J. KRYNSKI<sup>1</sup>, J.B. ROGOWSKI<sup>2</sup>

### 1. Introduction

Since 2006 the main geodetic activities at the national level in Poland concentrated on further research and computational work on a centimetre quasigeoid model in Poland, maintenance of the national gravity control, continuing operational work of permanent IGS/EUREF stations, conducting GPS data processing on the regular basis at the WUT Local Analysis Centre, activity in the framework of the EUREF IP project and GNSS antenna calibration, monitoring ionosphere and ionospheric storms, works towards monitoring troposphere, activity towards implementing the EUPOS project in Poland, activity within Galileo project, GNSS applications, and activity in satellite laser ranging.

### 2. Modelling a centimetre geoid for Poland

Research initiated in the framework of the project on the cm geoid in Poland (Krynski et al., 2007, Krynski and Rogowski, 2007) conducted in 2002-2005 has been continued (Krynski, 2007a, 2007b, 2007c).

The extensive study was conducted to improve the astrogravimetric geoid model in Poland by improving the procedure of astrogravimetric geoid modelling and by using improved data (Lyszkowicz and Krynski, 2008). Accuracy of the components of the deflections of the vertical was estimated and the weights of astrogeodetic and astrogravimetric deflections of the vertical were determined. Astrogeodetic and astrogravimetric geoid models were determined from archival deflections of the vertical with the use of astronomical levelling. Other astrogeodetic and astrogravimetric geoid models were calculated by least squares collocation with the use of gravity anomalies instead of archival astrogravimetric deflections of the vertical. Computed geoid models were mutually compared. They were also compared with the GPS/levelling geoid spanned on the sites of the POLREF network as well as with 2005 astrogravimetric geoid model. The results obtained (Fig. 1) indicate that both astrogeodetic geoid and astrogravimetric geoid determined from the same input data using least squares collocation approach are by factor 5 to 7 more accurate than the respective ones obtained using classical astronomical levelling. Both astrogeodetic and astrogravimetric geoid models developed with the use of least squares collocation approach are thus substantially improved as compared with the existing

models developed on the basis of astronomical levelling algorithm (Lyszkowicz and Krynski, 2008).



Fig. 1. External accuracy of astrogeodetic and astrogravimetric geoid models developed, represented by the standard deviation of their fit to the GPS/levelling geoid at the sites of the POLREF network

The methodology of quality assessment of heights of gravity stations in Poland was elaborated. That methodology was applied to assess quality of height and gravity data from Poland. Quality of heights of over a million gravity stations from the gravity database for Poland was assessed with the use of DTED2 and SRTM3 DTMs as well as with the use of Bouguer gravity anomalies. The outliers have been indicated and eliminated from the data set used for developing the consecutive geoid models (Kloch and Krynski, 2008a).

Quality estimate of "1992" terrain corrections and the analysis of their use for the computation of terrain corrections in Poland that fulfil the requirements of centimetre geoid was performed (Kloch and Krynski, 2007b).

Research on the optimisation of the strategy of the determination of terrain corrections in Poland with the use of prism method was conducted. It concerned the choice of heights of gravity stations (surveyed ones or obtained from DTM), the determination of the optimum radius of the integration cap when using both planar and spherical approaches, the issues of negative terrain corrections and convergence of terrain corrections with growing distance from the gravity station (Kloch and Krynski, 2007a). The strategy developed has been verified in 5 representative in terms of topography test areas in Poland using heights of gravity stations from the gravity database for Poland and from digital terrain models DTED2 as well as SRTM3 (Kloch and Krynski, 2008b).

<sup>&</sup>lt;sup>1</sup> Jan Krynski, Institute of Geodesy and Cartography, 27 Modzelewskiego St., PL 02-679 Warsaw, Fax: +48 22 3291950, Tel.: +48 22 3291904, Email: krynski@igik.edu.pl

<sup>&</sup>lt;sup>2</sup> Jerzy B. Rogowski, Department of Geodesy and Geodetic Astronomy, Warsaw University of Technology, 1 Pl. Politechniki, PL 00-661 Warsaw, Fax: +48 22 6210052, Tel.: +48 22 6607754/5, E-mail: jbr@gik.pw.edu.pl

# 3. Maintenance of the national gravity control

Since June 2005 the Institute of Geodesy and Geodetic Astronomy of the Warsaw University of Technology uses its absolute ballistic FG5 No 230 gravimeter. Repeatable gravity absolute measurements performed monthly at the Jozefoslaw Astrogeodetic Observatory are used for monitoring non-tidal gravity variations (Fig. 2).



Fig. 2. Results of absolute gravity measurements at Jozefoslaw

The absolute gravimeter FG5 No 230 took part in the European Comparison of Absolute Gravimeters campaign in November 2007 in Luxembourg. The preliminary results show that the data obtained with the FG5 No 230 are of high quality.

