National Report of Poland to EUREF 2009

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1. Introduction

Since 2007 the main geodetic activities at the national level in Poland concentrated on 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, works towards monitoring troposphere, monitoring and modelling ionosphere, activities towards implementing the ASG-EUPOS network in Poland, further research and computational work on a centimetre quasigeoid model in Poland, activity within Galileo project, monitoring of Earth tides and non-tidal gravity variations, and activity in satellite laser ranging.

2. Maintenance of the national gravity control

The modernization on the Polish zero-order absolute gravity control has started in 2006 and was continued in 2007 (Kryński and Rogowski, 2008) and 2008 as an effort of the joint team of the Institute of Geodesy and Cartography, Warsaw, and the Warsaw University of Technology. It consists of three stages: 1st – densification of the absolute gravity network, 2nd – modernization of two gravimetric calibration baselines for relative measurements, 3rd – re-measurement of gravity at the remaining absolute gravity stations in Poland (Barlik and Krynski, 2007).

In 2007 seven new absolute gravity stations were established (Barlik et al., 2008a) – 5 of them as the part of the Central Gravimetric Calibration Baseline, while in 2008 – nine new absolute gravity stations (Barlik et al., 2009) of which six belongs to the Western Gravimetric Calibration Baseline that contains a newly established Vertical Gravimetric Calibration Baseline in Sudeten Mountains.

Absolute gravity has been surveyed by the team of the Warsaw University of Technology with the use of FG5 No 230 gravimeter with an error not exceeding 3 μGal (Pachuta et al., 2009). 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. All new absolute gravity points established 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.

Since September 2008 the Institute of Geodesy and Cartography uses its absolute ballistic A-10 No 20 portable gravimeter. First gravity absolute measurements at the Borowa Gora Geodetic-Geophysical Observatory (Fig. 1) show high quality of A-10 data and its potentiality for monitoring non-tidal gravity variations.

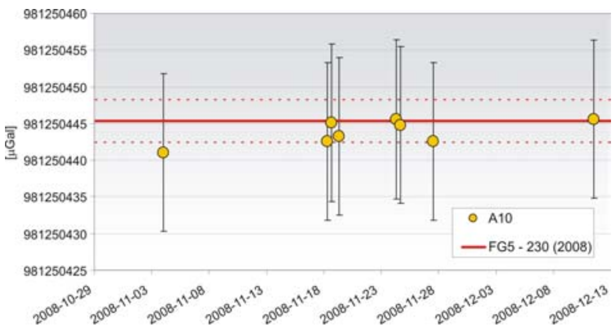

Fig. 1. Results of absolute gravity measurements with A-10 at Borowa Gora

The absolute gravimeter A-10 No 20 has also been successfully tested for field measurements and the mobile laboratory for absolute gravity survey has been set up.

Non-tidal gravity changes were further monitored at the Jozefoslaw Astrogeodetic Observatory of the Warsaw University of Technology (Barlik et al., 2006) as well as on four other absolute gravity stations: Borowiec (Borowiec Astrogeodynamic Observatory of the Polish Academy of Sciences), Giby (fundamental station of national gravity control), Lamkówko (Satellite Observatory of the University of Warmia and Mazury), Ojców (Seismic Observatory of the Polish Academy of Sciences) (Barlik et al., 2007). Obtained results in comparison with previous determinations indicate the decrease of gravity for about 15 μGal during 10 – 12 years (Barlik et al., 2008a, 2008b).

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3. Partcipation in IGS/EPN permanent GNSS networks

3.1. Operational work of permanent IGS/EPN stations

Permanent GNSS stations of IGS and EUREF Permanent Network (EPN) operate in Poland since 1993. Recently 17 permanent GNSS stations, i.e. Biala Podlaska (BPDL), Borowa Gora (BOGO, BOGI), Borowiec (BOR1), Bydgoszcz (BYDG), Gorzow Wielkopolski (GWWL), Jozefoslaw (JOZE, JOZ2), Krakow (KRAW), Lamkowko (LAMA), Lodz (LODZ), Katowice (KATO), Redzikowo REDZ (Suwalki (SWKI), Ustrzyki Dolne (USDL), Wroclaw (WROC) and Zywiec (ZYWI) (Fig. 2) 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; Krynski and Rogowski, 2008).

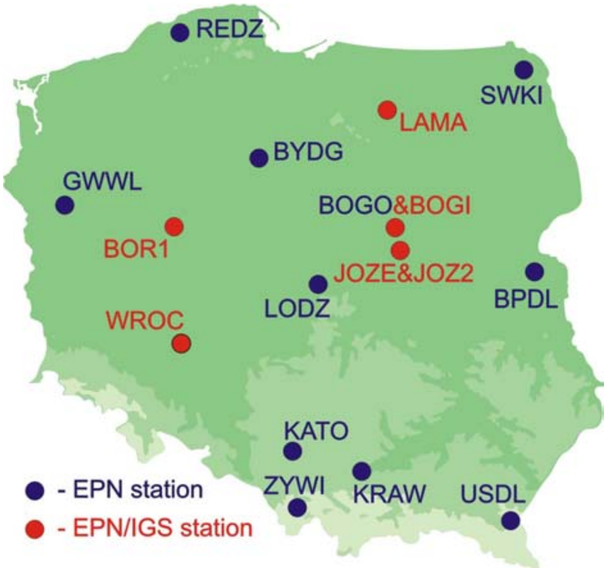

Fig. 2. EPN/IGS permanent GNSS stations in Poland (2009)

