

FIFTY YEARS OF OBSERVATION ACTIVITIES AT ASTRO–GEODETIC OBSERVATORY IN JÓZEFOSŁAW

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1. INTRODUCTION

The Astro–Geodetic Observatory in Józefosław of the Department of Geodesy and Geodetic Astronomy of the Warsaw University of Technology has been participating in international programs involving the tracking of global geodynamic phenomena since 1958. The first major international program in which the Observatory took part was International Longitude Operation, organized within the framework of the International Geophysical Year (IGY). Observations of latitude variations carry on to define polar motion started in 1959. Satellite, gravimetric, metrological, and hydro–geological observations were successively started up. Scientific research carried out at the Observatory is mainly tied with matters of global and regional geodynamics as well as the implementation of reference systems. Significant events from the Observatory’s history are presented in the next section of this article.



Fig. 1. Professor Felicjan Kępiński.

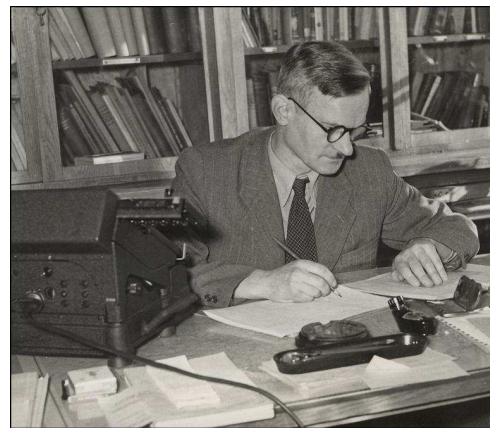


Fig. 2. Professor Wiesław Opalski.

2. CALENDARIUM

- 1949 The transfer of land that was to become the site of the Observatory to the Department of Geodesy and Cartography by Professor Edward Warchałowski, Rector of the Warsaw University of Technology.
- 1953–1955 Professor Felicjan Kępiński (Figure No. 1), then Head of the Chair of Geodetic Astronomy, ordered astrometric instruments from Carl Zeiss Jena and commenced the building of pavilions for astrometric observations.
- 1955 Professor Wiesław Opalski became the Head of the Chair of Geodetic Astronomy (Figure No. 2).



Fig. 3. The first Observatory building.

- 1956 Professor Wiesław Opalski adapted an existing single-story building for the needs of the Observatory (Figure No. 3).
- 1956 Construction of a transit instrument pavilion was started.
- 1957 A Zeiss zenith telescope was ordered (observations were commenced in 1959).
- 1957 Earth Artificial Satellite Observatory No. 1160 was registered (AT-1 telescopes).
- 1958 The Observatory took part in International Longitude Operation, organized within the framework of the International Geophysical Year.
- 1959–1997 Observations of latitude variations using the Zeiss zenith telescope were carried out.
- 1960–1964 Observations defining UT1 time using the Zeiss transit instrument were carried out.
- 1966–1970 Photographic observations of artificial Earth satellites were carried out.
- 1970 The merging of the chairs of Geodetic Astronomy, Geodesy and Geodetic Computation into the Institute of Geodesy and Geodetic Astronomy.



Fig. 4. The second Observatory building.

- 1976 Construction of a “Stolbud” pavilion (Figure No. 4).
1976 A gravimetric base with a length of 30 km was established on the Observatory’s meridian.
1983 The Polish-made DOG-3 Doppler receiver was bought, participation in the WEDOC II and FINPOLDOC campaigns.
1991 Trimble 4000 SE GPS receiver was bought.
1991 Commencement of permanent GPS observations at Józefosław.
1992 Incorporation of the Observatory into the International GPS Service for Geodynamics and participation in the epoch IGS campaign.
1993 Beginning of permanent observations within the framework of IGS.
1993 Startup of successive laboratories:
• Absolute Gravimetric Measurements Laboratory,
• Tidal Laboratory, conducting continuous observations.
1994 Startup of the Observatory’s meteorological services.
1995 Józefosław Observatory is approved as one of the stations defining the European Reference System—EUREF.
1996 Operations of the Local Analysis Center of the Warsaw University of Technology (WUT LAC) was start up as an integral part of the Observatory.
1998 Beginning of the implementation of the European UNIGRACE project.
1998 Beginning of construction of a new building.



Fig. 5. The newest Observatory building.

- 2002 The official opening of the Observatory's new building (Figure No. 5).
- 2001 The Observatory start up real-time GPS data transmission for DGPS and RTK users using radio as well as the Internet and the cellular phone network.
- 2001 The Observatory is equipped in:
 - Two new receivers, Trimble for the JOZ3 station and Ashtech for the JOZ2 station (GPS/GLONASS),
 - High accuracy spring static instrument for the Gravimetric Laboratory, for gravimetric measurements of Earth tides - LaCoste & Romberg model ET-26 gravimeter,
 - The automatic meteorological station for the Meteorological Laboratory.
- 2002 The organizing of the first scientific conference in the new Observatory building—a seminar entitled “Satellite Methods for Specifying Position in Contemporary Geodesy and Navigation.”
- 2002 Beginning of continuous transmission of data in RTCM format through the Internet (an EUREF IP project).
- 2005 Procurement of an FG5 No. 230 absolute ballistic gravimeter was bought.
- 2005 The signing of an agreement with the Chief Office of Geodesy and Cartography (GUGiK) on establishing a Polish Nationwide ASG-PL Active Geodetic Network Management Center.
- 2007 Installation of a HP computer cluster in the Observatory.
- 2008 Establishment of the Department of Geodesy and Geodetic Astronomy, start of a successive Leica 1200 GRX receiver.

3. ASTROMETRIC OBSERVATIONS FOR DETERMINATIONS OF LATITUDE VARIATIONS AND UNIVERSAL TIME CHANGES

The Astro-Geodetic Observatory of the Warsaw University of Technology in Józefosław began international scientific activities by astrometric observations with Zeiss transit instrument in 1958 and a Zeiss zenith telescope in 1959. The Observatory took part in the International Operation Longitude, a part of the International Geophysical Year—1958. Next, over the four year period determination of changes of universal time (UT) by the use of Zeiss transit instrument was carried out in collaboration with Bureau Internationale de l'Heure in Paris. Started in 1959 observations latitude variations using the Horrebow-Talcott method with Zeiss telescope. The twelve group program including seventy-two star pairs was worked out using the International Latitude Service (ILS) program as a model. Observations of latitude variations were conducted up to 1999. The observation program was modified twice due to the astronomical precession.

