5. GEODYNAMICS

5.1. INTRODUCTION

This part of the Polish National Report on Geodesy is the quadrennial report of geodynamic works performed in Poland in a period from 1999 to 2002. It summarises investigations such as establishment, maintenance and analysis of geodynamic networks of continental, regional and sub-regional scale, theoretical research and analysis of Earth rotation data, Earth tides monitoring, etc. Those activities were conducted mainly at the following research centres listed in an alphabetic order:

- Department of Geodesy and Geodynamics, Institute of Geodesy and Cartography in Warsaw;
- Department of Geodesy and Photogrammetry, Agricultural University in Wroclaw;
- Department of Mining Surveying and Environmental Engineering, University of Mining and Metallurgy in Cracow;
- Department of Planetary Geodesy, Space Research Centre, Polish Academy of Sciences in Warsaw;
- Institute of Geodesy and Geodetic Astronomy, Warsaw University of Technology.

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The bibliography of the related works is given in references.

5.2. GEODYNAMIC NETWORKS IN POLAND

5.2.1. Polish Geodynamic Network

The Polish Geodynamic Network (PGN) that consists of nearly evenly distributed 36 chosen carefully points marked with a solid monuments has been established by the team of the Institute of Geodesy and Cartography, Warsaw, in 1997-1998. The data acquired during zero-epoch GPS campaign was processed and the network was adjusted in co-operation with WUT Local Analysis Centre of EUREF using Bernese v.4.0 software, according to presently valid standards. Solution of PGN has been compared at the common stations with solutions for EUREF-POL and POLREF networks obtained from the earlier respective campaigns. The evidence of biases was found (Dobrzycka and Cisak, 2001). Biases have been carefully analysed. The effect of phase centre modelling was tested and discussed in particular.

5.2.2. Geodynamics Research in the Sudety Mountains and Fore-Sudetic Block (SW Poland)

The local geodynamic research in the area of South-western Poland was continued in the period 2000–2002 in the framework of the research project “GEOSUD II” (Fig. 5.1).

Regional Czech–Polish GPS SUDETY network as well as existing local geodynamic networks: GEOSUD, SNIEZNIK MASSIF, PACZKOW GRABEN and STOLOWE MTS. were re-surveyed and reprocessed (Barlik and Cacon, 2001; Blachowski and Cacon, 2002; Cacon, 2001; Cacon and Dyjor, 2002; Kontny, 2001; Schenk et al., 2000, 2001, 2002).