Precise absolute gravity measurements for geodynamics research have been carried out since 1990. at five stations in Poland (Barlik et al., 2007a, 2007b, 2007c): Borowiec (Borowiec Astrogeodynamic Observatory of the Polish Academy of Sciences), Giby (fundamental station of national gravity control), Jozefoslaw (Astrogeodetic Observatory of the Warsaw University of Technology), Lamkówko (Satellite Observatory of the University of Warmia and Mazury), Ojców (Seismic Observatory of the Polish Academy of Sciences) (Fig. 3).



Fig. 3. Location of gravity stations in Poland included in the geodynamics research

Information connected with 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 extend, in terms of vertical displacements of gravity stations.

The modernization on the Polish zero-order absolute gravity control consists of three stages:  $1^{st}$  – densification of the absolute gravity network,  $2^{nd}$  – modernization of two gravimetric calibration baselines for relative measurements,  $3^{rd}$  – re-measurement of gravity at the remaining absolute gravity stations in Poland (Barlik and Krynski, 2007). The joint laboratory for the regional absolute gravimeters comparison campaigns in Poland: Borowa Gora Geodetic-Geophysical Observatory and Jozefoslaw Astrogeodetic Observatory was set up (Krynski and Barlik, 2007). Four ballistic gravimeters can simultaneously be compared at each of those stations.

The modernization of gravimetric calibration baselines as well as the fundamental gravity control network in Poland, that started in 2006, has been continued in 2007 as an effort of the joint team of the Institute of Geodesy and Cartography, Warsaw, and the Warsaw University of Technology.

The team of the Institute of Geodesv and Geodetic Astronomy WUT surveyed absolute gravity at 5 new stations of the Central Gravimetric Calibration Baseline and two gravity points densifying zero-order gravity control in Eastern Poland with the use of FG5 No 230 gravimeter with an error not exceeding 3 µGal. At each absolute gravity station two eccentric gravity points were established; they were interconnected by relative gravity measurements with the precision not worse than 15 µGal. New absolute gravity points established in 2007 together with their eccentric points have also been linked with precise relative gravity survey to the stations of the fundamental gravity control network by the specialists of the Institute of Geodesy and Cartography, Warsaw, with the use of a set of L&R gravimeters. The reconnaissance at the Western Gravimetric Calibration Baseline was performed and six new absolute stations including the eccentric points were selected. Precise geodetic coordinates of those points were determined with static GPS survey. Stations of the Western Gravimetric Calibration Baseline after modifications following the reconnaissance are shown in Figure 4.

# 4. Operational work of permanent IGS/EPN stations

Permanent GNSS stations of IGS and EUREF Permanent Network (EPN) operate in Poland since 1993. Recently 10 permanent GNSS stations, i.e. Borowa Gora (BOGO, BOGI), Borowiec (BOR1), Jozefoslaw (JOZE, JOZ2), Lamkowko (LAMA), Katowice (KATO), Cracow (KRAW), Wroclaw (WROC) and Zywiec (ZYWI) (Fig. 5) operate in Poland within the EUREF program. The stations BOGI, BOR1, JOZE, JOZ2 and LAMA operate also within the IGS network (Krynski and Rogowski, 2007; http://www.epncb.oma.be/\_trackingnetwork/stations.ph p).

The new seven stations of the ASG-EUPOS network (BPDL, BYDG, GWWL, LODZ, REDZ, SWKI, USDL) started operating as EPN stations in March 2008 (Fig. 5).



Fig. 4. Modernised Gravity Calibration Baseline in Poland (2007)



Fig. 5. IGS/EPN Permanent GNSS stations in Poland including 7 newly established (March 2008) EPN stations (blue)

## 5. Data processing at Local Analysis Centre at WUT

The team of the Warsaw University of Technology elaborated in 1995 in close cooperation with the CODE Centre of the Institute of Astronomy of the University of Bern, the strategy of data processing in the networks of permanent GPS stations. Since 2005 GNSS data is processed in WUT LAC in cooperation between the Department of Geodesy and Geodetic Astronomy WUT and the Centre of Applied Geomatics of the Department of Civil Engineering and Geodesy of the Military University of Technology in Warsaw. The strategy developed, adjusted to EPN standards, is used since 1996 to process the EPN data at the WUT Local Analysis Centre of EUREF. Data from 58 permanent GNSS stations of EPN (Fig. 6) are processed at the WUT EUREF LAC on the daily basis using the Bernese v.5.0 software (Rogowski et al., 2006) according to EPN standards.

#### 6. Activity within the EUREF-IP Project

The EPN stations at Borowa Gora (BOGI), Cracow (KRAW), Jozefoslaw (JOZ2, JOZ3), and Wroclaw (WROC) take part in the EUREF IP project (http://www.epncb.oma.be/\_organisation/projects/euref \_IP/index.php). Since March 2005 Ntrip Broadcaster is installed at the AGH University of Science and Technology (gps1.geod.agh.edu.pl). The Ntrip Caster broadcasts RTCM and raw GNSS data from 17 sources, mainly from KRAW EPN permanent station in the framework of EUREF-IP project. It also broadcasts the same type of data from the other Polish semi-permanent and temporal GNSS stations.



