successfully used in 2011 to re-survey gravity control in Sweden, Norway and Denmark (Fig. 3).

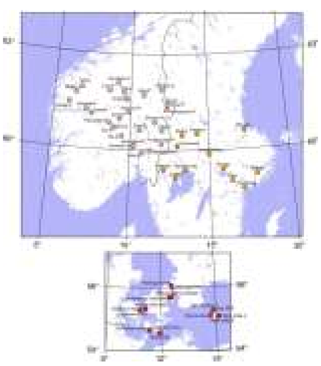

Fig. 3. Stations of gravity control networks of Sweden, Norway and Denmark surveyed with the A10-020 in 2011

Both Polish absolute gravimeters, i.e. FG5-230 and A10-020 took a part in the European calibration campaign ECAG 2011 in Walferdange, Luxemburg.

Research on modern vertical gravity reference systems was conducted at IGiK (Dykowski 2011; Krynski, 2011, 2012).

Activities towards modernization on the Polish gravity control were continued in 2011. The joint team of IGiK and WUT developed a detail project of a new gravity control based only on absolute gravity measurements (Krynski and Barlik, 2011; Kryński, 2012). The realization of the project is planned to start in 2012.

Three field campaigns: in Pieniny Klippen Belt, in Sudeten Mts. (Jamroz et al., 2011), and at Ksiaz Underground Geodynamic Laboratory (Kaczorowski et al., 2011) have been conducted in 2011 for geodynamic purposes using the FG5.

3. Participation in IGS/EPN permanent GNSS networks

3.1. Operational work of permanent IGS/EPN stations

Permanent IGS and EPN GNSS stations operate in Poland since 1993. Recently 18 GNSS stations: Biala Podlaska (BPDL), Borowa Gora (BOGO, BOGI), Borowiec (BOR1), Bydgoszcz (BYDG), Gorzow Wielkopolski (GWWL), Jozefoslaw (JOZE, JOZ2), Krakow (KRAW, KRA1), Lamkowko (LAMA), Lodz (LODZ), Katowice (KATO), Redzikowo REDZ (Suwalki (SWKI), Ustrzyki Dolne (USDL), Wroclaw (WROC) and Zywiec (ZYWI) (Fig. 3.1) operate in Poland within the EUREF program.

The stations BOGI, BOR1, JOZE, JOZ2, LAMA and WROC operate also within the IGS network (http://www.epncb.oma.be/_trackingnetwork/stations.php). The EPN stations: Borowa Gora (BOGI), Borowiec (BOR1), Jozefoslaw (JOZ2, JOZ3), Cracow (KRAW, KRA1), Lamkowko (LAM5), Wroclaw (WROC) and a number of other Polish GNSS stations take part in the EUREF-IP project. (http://igs.bkg.bund.de/root_ftp/NTRIP/streams/streamlist_euref-ip.htm). BOGI, BOR1 and JOZ2 participated also in IGS Real-time GNSS Data project. Since March 2005 Ntrip Broadcaster is installed at the AGH Univ. of Science and Techn. (http://home.agh.edu.pl/~kraw/ntrip.php). The Ntrip Caster broadcasts RTCM and raw GNSS data from 17 sources.

3.2. Data processing at WUT LAC

The WUT EPN Local Analysis Centre operates since 1996. It contributes to EUREF with weekly and daily solutions based on IGS final products, and with rapid daily coordinate solution based on IGS rapid products since Jan. 2010. Data from 80 EPN stations (March 2012) located mainly in Central Europe are processed at WUT LAC according to EPN AC guidelines with the use of the Bernese Software v5.0. Since Dec. 2010 solutions are based on both GPS and GLONASS observations (CODE products has been used in analysis since then) (Krynski and Rogowski, 2011). All WUT products are available at the EPN RDC at BKG (ftp://igs.bkg.bund.de/EUREF/products). Two new stations were added to the network in 2011.

3.3. Data processing at MUT LAC

The Military University of Technology in Warsaw (MUT) LAC Analysis Centre operates since Dec. 2009 (Araszkiewicz et al., 2011). The GNSS data from 117 EPN stations distributed evenly in Europe are processed in the Centre starting from 1558 GPS week (Araszkiewicz et al., 2011a). In 2011/2012 three sites TORA, SUUR, and BRUS have been excluded from processing by MUT LAC. Instead, few other sites KUNZ, ARGI, ALCI, CAKO, POZE, and ZADA have been added to the list of stations being processed.