Table No. 1 presents observation periods within the framework of successive programs as well as observation statistics.

Table 1. Statistical observation data at Józefosław in 1958-1997 (Kruczyk et al., 1999).

Program / Catalogue	Number of Nights	Number of Groups	Number of Pairs
Program I (1961–1975)/GC	838	1685	8599
Program II (1972–1984)/Yale	693	1518	6989
Program III (1982–1996)/AGK-3	780	1498	6798
Total	2311	4701	22386

Participants in the observations were: L. Cichowicz, B. Kołaczek, W. Opalski, K. Łatka, T. Chojnicki, L. Pieczyński, M. Dukwicz-Łatka, J. Zieliński, W. Pachelski, J. Bieniewski, S. Domaradzki, H. Bieniewska, I. Gajderowicz, J. Cisak, J. B. Rogowski, B. Chmielewska, A. Wódkiewicz, R. Galas, K. Borkowski, J. Serkuczewski, L. Kujawa.

Observation results were published on a running basis in the “Latitude Circular.” Observations of latitude variations at Józefosław were conducted within the framework of international collaboration with the Bureau Internationale l’Heure (BIH) and the International Polar Motion Service (IPMS). Twenty–nine stations took part in this cooperative in 1963 and fifty–three stations in 1979. After the reorganization of these services, collaboration was continued with the International Earth Rotation Service (IERS).

Following the development of a precise Hipparcos Catalogue with the coordinates and proper motions of all stars for the 1991.25 epoch with a star position accuracy of 0.001”, the observation data was reprocessed in the Hipparcos reference frame taking into account new models for precession, nutation and aberration. This uniform study was conducted in collaboration with Dr. J. Vondrak and C. Ron of the Institute of Astronomy of the Czech Academy of Sciences, who conducted a uniform elaboration of observations of changes in latitude variations for thirty–three stations in the period 1899-1996, including Józefosław, in the frame of the Hipparcos reference frame (Vondrak et al., 1997).

Figure No. 6 presents normal points of the latitude change curve for Józefosław applying the Hipparcos reference frame (Kruczyk et al., 1999).

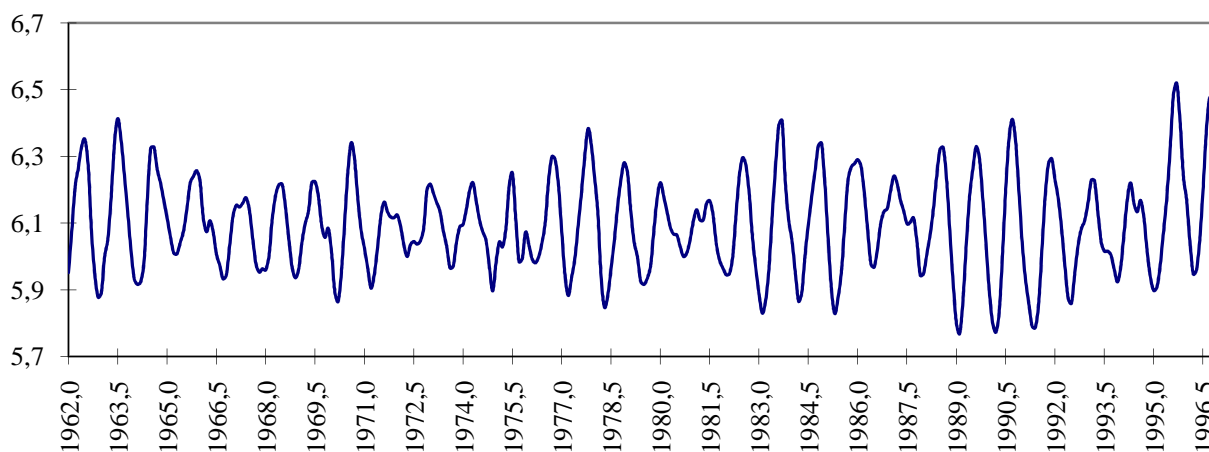


Fig. 6. Normal point of the latitude variations curve for Józefosław [“].

Figure No. 7 presents changes of the mean latitude for Józefosław applying the Hipparcos reference frame (Kruczyk et al., 1999).

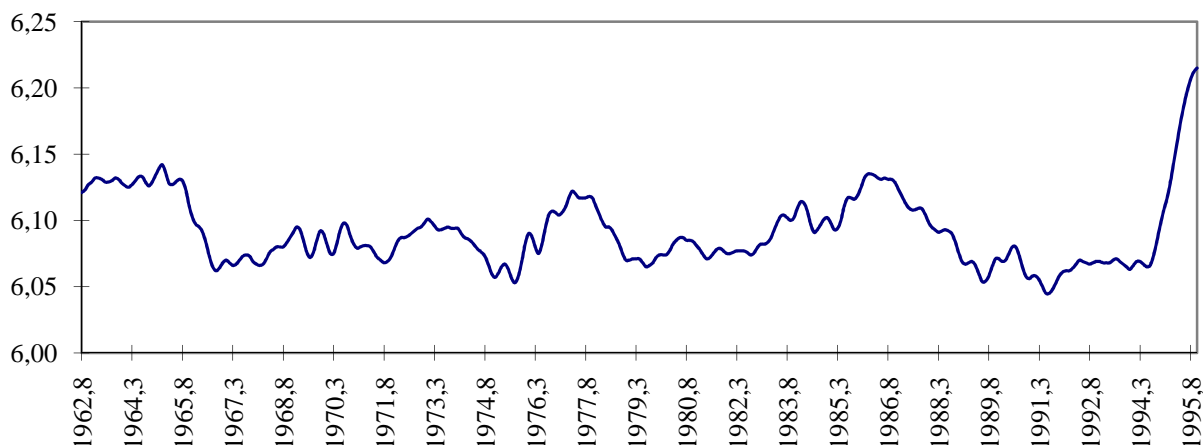


Fig. 7. Variations of the mean latitude of Józefosław in the Hipparcos reference system [“].