Fig. 6. EPN stations providing data processed at WUT EUREF LAC

### 7. GNSS antenna calibration

A simple, portable prototype of the device for antenna calibration was constructed at the Institute of Geodesy and Cartography, Warsaw, in co-operation with the "Metrologia" Institute, Kharkiv, Ukraine (Krynski et al., 2007a). Phase centre offset (PCO) is being measured with the use of a reference site, whose antenna does neither need a precise nor absolute calibration. On the other hand, phase centre variations (PCV) may be measured in single site mode with the usage of satellite--satellite carrier differences. Numerous test measurements were performed in Borowa Gora and Lamkowko Observatories in Poland as well as in the Ukrainian Antarctic "Akademik Vernadsky" station (Cisak and Zanimonskiy, 2008). The example of variations of phase centre offset averaged over observed satellites in one minute intervals is shown in Figure 7.



Fig. 7. Comparison of the results of the mean phase centre offset obtained from the observations with the results of NGS calibration

The research on the antenna calibration device and elaboration of the calibration method at the Institute of Geodesy and Cartography, Warsaw, is planned to be completed in 2008.

# 8. Monitoring ionosphere and ionospheric storms

The Institute of Geodesy of the University of Warmia and Mazury, Olsztyn, in collaboration with the West Department of the Institute of Geomagnetism, Ionosphere and Radio-Wave Propagation of the Russian Academy of Sciences, Kaliningrad, continues the analysis of long time series of GNSS data from EPN stations since 1994, to study the Earth's ionosphere. GNSS observations carried out at European and North American stations of the IGS/EPN networks, were used to study the response of the ionosphere to the severe geomagnetic storms (Krankowski et al., 2007a, 2007b). Also a modification of the ionosphere before the Hokkaido and Kythira earthquakes was presented (Zakharenkova et al., 2007a, 2007b).

Recently, many techniques have been developed to provide the ionospheric delay corrections that support fast on-the-fly (OTF) ambiguity resolution (AR) over longer distances. Most of these techniques can be divided into two groups. The first group consists of Network-RTK approach (or VRS - Virtual Reference Stations) where the ionospheric (and tropospheric) corrections are derived by a reference network in realtime, but no model of those is formed (Greiner-Brzezinska at al., 2007a, 2007b; Kashani et al., 2007). The second group consists of techniques that use external ionosphere information, e.g. from the ionospheric models, to form the ionospheric corrections. This approach is also based on reference network data. Most of the existing quality ionospheric models are, however, derived in post-processing or in near-real time. Therefore they cannot support real-time applications. Hence, the desired solution is to use ionosphere models capable of predicting the ionospheric delay over a given area.

Lately, such a model was developed at the University of Warmia and Mazury (UWM), Olsztyn, Poland. The predictive model (UWM-IPM) is based on several prediction techniques, such as autocovariance, autoregression moving average (ARMA) and Artificial Neural Networks, and uses a regional ionosphere model (UWM-IM) as an input to the prediction algorithm. The UWM-IM model was developed in cooperation with the West Department of the Institute of Ionosphere and Radio-Wave Propagation of the Russian Academy of Sciences (WD IZMIRAN), Kaliningrad, Russia (Wielgosz et al., 2007).

In order to determine the accuracy of the double difference (DD) ionospheric corrections from UWM-IPM, their values were compared to the true, observed DD ionospheric delays. Below an example is given for 50 km baseline (WODZ-KATO) for 24-hour period (8 May 2007). The differences (residuals) between the DD corrections and the true, observed DD ionospheric delays were analysed (Wielgosz et al., 2008). Those residuals are related to the L1 signal delay and directly show the accuracy of the DD corrections (Fig. 8).



WODZ-KATO (50 km)

The residuals are well below 1/2 of the L1 cycle and thus, allow for fast OTF AR. Subsequently, the accuracy of the kinematic positioning with the application of the DD ionospheric corrections over 50 km baseline is given in Figure 9.



Fig. 9. RTK coordinate residuals, KATO- WODZ (50 km)

The application of a predictive ionosphere model to the kinematic positioning provides very promising results. The predicted corrections may successfully be applied to the processing of 25-50 km baselines in a single-baseline mode, and up to ~70 km baselines in a multi-baseline mode, when a longer baseline is combined with 1-2 shorter baselines. It is expected, however, that when the base and the predicted models improve then this methodology may be successful for even longer baselines. It was shown that cm-level horizontal kinematic position can be achieved using the proposed methodology with dual-frequency GPS data over distances of tens of km with short initialization time (less than 15 seconds for short baseline or multibaseline solutions). However, it should be noted that during ionospheric disturbances (e.g., storms) the quality of the prediction may be much lower, and hence, the performance of AR may be worse than presented here.