3.4. Reprocessing of EPN data

The teams of WUT and MUT participate in the EPN Reprocessing Project that is another form of processing the archive GNSS data using the newest computing strategies, products and models (http://epn-repro.bek.badw.de/).

In 2011 data from 1996-2005 of 60 EPN stations had been reprocessed at WUT using Bernese software; it followed the pilot phase (processing of data from 2006 only) performed in 2010.

In 2011 archive GNSS data was further reprocessed at MUT using both Bernese and GAMIT/GLOBK software. Final solutions for weekly and daily coordinates for 1996-2007 of all sites of MUT subnetwork and troposphere parameters were delivered to BKG. Time series of daily solutions were investigated using time and frequency analysis (Araszkiewicz et al., 2011b).

The team of MUT processed also all data from EPN with PPP approach in the Bernese software. The example of PPP results against those obtained using differential method are shown in Figure 4 (Figurski et al., 2011a).

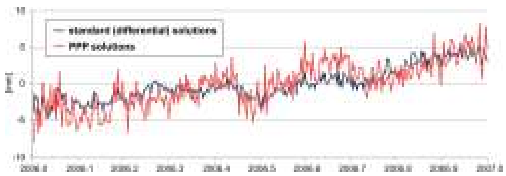

Fig. 4. Comparison of PPP results against those obtained using differential method (station NYA1, *Y* component)

3.5. Other EPN and IGS activities

GNSS for meteorology

Both, IPW derived from GPS tropospheric solutions as geophysical data, and ZTD derived from WUT LAC solutions and EPN combination were investigated. GPS-derived IPW values obtained in WUT were tested with three meteorological water vapour data sources: radiosoundings, sun photometer (CIMEL, Central Geophysical Observatory PAS, Belsk) and numerical weather prediction model COSMO-LM. (Kruczyk et al., 2011). Both CIMEL-318 sunphotometer and radiosounding data confirm that WUT LAC reprocessing ZTD values (in the years prior to 2006) are much less biased. (Kruczyk and Liwosz, 2012) (Fig. 5).

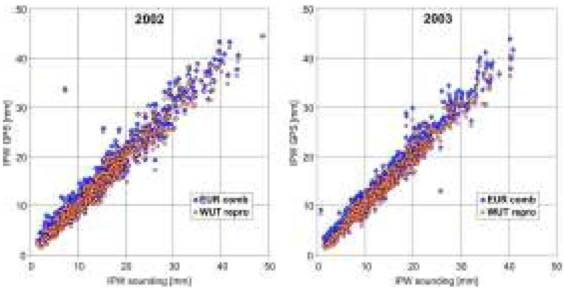

Fig. 5. IPW from radiosounding in Legionowo vs. GPS from JOZE in 2002 and 2003: dark blue points - original EPN combination, bright/orange points – WUT LAC reprocessing

Trimble 4000 SSE receiver placed on the roof of Belsk Observatory operates permanently since mid 2009. Data from that station provides tropospheric solution (EPN standard, smaller network).

At the Wroclaw University of Environmental and Life Sciences (WUELS) the investigations on developing the GNSS tomographic model were continued (Rohm and Bosy, 2011; Rohm et al., 2011). The GNSS tropospheric tomography model was verified in a mountainous area (Rohm and Bosy, 2011). The activities towards developing Near Real-Time application of the GNSS tomographic model on the area of Poland were continued (Bosy et al., 2011). To integrate meteorological data module the automatic software for real data streaming and processing was developed (Kaplon et al., 2011). The ground meteorological observations in Poland and neighbouring countries are available also from METAR and SYNOP meteo stations (Fig. 6).

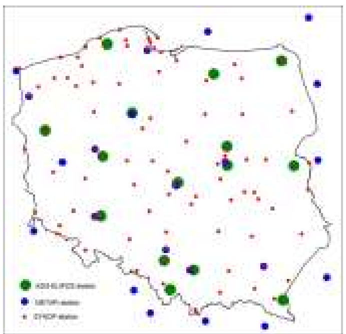

Fig. 6. Meteorological stations in Poland and neighbouring countries

The NRT troposphere model will be used for real time and post-processing ASG-EUPOS services. The model created from meteorological and GNSS data, could become competitive to NWP models in future new services of ASG-EUPOS system (Bosy et al., 2011; Figurski et al., 2011b).