4. SATELLITE MEASUREMENTS

The No. 1160 Earth Artificial Satellite Observation Station was registered in Józefosław immediately after the launching of the first artificial Earth satellite in 1957. Observations were carried out using AT-1 telescopes. However, it was not until 1966 that observations for geodetic purposes using a NAFA-25C photographic camera were started.

In light of the low accuracy of these observations, they were given up in 1970. A TRANSIT system Doppler receiver for satellite observations was purchased in 1983. The Observatory took part in the WEDOC II and FINPOLDOC campaigns.

The Observatory took part of the International GNSS Service (IGS) in 1991. It achieved the status of a permanent fiducial station in 1993 and that of a global station in 1995. Starting with 1996, the Observatory has been operating as one of the continuous observation points of the EUREF Permanent Network (EPN) which define the European Reference System. Currently, observations are being conducted at three observation stations—JOZE, using a TRIMBLE 4000 SSE receiver (continuously starting with 1993), JOZ2, using a GPS/GLONASS Leica 1300 receiver, and JOZ3, using a TRIMBLE 4000 Corsstation receiver (GPS receiver). Data from the JOZE and JOZ2 stations are sent every hour and every twenty-four hours to the IGS and EPN data centers in Frankfurt am Main (Germany) and Graz (Austria). Two stations—JOZ2 and JOZ3—are participants in the IGS and EPN projects and generate continuous data streams for individual RTK technique users. These projects are known as IGS IP and EUREF IP (IP – Internet protocol) and are accessible through the Internet using cellular telephony and GPRS, UMTS, and EDGE transmissions. Following modernization of the JOZ3 station through the installation of a Leica GRX1200 Pro receiver, all three stations will operate in hourly, daily, and RTCM format continuous stream data transmission modes.

Major organizational changes in the functioning of GPS measurements were conducted in 2007. A new dual-system Leica GRX1200 Pro (14 GPS and 12 Glonass channels), inclusive of antenna and multitasking Leica Spider software were purchased as a replacement for the breakdown-prone Ashtech Z-18 at JOZ2. Specialized HP ProLiant 380 G5 servers were installed as a replacement for the set of several PCs being used. In order for servers operating under Linux to be able to use Leica and Trimble proprietary software servicing the permanent station, it was necessary to set up virtual machine software and install the Windows XP Professional operating system with Spider software on top of it.

This involved several major questions relating to selection of an appropriate virtual machine that would be capable of guaranteeing stable operation in such a multilayered software system. Ultimately, a VirtualBox machine (as opposed to VMWare) tested positive and after several months of operational testing the new receiver was made a part of the EPN in March of 2008. It should be stressed that the solution applied is very novel (and as far as we know, without precedent in the EPN). Meteorological observations in RINEX Meteo format are added to the GNSS observations.

Participants in the observations were: K. Łatka, J. Bieniewski, J. B. Rogowski, K. Czarnecki, L. Kujawa, M. Piraszewski, W. Kurka, M. Kruczyk.

5. GNSS DATA PROCESSING

The GNSS Analysis Center has been active within the Warsaw University of Technology since the mid-nineties. The Local EPN Analysis Center is a part of it (operating since January 1, 1996). Initially, it operated within the Institute of Geodesy and Geodetic Astronomy starting with 1995. The main task of the Center is to provide EUREF processing services—the collection, analysis, and archiving of observations from GPS/GLONASS data centers. It is within the framework of EUREF sub-network analysis that data from 69 permanent European stations are processed. The stations are presented in Figure No. 8

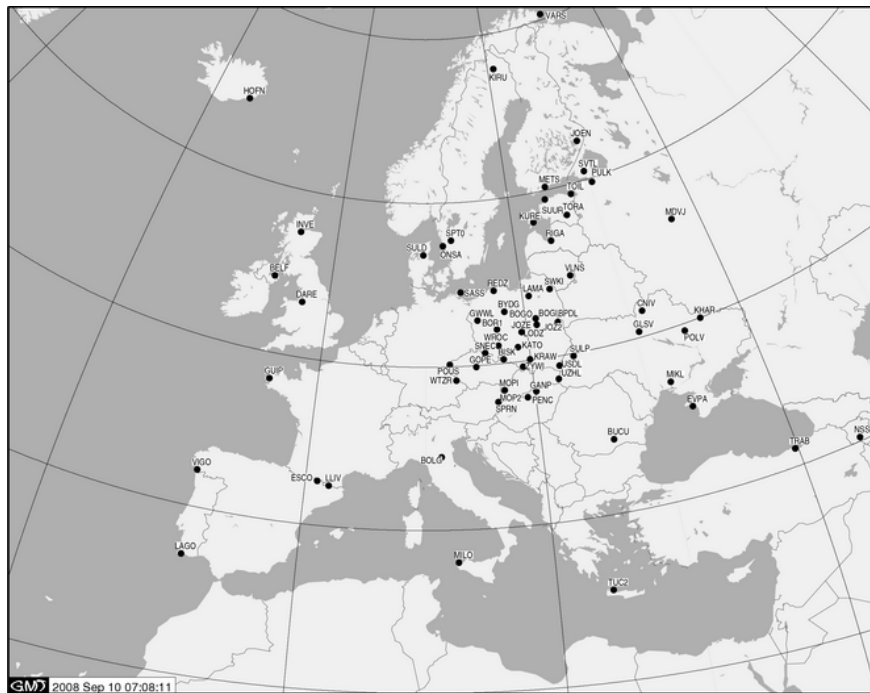


Fig. 8. Station Network processed through WUT EPN LAC.

It is within the framework of the Center that work is conducted on improving the efficiency of the automatic GPS OGPSP data processing system, guaranteeing the joint analysis of satellite data from permanent IGS/EUREF stations and the GPS measurements of individual users. All that is necessary is for the user to provide the type and height of the GPS antenna used, a RINEX format file with observations, and the user's e-mail address.