3.2. 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 at the WUT Local Analysis Centre of EUREF the data from 71 EPN stations vastly distributed all over the Europe, mostly in Central and Eastern Europe (Fig. 6)The Centre provides weekly and daily coordinates (SINEX format) and daily tropospheric solution (TRO-SINEX) (Rogowski et al. 2006). Actually new processing strategy using Bernese 5.0 is prepared for routine data processing (Figurski et al., 2008)

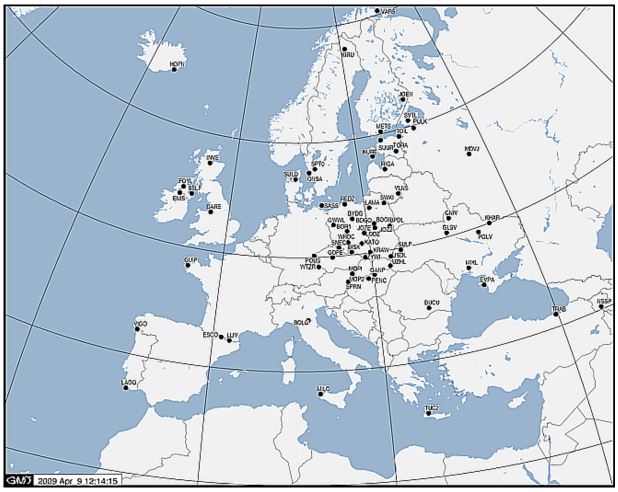

Fig. 3. EPN stations providing data processed at WUT EUREF LAC (2009)

3.3. Activity within the EUREF-IP Project

The EPN stations at Borowa Gora (BOGI), Borowiec (BOR), Jozefoslaw (JOZ2, JOZ3), Krakow (KRAW), Lamkowko (LAM5), Warszawa (WARS) and Wroclaw (WROC) take part in the EUREF-IP project (http://www.epncb.oma.be/_organisation/projects/euref_IP/index.php). Characteristics of the Polish stations participating in EUREF-IP project are presented in Table 2.

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.

Table 2. Polish stations participating in EUREF–IP project

Location	Station ID	Observations	Lat. [deg]	Long.[deg]	Receiver	RTCM type - message types (update rate [s])
Borowa Gora	BOGI	GPS+GLO	52.48	21.04	JPS Legacy	RTCM 2.1 - 3(10),18(1),19(1),22(10)
Borowiec	BOR1	GPS	52.28	17.07	Trimble NetRS	RTCM 2.3 - 1(1),3(10),18(1),19(1),22(10)
Jozefoslaw	JOZ2	GPS+GLO	52.02	21.03	Leica GRX1200GGPro	RTCM 3.0 - 1004(1),1006(60),1008(60),1012(1)
Jozefoslaw	JOZ3	GPS	52.02	21.03	Trimble 4000SSI-SS	RTCM 2.3 - 1(1),3(10),16(10),18(1),19(1),59(5)
Krakow	KRAW	GPS	50.01	19.92	Ashtech μZ-12	RTCM 2.2 - 1(1),3(60),16(60),18(1),19(1),22(60)
Lamkowko	LAM5	GPS	53.89	20.67	Ashtech Z-XII3	RTCM 2.1 - 1(1),3(60),6(3),18(3),19(3)
Warsaw	WARS	GPS+GLO	52.00	21.00	Leica GRX1200GGPro	RTCM 3.0 - 1004(1),1006(15),1008(15),1012(1)
Wrocław	WROC	GPS+GLO	51.11	17.06	Leica GRX1200GGPro	RTCM 3.0 - 1004(1),1006(15),1008(15),1012(1)

3.4. Other EPN and IGS activities

GNSS for meteorology

The team of the Warsaw University of Technology analysed ZTD estimation results as well as IPW time series derived from GPS solutions. A dramatic decrease of ZTD differences between individual LAC solutions in 2007 (solutions after GPS week 1400 showing best conformity since the year 2003) was observed (Fig. 4). The excellent conformity starting from the GPS week 1400 is most probably a cumulative effect of Bernese v.5.0 almost exclusive 'reign', absolute antenna PCVs and new reference frame ITRF2005/IGS05 (Kruczyk and Liwosz, 2008).

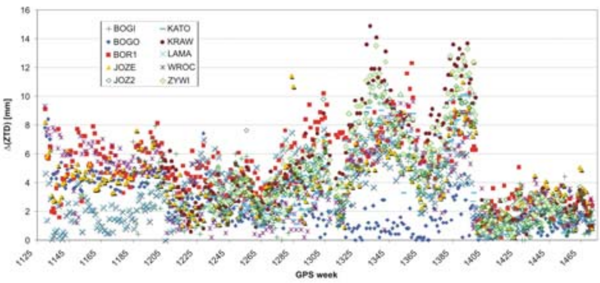

Fig. 4. ZTD weekly mean absolute differences:
EUR combined product - individual LAC
for all EPN stations in Poland

IPW values coming from GPS (different EPN solutions and combination) are reliable as compared with routinely derived water vapour data from radiosoundings, sun photometer (CIMEL, Central Geophysical Observatory PAS, Belsk), and input data of numerical prediction model (NWP) COSMO-LM (maintained by the Polish Institute of Meteorology and Water Management) (Fig. 5). Among three meteorological water vapour data sources the CIMEL sunphotometer data seems most genuine. It has been shown that NWP model (COSMO-LM) treated as meteorological database can provide ZTD and IWV for all stations independently from sparse RAOB network, however NWP topography is greatest concern for the proper ZTD derivation (Kruczyk, 2008).