Independent research on troposphere modelling for precise GPS rapid static positioning in mountainous areas (Wielgosz et al., 2011a) and on constraining ZTDs in processing of local GPS networks with Bernese software (Wielgosz et al., 2011b) was undertaken at the University of Warmia and Mazury (UWM) in Olsztyn.

Monitoring ionosphere and ionospheric storms

The Geodynamic Research Laboratory (GRL) of UWM in collaboration with West Department of the Institute of Geomagnetism, Ionosphere and Radio-Wave Propagation of RAS in Kaliningrad continues the analysis of long time series of GNSS data from EPN stations to study the ionosphere. GPS measurements of global IGS network were also used to study the occurrence of TEC fluctuations at the northern and southern high latitude ionosphere during severe geomagnetic storm (Shagimiratov et al., 2011). Dual-frequency GPS measurements for individual satellite passes served as raw data. As a measure of fluctuation activity the rate of TEC (ROT) was used, and fluctuation intensity was evaluated using ROTI index.

FORMOSAT-3/COSMIC RO measurements were used in the analysis of the ionosphere during geomagnetic disturbances (Krankowski et al., 2011; Zakharenkova et al., 2011a, 2011b). It was shown that there is a possibility to complement the ionosphere studies based on the standard ground-based GPS measurements with the information about the vertical electron density distribution retrieved from LEO GPS measurements.

4. ASG-EUPOS network

4.1. Status of the ASG-EUPOS network

100 ASG-EUPOS permanent reference stations operated in Poland (24 with GPS/GLONASS receivers) at the end of 2011. Other 22 reference stations from neighbouring countries were included to the common solutions within (www.asgeupos.pl).

In 2011 six stations of the ASG-EUPOS were upgraded, one new station (MIES) was established, and two new stations KRA1 and KROL replaced KRAW and OLST, respectively. Stations: CBKA ELBL, OLST, POZN, and WLAD were excluded from the network RTK solution due to obsolete hardware.

In 2011 also a significant development in ASG-EUPOS network management was made. A new Trimble VRS3Net v.1.4.1 software was implemented replacing Trimble GPSNet/RTKNet software. Also new service based on CMR format was lunched, what allowed to use ASG-EUPOS system in precise farming.

Coordinates of reference stations in ETRF2000 (epoch 2011) have already been tested in terms of system stability and RTK surveying accuracy and since 1 May 2012 new coordinates will be implemented in the ASG-EUPOS system.

The use of ASG-EUPOS services is continuously growing. The number of registered users exceeds 6700. The most popular real-time service NAWGEO (RTK) has up to 1500-2000 individual users every working day (up to 650 simultaneous connections in the peak hours).

4.2. ETRS89 extension campaign

In 2011 the Head Office of Geodesy and Cartography has completed an integration of ASG-EUPOS reference station network with 1st order geodetic control network (including EUREF-POL, EUVN and POLREF points). Simultaneous GNSS measurements performed in 2008–2011 on all stations of ASG-EUPOS as well as on geodetic control points were independently processed by Space Research Centre of PAS and WUT and then verified at WUELS and MUT showing correctness of data processing. Coordinates in ETRF2000 (epoch 2011.0) of ASG-EUPOS reference stations will be implemented since 1 May 2012 in the ASG-EUPOS system and used as the new realization of ETRS89 in Poland. However, ordinary reduction of the new coordinates to the ground control network in EUREF89 (epoch 1992) has not been accepted because of too many unknowns in defining of velocity vectors of the control points. ETRF2000 and EUREF89 frames have been linked by standard Helmert's transformation parameters. Differences between the frames obtained from a direct comparison of coordinates and those after transformation are given in Figures 7, 8, 9.