### 9. GPS for meteorology

At the Institute of Geodesy and Geoinformatics of the Wroclaw University of Environmental and Life Sciences the investigations are carried out in the area of GPS meteorology, especially to provide the optimum solution for tropospheric tomography with the use of Zenith Tropospheric Delays estimated from the GPS network. The main product of tomography is water vapour (WV) distribution in free atmosphere which may be included in Numerical Weather Prediction models. The algorithm for obtaining WV from ZTD, involves the use of auxiliary meteorological data like *in situ* measurements, radiosonde profiles, and extensive modelling (Rohm and Bosy, 2007). The meteorological data accuracy assessment, validation of estimated GPS delays, and data interpolation is carried out for the local GPS network. The case study - epoch GPS observations in Karkonosze mountains is being presently investigated.

The second topic of the studies concerns the regional use of ZTD as an additional data source for weather forecasting. The comparison of different ZTD sources shows that precise and reliable meteorological data in the EUREF network is required (Bosy and Rohm, 2007).

The problem of GPS slant delay determination using data from mesoscale non-hydrostatic models of the atmosphere which are run on IA64 Feniks computer cluster in the Centre of Applied Geomatics of the Department of Civil Engineering and Geodesy of the Military University of Technology, Warsaw, was investigated. The slant delay is the result of integrating the ray equation for the spatial function of tropospheric refraction along the GPS wave propagation path. A module for the determination of slant delay  $\tau$  using data from the COAMPS model was developed. The module enables to investigate angular characteristics of the delay for various atmospheric conditions. The delay may be determined for any GNSS station location in the working area of the model and any elevation angle of a satellite observed. The results obtained show that for small elevation angles the slant delay depends on the observation direction. Hence, it includes information concerning heterogeneity of atmospheric humidity distribution along the GPS signal path. The present research concern operational methods of GPS slant delay determination using data from mesoscale nonhydrostatic models of the atmosphere, like COAMPS (Coupled Ocean/Atmosphere Mesoscale Prediction System) of the Naval Research Laboratory and the WRF (Weather Research and Forecasting). Further research of the relation between the slant delay and the atmospheric conditions will include the module subroutines for satellite and radar images analysis (Figurski and Kroszczyński, 2007).

The team of the Warsaw University of Technology analysed the results of IPW time series derived from GPS solutions as geophysical data. Integrated Precipitable Water (IPW, also called IWV) is an important meteorological parameter easily derivable from GPS tropospheric solutions (ZTD's). IPW values obtained from other sources can be much more problematic due to various technical shortages. Comparisons of different GNSS solutions (mainly using IGS and EPN data) with three meteorological water vapour data sources, i.e. radiosoundings, sun photometer (CIMEL, Central Geophysical Observatory PAS, Belsk, data - courtesy of Dr. Krzyścin) (Fig. 10), and input data of numerical prediction model (NWP) COSMO-LM (maintained by the Polish Institute of Meteorology and Water Management, data made

accessible by Mr. Mazur) (Fig. 11) indicated highest quality of IPW coming from GPS data analysis (Kruczyk, 2007).



Fig. 10. Integrated Precipitable Water values validated by independent technique: sunphotometer CIMEL CF-318 (Central Geophysical Observatory, Belsk near Warsaw, 33 km from JOZE) – results shown for 2005

It is worth to emphasize that while inter-technique comparisons of directly measured IPW is attainable only for best equipped observatories, from NWP models treated as meteorological database one can obtain ZTD and IWV for all GPS stations independently from sparse RAOB network.



Fig. 11. Integrated Precipitable Water values: from EPN WUT LAC and numerical weather prediction model COSMO-LM input data – year 2006

Value of GPS IPW as a geophysical parameter has been demonstrated by finding clear physical effects depending on station location (e.g. height), weather pattern, significant decrease of ZTD & IPW time series correlation coefficient with distance, as well as intriguing regularities in long IPW time series.

Deficiency of surface humidity data for precise modelling IPW encourages for investigating of information exchange potential between numerical weather prediction model and GPS network solution. Best possible troposphere refractivity data is needed both for future development of weather prediction and less laborious methods of GNSS precise positioning.

#### 10. The ASG-EUPOS network in Poland

The technical project of the ASG-PL network of active multifunctional permanently operating GPS stations in Poland, ordered by the Head Office of Geodesy and Cartography in Poland, was reviewed in 2000 by the Special Study Group of the Committee on Geodesy and the Committee on Space and Satellite Research of the Polish Academy of Sciences. A sub-network of the ASG-PL with data processing centre was established in Upper Silesia by the end of 2002, as a pilot project of governmental and regional Silesian authorities. It has reached a preliminary operational stage in February 2003 (Krynski et al., 2004, 2005). In 2006, new 4 stations in Malopolska region joined the ASG-PL network. The map of the extended network is given in Figure 12. Finally the network consisted of 9 permanent stations and was linked to 10 EPN and IGS stations (BOGI, BOGO, BOR1, JOZE, JOZ2, KRAW, LAMA, WROC, KATO, ZYWI) and eight other permanent GPS stations (CBKA, ELBL, GDAN, JOZ3, KWBB, LAM6, POZN, TORU) (Fig. 13) that provided GPS data at 5 s sampling rate. The ASG-PL network stations in Upper Silesia and Malopolska region were equipped with Ashtech µZ-12-CGRS receivers with ASH701945C M SNOW antennae. Observations were acquired at 5 sec sampling rate and were transferred to the processing centre hourly. The ASG-PL network operating in the Upper Silesia and Malopolska region was the first stage of the ASG-EUPOS - project for the entire territory of Poland and was joined to the ASG-EUPOS on 1 April 2008.