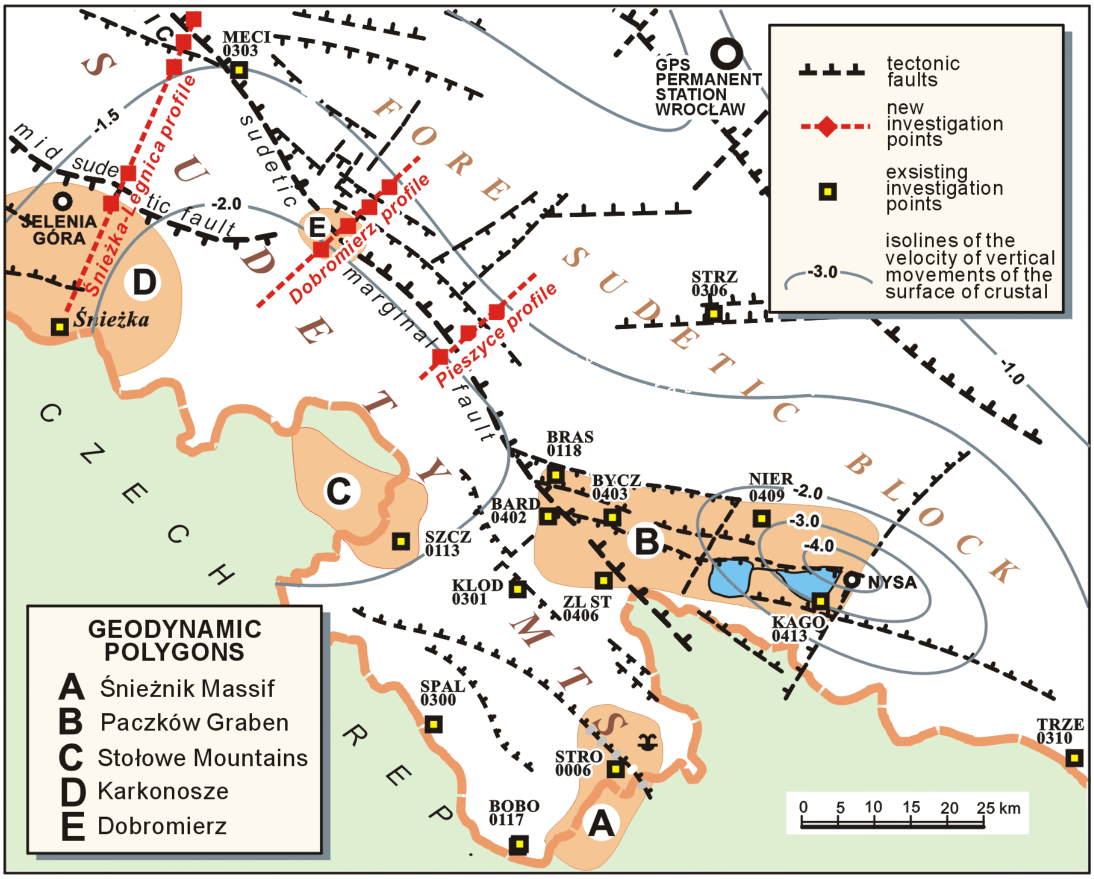

Fig. 5.1. Location of the investigated points in Sudety Mts. and Fore-Sudetic Block

GEOSUD network was modernized and expanded to the western part of Sudetes (Cacon and Dyjor, 2000). Also the new test micro–network DOBROMIERZ, suitable for repeatable terrestrial geodetic, GPS, gravimetric and relative (extensometric) measurements, was established for monitoring the tectonic dislocations node close to the water dam located in the area (Cacon et al., 2002). The new local geodynamic GPS and gravimetric KARKONOSZE network, covering highest part of Polish Sudetes, was established in 2000 and two first measurement campaigns were performed (Kontny et al., 2002; Makolski et al., 2001). The investigation of natural tectonic hazard for engineering objects in Lower Silesia on the basis of GPS data has been initiated (Kontny, 2002).

5.2.3. Tatra Mountains Geodynamics

Project on Geodynamics of Tatra Mountains “Tatra Mts. without border” was launched in 1997 (Czarnecki and Mojzes, 1999; Mojzes et al., 2001). The general objectives of the project are investigation of geodynamics of the Tatra Mts. and determination of the local quasigeoid in the region. As a by-product the heights of some Tatra's picks will be determined. GPS monitoring campaigns are organised every year by Slovak and Polish teams to survey the Tatra reference satellite network (Czarnecki et al., 2001b). The seminars on geodynamics of Tatra Mts. take place every year in fall.

5.2.4. Geodynamic Network in Cracow Area

The recent geodynamic network in Cracow area can be considered as consisting of two parts. The eastern part comprises the area of “Wieliczka” salt-mine and its vicinity (including Cracow area). The western part covers the eastern Silesian Coal Basin, one of the biggest in the world. The network is situated in the foothills of Carpathian massive, about 100 km north of its highest part – the Tatra Mountains. The area is densely populated and highly industrialised.

The Wieliczka salt mine area (1 km × 10 km) is located about 15 km south-east of the centre of Cracow. In 1994-1996, an integrated control network of high precision in Wieliczka and Cracow area was established for terrain deformation monitoring and geodynamics research.

Upper Silesia Industrial Area is situated about 40 km west of Cracow. It is a region that suffers the biggest changes in Poland due to extensive mining and industry. Measurements of deformations carried out for more than a century in the areas influenced by mining exploitation, in most cases refer to the mining area of a single mine or at most a few mines. At the same time there are many regions where mining activities are simultaneously run by many mines. In 1968, observations of vertical movements of benchmarks of GOP vertical control, called GIGANT (Giant), have started. The network recently consists of 1655 node benchmarks, including 23 reference points. Total length of the network in 1998 was 1370 km (Banasik et al., 1999). One of the future tasks is to integrate the GIGANT network with GPS network and to determine local geoid (Banasik, 2001). The GIGANT network is a natural development in the western direction of the geodynamic traverse established in 1994-96 in the region of Cracow and Wieliczka (Goral et al., 1999; Banasik et al., 2000a, 2000b). Research on results of repeated levelling (Banasik, 1999) and with support of high precision GPS positioning, especially for height determination, has been carried out (Goral et al., 1999; Goral, 1999).