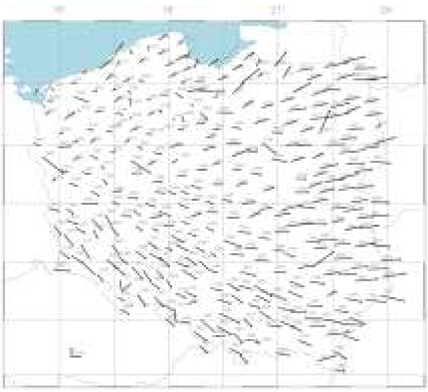

Fig. 7. Direct comparison of ETRF2000 (epoch 2011) and EUREF89 (epoch 1992) horizontal coordinates

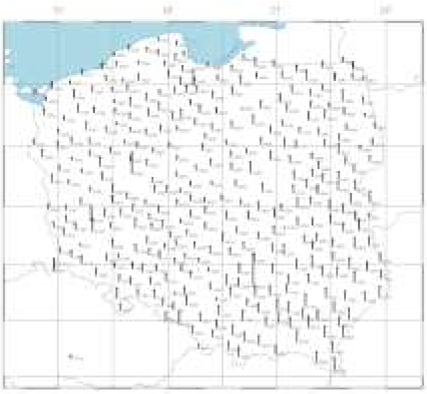

Fig. 8. Direct comparison of ETRF2000 (epoch 2011) and EUREF89 (epoch 1992) ellipsoidal heights

Fig. 9. Horizontal residuals obtained after 7-parameter Helmert's transformation between ETRF2000 (epoch 2011) and EUREF89 (epoch 1992)

5. Levelling network

Modernization of 2nd order levelling network in Silesia region that started in 2011 will be completed in 2012. 332 new benchmarks were established and about 2700 km of levelling lines will be measured. The work concludes levelling measurements campaign over Poland and will allow readjustment of whole levelling network in EVRF2007 vertical system.

6. The use of data from satellite gravity missions

Temporal variations of the gravity field over Europe obtained from GRACE data in terms of geoid height and mass variation were analysed. They can efficiently be modelled with the model consisting of the seasonal term with the period of 12 month, and a trend in the form of 2nd order polynomial (Kloch-Glowka et al., 2011a). Estimated averaged variations of geoid heights in the period 2002 – 2010 in the subarea covering Poland are within 7 mm. In reality variations larger than 1 cm should be expected (Kloch-Glowka et al., 2011b).

GOCE geopotential models were validated over Poland using the EGM2008 and GPS/levelling data (Godah and Krynski, 2011). The fit of GOCE GGMs with the EGM2008 in height anomalies and gravity anomalies measured with a standard deviation is below 10 cm, and 3 mGal, respectively.

7. Earth tides monitoring

Earth tides were further monitored in the WUT Jozefoslaw Astrogeodetic Observatory using LCR ET-26 gravimeter. Tidal record was used to study subtle geophysical processes, e.g. free oscillations of the Earth. Despite very high noise the gravest fundamental modes were observed and agreement of their frequencies with theoretical values was confirmed (Rajner and Rogowski, 2011).

Earth tides were continued to be monitored in 2011 in the Borowa Gora Observatory of IGiK with the LCR G gravimeter equipped with the modern feedback.

8. Activity in Satellite Laser Ranging

The SLR station in the SRC PAS Borowiec Astrogeodynamic Observatory (ILRS 7811) did not operate in 2011 due to the laser damage. Quality of terrestrial reference frames ITRF2000, ITRF2005 and ITRF2008 was analysed on the basis of the SLR station positions and velocities (Schillak, 2011a). Superiority of ITRF2005 was indicated. Accuracy of the SLR data was estimated using the SLR stations coordinates determined from the observations of LAGEOS-1 and LAGEOS-2 from 1994-2008 (Schillak, 2011b, 2011c, 2012). The best results were obtained for the period 1999-2003 when larger number of normal points was observed. The models, parameters and assumptions concerning SLR and GNSS were determined for combined processing (Szafranek and Schillak, 2012). Spin of the Japanese Experimental Geodetic Satellite (EGP) was determined from more than 15 years of 10 Hz SLR data from Borowiec (Kucharski et al., 2011). The orbits of the satellites Ajisai, CHAMP, GOCE, Larets, Starlette/Stella and LAGEOS-1/LAGEOS-2 were analysed (Lejba and Schillak, 2011) to test orbital parameters and models. The best orbital solution were obtained for EGM2008, EIGEN-GRACE02S and GOCE2010S.