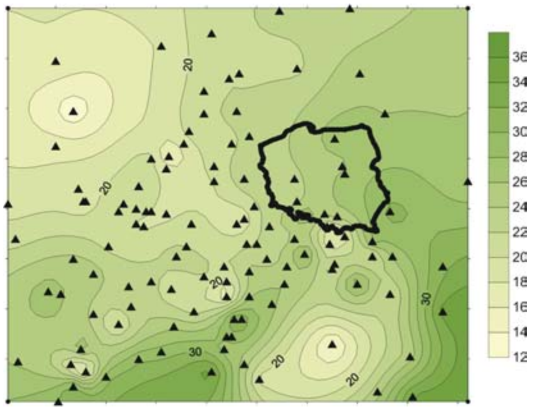

Fig. 5. ZTD differences RMS [mm] map in 2007
(EPN combined tropospheric product minus COSMO-LM
input fields derived ZTD)

Value of GPS IPW as a geophysical parameter has been demonstrated by finding clear physical effects depending on station location (e.g. height) and weather pattern. Especially intriguing are long series of IPW (daily averaged) which can serve as 'climatological' information. Figure 6 shows sinusoidal model adjusted to the IPW series (LS method) derived from IGS CODE ZTD solution for JOZE every year separately. Different are not only amplitudes but also phases. For 5 year period the IPW trend of +0.6 mm/year was obtained (Kruczyk, 2009).

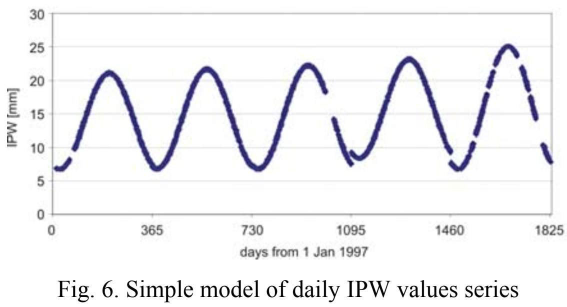

Fig. 6. Simple model of daily IPW values series
(sinusoid + constant) derived from IGS CODE ZTD solution
for JOZE 1997-2001

Monitoring ionosphere and ionospheric models

Study the ionosphere and its changes with the use of GNSS signals was continued in 2008 by the team of the Geodynamic Research Laboratory of the Institute of Geodesy of the University of Warmia and Mazury in Olsztyn in cooperation with a number of foreign research groups. The methodology for TEC changes monitoring with 5-minute temporal and 150-250 km spatial resolution during severe ionospheric storms was developed and new index describing ionospheric disturbances was introduced (Jakowski et al., 2008). Application of high resolution ionospheric TEC maps to studying the ionosphere during eclipses was investigated (Krankowski et al., 2008a). Also mid-latitude ionospheric trough over Europe was extensively studied (Krankowski et al., 2008b, Rothkaehl et al., 2008). Research on ionospheric precursors of the earthquakes was conducted (Zakharenkova et al., 2008). Also the application of several complementary observing techniques to improvement of the ionosphere models derived from satellite data was investigated (Rothkaehl et al., 2008).

Another research topic carried out by the same team included studies on the improvement of GNSS precise positioning. The development of the methodology algorithms for application of predicted, local ionosphere model to support RTK GNSS positioning over long ranges was conducted (Wielgosz et al., 2008). Another methodology developed concerned application of weighted ionospheric corrections for rapid-static GNSS positioning over long ranges (Kashani et al., 2008).

4. Status of ASG-EUPOS network

At the beginning of 2008 the ASG-EUPOS main infrastructure and software were installed and first testing procedures started. In June 2008 the system became entirely operational and the services were enabled to wide public.

Currently the system consists of three main segments: reference segment, management segment and users segment. The reference segment consists of 98 GNSS permanent reference stations located in Poland as well as 20 foreign stations that contribute to the ASG-EUPOS network on the basis of bilateral agreements within EUPOS countries (Fig. 7).