Fig. 12. Operating in 2007 part of the Polish Active Control Network for Upper Silesia and Malopolska region



Fig. 13. ASG-PL stations as well as collaborating stations (status at the end of 2006)

The European Project EUPOS (European Position Determination System) consists in establishment of about 440 multifunctional satellite reference stations in fourteen Central and Eastern Europe countries. The system will use standard signal of the European system Galileo as the basis, as soon as it is available, and is optional for GPS and GLONASS. The EPN stations included in the EUPOS network give a proper realisation of the reference frame in that network (Krynski et al., 2006).

In Poland the ASG-EUPOS multifunctional system for precise satellite positioning is a part of the EUPOS® project involving the countries of Central and Eastern Europe. The ASG-EUPOS reference stations will consist of 68 RTK reference stations (GPS module) built within the project, 8 stations (GPS/GLONASS module) built within the project, 16 existing RTK reference stations (GPS module) situated in Poland, 6 existing **RTK/DGPS** reference stations (GPS/GLONASS module) admissioned into the system, situated in Poland (Fig. 14), and about 30 foreign reference stations situated in the border zone, working within the EUPOS System. All EPN Polish stations are included in the EUPOS network and give a proper realisation of the reference frame in that network (Bosy et al., 2007).



Fig. 14. Reference stations of the ASG-EUPOS, the Polish part of the EUPOS network

The ASG-EUPOS multifunctional precise positioning system project is conducted with the use of the resources of the European Regional Development Fund within the Sectoral Operational Programme "Improvement of the Competitiveness of Enterprises". The contract for project subsidising was signed on 2 August 2005. The Ministry of Regional Development is the Managing Authority, while the Department of European Funds acting within the Ministry of Science and Higher Education is the Implementing Authority and the Surveyor General of Poland is the Final Beneficiary (Bosy et al., 2007).

The network of reference stations (Fig. 14) should become operational by June 2008. It will provide a signal for both positioning of geodetic control points and for land, air and marine navigation. Several levels of positioning accuracy will be offered. Standard services, as required by the general EUPOS assumptions including the following sub-services: NAVGIS and CODGIS (network RTK for real time kinematic DGNSS applications), NAVGEO (network RTK for precise real time kinematic DGNSS applications), POSGEO and POSGEO D DGNSS for precise DGNSS post processing applications will be offered (Sledzinski and Graszka, 2006; Bosy et al., 2007, Krynski et al., 2007). Connection to the European reference system ETRS89 will be realised by the 10 existing EPN stations in Poland (BOGI, BOGO, BOR1, JOZE, JOZ2, KRAW, LAMA, WROC, KATO, ZYWI) and 7 new EPN stations (BPDL, BYDG, GWWL, LODZ, REDZ, SWKI, USDL).

The ASG-EUPOS system will ensure a stable and uniform reference system in Poland. The system accessibility and the realisation of precise positioning and navigation service will be carried out in real time. According to the assumptions, the ASG-EUPOS system may constitute the basis for building own systems (applications) for users utilising the positioning or navigation function. The realisation of the ASG-EUPOS system also requires the coordination of operations with the neighbouring countries, especially in the scope of common technical standards and the exchange of observational data from border stations.

### 11. Galileo project

Borowiec Astrogeodynamic Observatory (AOS) of the Space Research Centre PAS takes part in the framework of the international consortium Fidelity in the realization of the reference time for the European Satellite Navigation System Galileo called Galileo System Time. The Galileo System Time will be based on an ensemble of clocks from the best European time laboratories and clocks from Galileo ground segment. The AOS is responsible for the time transfer techniques of the Precise Time Facility. Two methods of time transfer will be applied: GPS/Galileo P3 (iono-free) method according to the CGGTTS standards of Common View method (uncertainty of the method: RMS<1.5 ns), and Two Way Satellite Time and Frequency Transfer (TWSTFT), the method using geostationary telecommunication satellite for time transfer (uncertainty of the method: RMS<1 ns).

The University of Warmia and Mazury in Olsztyn together with some companies from Czech Republic, Italy, and The Netherlands participated in the FieldFact project related to the promotion of GNSS in agriculture user community, partly funded by Galileo Joint Undertaking.

