National Report of Poland to EUREF 2011

J. Krynski
Institute of Geodesy and Cartography, 27 Modzelewskiego St., 02-679 Warsaw, E-mail: krynski@igik.edu.pl
J.B. Rogowski
Department of Geodesy and Geodetic Astronomy, Warsaw University of Technology, 1 Pl. Politechniki
00-661 Warsaw, E-mail: jbr@gik.pw.edu.pl

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, activity within Galileo project, monitoring of Earth tides and non-tidal gravity variations, activity in satellite laser ranging and in geodynamics.

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

Quasi-permanent absolute measurements of gravity have been carried out with the use of FG5-230 gravimeter in the Astrogeodetic Observatory in Jozefoslaw of the Warsaw University of Technology (WUT) since 2005 (Barlik et al., 2010) (Fig. 1).

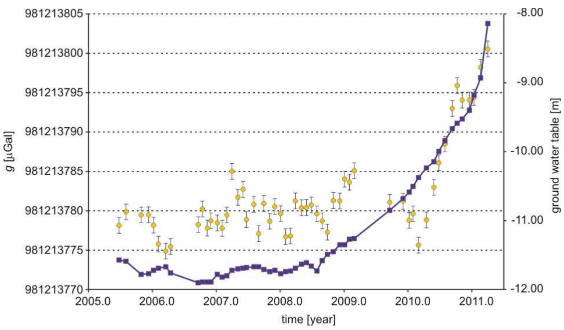

Fig. 1. Results of absolute gravity measurements with FG5-230 at Jozefoslaw (100 cm height)

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. It also indicates its potentiality for monitoring non-tidal gravity variations (Kryński and Sękowski, 2010; Sękowski and Krynski, 2010).

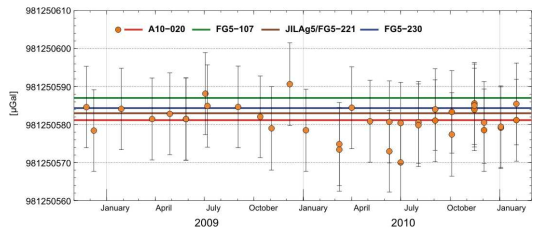

Fig. 2. Results of absolute gravity measurements with A10-020 at Borowa Gora

The absolute gravimeter A10-020 has further been successfully tested for field measurements with the use of the mobile laboratory for precise absolute gravity survey. 40 stations of the Finnish gravity network were surveyed in 2010 with the A10-020 gravimeter (Fig. 3) (Mäkinen et al., 2010a, 2010b, 2010c).

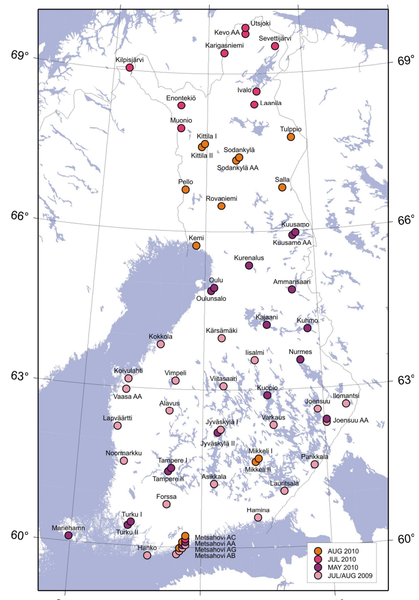

Fig. 3. Stations of the Finnish Gravity Control Network re-surveyed with the A10-020 in 2009 and 2010

Precise absolute gravity measurements with the FG5-230 of WUT carried out for geodynamics research since 1990 at five stations in Poland were further analysed. Information on soil moistures have been included into the analysis. The results obtained indicate the decrease of gravity at each station. A rate of gravity change can be interpreted in terms of hydrological effects and probably, up to certain extent, in terms of vertical displacements of gravity stations. Obtained results in comparison with previous determinations indicate the decrease of gravity for about 15 μGal during 10÷12 years (Krynski and Rogowski, 2010; Walo, 2010).