Subsequent user observations are then automatically processed on the basis of IGS (IGS 2007) and EPN (EPN 2007) station data and products (observations from reference stations, orbits), and the results are forwarded to the provided e-mail address. The system facilitates the conversion of GPS observations made at any point on the globe. The automatic processing system is available at <http://ogpsp.gik.pw.edu.pl> (Figure No. 11). The user may receive results in ETRF89 form. Processing centers for the CERGOP and CERGOP-2 projects were active in the GNSS Analysis Center of the Warsaw University of Technology over the years 1994–2007. All measurement campaigns for that period were analyzed there. The results received served kinematic and dynamic studies of the Earth's crust in Central Europe. Points of the CERGOP-2 network are presented on Figure No. 9. Examples of interplate velocities are presented on Figure No. 10. The Analysis Center also processes many GPS networks from the epoch campaigns of national and international range, including the European Vertical Network (EUVN), WSSG, and PSSG.

Participants in data processing were: M. Piraszewski, M. Figurski, T. Liwosz.

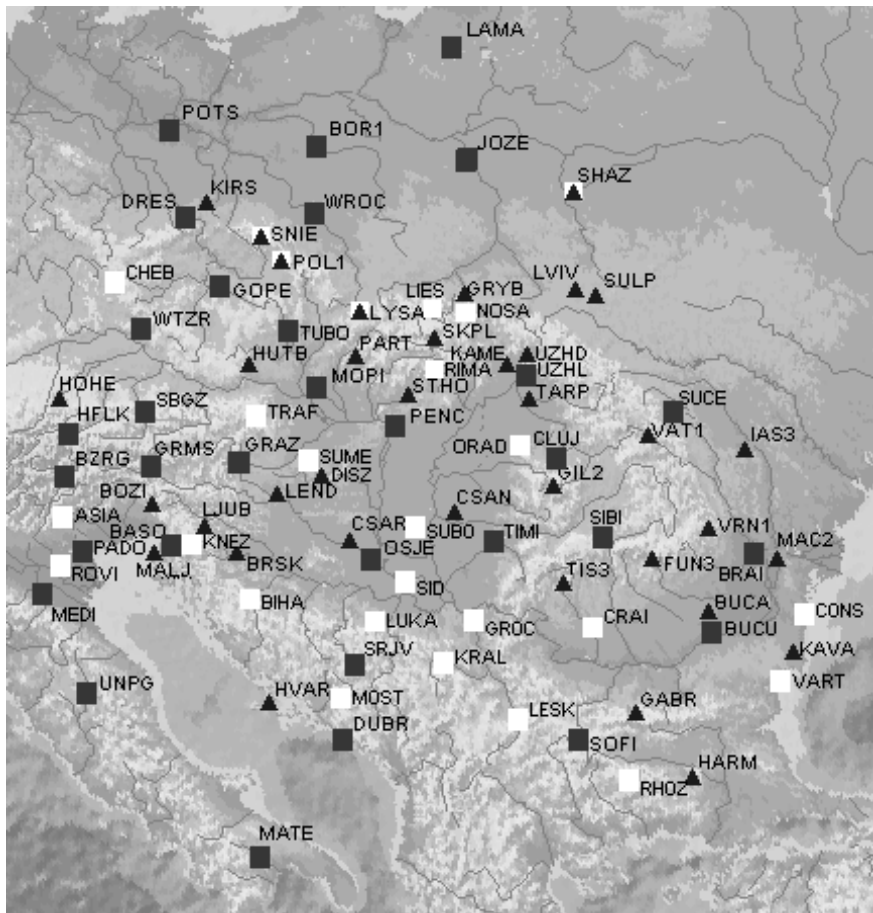


Fig. 9. Map of the CERGOP-2 Network.

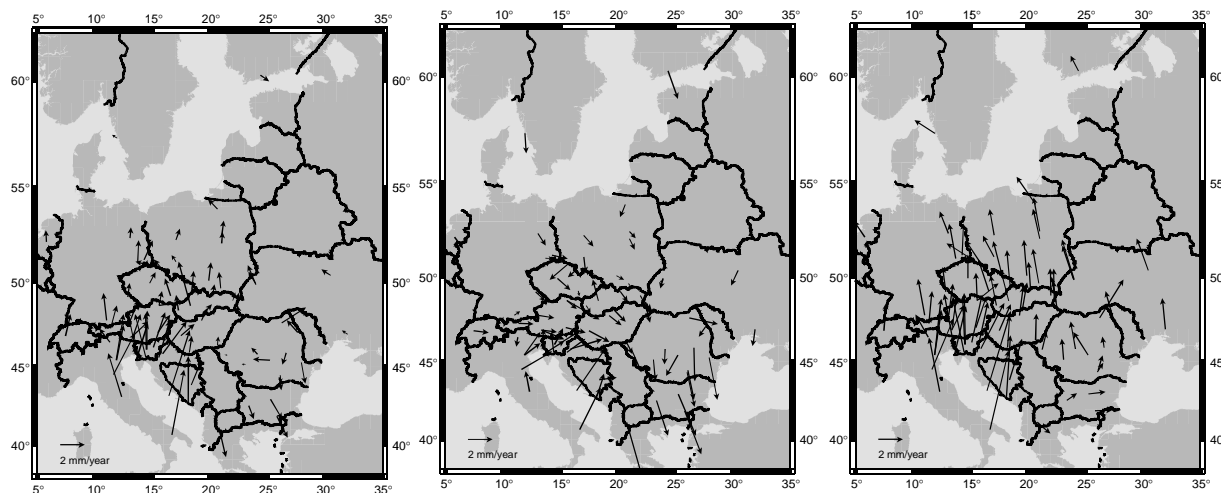


Fig. 10. Examples of the interplate velocities maps obtained from CERGOP campaigns data processing using APKIM 2000, APKIM 2005, NUVEL 1A.