## 12. GNSS applications

The area aid applications across the 27 EU member countries covers almost 133 million hectares. According to EU regulations the area of agricultural fields must be checked against claims to ensure that farmers receive the right amount of subsidies. The checks are made with the use of remote sensing technology supported with GNSS technology. According to Commission Regulation (EC) No 796/2004 (last modification on 20 August 2007) "agricultural parcel areas shall be determined by any means proven to assure measurement of quality at least equivalent to that required by applicable technical standard, as drawn up at Community level".

The University of Warmia and Mazury in Olsztyn participated in certification and validation of GNSS receivers and observers for IACS (Integrated Administration and Control System) on-the-spot checks, to ensure the required level of accuracy and reliability for parcel area measurements (Oszczak and Ciecko, 2006), (Oszczak et al., 2007), (Ciecko et al., 2008).

#### 13. Activity in Satellite Laser Ranging

The Satellite Laser Ranging station Borowiec (7811) at the Borowiec Astrogeodynamic Observatory of the Polish Academy of Sciences continued laser measurements in the framework of the International Laser Ranging Service (ILRS) and EUROLAS Consortium. In 2007 the Borowiec SLR station tracked 465 successful passes of 20 SLR satellites with the normal point precision of 3 mm and accuracy of 10 mm (results in CDDIS and EDC data centres). The data of the Borowiec SLR station supported research programs and was used for orbits calculations and the determination of geodynamic parameters by many institutions and international organizations.

The activity of the Borowiec SLR station was limited in 2007 by renovation of the laser building and significant modernization of the hardware and software of the SLR system. The modernization included new cover of the main and secondary telescope mirrors, installation of the new dielectric mirrors in Coude path and their regulation systems, installation of a new gating system for stop channel of the time interval counter and photomultiplier photocathode, implementation of the new controller computers and significant modernization of the station software (Schillak, 2007).

The determination of the satellite spin parameters based on Graz kHz laser measurements were continued (Kucharski et al., 2007).

Processing of the SLR observations was continued in Borowiec by means of NASA GEODYN-II orbital program. The SLR station positions and velocities were determined from the observations of low satellites Starlette, Stella and Ajisai (Lejba et al., 2007). The results are in good agreement with the LAGEOS data. Quality comparison between two terrestrial reference frames ITRF2000 and ITRF2005 for SLR stations was realized on the basis of five years of LAGEOS data (Schillak, 2008). The automation of the GEODYN-II program was continued providing fully automatic process of the orbits calculation.

#### References

BARLIK M., KRYNSKI J., (2007): Gravimetric Calibration Baselines and Modernization of the Polish Gravity Control, Workshop of gravimetric departments of Middle-European countries, 26-27 June 2007, Prague, Czech Republic.

- BARLIK M., OLSZAK T., PACHUTA A., (2007a): Investigations of the long-standing non-tidal absolute gravity changes on the main tectonic units at the Poland territory, General Assembly of the European Geosciences Union, Vienna, 12–18 April 2007.
- BARLIK M., OLSZAK T., PACHUTA A., (2007b): *Monitoring* of the long-standing absolute gravity changes on the Poland territory (in Polish), Presented on XX Autumn Geodetic School, Polanica-Zdrój, Poland, 16-18 September 2007.
- BARLIK M., OLSZAK T., PACHUTA A., (2007c): Investigations of the long-standing gravity non-tidal variations at main tectonic units of Poland territory, Workshop of Gravimetric Departments of Middle-European Countries, 26-27 June 2007, Prague, Czech Republic.
- BOSY J., GRASZKA W., LEOŃCZYK M., (2007): ASG-EUPOS - A Multifunctional Precise Satellite Positioning System in Poland, European Journal of Navigation, Vol. 5, No 4, September 2007, pp. 30-34.
- BOSY J., ROHM W., (2007): Verification of the meteorological observations on the EPN stations, Symposium of the IAG Subcommission for Europe (EUREF) held in London, UK, 6– 9 June 2007, EUREF Publication No 17, Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Frankfurt am Main (in print).
- CIECKO A., OSZCZAK S., JARMOLOWSKI W., (2008): Official Voluntary Certification of GNSS Instruments and Observers for IACS On-the-Spot Checks, ION NTM, San Diego, CA, USA, 28-30 January 2008, CD ROM proceedings, pp. 614-619.
- CISAK J., ZANIMONSKIY Y.M., (2008): Results of the investigations of the GNSS antennae in the framework of SCAR GIANT project "In situ GNSS antenna tests and validation of phase centre calibration data", Springer Verlag (in print).
- FIGURŠKI M., KROSZCZYŃSKI K., (2007): Mesoscale functions of GPS slant delay, Acta Geodynamica et Geomaterialia (formerly Acta Montana), Vol. 4, No 4(148), pp. 141-144.
- GREINER-BRZEZINSKA D.A., KASHANI I., WIELGOSZ P., SMITH D.A., SPENCER P.S.J., ROBERTSON D.S., MADER G.L., (2007a): On efficiency and reliability of ambiguity resolution in network-based RTK GPS, Journal of Surveying Engineering, Vol. 133, No 2, pp. 56-65.
- GREJNER-BRZEZINSKA D.A., HONG C.-K., WIELGOSZ P., HOTHEM L., (2007b): The Impact of Severe Ionospheric Conditions on the GPS Hardware in the Southern Polar Region, Proceedings of the IAG, IAPSO and IABO SYMPOSIUM: Dynamic Planet 2005, 22-26 August, Cairns, Australia, Series: IAG Symposia, Springer, Vol. 130, pp. 867-875.
- JAROSIŃSKI M., KRYŃSKI J., ROGOWSKI J.B., (2007): Study of the relationship between the tectonic stress and the deformation of the lithosphere in the territory of Poland – a new geodynamics research project, Proceedings of the EGU G11 Symposium "Geodetic and Geodynamic Programmes of the CEI", Vienna, Austria, 15–20 April 2007, Reports of Geodesy, Warsaw University of Technology, No 2(83), 2007, pp. 109-116.
- KASHANI I., WIELGOSZ P., GREJNER-BRZEZINSKA D.A., (2007): The Impact of the Ionospheric Correction Latency on Long-Baseline Instantaneous Kinematic GPS Positioning, Survey Review, Vol. 39, No 305, pp. 238-251.
- KLOCH G., KRYNSKI J., (2007a): *Towards the optimum* strategy of determination of terrain corrections in Poland, Earth: our Changing Planet, XXIV IUGG General Assembly, Perugia, Italy, 2-13 July 2007.
- KLOCH G., KRYNSKI J., (2007b): Quality estimate of "1992" terrain corrections and the analysis of their use for the computation of terrain corrections in Poland that fulfil the requirements of centimetre geoid (in Polish), Proceedings of the Institute of Geodesy and Cartography, t. LIII, z. 111, Warsaw 2007, pp. 64-89.