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 permanent GNSS stations (Fig. 4) 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).

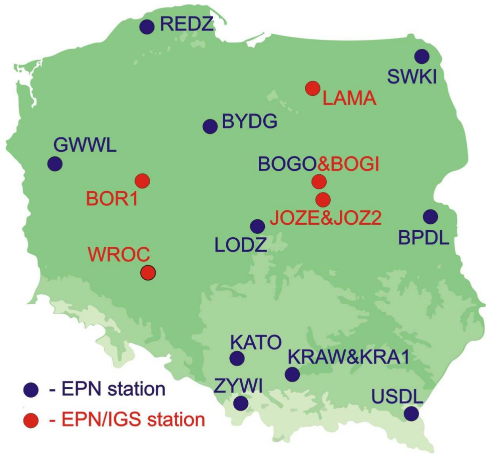

Fig. 4. EPN/IGS permanent GNSS stations in Poland (2010)

3.2. Data processing at WUT LAC

The WUT EPN Local Analysis Centre operates since 1996. Data from 80 EPN stations are processed at WUT LAC (Dec. 2010) located mainly in Central Europe (Fig. 5). 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 Dec. 2009. The official submission of WUT rapid daily solutions to EPN started in early January 2010 (Krynski and Rogowski, 2010).

The WUT LAC uses the Bernese Software v5.0 to analyse GPS observations. Data are processed according to EPN AC guidelines. All WUT products are available at the EPN RDC at BKG (ftp://igs.bkg.bund.de/EUREF/products). Six new stations were added to the network in 2010.

Fig. 5. EPN stations providing data processed at WUT EUREF LAC (April 2011)

3.3. Data processing at MUT LAC

The Military University of Technology in Warsaw (MUT) LAC Analysis Centre operates since Dec. 2009. The GNSS data from 114 EPN stations distributed evenly in Europe (Fig. 6) are processed in the Centre starting from 1560 GPS week.

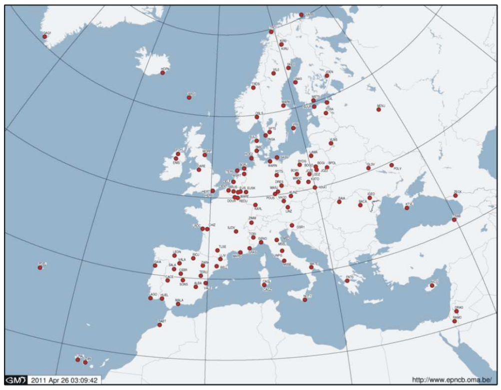

Fig. 6. EPN stations providing data processed at MUT EUREF LAC (April 2011)

Every week the solutions are delivered to the RDC BKG, where together with the respective ones from other LACs they are used to produce final official weekly EPN solutions (Krynski and Rogowski, 2010).

3.4. Reprocessing of EPN data

The team of WUT as well as the team of MUT participate in the EPN Reprocessing Project (http://epn-repro.bek.badw.de/) that is another form of processing the archive GNSS data using the newest computing strategies, products and models. The main purpose of the project is to obtain homogenous time series of sites' coordinates and to provide the realization of the ETRS89 using cumulative weekly solutions obtained with the highest possible accuracy. The results of the reprocessing in the form of daily and weekly coordinates time series give a comprehensive set of data for a variety of geodetic, geodynamic and geophysical analyses.

The test reprocessing of the whole EPN data was done simultaneously by MUT and by the Royal Observatory of Belgium (where global IGS stations were considered). The results of the tests gave rise to a new strategy for official EPN reprocessing, which is under preparation (Krynski, 2011).

3.5. Activity within the EUREF-IP Project

The following EPN stations: Borowa Gora (BOGI), Borowiec (BOR1), Jozefoslaw (JOZ2, JOZ3), Cracow (KRAW, KRA1), Lamkowko (LAM5), and Wroclaw (WROC) as well as a number of other Polish GNSS stations take part in the EUREF-IP (http://www.epncb.oma.be/_organisation/projects/euref_IP/index.php) project (Fig. 7). BOGI, BOR1 and JOZ2 participated also in IGS IP project.