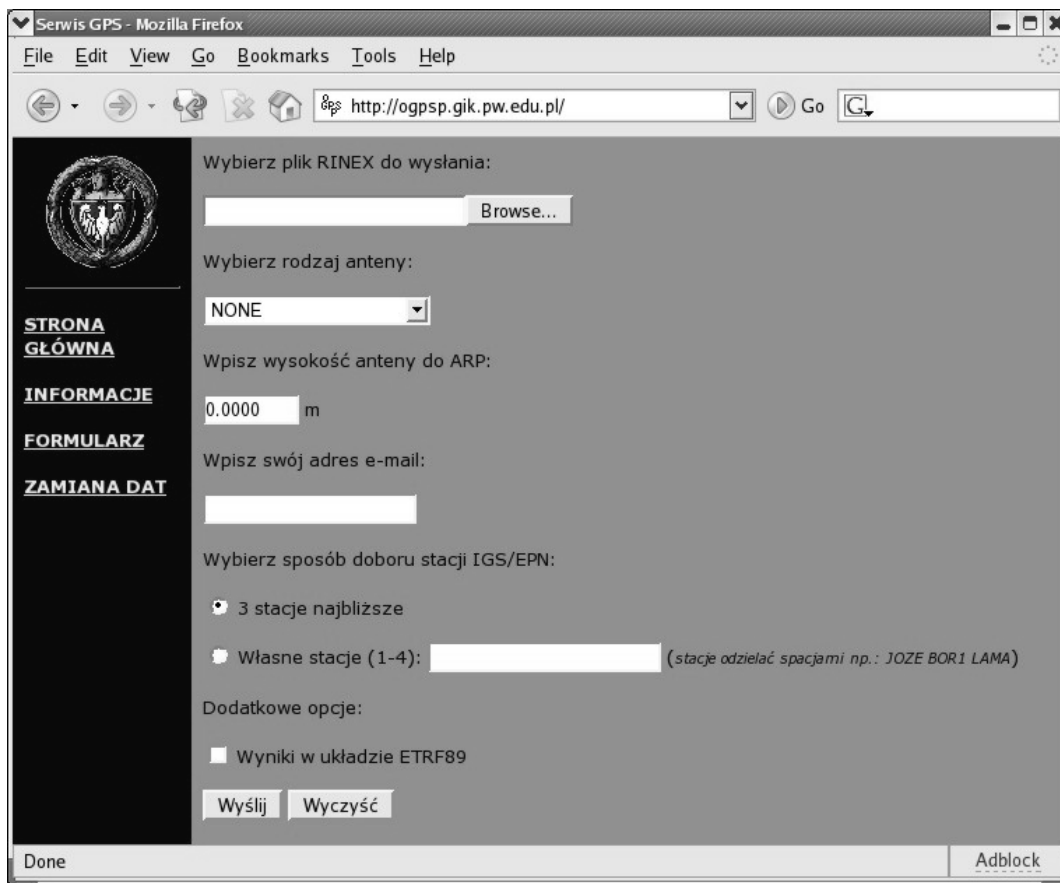


Fig. 11. Home page of the OGSP system.

6. METEOROLOGICAL OBSERVATIONS AND ANALYSIS OF INTEGRATED WATER VAPOR CONTENT

The Astro–Geodetic Observatory in Józefosław has been using the Lab–El meteorological set (LB–716 pressure sensor and LB–710RHMS thermo–hygrometer) as of 2002. The NAVI SC. HPTL3.A (s/n 4) meteorological station that had been in service over the 1995–2005 period is no longer operational. Since 2002, three parameters—atmospheric pressure, temperature, and relative humidity—have been registered every five minutes in the form of hourly RINEX format files (meteorology) and automatically sent to the EPN and IGS data centers. For a two–year period when two independent meteorological sets were in operation, it was possible to compare pressure and temperature readings. Observations made by the two modules demonstrated very good agreement (an average temperature difference of approximately 0.2°C and pressure difference of 0.22 hPa). In addition to being a supplement to observations from permanent GPS stations, the meteorological measurements are used in research on integrated water value (IWV) in the atmosphere and are the subject of multifaceted analysis of climatological character.

Studies aimed at applying sets of values for zenith tropospheric delays (ZDT) over the station, aimed at defining integrated water vapour content in the atmosphere (IWV and IPWV) as a valuable and unique source of information about the troposphere, were conducted on the basis of meteorological observations collected at Józefosław and accessible within the framework of IGS. Special dedicated tropospheric solutions are applied in studies of the atmosphere, where both solutions developed by the EUREF Analysis Centre of the Warsaw University of Technology and those of other centres, as well as the combined EPN and IGS tropospheric product, are the subject of analysis. Tropospheric delays for selected IGS/EPN stations are converted into integrated water vapour content and compared with independent meteorological data sources—radio probes (e.g. Legionowo and Wrocław), CIMEL solar photometer measurements at the Central Geophysical Observatory of the Polish Academy of Sciences in Belsk, and input data for COSMO–LM, the operational numerical weather forecasting model of the Institute for Meteorology and Water Management (IMGW). Work was also continued that was targeted at GPS observations in near real time (NRT) using ultra–rapid orbits. Testing was launched in May of 2005 (Kruczyk, 2007).

7. GRAVIMETRIC OBSERVATIONS

A significant aspect of scientific research conducted at the Józefosław Observatory is research into periodic and secular fluctuations in gravitational acceleration. The Józefosław tidal station conducts periodic studies on gravity changes and is registered with the International Center for Earth Tides (ICET) of the Federation of Astronomical and Geophysical Data Analysis Services (FAGS) under number 0909. The station conducts continuous registration of gravity using firstly LaCoste&Romberg G–981, then D–196 and finally ET–26 gravimeters. Continuous observations of tidal fluctuations in gravitational acceleration were started at the beginning of the year 2002.

Participants in the observations were: J. Bogusz, J. B. Rogowski.

Graphs of observations from individual instruments as taken in 2007 are presented in Figures No. 12 and No. 13.