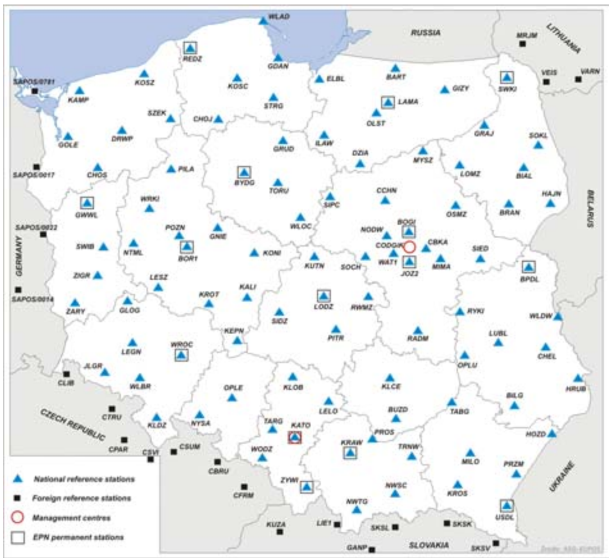

Fig. 7. Reference stations and management centres of the ASG-EUPOS system

The management segment of the system consists of two processing centres that operate simultaneously. In case of major malfunction in the active centre, a controlled script switches the services to the passive one. Such a solution is provided to ensure the highest availability and continuity of services. The services provided are divided into three groups: real-time positioning (NAWGEO, NAWGIS, KODGIS), post-processing data access (POZGEO, POZGEO D) and HelpDesk service as well.

In May 2008, 7 new Polish stations started their full operation in the EPN (BPDL, BYDG, GWWL, LODZ, REDZ, SWKI, USDL). This improved the distribution of EPN stations across Poland (Bosy et al., 2007) and enabled direct link between ASG-EUPOS and EPN station networks. The EPN network solutions are used in the ASG-EUPOS system to monitor the stability of the reference frame, realized by the ASG-EUPOS stations.

The ETRF2000 epoch 2005.0 datum has been used in Poland for permanent stations of the ASG-EUPOS network as the best realization of ETRF. The coordinates have been determined in a common adjustment for all ASG-EUPOS stations using the Bernese Software. The EPN stations: BOR1, WTZR, METS, POTS, ONSA were included into adjustment as reference points. The observations from December 2007 – February 2009 were used for calculations daily SINEX solutions. Final coordinates were determined with the use of CAREF software. The data was processed at the Military University of Technology in Warsaw within the cooperation with the Head Office of Geodesy and Cartography. The coordinates of the stations are being continuously monitored.

The official coordinates of EPN stations in Poland were compared with the coordinates published by EUREF in December 2008 (Table 3). Due to short period of permanent observations the coordinates of some stations could not been determined as the EPN solutions. Taking into account the differences of reference epochs, the EUREF coordinates were calculated for the epoch 2005 using published velocities.

In order to improve the atmospheric modeling in rapid solutions, the above mentioned – among the total of 14 – permanent stations were equipped with the newest meteorological probes (Paroscientific MET-4A). Unfortunately problems with data collection and transfer postponed the inclusion of meteorological observations from those stations to the EPN.

While ASG-EUPOS system has been established to provide the uniform realization of the reference frame across the territory of Poland, it was necessary to link its reference stations to the ground control and create one framework. The first stage of calibration campaign linking those networks was conducted in April 2008. Although it proved high accuracy of ground control, it also triggered the discussion on the preferred realization of ETRS89 in Poland (currently it is EUREF89). Additional surveys are needed for the solution to be pointed out.

Table 3. ETRF 2000 PL solutions for the epoch 2005.0 and their differences with EUREF-PL

Station ID	PL solution ETRF2000 (epoch 2005.0) [m]			EUREF solution (Dec. 2008) ETRF2000 (epoch 2005.0) calculated using velocities [m]			EUREF – PL ETRF2000 (epoch 2005.0) [m]		
	X	*Y*	*Z*	*X*	*Y*	*Z*	*dX*	*dY*	*dZ*
BOGI	3633815.680	1397453.920	5035280.800	3633815.675	1397453.921	5035280.793	–0.005	0.001	–0.008
BOGO	3633739.307	1397433.931	5035353.286	3633739.307	1397433.931	5035353.284	–0.001	0.000	–0.002
BOR1	3738358.775	1148173.501	5021815.579	3738358.778	1148173.504	5021815.586	0.003	0.002	0.007
BPDL	3615990.141	1544390.857	5005373.519						
BYDG	3647217.195	1184604.086	5079624.975						
GWWL	3734526.173	1015012.795	5053042.551						
JOZ2	3664880.908	1409190.383	5009618.280	3664880.901	1409190.390	5009618.273	–0.007	0.007	–0.007
KATO	3862992.378	1332822.661	4881105.459	3862992.363	1332822.660	4881105.450	–0.015	–0.001	–0.010
KRAW	3856936.166	1397750.473	4867719.440	3856936.159	1397750.474	4867719.434	–0.008	0.001	–0.006
LAMA	3524523.257	1329693.429	5129846.164	3524523.260	1329693.435	5129846.166	0.002	0.005	0.002
LODZ	3728601.881	1317402.261	4987811.131						
REDZ	3550066.919	1093331.791	5167561.947						
SWKI	3452304.864	1460314.595	5143362.416						
USDL	3837558.220	1596303.040	4822409.632						
WROC	3835751.627	1177249.747	4941605.053	3835751.618	1177249.745	4941605.049	–0.010	–0.002	–0.004
ZYWI	3904633.328	1360191.886	4840630.785	3904633.312	1360191.884	4840630.775	–0.016	–0.002	–0.010

At the end of 2008 the user segment of the ASG-EUPOS system consisted of 2820 registered users (Oruba et al., 2009), and the number of users is continuously growing (Fig. 8). This proved how demanded the system was in Poland.