Fig. 7. Polish GNSS stations participating in EUREF–IP project

3.6. Other EPN and IGS activities

GNSS for meteorology

One of main objectives of WUT LAC is a standard ZTD estimation (Fig. 8), monitoring of the results and research on Integrated Precipitable Water (IPW) time series (Fig. 9). Both, IPW – derived from GPS tropospheric solutions as geophysical data – and ZTD itself derived from WUT LAC solutions and EPN combination are investigated. A dramatic decrease of ZTD differences between individual LAC solutions in 2007 (solutions after GPS week 1400 showing best conformity since 2003) (Fig. 8) was observed. Results from 2005, when a new Bernese software v.5.0 was introduced, show greater discrepancies in some LACs only. The excellent conformity starting from the GPS week 1400 is most probably due to a cumulative effect of using almost exclusively the Bernese v.5.0, absolute antenna PCVs and a new reference frame ITRF2005/IGS05 (Kruczyk et al., 2010).

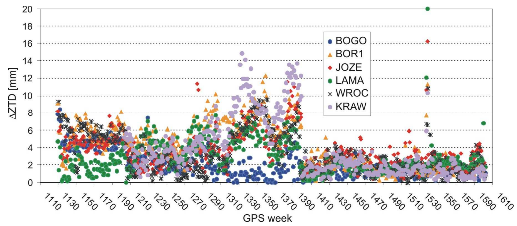

Fig. 8. ZTD weekly mean absolute differences: EUR combined product – product of individual LAC for all EPN stations processed

Two techniques of independent direct measurements of IPW, i.e. CIMEL – 318 sunphotometer at the Central Geophysical Observatory PAS in Belsk and radiosounding data from Legionowo were compared to verify GPS tropospheric solutions for two GPS stations BOGO and JOZE (Kruczyk et al., 2010). Results of radiosoundings can be problematic due to various technical shortages, e.g. sparse RAOB network, accuracy of humidity sensor, various heights attained by sounding systems, etc. Thus sunphotometer seems more genuine source of IPW (Kruczyk, 2010).

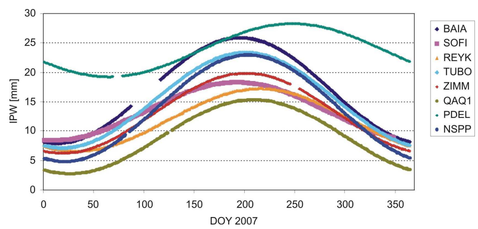

Fig. 9. Simple model of daily IPW values series (sinusoid + constant) EPN ZTD combination in 2007 for 8 EPN stations representing diversity of European climates

The most recent investigations at the Wroclaw University of Environmental and Life Sciences (WUELS) in the field of GNSS meteorology were directed into Near Real-Time application of the tomographic model (Bosy et al., 2010). The GNSS tomography method will be used to create models of water vapour NRT 4DWVD and meteorological parameters: temperature and pressure NRT 4DTPD in atmosphere. Meteorological observations from ASG-EUPOS (www.asgeupos.pl) and IMGW synoptic stations after mutual validation and integration procedure will be used for Slant Wet Delay computation. The above meteorological observations, radiosoundings observations and NWP COAMPS model outputs will also be used for verification of GNSS tomography model. The NRT atmosphere model created from meteorological and GNSS data, could be competitive to NWP model, especially for nowcasting. The improvement in positioning is that tropospheric delays will be calculated directly from observations, not like now from deterministic models (Bosy et al., 2010).

Monitoring ionosphere and ionospheric models

The Geodynamic Research Laboratory (GRL) of the University of Warmia and Mazury (UWM) in Olsztyn 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. A new mechanism for explaining unusual wave-like disturbances of a period of 4–6h with amplitudes increasing from high to low latitudes, observed frequently in TEC observations was proposed (Shagimuratov et al., 2010). The phase of the perturbations is weakly depended on latitude, so in observations they can be detected as a standing wave. The unusual structures can be explained by ionospheric effects of Poincare wave. Planetary Poincare waves propagate along longitudes westward and eastward and can generate standing waves with corresponding scales. The preliminary calculations show that spatial and temporal features of the observed TEC disturbances can be qualitatively explained by standing Poincare waves.