Establishing of KRAW permanent GPS station in Cracow that was included in January 2003 into EUREF Permanent Network, as well as establishing of local Active Geodetic Network (ASG-PL), composed of six permanent GPS stations, west of Cracow (about 70 km) makes possible the intensification of geodynamic research in Cracow area (Goral 2002).

Rock mass changes observed in the “Kinga” and the “Danilowicz” shafts in Wieliczka salt mine were analysed (Jozwik and Szczerbowski, 2002). They are interpreted in terms of geodynamics. The main aim of that work is to proof that in the case of non-typical rock mass existing in Wieliczka there is a need for full description of its movement including horizontal observations. The results of analysis of such observations were presented. The results of the shaft guides vertical measurement indicate directions of geodynamic movements that occur in Wieliczka rock mass. The described method of observation can be defined as the underground monitoring of the geodynamics movements.

5.2.5. Cross-Border Czech-Polish-Slovak Geodynamics Research

Project “Czech-Polish-Slovak cross-border studies of regional geodynamics (Sudetes, Beskydy, Tatra, Pieniny Mts.)” is realised as bilateral/multilateral agreement (Mojzes et al., 2001). Long borderline between Poland, Czech Republic and Slovakia coincides generally with interesting geotectonic formations of different age. That gives an excellent opportunity to undertake comparative studies of a significant scientific and practical value. The main objectives of the Project have been defined as long-term investigation of variations of the recent crustal movements, periodic monitoring of the horizontal and vertical displacements in the structural tectonic zones of the Polish and Czech parts of the Sudetes Mts., Western Carpathians (Tatra Mts. and Pieniny) as well as in the regions neighbouring with the existing and planned investments and technical constructions (water reservoirs and dams, power stations, communication lines, etc.). Since 1999 the co-ordinated GPS surveying campaigns with use of about 35 GPS receivers from the Czech Republic, Poland and Slovakia were conducted to in Sudetes Mts., Pieniny and Tatra Mts.

The studies of geodynamics of the Pieniny Klippen Belt were initiated in the mid-wars period. The Pieniny Klippen Belt test-field was established in the sixties. Geodetic, geophysical and geomorphologic methods were applied to study recent geodynamics in the area (Czarnecki et al., 2000; 2001c; 2002). The water dam on the Dunajec river and artificial lake covering the river valley were established in mid-nineties. The water loading and probable water penetration in limestone structures might contribute to the stresses and movements distribution over the area. The Pieniny test-field is currently revisited as the present geodynamical status of the area has been changed. The project includes re-observing the control networks and executing auxiliary geophysical studies: shallow seismic and electric resistance profiling. The project is sponsored by the Polish State Committee for Scientific Research. Last geodetic measuring campaigns were performed in 2000-2002; also geophysical studies have already been executed.

5.2.6. Geodynamic Network in Copper Basin Area

Polish Copper Basin is located in South-western Poland, between two towns: Lubin and Glogow. In this area the following influences of mining exploitation on the surface and the rocks mass can be established:

- direct influences caused by displacement of the rocks filling free space created as a result of mining activity,
- indirect influences caused by water draining action in the mines.

Since 1992 the new concept of 3D control network measured with GPS was developed. The primary GPS control network in the Copper Basin area consisting of 53 new points was established (Wasilewski et al., 2000). The classical horizontal control network has been integrated with GPS determined one and tied to the POLREF network (Oszczak et al, 2000).

The method for deformation analysis and prediction of displacement has been developed (Wasilewski et al., 2001).