- KLOCH G., KRYNSKI J., (2008a): Methodology of quality assessment of height data, used for precise geoid modelling, The 7<sup>th</sup> International Conference on "Environmental Engineering", 22–23 May 2008, Vilnius, Lithuania, pp. 1339-1344.
- KLOCH G., KRYNSKI J., (2008b): Towards optimisation of the determination of terrain corrections with the use of prism method, The 7<sup>th</sup> International Conference on "Environmental Engineering", 22–23 May 2008, Vilnius, Lithuania, pp. 1345-1353.
- KRANKOWSKI A., SHAGIMURATOV I.I., BARAN L.W., (2007a): Mapping of foF2 over Europe based on GPS-derived TEC data, Advances in Space Research 39, pp. 651-660; doi: 10.1016/j.asr.2006.09.034.
- KRANKOWSKI A., SHAGIMURATOV I.I., BARAN L.W., YAKIMOVA G.A., (2007b): The structure of the mid- and high-latitude ionosphere during the November 2004 storm event obtained from GPS observations, Acta Geophysica, Vol. 55, No 4, pp. 490-508; doi. 10.2478/s11600-007-0033-3.
- KRUCZYK M., (2007): Verification of GPS derived ZTD and IWV potential for meteorology, Earth: our Changing Planet, XXIV IUGG General Assembly, Perugia, Italy, 2-13 July 2007.
- KRYNSKI J., ROGOWSKI J.B., ZIELIŃSKI J.B., (2004): National Report of Poland to EUREF 2003, Report on the Symposium of the IAG Subcommission for Europe (EUREF) held in Toledo, Spain, 4–7 June 2003, EUREF Publication No 13, Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Band 33, Frankfurt am Main, pp. 264-268.
- KRYNSKI J., ROGOWSKI J.B., ZIELIŃSKI J.B., (2005): National Report of Poland to EUREF 2004, Report on the Symposium of the IAG Subcommission for Europe (EUREF) held in Bratislava, Slovak Republic, 2–5 June 2004, EUREF Publication No 14, Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Band 35, Frankfurt am Main, pp. 258-262.
- KRYNSKI J., ROGOWSKI J.B., ZIELIŃSKI J.B., (2006): National Report of Poland to EUREF 2005, Report on the Symposium of the IAG Subcommission for Europe (EUREF) held in Vienna, Austria, 1-4 June 2005, EUREF Publication No 15, Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Frankfurt am Main, pp. 269-274.
- KRYNSKI J., (2007a): Geoid model of a centimetre accuracy in Poland – reality and perspectives (in Polish), Proceedings of the Institute of Geodesy and Cartography, t. LIII, z. 111, Warsaw 2007, pp. 5-46.
- KRYNSKI J., (2007b): Precise quasigeoid modelling in Poland results and accuracy estimate (in Polish), Monographic series of the Institute of Geodesy and Cartography, Nr 13, Warsaw 2007, (266 pp).
- KRYNSKI J., (editor) (2007c): Polish National Report on Geodesy 2003-2006, XXIV General Assembly of the International Union of Geodesy and Geophysics, Perugia, Italy, 2007 (126 pp).
- KRYNSKI J., BARLIK M., (2007): The laboratory for the regional absolute gravimeters comparison campaigns in Poland: Geodetic-Geophysical Observatory Borowa Gora and Astro-Geodetic Observatory at Jozefoslaw, Workshop of gravimetric departments of Middle-European countries, 26-27 June 2007, Prague, Czech Republic.
- KRYNSKI J., ROGOWSKI J.B., (2007): National Report of Poland to EUREF 2007, Report on the Symposium of the IAG Subcommission for Europe (EUREF) held in London, UK, 6–9 June 2007, EUREF Publication No 17, Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Frankfurt am Main (in print).
- KRYNSKI J., ROGOWSKI J.B., ZIELIŃSKI J.B., (2007): National Report of Poland to EUREF 2006, Report on the Symposium of the IAG Subcommission for Europe (EUREF)