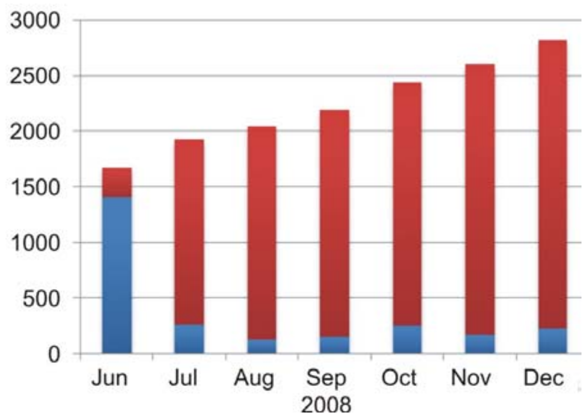

Fig. 8. The number of ASG-EUPOS registered users in 2008 (blue bars indicate new users in a specific month)

Among the real-time services the most popular one is definitely NAWGEO – an RTK service for highest precision real-time measurements, used mainly by surveyors in the field (Fig. 9). It has been observed that approximately over one thousand connections to the NAWGEO service is being done every day. Additionally, approximately 30 RINEX data files are being submitted each day for automated processing in the POZGEO service.

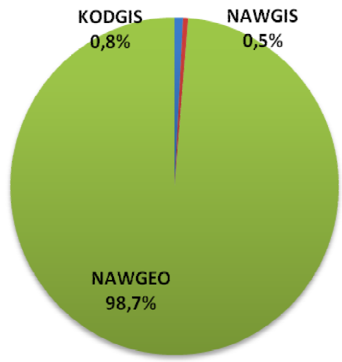

Fig. 9. The percentage of real-time services usage of the ASG-EUPOS system

The system is being used mostly where construction of roads and railways takes place and also in large municipalities. Approximate coordinates of users were the basis for creating a map of system usage in its first operational year (Fig. 10).

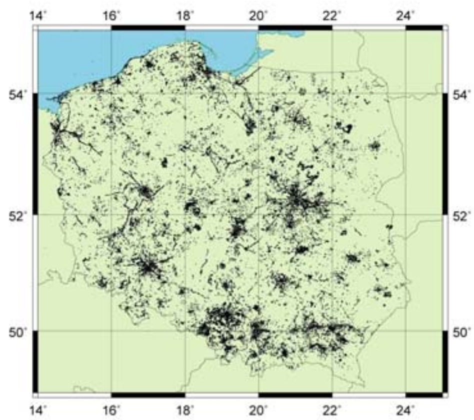

Fig. 10. The map of the usage of real-time services of the ASG-EUPOS system in 2008

In the period 2009-2011 the ASG-EUPOS system will be modernized and receivers installed on adapted stations are going to be exchanged to modern one. Also some trainings and workshops for the ASG-EUPOS services users are to be organized.

5. Modelling precise geoid for Poland

Research initiated in the framework of the project on the cm geoid in Poland (Krynski and Rogowski, 2007) conducted in 2002-2005 has been continued. A suitable methodology of combined use of gravity data with the deflections of the vertical for quasigeoid modelling was developed. Gravity data and deflections of the vertical were used to calculate combined quasigeoid model with the use of least squares collocation. That model was first compared with astrogeodetic and astrogravimetric geoid models developed with both astrogeodetic levelling and least squares collocation (Lyszkowicz and Krynski, 2008) an then with pure gravimetric quasigeoid model developed also with least squares collocation. The results obtained show the improvement of pure gravimetric quasigeoid model by simultaneous use of deflections of the vertical with gravity data for modelling quasigeoid (Lyszkowicz et al., 2009).

The effect of uncertainty in height and position of gravity points as well as uncertainty of digital terrain model on the accuracy of computed terrain corrections was extensively investigated. Analytical formulae for the respective error propagation were developed and they were supported, when needed, by numerical evaluations. Propagation of height data errors on calculated terrain corrections was independently conducted purely numerically. Numerical calculations were performed with the use of data from gravity database for Poland and digital terrain models DTED2 and SRTM3. The results obtained using analytical estimation are compatible with the respective ones obtained using pure numerical estimation. The estimated accuracy of terrain corrections computed using height data available for Poland is sufficient to model gravimetric geoid with a centimetre accuracy (Szelachowska and Krynski, 2009).

6. Activities in Galileo project

In the Space Research Centre PAS the EGNOS Ranging and Integrity Monitoring Station (RIMS) abbreviated with WRS has been upgraded and accepted to the operational network of the EGNOS system. Parallel to RIMS the EGNOS Real Time Performance stations is operating allowing to assess the availability, accuracy and other parameters of EGNOS over Europe.

In March 2009 in the same location the new station has been established for signal monitoring of Galileo satellites (Fig. 11). It is an element of the global Galileo ground control network. This station GESS+ is devoted to experimentation with Giove A and B satellites and later on for the Galileo In Orbit Validation Phase. The station will become operational in May 2009.