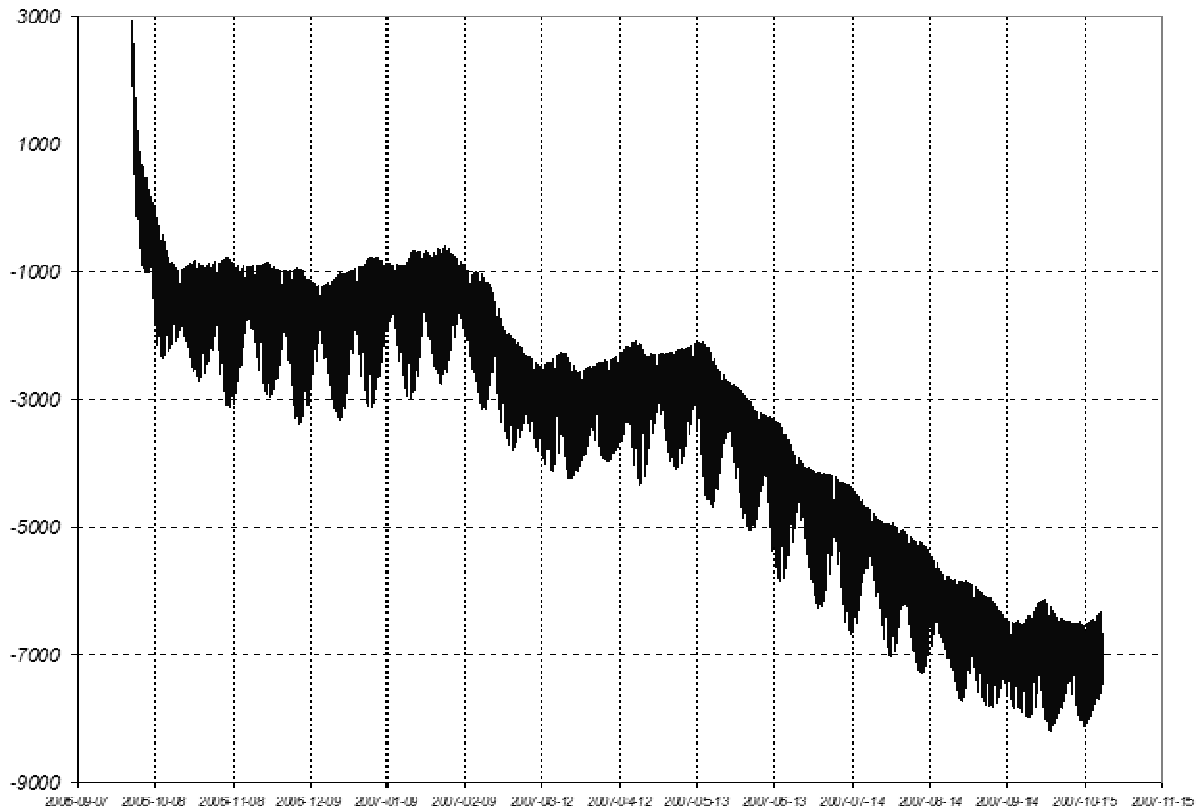


Fig. 12. Graph of gravity changes [nm/s^2] as observed at the Józefosław Observatory using an ET-26 gravimeter.



Fig. 13. Graph of gravity changes [nm/s^2] as observed at the Józefosław Observatory using a D-196 gravimeter.

Observations are analyzed in annual cycles using the least square method. The values of amplitude coefficients as well as phase shifts for thirty-one components of the harmonic constituents of tidal potential development from observations were determined using ET-26 gravimeter observations are presented in the figures No 14 and 15.

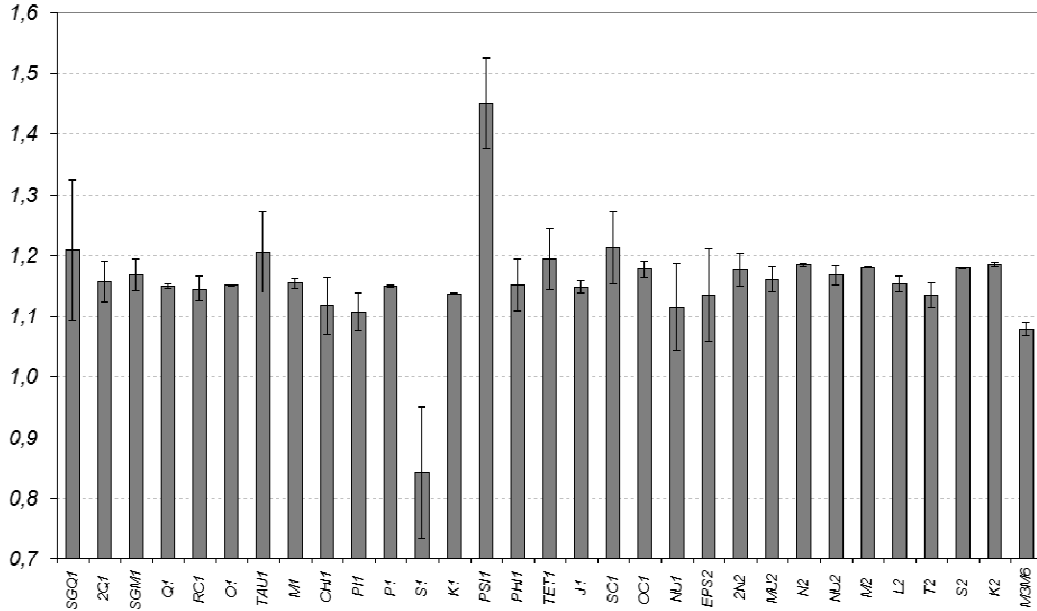


Fig. 14. Amplitude coefficient (δ) –ET-26 gravimeter.