held in Riga, Latvia, 14–17 June 2006, EUREF Publication No 16, Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Frankfurt am Main (in print).

- KUCHARSKI D., KIRCHNER G., SCHILLAK S., CRISTEA E., (2007): Spin determination of LAGEOS-1 from kHz laser observations, Advances in Space Research, Vol. 39, No 10, pp. 1576-1581.
- LEJBA P., SCHILLAK S., WNUK E., (2007): Determination of orbits and SLR stations' coordinates on the basis of laser observations of the satellites Starlette and Stella, Advances in Space Research, Vol. 40, No 1, pp. 143-149.
- LYSZKOWICZ A., KRYNSKI J., (2008): Improved astrogravimetric geoid in Poland, The 7<sup>th</sup> International Conference on "Environmental Engineering", 22–23 May 2008, Vilnius, Lithuania, pp. 1391–1400.
- OSZCZAK S., CIECKO A., (2006): Proposed Procedure of Validation and Certification of GNSS Instruments and Observers, 12<sup>th</sup> MARS-PAC Conference "Geographical information in support of the CAP", Toulouse, France, 27-29 November 2006, JRC Scientific and Technical Reports, EUR 22160 EN, 2007, pp. 13-15.
- OSZCZAK S., CIECKO A., JARMOLOWSKI W., (2007): Certification of GPS measurements: tests in Poland, 7<sup>th</sup> GPS Workshop, World Trade Centre in Rotterdam, The Netherlands, 25–27 April 2007, CD ROM proceedings.
- ROGOWSKI J.B., BOGUSZ J., FIGURSKI M., LIWOSZ T., KRUCZYK M., KUJAWA J., KLEK M., (2006): Current Activities of the Astro-Geodetic Observatory in Jozefoslaw, Reports on Geodesy, No 2(77), IG&GA WUT, pp. 39-46.
- ROHM W., BOSY J., (2007): The quality of meteorological observations and tropospheric delay from EPN/IGS permanent stations located in the Sudety Mountains and in the adjacent areas, Acta Geodynamica et Geomaterialia (formerly Acta Montana), Vol 4, No 4 (148), pp. 145-152.
- SCHILLAK S., (2007): Upgrading of the Borowiec SLR station in 2006/2007, Proceedings ILRS Fall 2007 Workshop, Grasse, 25-28 September 2007 (in print).
- SCHILLAK S., (2008): The comparison of the reference frames ITRF2000 and ITRF2005 in the determination SLR station positions and velocities, European Geosciences Union General Assembly 2008, Vienna, Austria, 13-18 April 2008 (submitted).
- SLEDZINSKI J., GRASZKA W., (2006): EUPOS a new European initiative, Reports on Geodesy, No 2(77), IG&GA WUT, pp. 29-38.
- WIELGOSZ P., KRANKOWSKI A., BARAN L.W., GREJNER-BRZEZINSKA D.A., (2007): Application of Predicted Ionosphere Model to Medium Range RTK Positioning: Performance Assessment, Proceedings of the ION GNSS 2007, 25-28 September, Fort Worth, Texas.
- WIELGOSZ P., KRANKOWSKI A., SIERADZKI R., (2008): Application of Predictive Regional Ionosphere Model to Medium Range RTK Positioning, Acta Geophysica (submitted).
- ZAKHARENKOVA I.E., SHAGIMURATOV I.I., KRANKOWSKI A., LAGOVSKY A.F., (2007a): Precursory phenomena observed in the total electron content measurements before great Hokkaido earthquake of September 25, 2003 (M = 8.3), Studia Geophysica et Geodaetica, Vol. 51, No 2, Springer Netherlands, pp. 267-278.
- ZAKHARENKOVA I.E., SHAGIMURATOV I.I., KRANKOWSKI A., (2007b): Features of the ionosphere behavior before the Kythira 2006 earthquake, Acta Geophysica, Vol. 55, No 4, pp. 524-534; doi. 10.2478/s11600-007-0031-5.