The IGS Ionosphere Combination Centre located at GRL/UWM operates successfully since January 2008. It computes and provides official IGS combined products. Latency of the final and rapid GIMs is 10 days and 1 day, respectively.

4. Status of the ASG-EUPOS network

The ASG-EUPOS network, established for designed for surveying practice, fully operates since 2008 (Krynski and Rogowski, 2010). The network, is based on 98 reference stations located on the Polish territory and 22 foreign stations located in neighbouring countries: 3 from Lithuania (LITPOS), 6 from Germany (SAPOS), 7 from Czech Republic (CZEPOS), and 6 from Slovakia (SKPOS) (Fig. 10, Table 1).

The ASG-EUPOS network provides a signal for both positioning of geodetic control points as well as for land, air and marine navigation. Several levels of positioning accuracy are offered. Standard services, as required by the general EUPOS assumptions including the following sub-services: NAVGIS (network RTK for real time kinematic DGNSS applications), NAV-GEO (network RTK for precise real time kinematic DGNSS applications), POSGEO DGNSS for precise DGNSS post processing applications are offered The ASG-EUPOS network will define the ETRS89 in Poland. A close connection of the ASG-EUPOS stations and 15 out of 18 Polish EPN stations will control the realization of the ETRS89 on the Polish territory (Krynski, 2010).

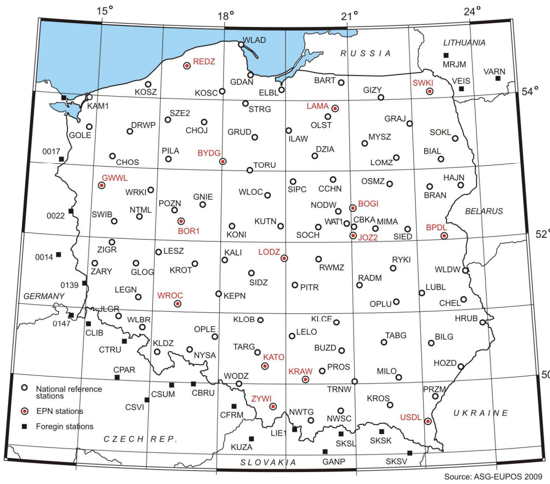

Fig. 10. Reference stations of the ASG-EUPOS system (www.asgeupos.pl)

Table 1. GNSS equipment on the ASG-EUPOS reference stations

Number of stations	Receiver	Antenna
72	Trimble NetR5	Trimble Zephyr Geodetic w/Radome (*TRM41249.00 TZGD*)
12	Ashtech μZ-12	Ashtech L1/L2 Choke Ring SNOW (*ASH701945C M SNOW* - D/M element, REV.C, chokering with radome NGS)
8	Trimble NetR5	Trimble Zephyr GNSS Geodetic II w/Radome (*TRM55971.00 TZGD*)
4	Leica GRX1200GGPro	Leica L1/L2 Choke Ring, using DM-T style (*LEIAT504GG LEIS*)
1	Javad TRE_G3T DELTA	Ashtech L1/L2 Choke Ring SNOW (*ASH701945C M SNOW* - D/M element, REV.C, chokering with radome NGS)
1	Trimble NetRS	Dorne Margolin T Choke Ring (*AOAD/M T NONE*)

At 14 Polish EPN stations the new uniform meteorological infrastructure Paroscientic, Inc. MET4A sensors were installed.

Since April 2009 MUT processes the archive data from the ASG-EUPOS stations to evaluate the most reliable coordinates on those stations and to estimate sites' activity (Figurski et al., 2010a). In particular, the stability of the ASG-EUPOS stations was investigated (Figurski et al., 2010b).