Fig. 11. GESS+ in Warsaw - station of the global Galileo ground control network

7. Earth tides monitoring

Earth tides are monitored in the Astrogeodetic Observatory of the Warsaw University of Technology in Jozefoslaw using L&R ET-26 gravimeter since January 2002. Tidal record was used to create new model of the gravimetric Earth tides for Jozefoslaw Observatory with accuracy of 3.2 nm/s^2. The data acquired is analysed with one year spacing and the results are sent to the International Centre for Earth Tides. To obtain more reliable Earth tides model many environmental effects like ocean, atmosphere and ground water level tides, influence of soil moisture changes, rainfalls and snowfalls should be taken into consideration. Monitoring of those effects started in 2004 and were continued in 2008 (Bogusz, 2008). In 2008 the calibration factor of L&R ET-26 was determined using absolute gravity measurements with FG5-230 (Bogusz and Klek, 2008b, 2008c). The theoretical studies on the modulation of the tidal waves confirmed the annual periodicity changes of the amplitude and phase of particular tidal waves (Bogusz and Klek, 2008a). 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, 2008).

The Geodynamic Laboratory of Space Research Centre PAS in Ksiaz in Sudeten Mountains operates since 1974. Primarily there were installed quartz horizontal pendulums equipped with photographic system of registration that was later replaced with electronic registration. In 2002 in the Laboratory there were built two long water-tube tiltmeters consisting of perpendicular tubes 65 and 83 m long, partially filled with water (Kaczorowski, 2006a). In 2007 the laboratory equipment was extended LC&R G-648 gravimeter of tidal resolution for future investigation of Love's numbers *h* and *k* for Sudeten Mountain area.

Investigations of systematic and long periodic plumbline variations are conducted (Kaczorowski, 2007, 2008) (Fig. 12).

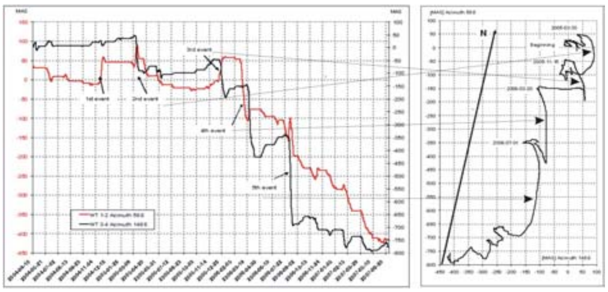

Fig. 12. Non-tidal signal observed by long water-tube tiltmeter in period 2004-2007

Short period (non-tidal) plumbline variations associated with phenomenon of the Earth free oscillations are also investigated (Kaczorowski, 2006b) (Fig. 13).

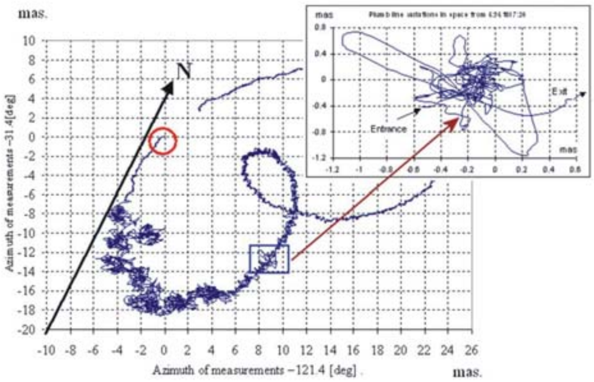

Fig. 13. Plumbline variations from long water-tube measurements in 26 December 2004

8. Activity in Satellite Laser Ranging

In 2008 the Satellite Laser Ranging station at Borowiec (7811) in the framework of the International Laser Ranging Service (ILRS) and EUROLAS Consortium performed 208 successful passes (81428 normal points) of 16 SLR satellites with the mean normal point precision of all passes at a level of 3 mm and accuracy of 20 mm. The results of observations were transferred in the near real time to EUROLAS Data Center and Crustal Dynamics Data Information System NASA. The data of the Borowiec SLR station supported research programs of the observed satellites and was used for orbits calculations by ESA, NASA and many other institutions and international organizations.

The activity of the Borowiec SLR station was limited in 2008 due to significant modernization of hardware and software of the SLR system. The modernization included the following tasks (Schillak et al., 2008): installation of the Microchannel Plate Photomultiplier Tube HAMAMATSU R5916U-64-3MCP with photocathode gating system, tests of the new MCP-PMT, adjustment of the constant fraction discriminator TENNELEC TC-454, formatting of the triggering pulse of the epoch registration, tests of the two transmitting telescopes, determination of the telescope model errors, installation of the Event Timer A032-ET with the software, and introduction of new procedures in the software of the main control program.

The orbital analysis group of the Borowiec SLR station realized in 2008 several tasks. First one was the comparison of the station positions and velocities determined in the period 1993.0-2004.0 by two satellite techniques: GPS and SLR. The calculations were performed for first day of each month in ITRF2005. The results show a good agreement of positions (several mm) and velocities (below 1 mm/year) for both satellite techniques for the most stations. The significant differences (2-3 cm) were detected in the vertical component for several stations (Schillak and Lehmann, 2008a, 2008b). The determination of the SLR station positions and velocities from low satellites Starlette, Stella and Ajisai as well as the determination of coordinates of the satellites CHAMP and Larets were continued. The significant disturbances on the quality of the satellite positions are from Earth gravity field model, atmospheric drag and the frequency of determination of empirical accelerations. The satellites RMS of fit was in the range from 1 cm to 6 cm, depending on the satellite, and the station stabilities were on the level 1-2 cm (Lejba and Schillak, 2008).