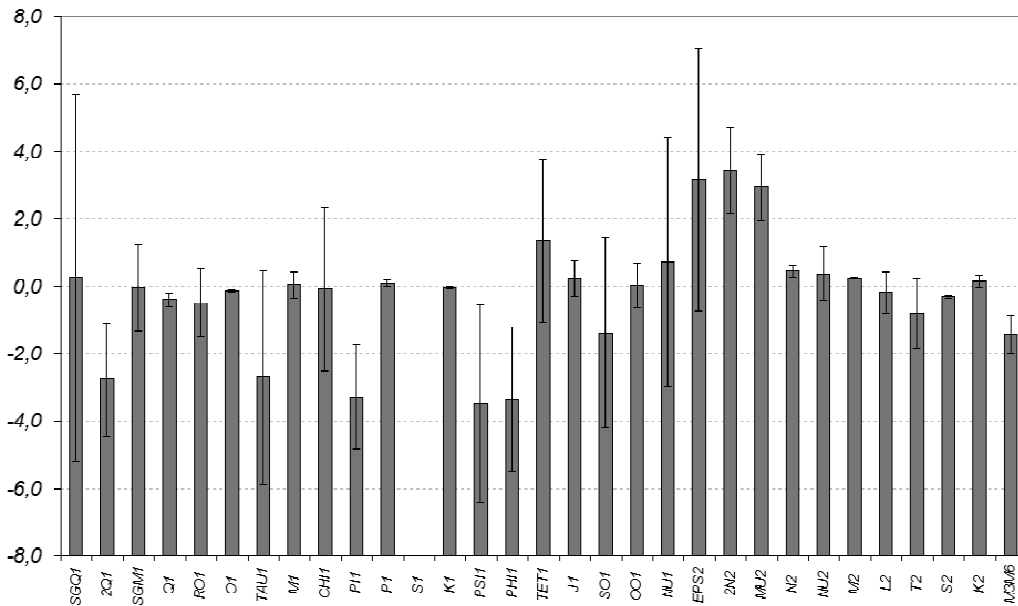


Fig.15. Phase shift ($\Delta\phi$) – ET-26 gravimeter [°].

8. STUDIES ON SECULAR VARIATIONS OF GRAVITY

Observations of absolute gravity changes at the Astro–Geodetic Observatory in Józefosław started in the nineties using a ZZG ballistic apparatus built by Z. Ząbek at the Warsaw University of Technology (Ząbek and Pachuta, 1999). Starting with the year 2007, they were continued using an FG–5 No. 230 ballistic gravimeter bought by the Institute of Geodesy and Geodetic Astronomy in 2005, Figure No. 16.

Participants in the observations were: Z. Ząbek, M. Barlik, A. Pachuta, J.Walo, T. Olszak, R. Szpunar, D. Próchniewicz.

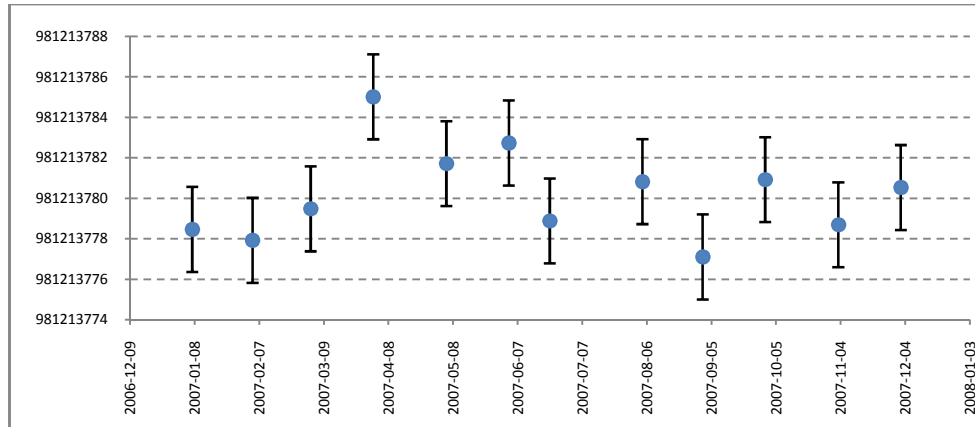


Fig. 16. Absolute measurement results using the FG–5 No. 230 ballistic gravimeter [µGal].

9. GRAVIMETRIC MEASUREMENTS ON THE BASE MERIDIAN OF THE OBSERVATORY IN JÓZEFOSŁAW

Gravimetric observations were conducted on the 30 km meridian base of the Józefosław Observatory over the years 1976–2006. They served the identification of variations in vertical component of the meridian (Barlik and Rogowski, 1988). The objective of these studies was to explain the reason for variations in the mean latitude observed in astrometric observations. Variations in the vertical direction received using this method, taking into account the influence of variations in ground water level and soil humidity, are presented in Figure No. 17. The measured variations in ground water level and their impact on point heights and gravity are presented in the next section of this paper.

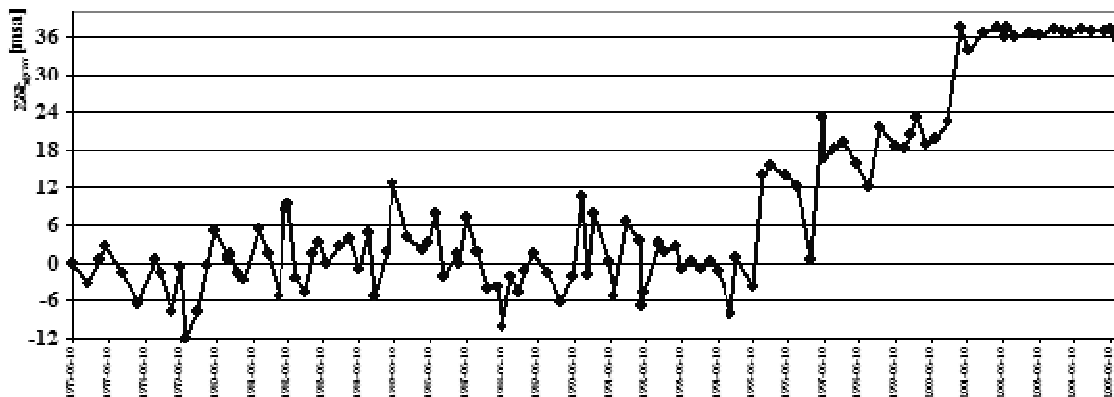


Fig. 17. Plumb line variations obtained using gravity measurements.

Participants in the observations were: J. B. Rogowski, M. Barlik, A. Pachuta.

10. STUDIES INTO THE IMPACT OF VARIATIONS IN THE GROUND WATER LEVEL ON POINT HEIGHTS AND GRAVITY

Research into centennial fluctuations in gravity are accompanied by measurements in the ground water level conducted as of 1988 using a piezometer installed on the Observatory grounds. Variations in ground water level may be converted into variations in gravitational acceleration (Barlik and Rogowski, 1989) using the following formula:

$$\Delta g[\mu\text{Gal}] = 10.27 * \Delta H[\text{m}]$$

where:

Δg – variation in gravitational acceleration

ΔH – variation in ground water level.