5.3. INTERNATIONAL GEODYNAMIC NETWORKS

5.3.1. CERGOP Project

The Institute of Geodesy and Geodetic Astronomy WUT is deeply involved in realisation of scientific geodetic and geodynamic programmes of the Central European Initiative (CEI) Working Group “Science and Technology” Section C “Geodesy” chaired by the Institute. The programme of activities of this Section includes regional European programmes (e.g. CERGOP - Central Europe Regional Geodynamics Project), local geodynamic projects and projects realised by the subgroups of the CERGOP Study Group CSG.5 “Geotectonic Analysis of the Region of Central Europe” (e.g. Geodynamics of Tatra Mts.), projects realised in bilateral/multilateral agreements of CEI countries, (e.g. Czech-Polish-Slovak Cross-Border Studies of Regional Geodynamics (Sudetes, Beskydy, Tatra, Pieniny Mts). Section’s Working Groups on University Education Standards and on Satellite

Navigation Systems are very active. Section C “Geodesy” undertakes close links with European Geophysical Society (every year EGS-CEI symposia “Geodetic and geodynamic programmes of the CEI”) and the International Association of Geodesy (IAG Subcommission “Geodetic and geodynamic programmes of the CEI”) within the IAG Section V “Geodynamics” Commission XIV “Crustal Deformation”.

The first phase of the Project CERGOP was concluded in 1998 and now the second phase of the Project is being realised. Main objectives of the project are the establishment of the Central European GPS Reference Network CEGRN and studies on geodynamics in Central Europe. The proposal of the second phase of the Project CERGOP-2 "A Multipurpose and Interdisciplinary Sensor Array for Environmental Research in Central Europe (CERGOP-2/Environment)” was accepted by the European Commission and will be financially supported during the next three years. The Contract with European Union was signed early 2003. The following 14 countries participate in the second phase of the project: Albania, Austria, Bosnia and Herzegovina, Bulgaria, Croatia, the Czech Republic, Germany, Hungary, Italy, Romania, Poland, Slovakia, Slovenia and Ukraine. CERGOP-2 covers 63 stations. About thirty CERGOP-2 sites are permanent stations. Six monitoring GPS CEGRN campaigns were performed in 1994, 1995, 1996, 1997 (CERGOP-1) and in 1999 and 2001 (CERGOP-2). Graz Lustbühel Observatory hosts CERGOP Data Centre. Five research institutes have declared to maintain and operate CEGRN Processing Centres in the second phase of the project. They are FÖMI, Satellite Geodetic Observatory, Penc, Hungary; Institute of Geodesy and Geodetic Astronomy of the Warsaw University of Technology, Warsaw, Poland; Agenzia Spaziale Italiana Centro di Geodesia Spaziale, Matera, Italy; Space Research Institute of the Austrian Academy of Sciences, Austria and Department of Theoretical Geodesy of the Faculty of Civil Engineering of the Slovak University of Technology, Bratislava, Slovakia. In the programme of CERGOP-2 there are at present thirteen study groups. They cover particular fields of activities supporting realisation of the project and form the respective ”workpackages” of the EU Project CERGOP-2/Environment (Figurski et al., 2000; Figurski and Pfeil, 2000; Liwosz et al., 2001; Becker et al., 2002).

The CERGOP project was an impulse for establishment of the CEGRN Consortium of institutes. The CEGRN Consortium is a non-profit organisation of institutes that supports and promotes the establishment, maintenance and upgrade of CEGRN sites, monitoring the CEGRN by permanent and epoch type measurements and the establishment, maintenance and development of CEGRN Data Centre and Processing Centres. The member institutes contribute to the CEGRN with their own established and accepted sites, with site maintenance and with coordinated observations on these sites. They are committed for the highest quality standards of five-day observations every second year. They supply observational data to the common Data Centre. Additional contribution of designated institutes consists of operation the Data Centre and/or Processing Centres. The Consortium will also be a seedbed of new European projects and initiatives (Sledzinski 1999a, 1999b, 1999c, 1999d, 1999e, 2000a, 2000b, 2001a, 2001b; Fejes and Sledzinski, 2000).

5.3.2. Extended SAGET Programme

The main scientific objective of the EXTENDED SAGET (SAtellite GEodynamic Traverses) programme, initiated and coordinated by the IGGA WUT, was to organise GPS campaigns that give the precise geodetic frame for studies on the entire Teisseyre-Tornquist zone, investigations on the Carpathian Orogenic Belt and connection of geodynamic networks and local geodynamic test fields of Central European countries. Besides, the EXTENDED SAGET network joins geodynamic networks of the Mediterranean area and Scandinavia, i.e. two regions essential for European geodynamics. First EXTENDED SAGET campaign was organised in 1992. A follow up campaigns EXTENDED SAGET were performed in 1993, 1994, 1995, 1996, 1997, 1998 and in 1999. About 45-50 European stations participated every year in the campaigns EXTENDED SAGET (Hefty et al., 1999; Sledzinski et al., 1999; Figurski et al., 1999).