References

ARASZKIEWICZ A., BOGUSZ J., (2008): *Tidal parameters evaluation using Wavelet Transform*, Proceedings of the Seminar „Studies of the Earth Crust Deformation in Central Europe", 29-30 September 2008, Jozefoslaw, Reports on Geodesy No 2 (85), pp. 95-104.

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., KRYŃSKI J., (2008a): *Monitoring of the gravity variations using geodetic methods.* Seminar: *Geodynamical investigations in Middle Europe Countries,* Jozefoslaw, 29 – 30 September 2008.

BARLIK M., OLSZAK T., PACHUTA A., (2008b): *Monitoring of the long-standing gravity absolute changes in Józefosław Observatory and on the main tectonic units of the Poland territory*, EGU General Assembly, 19 – 25 April, 2008, Vienna, Austria.

BARLIK M., OLSZAK T., PACHUTA A., (2007): *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., PRÓCHNIEWICZ D., WALO J., SZPUNAR R., (2008a): *Modernization of absolute gravity zero order network in Poland – first stage,* General Assembly of the European Geosciences Union, 18 – 23 April 2008, Vienna, Austria.

BARLIK M., OLSZAK T., PACHUTA A., PRÓCHNIEWICZ D., SZPUNAR R., WALO J., (2009): *Modernization of the gravimetric absolute points net in Poland* (in Polish), IX Technical Conference "Recent problems of applied geodesy", Warsaw, 27 March 2009.

BARLIK M., PACHUTA A., OLSZAK T., (2006): *Monitoring of non-tidal gravity changes at the Astro-Geodetic Observatory in Jozefoslaw,* Geodetic Week, 2006, Munich, Germany.

BOGUSZ J., (2008): *Tidal Observations in Astro-Geodetic Observatory in Jozefoslaw*, Proceedings of the EGU General Assembly 2008 session G10 "Geodetic and Geodynamic Programmes of the CEI", Vienna, Austria, 13 – 18 April 2008, Reports on Geodesy No 1(84), pp. 61-68.

BOGUSZ J., KLEK M., (2008a): *Seasonal Modulation of the Tidal Waves*, Proceedings of the EGU General Assembly 2008 session G10 "Geodetic and Geodynamic Programmes of the CEI", Vienna, Austria, 13 – 18 April 2008, Reports on Geodesy No 1(84), pp. 79-86.

BOGUSZ J., KLEK M., (2008b): *Calibration of Spring Gravimeter ET-26 Using Absolute Gravity Measurements*, Proceedings of the EGU General Assembly 2008 session G10 "Geodetic and Geodynamic Programmes of the CEI", Vienna, Austria, 13 – 18 April 2008, Reports on Geodesy No 1(84), pp. 111-118.

BOGUSZ J., KLEK M., (2008c): *Application of the AG measurements to the tidal gravimeter calibration*, Proceedings of the Seminar „Studies of the Earth Crust Deformation in Central Europe", 29-30 September 2008, Jozefoslaw, Reports on Geodesy No 2 (85), pp. 87-94.

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.

FIGURSKI M., KAMINSKI P., KENYERES A., (2009): *Preliminary results of the complete EPN reprocessing computed by the MUT EPN Local Analysis Centre*; Bulletin of Geodesy and Geomatics (in print).

JAKOWSKI N., MIELICH J., BORRIES C., CANDER L., KRANKOWSKI A., NAVA B., STANKOV S.M., (2008): *Large scale ionospheric gradients over Europe observed in October 2003*, Journal of Atmospheric and Solar-Terrestrial Physics, doi: 10.1016/j.jastp.2008.03.020 (in print).

KACZOROWSKI M., (2006a): *High-Resolution Wide-Range Tiltmeter: Observations of Earth Free Oscillations Excited by the 26 December 2004 Sumatra –Andaman Earthquake*, Monograph: - Earthquake Source Asymmetry, Structural Media and Rotation Effects, Springer-Verlag, Berlin Heidelberg, pp. 493-520.

KACZOROWSKI M., (2006b): *Earth free oscillations observed in plumb line variations from the 26 December 2004 earthquake*, Acta Geodynamica et Geomaterialia, Vol.3, No 3(143), pp. 79-84.

KACZOROWSKI M., (2007): *Preliminary investigations of long lasting non-tidal signals observed by horizontal pendulums and long water tube tiltmeters in Low Silesian Geodynamic Laboratory of PAS in Ksiaz*, Acta Geodynamica et Geomaterialia, Vol. 4, No 4(148), pp. 1-11.

KACZOROWSKI M., (2008): *Non tidal plumb line variations observed with help of the long water-tube and horizontal pendulums tiltmeters in Geodynamic Laboratory of PAS in Ksiaz*, Proceedings of the Seminar "Studies on Earth crust deformations in Central Europe", Jozefoslaw, 29-30 September 2008, Reports on Geodesy, No 2(85), pp. 79-86.

KASHANI I., WIELGOSZ P., GREJNER-BRZEZINSKA D.A., MADER G.L., (2008), *A New Network-Based Rapid-Static Module for the NGS Online Positioning User Service - OPUS-RS*, Navigation (in print).