5. The use of data from satellite gravity missions

Geopotential models developed from GRACE data at different computation centres, i.e. CSR, GFZ, JPL, GRGS were analysed at IGiK in terms of their best suitability for the determination of time variations of the gravity field. The effect of filtering method on the calculated results was investigated. Also the usefulness of the available hydrological models was analysed. The most suitable time series of geopotential models, filtering method for the determination of time variations of geoid heights over Europe as well as the hydrological data appropriate for comparing with GRACE models were indicated (Szelachowska et al., 2010).

6. Activities in Galileo project

At the Astrogeodynamic Observatory (AOS) of the SRC PAS in Borowiec the realization of Harrison Project (6^{th} Framework Program) on application of Galileo for precise time and frequency, as well as legal applications of Galileo Time was completed (Nawrocki and Nogas, 2010).

7. Earth tides monitoring

Earth tides are monitored in the Astrogeodetic Observatory of WUT in Jozefoslaw using LCR ET-26 gravimeter since January 2002. Research on the application of wavelet transform for the analysis tidal record was conducted. Analysis of the 3-year data record indicated the usefulness of the method for investigating frequencies and calculating the amplitude, but the determination of the phase shift is impossible which is its serious limitation (Araszkiewicz and Bogusz, 2010).

Monitoring of the horizontal components of the tidal signal with the use of the system of two long water-tube tiltmeters at the Geodynamic Laboratory of the SRC PAS in Ksiaz in Sudeten Mountains was continued. In 2007 the laboratory equipment was extended by the LCR G-648 gravimeter of tidal resolution for future investigation of Love's numbers *h* and *k* for Sudeten area. The LCR G-648 gravimeter operates in the underground chamber equipped with the pillar for at which absolute gravity was three times measured with the FG5 gravimeter. The measurements with LCR were used for reduction of absolute gravity measurements (Kaczorowski and Olszak, 2010).

After certain break Earth tides are continued to be monitored at the Borowa Gora Observatory of IGiK with the LCR G gravimeter equipped with the modern feedback (Krynski, 2011).

8. Activity in Satellite Laser Ranging

The SLR station in Astrogeodynamic Observatory of the SRC PAS at Borowiec (ILRS 7811) during 2007–2010 acquired and delivered almost 600 000 observed raw points tracking 1476 successful passes of 27 satellites in the framework of ILRS and EUROLAS Consortium. Average single shot RMS, normal points RMS and orbital analysis provided by Analysis Centres that reflect the quality of SLR data provided by Borowiec SLR station, equal to 25 mm, 3 mm, and 15 mm, respectively. The results of observations are available at EUROLAS Data Center (www.dgfi.badw-muenchen.de/edc/) and Crustal Dynamics Data Information System NASA (http://cddis.nasa.gov/slr_datasum.html). The data of the Borowiec SLR station supported research programs and was used for orbit calculations and the determination of geodynamic parameters by many institutions and international organizations (Krynski and Rogowski, 2010; Krynski, 2011).

9. Geodynamics

Monitoring of active tectonic structures of Sudeten Mountains and Fore-Sudetic Block were continued by the team of the WUELS with partners. The probabilistic thresholds defining reliable site movements brought an important recommendation for the GPS practice. It is evident, if any GPS measurements are planned on regional networks aimed to geodynamic studies then the whole period of the measurements should not be shorter than six years (Schenk et al., 2010). Results of epoch satellite GPS and gravimetric measurements performed on the geodynamic network in central part of the Stolowe Mts. between 1993 and 2009 were presented (Cacon et al., 2010). They show significant changes of gravity on most of the points and significant horizontal movement of one point in the central part of the area. The results confirm present day activity of the zone where faults Policky, Belsky and Czerwona Woda Fault Zone exist. In addition, they correspond with the studies of seismic activity in this part of the Sudeten Mts.