Progress and achievements in the projects CERGOP, EXTENDED SAGET and other programmes of the Section C are exhaustively reported at the Summit Meetings of the Heads of Governments of the CEI countries, at the meetings of the International Civil GPS Service Interface Committee, at the IAG EUREF symposia and at the General Assemblies of European Geophysical Society.

5.4. EARTH ROTATION

5.4.1. Theoretical Problem Related to Modelling and Monitoring Earth Rotation

Theoretical investigations concerning geophysical interpretation of modern Earth rotation observations and the related geophysical data, in particular, the study on the conceptual definition and practical realization of the conventional reference pole, taking into account current progress in monitoring changes in the orientation of the Earth and variations of the related geophysical processes, was continued. The results obtained could contribute to the scientific discussion organized and coordinated by the Sub-group T5 "Computational Consequences" of the IAU Working Group on the International Celestial Reference System. The discussion was finalized by the adoption of the new definition of the conventional reference pole (Resolution B1.7 of the IAU General Assembly 2000). Results of the work were presented in several publications (Brzezinski, 1999, 2000a; Capitaine and Brzezinski, 1999). Another theoretical study concerned the high precision numerical model of the rigid Earth rotation (Eroshkin et al., 2002).

5.4.2. Rotational Variations due to the Luni-Solar Torque on the Tri-axial Figure of the Earth

The luni-solar perturbations in Earth rotation associated with the multipole structure of the mass distribution within the Earth were studied in detail (Brzezinski, 2000c, 2001; Brzezinski and Capitaine, 2002). The analytical model of that fine effect (its total size is of the order of 0.1 mas) for a 2-layer model of the Earth comprising an elastic mantle and a liquid core was developed. Comparison of the model with the results of other research groups, executed during the discussion of the IAU Commission 19 Working Group on "Non-rigid Earth Nutation Theory", showed the sub-microarcsecond agreement. The discussion led to a consensus on the model of polar motion corresponding to high frequency nutation. It will be published in IERS Conventions 2000 as a part of realization of the new reference pole CIP (Celestial Intermediate Pole).

5.4.3. Regional Atmospheric Angular Momentum and its Impact on Polar Motion

The analyses of regional patterns of equatorial components of Effective Atmospheric Angular Momentum (EAAM) data computed both globally and in 108 geographic regions from the National Centres for Environmental Prediction and National Centre for Atmospheric Research (NCEP/NCAR) reanalysis data, for the period 1948-1999 were performed at different spectral ranges from seasonal to short period oscillations (Nastula and Salstein, 1999, 2000; Nastula, 2001). The coherence, correlation coefficients, fractional covariance between regional and global atmospheric or geodetic excitation functions were computed to identify the sectors of the globe over which changes contribute most significantly. Air pressure variations over Eurasia, North Pacific, Greenland and North Atlantic, and Southern Ocean near South America regions are important in exciting polar motion in spectral band from seasonal to short period oscillations. Applying the inverted barometer IB correction results in the dominance of Eurasia and North America, with disappearing contributions in almost all the ocean-dominated Southern Hemisphere regions, but the influence of the IB also depends on spectral band (Nastula, 2001). Results obtained from complex Empirical Orthogonal Functions (EOF) analysis of EAAM confirmed that regionally, the atmosphere over Eurasia and North America are particularly important (Nastula and Salstein, 2000).

5.4.4. Correlation of Seasonal and Sub-seasonal Variations of the Geodetic and Atmospheric Excitation Function of Polar Motion

The correlation of seasonal and sub-seasonal variations of the geodetic and atmospheric excitation functions of polar motion was investigated. The homogenous series of 50 years long atmospheric angular momentum, developed by the National Centre for Environmental Prediction/National Centre for Atmospheric Research and 40-years long time series of polar motion, EOP IERS 97C 04, developed by IERS were applied. High, stable correlation coefficient of the order of 0.8 was obtained for annual oscillations in the years 1970-2000. In the case of semi-annual and 120 days oscillations correlation coefficients became more stable starting from 1970 and 1980 and they reach 0.7-0.8 and 0.6—0.8, respectively (Kolaczek and Nastula, 2001; Nastula and Kolaczek, 2001, 2002).