9. Geodynamics

Complex spectral analysis of a long-standing rotational time data series from 1986.0-2010.6 based on astronomical observations conducted at Borowa Gora Observatory was performed at IGiK (Krynski and Zanimonskiy, 2011a). A number of periodic terms separated from the series were used to create numerical model of the series (Fig. 10).

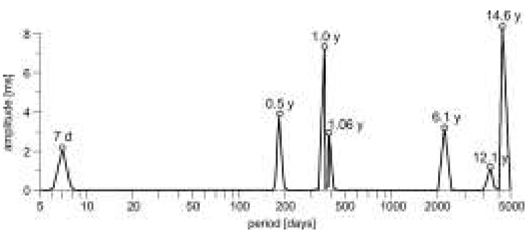

Fig. 10. Spectrum of rotational time $(UT1{-}UTC)^{BG} - (UT1{-}UTC)^{BIH}$ data series

The effects of beat observed in the numerical model were discussed. The existence of a distinguished weekly term in the data investigated has been observed (Krynski and Zanimonskiy, 2011b).

The influence of continental water storage on geodetic measurements was investigated at WUT. The impact of the hydrology loading on GPS site coordinates in the region of Poland was analysed. The peak-to-peak amplitude of seasonal height variation due to variable continental water storage loads can reach as much as a centimetre. This was confirmed with GNSS data even using PPP processing technique (Rajner and Liwosz, 2011). and network solution (Rajner et al., 2012a, 2012b). The “jump” of 10 mm found for flood event in southern Poland in 2010 in GNSS height time series could be partially explained with loading approach (2 mm) (Liwosz and Rajner, 2011).

A distinct correlation between absolute gravity measurements and hydrological loading was found for chosen periods (Rajner et al., 2012c) but contribution of local hydrology and other effects on absolute gravity measurements are more significant. The seasonal gravity variation of 3 μGal is often hidden by environmental effects.

Geodynamic studies based on GNSS data were conducted at WUELS in cooperation with MUT. The sub-diurnal noise in time series of GPS network solutions was analysed (Bogusz and Kontny, 2011).

References

Araszkiewicz A., Bogusz J., Figurski M., Szafranek K., (2011a): *Centre of Applied Geomatics: scientific activities in the frame of EUREF Permanent Network*, Rep. on Geod., No 2(91), pp. 75-80.

Araszkiewicz A., Figurski M., Kamiński P. (2011b): *Time and frequency analysis of daily time series after the re-processing*, Acta Geod. et Geomat. (subm.).

Bogusz J., Kontny B., (2011): *Estimation of sub-diurnal noise level in GPS time series*, Acta Geod. et Geomat., Vol. 8, No 3(163), pp. 273-281.

Bosy J., Rohm W., Sierny J., Kapłon J., (2011): *GNSS Meteorology*, In: Navigational Systems and Simulators. Marine Navigation and Safety of Sea Transportation, (ed.) A. Weintrit, CRC Press/Balkema, Taylor & Francis Group, pp. 19-23.

Dykowski P., (2011): *Vertical gravity gradient determination for the needs of contemporary absolute gravity measurements - first results*, Rep. on Geod., No 3(92) (in print).

Dykowski P., Krynski J., Sękowski M., (2012): *Stability of metrological parameters and performance of the A10 free-fall gravimeter*, Geoph. Res. Abstr., Vol. 14, EGU2012-4449.

Figurski M., Szafranek K., Galuszkiewicz M., (2011a): *Precise Point Positioning method in the EPN re-processing*, Geoph. Res. Abstr., Vol. 13, EGU2011-1912.

Figurski M., Bogusz J., Bosy J., Kontny B., Krankowski A., Wielgosz P., (2011b): *ASG project for improving Polish multifunctional precise satellite positioning system*, Rep. on Geod., No 2(91), pp. 51-58.

Godah W., Krynski J., (2011): *Validation of GOCE gravity field models using the EGM2008 and GPS/levelling data over Poland*, Geoinf. Issues, Vol. 3, No 1 (in print).

Jamoz, O., Olszak T., Barlik M., Pachuta A., (2011): *Absolute and relative gravity measurements in Snieznik Massif (Sudety Mountains)*, Acta Geod. et Geomat. (subm.).

Kaczorowski M., Olszak T., Barlik M., Walo J., (2011): *Research on absolute gravity variations in geodynamic laboratory in Książ in the period of 2007- 2011*, Acta Geod. et Geomat. (subm.).