Subsequently, this may be converted into variations of a deformational character. These are then taken into account as adjustments to gravimetric observations conducted at the Observatory (absolute and relative). Fluctuations in gravity may also be used to calculate variations in height. The impact of variations in the ground water level on gravitational acceleration and heights as received from observations conducted over the years 2002–2006 are presented in Figures No.: 18, 19, 20.

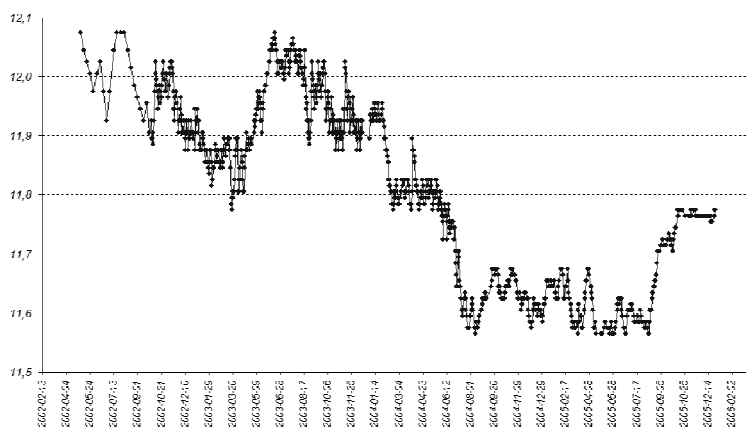


Fig. 18. Variation in ground water level [m].

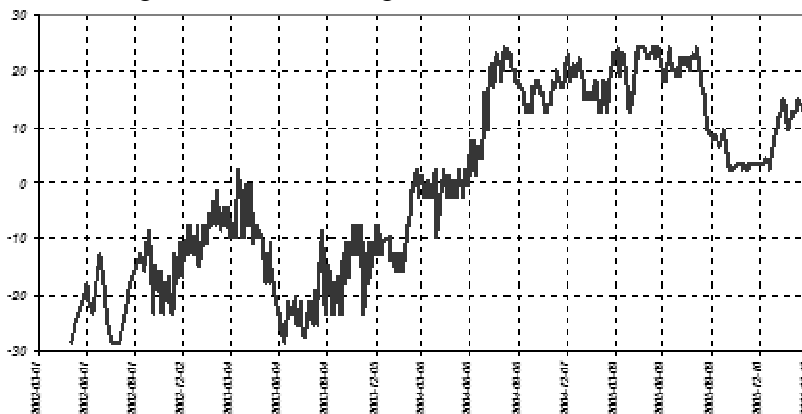


Fig. 19. Gravity variations [μGal].

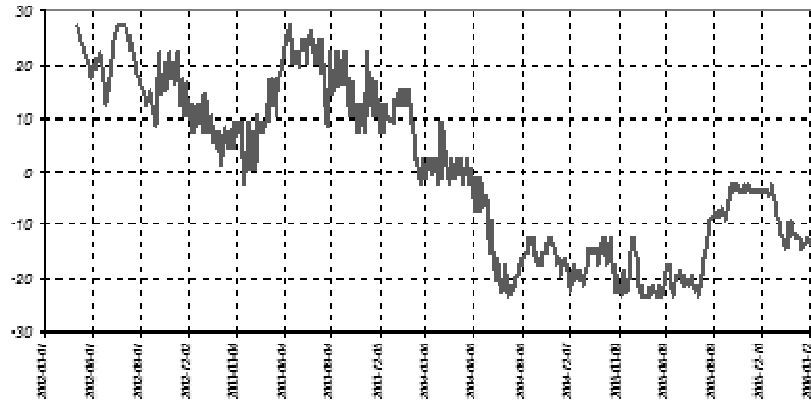


Fig. 20. Height variation [m].

11. FUTURE PLANS

Improvement of the efficiency in the method of managing and analyzing the following continuous observations: GPS gravimetric tidal, as well as absolute gravimetric and meteorological. Incorporation of the JOZ3 station into the EPN following installation of a new Leica 1200 GRX receiver. Improvement in the efficiency of the functioning of the GPS Analysis Centre.

ACKNOWLEDGEMENTS

The work presented in this paper was performed within the framework of charter activities (Task No. 504G/1063/0960 – “Conducting Continuous Satellite Observations at the International IGS Station in Józefosław) co-financed out of funding for SPUB: 134/E-365/SPUB/ZR6/061/2008.

BIBLIOGRAPHY

1. Annual Report of the Bureau International de l'Heure, 1962 - 1987, Paris, France
2. Annual Report of the International Polar Motion Service , 1962 - 1987 , Mizusawa, Japan.
3. Barlik M., Rogowski J. B., Variation of the plumb-line direction obtained from astronomical and gravimetric observations, *Prace Naukowe Politechniki Warszawskiej*, z.33, 1989.
4. Latitude Circular No 1 - 139, 1959 - 1998, Astronomical-Geodetic Observatory, Warsaw University of Technology, Warsaw, Poland. Jerzy B. Rogowski, Janusz Bogusz, Mariusz Figurski, Magdalena Klek,
5. Kruczyk M., Rogowski J. B., Vondrak J., Preliminary results of astrometric observations In Józefosław. Reports on Geodesy No. 4 (45), 1999.
6. Kruczyk M.: 'Verification of GPS derived ZTD and IWV potential for meteorology'. Poster presented at XXIV General Assembly IUGG, Perugia, Session GS004 July 2007.
7. J. Vondrak, C. Ron, I. Pesek (1997) Earth Rotation in the Hipparcos Reference Frame, *Celestial Mechanics and Dynamical Astronomy* , 66, pp. 115-122.
8. Rogowski J. B., Bogusz J., Figurski M., Kłęk M., Kruczyk M., Kujawa L., Kurka W., Liwosz T., Obserwatorium Astronomiczno-Geodezyjne w Józefosławiu - Historia, Stan Obecny, Zamierzenia na Przyszłość, Seminarium z okazji 85 lecia Wydziału Geodezji i Kartografii PW, 2006.
9. Ząbek Z., Pachuta A. (1999) – "Measurements with Polish absolute ballistic gravimeter ZZG". Paper presented at XXIV EGS General Assembly, the Hague, the Netherlands, 19-23 April 1999. Reports on Geodesy No 4(45), 1999.

Reviewed by Dr. Janusz Bogusz.