5.4.5. Frequency-Dependent Time Lag Between Atmospheric and Geodetic Excitation Functions of Earth Rotation

The Fourier transform band-pass filter and the wavelet transform techniques were applied to compute time-frequency spectra of polar motion and its atmospheric excitation as well as spectra-temporal coherences and cross-covariance functions between these functions (Kosek and Popinski, 1999, 2000; Popinski and Kosek, 2000; Popinski et al., 2002). The maxima of the modules of cross-covariance functions allow the determination of frequency-dependent time lag functions between the polar motion and atmospheric excitation functions. A negative time delay for oscillations with periods of 180 and 120 days indicate that these oscillations in the equatorial components of the atmospheric excitation functions precede analogous oscillations in the geodetic excitation function by about 20 to 60 days (Popinski et al., 2002).

5.4.6. El Niño Impact On Polar Motion Variations

The influence of El Niño on the correlation between seasonal, namely annual, semi-annual and 120-day (ter-annual) oscillations of atmospheric and geodetic excitation functions of polar motion in forty years period, from 1962 to 2000 was investigated. It was found that disturbances of those correlation coefficients are highly correlated with epochs of El Niño /La Niña phenomena (Kolaczek et al., 1999, 2000; Salstein et al., 1999).

5.4.7. Atmospheric and Oceanic Excitation of Earth Rotation

An extensive analysis of a 40-year reanalysis time series of the atmospheric angular momentum (AAM) to estimate the high frequency effects, such as diurnal and semidiurnal variations, free core nutation, influence of the atmospheric normal modes was performed

(Brzezinski, 2000b; Brzezinski and Petrov, 1999, 2000); for review see the paper (Brzezinski et al., 2002a). In case of the oceanic effects (Brzezinski, 2003) the attention was focused on the excitation of the 14-month free Chandler wobble. By using a 11-year time series of the ocean angular momentum (OAM) it has been concluded (Brzezinski and Nastula, 2002) that within the limits of accuracy the coupled atmosphere/ocean system fully explains the observed Chandler wobble during the period 1985-1996. Similar study using a 50-year OAM series (Brzezinski et al., 2002b) yielded less promising results that could be attributed to the differences in the underlying ocean circulation models. The first attempt to estimate the non-tidal oceanic contribution to nutation (Petrov et al., 1999) showed that the OAM data is still not adequate for studying the diurnal and sub-diurnal effects.

5.4.8. Combined Oceanic and Atmospheric Excitation Function of Seasonal and Sub-seasonal Polar Motion

A constant-density ocean model driven by observed surface wind stresses and atmospheric pressure, for the period 1993-1995, was used to estimate the equatorial excitation functions for the ocean velocity and mass fields (Nastula and Ponte, 1999). The results of the analysis confirmed findings that oceanic excitation, when added to atmospheric excitation, leads to substantial improvements in the agreement with observed polar motion excitation at seasonal and intra-seasonal periods. In addition, the results point to the role of Effective Oceanic Angular Momentum (EOAM) signals in exciting polar motion at the period between 5 and 10 days. The combined oceanic-atmospheric excitation does not explain, however, all the observed polar motion excitation, especially for the equatorial component CHI2.

Comparisons of regional variations of EAAM and EOAM signals were performed for monthly and longer periods (Nastula et al., 2000) and for periods shorter than 10 days (Nastula et al., 2002). They have revealed the importance of specific areas for polar motion excitation. The results also confirm findings that oceans supplement the atmosphere as an important source of polar motion excitation. Regional characteristics of short period excitation are generally in agreement with those obtained from analyses performed for signals at monthly and longer periods. The EAAM and EOAM signals associated with pressure terms were found to be of the same order of magnitude while signals associated with winds were substantially larger then those associated with ocean currents. The strongest polar motion excitation due to variability of atmospheric pressure, oceanic pressure and wind terms is connected with areas over northern and southern mid-latitudes. The spatial pattern of pressure + inverted barometer (IB) term is dominated, however, by maxima over land areas. Oceanic excitation due to currents is strong in the North Pacific and the southern oceans.