Kapłon J., Rohm W., Bosy J., Sierny J., (2011a): *NRT GNSS data processing service for regional GNSS tomography*, Geoph. Res. Abstr., Vol. 13, EGU2011-10240.

Kloch-Glowka G., Szelachowska M., Krynski J., (2011a): *Analysis of time variations of the gravity field over Europe obtained from GRACE data in terms of geoid height and mass variation*, IAG Symposia Vol. 138, (ed.) P. Willis, XXV IUGG General Assembly, Melbourne, Australia, 28 June – 7 July 2011 (subm.).

Kloch-Glowka G., Krynski J., Szelachowska M., (2011b): *Time variations of the gravity field over Europe obtained from GRACE data*, Rep. on Geod., No 3(92) (in print).

Krankowski A., Zakharenkova I., Krypiak-Gregorczyk A., Shagimuratov I.I., Wielgosz P., (2011): *Ionospheric Electron Density Observed by FORMOSAT-3/COSMIC over European Region*, Journal of Geodesy, pp. 949-964.

Kruczyk M., Liwosz T., (2012): *Tropospheric Delay from EPN Reprocessing by WUT LAC as Valuable Data Source–in Comparison to Operational EPN Products and Aerological Data*, Rep. on Geod., No 3(92) (in print).

Kruczyk M., Liwosz T., Rogowski J., (2011): *IPW from various sources: GPS tropospheric solution, sunphotometer, radiosounding and numerical weather prediction model - conformity analysis*, Geoph. Res. Abstr., Vol. 13, EGU2011-12348).

Krynski J., (2011): *Gravimetry for geodesy and geodynamics - brief historical review,* Rep. on Geod., No 3(92) (in print).

Krynski J., (2012): *On the new International Gravity Reference System*, Workshop of JWG 2.1 Techn. and Metrology in Abs. Grav. and JWG 2.2 Abs. Grav and Abs. Grav. Ref. System, Vienna, Austria, 14–15 Febr.

Krynski J., Barlik M., (2011): *On a lasting role of geodynamics in modern vertical and gravity reference systems*, Rep. on Geod., No 3(92) (in print).

Krynski J., Rogowski J.B., (2011): *National Report of Poland to EUREF 2011*, Symp. EUREF, Chisinau, Moldova, 25–28 June 2011, EUREF Publ. No 21, Mitteilungen des BKG, Frankfurt am Main (in print).

Krynski J., Zanimonskiy Y.M., (2011a): *Geodynamic signals in time series of astrometric observations at Borowa Gora Observatory*, Proc. Journées 2011 "Systèmes de référence spatio-temporels", Vienna, Austria, 19–21 September 2011 (in print).

Krynski J., Zanimonskiy Y.M., (2011b): *Search for geodynamic signals in time series of astrometric observations*, Rep. on Geod., No 3(92) (in print).

Kucharski D., Schillak S., Otsubo T., Hyung-Chul Lim, (2011): *Spectral analysis of Borowiec SLR data for spin determination of geodetic satellite EGP*, Earth, Planets and Space (subm.).

Lejba P., Schillak S., (2011): *Borowiec activity in satellite orbit determination*, Proc. 17th Intern. Workshop on Laser Ranging, Bad Kötzting, Germany, 16–20 May (in press).

Liwosz T., Rajner M., (2011): *Detection of site displacements caused by the 2010 flood in Poland,* Geoph. Res. Abstr., Vol. 13, EGU2011-11889.

Mäkinen J., Sękowski M., Kryński J., Näränen J., Raja-Halli., Ruotsalainen H., Virtanen H., (2011): *Gravity change in Finland 1962-2010 from the comparison of legacy relative measurements with new measurements made with the outdoor absolute gravimeter A10*, Geoph. Res. Abstr., Vol. 13, EGU2011-12587.

Olszak T., (2011): *Analisis of conditions required fort he use of absolute gravity measurements in geodynamics* (in Polish), PhD Thesis, Warsaw University of Technology.

Rajner M., Liwosz T., (2011): *Studies of crustal deformation due to hydrological loading on GPS height estimates*, Geodesy and Cartography, Vol. 60, No 2, pp. 137-146.