Geodynamic investigations were continued in the Pieniny Klippen Belt by WUT using geodetic methods. The results of levelling, gravimetric and distance measurements as well as GPS and absolute gravity measurements revealed vertical and horizontal movements of the crust and periodic gravity changes. Periodic vertical movements of 0.5÷1.5 mm/year are correlated with the interaction between the geological structures of the Magura Nappe and the Podhale Flysh. The direction and velocity of the horizontal movements have changed in irregular manner, reaching maximum of 10 mm over 17 years (Pachuta et al., 2010).

The MUT processes the data and analyses solutions to ensure additional control and monitoring of the ASG-EUPOS system (Figurski et al., 2010b). The research on the application of GNSS solutions within short observational periods to geodynamic investigations was conducted in MUT (Araszkiewicz et al., 2010). Data collected at the ASG-EUPOS system's sites may also contain information about the local dynamics. Basing on GPS data, MUT conducts geodynamical research using the time and time-frequency analyses (Figurski et al., 2010c).

Study of the second degree Love and Shida numbers h_2 and l_2 was conducted using SLR data from the LAGEOS 1, LAGEOS 2 and STELLA satellites observed during 2 years 2005-2006 by 17 globally distributed ground stations (Rutkowska and Jagoda, 2010). SLR data for satellite passes above stations were compressed to normal points which further were processed in 30-day arcs for LAGEOS 1 and LAGEOS 2, and 7-day arcs for STELLA. using the GEODYN II software.

References

Araszkiewicz A., Bogusz J. (2010): *Application of Wavelet Technique to the Earth Tides Observations Analyses*, Marées Terrestres Bulletin d'Informations (BIM), No 146, ISSN No 0542-6766, 2010, pp. 11789-11798.

Araszkiewicz A., Bogusz J., Figurski M., Szafranek K., (2010): *Application of short-time GNSS solution geodynamical studies – preliminary results*, Acta Geod. et Geomaterialia (in print).

Barlik M., Olszak T., Pachuta A., Próchniewicz D., (2010): *Absolute gravimetric determinations of long-standing non-tidal gravity changes in Józefosław Astro-Geodetic Observatory of Warsaw University of Technology and at main tectonic units on Poland territory*, Reports on Geodesy, No 2(89), WUT, pp. 11-19.

Bosy J., Rohm W., Sierny J., (2010): *The concept of Near Real Time atmosphere model based of GNSS and meteorological data from ASG-EUPOS reference stations*, Acta Geod. et Geomaterialia, Vol. 7 No 3(159), pp. 253-261.

Cacon S., Kaplon J., Kontny B., Weigel J., Svabensky O., Kopecky J., (2010): *Recent local geodynamics in the central part of the Stolowe Mts.*, Acta Geod. et Geomaterialia., Vol. 7, No 3(159), pp. 335-342.

Figurski M., Szafranek K., Kaminski P., Kroszczynski K., (2010a): *Preliminary results of ASG-EUPOS processing in the context of EPN densification and system monitoring*, Bulletin of Geodesy and Geomatics (in print).

Figurski M., Szafranek K., Kaminski P., Bogusz J., (2010b): *Investigation on stability of mountainous EUPOS sites' coordinates*, Acta Geod. et Geomaterialia (in print).

Figurski M., Kaminski P., Szafranek K., Kroszczynski K., (2010c): *Frequency and phase analysis of daily reprocessed solutions from selected EPN stations relating to geological phenomena*, Acta Geod. et Geomaterialia, Vol. 7, No 3(159) (in print).

Kaczorowski M., Olszak T., (2010): *Absolute gravity measurements as supplement to the research program of Geodynamic Laboratory of PAS in Ksiaz* (in Polish), Monograph: Unified gravimetric reference system for the Polish permanent GNSS stations and geodynamic polygons, WUT, (ed.) J. Walo, pp. 101-126.

Kruczyk M., (2010): *Tropospheric delay EPN products – some statistics in relation to COSMO NWP model*, Symp.of the IAG Subcomm. fof Europe (EUREF) held in Florence, Italy, 27–29 May 2008, EUREF Publ.No 19, Mitteilungen des BKG, Frankfurt am Main (in print).