5.4.9. Improvements of Polar Motion Prediction

The accuracy of the least-squares prediction of polar motion carried out in the IERS Sub-Bureau for Rapid Service and Prediction depends on starting prediction epochs due to irregular short period variations in Earth rotation (Kosek, 2000) but also on the irregular phase variation of the annual oscillation (Kosek et al., 2001a, 2001b). There were two significant increases of the annual oscillation phase of the order of 30°-40° associated with increase of polar motion prediction errors before and during the two largest 1992/93 and 1997/98 El Niño events, respectively. Auto-covariance prediction formulae of complex-valued time series were derived and applied to predict pole coordinate data transformed into the radius and angular distance (Kosek, 2002). The prediction errors of this method are of the same order of magnitude as the errors of the prediction method used in the IERS Sub-Bureau for Rapid Service and Prediction.

5.4.10. Rapid Oscillations of Polar Motion Determined by GPS

Spectral analysis of the GPS (CODE) polar motion series computed with a resolution of two hours in the years 1996 – 2001 show that data considered is sufficiently accurate to detect rapid oscillations of polar motion with periods shorter than 12 hours. Oscillations with periods of 6, 8, 12 hours and amplitudes of the order of 0.02 - 0.05 mas were detected. Oscillations with 8 and 12 hours were also detected in the dense set of equatorial components of EAAM based on surface pressure of the NASA GEOS Data Assimilation System with the resolution of three hours for the year 1995. It shows a possible association of high frequency polar motion oscillation and the atmospheric forcing (Weber et al., 2001).

Spectra of short period oscillations of Earth rotation parameters were computed for the period ranges from 150 days to daily and sub-daily periods (Kolaczek et al., 2000).

5.5. EARTH TIDE INVESTIGATIONS IN POLAND IN 1999–2003

Space Research Centre is carrying out tide gauge observations at the Ksiaz station (horizontal components) and at the Warsaw station (vertical component). At the Ksiaz station observations are made using Blum's pendulum and the observational series is already almost 30 years long.

Annual series of tidal observations is analysed and then the results are published. At the same time the observations are delivered to International Centre for Earth Tides in Brussels.

5.5.1. Monitoring of Tidal Signals:

Warsaw Gravity Station 0907

During the years 1999-2003 the gravimetric observations of Earth tides were continuously conducted at station 0907. Since May 1995 the station is equipped with LCR G-648 gravimeter with a digital force feedback system. The station 0907 is located in the premises of the Space Research Centre of the Polish Academy of Sciences in Warsaw. Data collected at the station is processed with a classic method of analysis based on the LS technique (Chojnicki, 1999, 2000, 2002). The results of analysis confirm a good quality of gravimetric data (m_0 = 0.52 μGal).

Ksiaz clinometric station 0906

Gravimetric as well as the clinometric data were continuously acquired at station 0906 during years 1999-2003. The station is situated at the Low Silesian Geophysical Observatory in Ksiaz. The clinometric station 0906 in Ksiaz is equipped with a pair of quartz horizontal pendulums. The instruments, numbered H-74 and H-75, are continuously operating since November 1973. The clinometric observations of Earth tides performed at the Ksiaz station are processed with a classic method of analysis based on the LS technique (Chojnicki and Weiss, 1999, 2000, 2002). The results obtained indicate high quality of clinometric data (m_{0NS} = 1.12 mas, m_{0EW} = 0.99 mas).

5.5.2. Improvement of Clinometric Measurement Technique

In 1997 the installation of the long water tube tiltmeter in the Low Silesian Geophysical Observatory in Ksiaz started. The works on a new tiltmeter were simultaneously conducted at Ksiaz Observatory as well as in the Space Research Centre of the Polish Academy of

Sciences, Warsaw. The instrument consists of two perpendicular to each other water tubes of 65 and 84 meters long. At the end of the tubes the interferometer gauges are installed. The classical Newtonian interferometers were applied to the measuring system of water level variations. Single mode red colour gas lasers were applied as a source of light for interferometers. The resultant pictures of the Newtonian rings are observed by a CCD camera and sent to a PC where they are stored on the hard disc. The long water tube tiltmeter possesses several valuable proprieties:

- the lack of instrumental drift,
- the extremely high sensitivity, at least three orders of magnitude larger then the accuracy of horizontal pendulum (0.002 msec),
- an extensive base of measurement (area with a radius of about a hundred meters, from which instrument collects signals).