Rajner M., Rogowski J., (2011): *Earth free oscillations measurements with LCR ET-26 spring gravimeter*, Rep. on Geod. (in print).

Rajner M., Liwosz T., Rogowski J., (2012a): *Comparison of GRACE Derived Seasonal Deformation with Hydrology Model and GNSS Measurements in Poland: Global vs Regional GNSS solution*, Symp. EUREF, Chisinau, Moldova, 25–28 June 2011, EUREF Publ. No 21, Mitteilungen des BKG, Frankfurt am Main (in print).

Rajner M., Liwosz T., Rogowski J., (2012b): *Analysis of seasonal position variation for selected GNSS sites - validation of results using GRACE data*, Artificial Satellites (in print).

Rajner M., Olszak T., Rogowski J., Walo J., (2012c): *The influence of continental water storage on gravity rates estimates: case study using absolute gravity measurements from Lower Silesia area on recent geodynamics of the Sudeten and adjacent areas*, Acta Geod. et Geomat. (in print).

Rohm W., Bosy J., (2011): *The verification of GNSS tropospheric tomography model in a mountainous area*, Geoph. Res. Abstr.,, Vol. 47, pp. 1721-1730.

Rohm W., Sierny J., Kapłon J., Bosy J., (2011): *In-situ meteorological data interpolation and homogenization procedure for NRT GNSS tomography*, Geoph. Res. Abstr., Vol. 13, EGU2011-12349.

Schillak S., (2011a): *The comparison of the terrestrial reference frames ITRF2000, ITRF2005 and ITRF2008 in the determination of the SLR station positions and velocities*, Geoph. Res. Abstr., Vol. 13, EGU2011-3011.

Schillak S., (2011b): *The estimation of the SLR data,* Proc. 17th Intern. Workshop on Laser Ranging, Bad Kötzting, Germany, 16–20 May (in press).

Schillak S., (2011c): International SLR Service, Artificial Satellites (in press).

Schillak S., (2012): *Determination of the SLR station coordinates in 1994-2008*, Rep. on Geod. (subm.).

Sękowski M., Krynski J., Mäkinen J., Dykowski P., (2011a): *On the estimate of accuracy and reliability of the A10 free fall gravimeter*, IAG Symposia Vol. 138, (ed.) P. Willis, XXV IUGG General Assembly, Melbourne, Australia, 28 June – 7 July 2011 (in print).

Sękowski M., Krynski J., Dykowski P., Mäkinen J., (2011b): *Effect of laser and clock stability and meteorological conditions on gravity surveyed with the A10 free-fall gravimeter – first results,* Rep. on Geod., No 3(92) (in print).

Shagimuratov I.I., Krankowski A., Ephishov I., Cherniak Yu., Wielgosz P., Zakharenkova I., (2011): *High latitude TEC fluctuations and irregularity oval during geomagnetic storms, Earth*, Planets and Space (in print).

Szafranek K., Schillak S., (2012): *Problems of joint elaboration of SLR and GNSS data performed in the context of GGOS realization*, Rep. on Geod., (subm.)

Wielgosz P., Cellmer S., Rzepecka Z. Paziewski J., Grejner-Brzezinska D.A., (2011a): *Troposphere modeling for precise GPS rapid static positioning in mountainous areas*, Meas. Sc. and Techn., Vol. 22, No 4, pp. 89-99.

Wielgosz P., Paziewski J., Baryla R., (2011): *On Constraining Zenith Tropospheric Delays in Processing of Local GPS Networks with Bernese Software*, Survey Review, Vol. 43, No 323, October 2011, pp. 472-483.

Zakharenkova I.E., Krankowski A., Shagimuratov I.I., Cherniak Yu.V., Krypiak-Gregorczyk A., Wielgosz P., Lagovsky A.F., (2011a): *The occurrence of the geomagnetic storm observed by FORMOSAT-3 / COSMIC during solar minimum*, Earth, Planets and Space (EPS), DOI 10.5047/eps.2011.05.019 (in print).

Zakharenkova I., Krankowski A., Bilitza D., Cherniak Yu., Shagimuratov I.I., Sieradzki R., (2011b): *Comparative study of foF2 measurements with IRI-2007 model predictions during extended solar minimum*, Adv. in Space Res., DOI 10.1016/j.asr.2011.11.015.