Kruczyk M., Liwosz T. Rogowski J., (2010): *Tropospheric delay for EPN stations in Poland – verification by various aerological data*, Polish J. of Env. St., 2010 (in print).

Krynski J., (ed.) (2011): *Polish National Report on Geodesy 2007-2010*, XXV IUGG, Melbourne, Australia (134 pp).

Krynski J., Rogowski J.B., (2010): *National Report of Poland to EUREF 2010*, Symp. o the IAG Subcomm. for Europe (EUREF) held in Gävle, Sweden, 2–5 June 2010, EUREF Publ. No 20, Mitteilungen des BKG, Frankfurt am Main (in print).

Krynski J., Sekowski M., (2010): *Surveying with the A10-20 Absolute Gravimeter for Geodesy and Geodynamics – first results*, Reports on Geodesy, No 1(88), WUT, pp. 27-35.

Mäkinen J., Sękowski M., Kryński J., Ruotsalainen H., Bilker-Koivula M., (2010a): *Remeasurement of the Finnish First Order Gravity Net with the A10-020 gravimeter and revision of the national gravity net. First experiences 2009*, NKG WG-Geoid Symp., 10–11 Mar. 2010, Helsinki, Finland.

Mäkinen J., Sękowski M., Kryński J., Ruotsalainen H., (2010b): *Remeasurement of the Finnish First Order Gravity Net with the A10-020 gravimeter of the IGiK was started in 2009. Is there a capability for detecting PGR?*, NKG WG- Geodynamics Symp., 11–12 Mar. 2010, Helsinki, Finland.

Mäkinen J., Sękowski M., Kryński J., (2010c): *The use of the A10-020 gravimeter for the modernization of the Finnish First Order Gravity Network*, Geoinformation Issues, Vol. 2, No 1(2), pp. 5-17.

Nawrocki J., Nogaś P., (2010): *Report on Development of Multi-System Time Transfer AT AOS*, Proceedings of the European Frequency and Time Forum 10, Noordwijk (ESA), The Netherlands, 12–16 Apr. 2010 (in print).

Pachuta A., Barlik M., Olszak T., Próchniewicz D., Szpunar R., Walo J., (2010): *Geodynamical investigations in the Pieniny Mountains before and after construction of water reservoirs in the Czorsztyn region*, Monographs of the Pieniny National Park. „Pieniny Dam Changes", Krościenko, 2010, Vol. 2, pp. 53-61.

Rutkowska M., Jagoda M., (2010): *Estimation of the elastic Earth parameters using the SLR LAGEOS 1 and LAGEOS 2 data*, Acta Geoph. Vol. 58, No 4, pp. 705-716, DOI: 10.2478/s11600-009-0062-1.

Schenk V., Schenkova Z., Bosy J., Kontny B., (2010): *Reliability of GPS data for geodynamic studies case study: Sudeten area, The Bohemian Massif*, Acta Geod.et Geomaterialia**,** Vol. 7, No 1(157), pp. 113-128.

Sękowski M., Kryński J., (2010): *Gravity survey with the A10-20 absolute gravimeter – first results*, IAG Symp. on Terrestrial Gravimetry: Static and Mobile Measurements (TG-SMM2010), 22–25 June 2010, StPetersburg, Russia.

Shagimuratov I.I., Karpov I.V., Krankowski A., Zakharenkova I.E., (2010): *The Spatial-temporal Wave-like TEC Variations Associated With Poincare Waves*, Proceedings of 6th Asia Oceania Geosciences Society General Meeting (AOGS 2009), Singapore, 11–15 Aug. 2009, Adv. in Geosciences (in print).

Szelachowska M., Kloch-Główka G., Kryński J., (2010): *Choice of data from GRACE as well as filtering method for the analysis of time variations of the gravity field over Europe*, 2nd GA of the IGFS – Int.. Gravity Field Service, 20–22 Sept. 2010, Fairbanks, Alaska, USA.

Walo J., (ed.) (2010): *The Unified Gravimetric Reference System for Polish GNSS Stations and Geodynamic Fields* (in Polish), WUT (184 pp)