KRANKOWSKI A., SHAGIMURATOV I.I., BARAN L.W., YAKIMOVA G.A, (2008a): *The occurrence of total solar eclipse on October 3, 2005 in TEC over Europe,* Advances in Space Research, Vol. 41, No 4, pp. 628-638, doi: 10.1016/j.asr.2007.11.002.

KRANKOWSKI A., SHAGIMURATOV I.I., EPHISHOV I.I., KRYPIAK-GREGORCZYK A., YAKIMOVA G., (2008b): *The occurrence of the mid-latitude ionospheric trough in GPS-TEC measurements,* Advances in Space Research (in print).

KRUCZYK M., (2008): *Tropospheric Delay in GNSS and Meteorological ZTD and IPW Data Sources*, Proceedings of the Seminar "Studies of the Earth Crust Deformation in Central Europe", Jozefoslaw, 29-30 September 2008, Reports on Geodesy, No 2(85), pp. 125-137.

KRUCZYK M., (2009): *Tropospheric delay EPN products and meteorological ZTD and IPW data sources - conformity study*, Report on the Symposium of the IAG Subcommission for Europe (EUREF) held in Brussels, Belgium, 18–20 June 2008, EUREF Publication No 18, Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Frankfurt am Main (in print).

KRUCZYK M., LIWOSZ T., (2008): *Troposheric Delay EPN products verified by various ZTD and IPW data sources*, 6th EUREF LAC Workshop, Frankfurt Main, Germany, 22-23 October 2008.

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., (2008): *National Report of Poland to EUREF 2008*, Report on the Symposium of the IAG Subcommission for Europe (EUREF) held in Brussels, Belgium, 18–20 June 2008, EUREF Publication No 18, Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Frankfurt am Main (in print).

LEJBA P., SCHILLAK S., (2008): *Determination of the SLR station coordinates and velocities on the basis of laser observations of low satellites,* Proc. 16th International Workshop on Laser Ranging, Poznan, 13-17 October 2008 (in print).

LYSZKOWICZ A., KRYNSKI J., (2008): *Improved astro-gravimetric geoid in Poland*, The 7th International Conference on "Environmental Engineering", 22–23 May 2008, Vilnius, Lithuania, pp. 1391–1400.

LYSZKOWICZ A., KRYNSKI J., KLOCH-GLOWKA G., (2009): *Improvement of gravimetric quasigeoid model in Poland by the use of deflections of the vertical*, IAG Scientific Assembly Symposium 2009 „Geodesy for Planet Earth", Buenos Aires, Argentina, 31 August – 4 September 2009.

ORUBA A., LEONCZYK M., RYCZYWOLSKI M., WAJDA S., (2009): *ASG-EUPOS after one year*, Geodeta, Geoinformational Magazine, No 4 (167), April 2009, pp. 10-14.

PACHUTA A., BARLIK M., OLSZAK T., PRÓCHNIEWICZ D., SZPUNAR R., WALO J., (2009): *Absolute gravity measurements in Poland* (in Polish), Miżdunarodnaja naukovo - tiechniczna konferencija – GEOFORUM, 23–25 April 2009, Lviv, Ukraine.

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.

ROTHKAEHL H., KRANKOWSKI A., STANISLAWSKA I., BŁĘCKI J., PARROT M., BERTHELIER J-J., LEBRETON J-P., (2008): *HF wave measurements and GPS diagnostic of main ionospheric trough as a hybrid method used for Space Weather purposes*, Annales Geophysicae, Vol. 26, pp. 295-304.

SCHILLAK S., BARTOSZAK J., MICHAŁEK P., (2008): *The upgrading of the Borowiec SLR station,* Proc. 16th International Workshop on Laser Ranging, Poznań, 13-17 October 2008 (in print).

SCHILLAK S., LEHMANN M., (2008a): *Determination of the station positions and velocities in the Central Europe area by Satellite Laser Ranging and GPS*, Seminar "Studies of the Earth's Crust Deformation in Central Europe", Józefosław, 29-30 September 2008 (CD).

SCHILLAK S., LEHMANN M., (2008b): *The comparison of the station coordinates between SLR and GPS*, Proc. 16th International Workshop on Laser Ranging, Poznań, 13-17 October 2008 (in print).

SZELACHOWSKA M., KRYNSKI J., (2009): *The effect of the quality of height data on the accuracy of terrain corrections*, IAG Scientific Assembly Symposium 2009 „Geodesy for Planet Earth", Buenos Aires, Argentina, 31 August – 4 September 2009.

WIELGOSZ P., KRANKOWSKI A., SIERADZKI R., GREJNER-BRZEZINSKA D.A., (2008): *Application of Predictive Regional Ionosphere Model to Medium Range RTK Positioning*, Acta Geophysica, Vol. 56, No 4, pp. 1147-1161.

ZAKHARENKOVA I.E., SHAGIMURATOV I.I., TEPENITZINA N.YU., KRANKOWSKI A., (2008): *Anomalous modification of the ionospheric total electron content prior to the 26 September 2005 Peru earthquake*, Journal of Atmospheric and Solar-Terrestrial Physics, doi:10.1016/j.jastp.2008.06.003 (in print).