The long water tube clinometer in Ksiaz station became fully operational in the middle of 2002. Preliminary results of observations fully confirmed a quality of the new instrument. The observing noise does not exceed 0.01 mas (Kaczorowski, 1999a, 1999b, 1999c).

The proprieties of the long water tube tiltmeter open a new range of investigations in geodesy and geodynamics, including

- the investigation of the second order tidal effects and non-linear theory of the Earth tidal response,
- the investigation of secular variations of gravity field produced by "global greenhouse effect”,
- the investigation of present movements of the tectonic plates,
- the research on tectonic formation and erosion processes (Sudeten).

The list of applications of a new tiltmeter also contains investigations of non-periodic effects of plumb line variations due to atmosphere. The horizontal pendulums applied till now have an instrumental drift that makes impossible to interpret the non-periodic parts of the long series of observation.

5.5.3. Investigation of Tidal Waves Modulation

Seasonal modulation of tidal waves is investigated during several years. The role of the Earth atmosphere as a main source of that phenomenon has not been, however, explained. Research on atmosphere tides was undertaken. The method of determination of non-seasonal modulation was elaborated. The preliminary investigations in the range of periods of 263 – 569 days show modulation in the range of Chandler periodicity, i.e. of 430-460 days (Chojnicki, 2000; Bogusz and Chojnicki, 2000).

5.6. GRAVITY AND GPS FOR GEODYNAMICS

The experiments conducted showed that LCR-G gravimeter equipped with electronic data recording and operating in thermostatic chamber provides high quality record of gravity data over the interval from a few hours to a few days. The usefulness of a few week long record of gravity data acquired with LCR-G gravimeter for analysis of short period variations of gravity has also been shown. The analysis of short time series of gravity could become a useful tool for improving Earth tide models. Such series together with time series of GPS solutions could be applied for modelling local geodynamics phenomena (Zanimonskiy and Krynski, 2000; Krynski and Zanimonskiy, 2001).

A particular attention has been paid to the analysis of variations of gravity residuals due to their relation to the variations in vertical component. Stands for continuous gravity surveying with automatic data recording with LCR-G gravimeter have been developed at Borowa Gora and Lamkowko observatories. Also automatic meteorological data recording was established in both observatories.

Time series of residual gravity acquired at those stations were analysed together with respective time series obtained from gravity recorded at a few European tidal stations participating in the GPP project. Correlation analysis shows common origin of part of the signal of variations of GPS solutions with variations of residual gravity. The observed signal is of local character (Zanimonskiy and Krynski, 2000).

5.7. SECULAR VARIATIONS OF THE EARTH MAGNETIC FIELD

The distribution of the geomagnetic field in space and time in the Baltic Sea has been investigated. On the grounds of the component magnetic survey on the profiles of about 55000 km long, the grid of 2 x 2 km has been generated. The grid consisting of about 220000 points has been used for working out the Magnetic Atlas of the Baltic Sea, which contains 5 maps of D, H, F, Z, and I magnetic components, the map of the secular variations of measured D, H and F components, 2 maps of the magnetic anomalies (for F, H) and also 2 maps of the normal field (for F and H), as well as the map of data coverage. The maps are made the scale of 1:5000000. The maps of D and F are also given in the scale of 1:1500000. (Sas-Uhrynowski et al., 1999b, 2000b, 2001b).

The magnetic anomaly field over Poland and adjacent regions by using MAGSAT Satellite Data has been also investigated (Rotanova et al., 2000).

Secular variations of the geomagnetic field have been investigated on the basis of the results of the magnetic measurements periodically repeated at the secular stations of magnetic network. The network of 19 stations in Poland exists already for almost 50 years. The 11 stations in Belarus and 6 stations in Lithuania have been established in the late 90-ties and then surveyed twice with use of Flux D/I absolute magnetometers and proton magnetometers (Sas-Uhrynowski et al., 2000a, 2001b, 2002).

Morphology and dynamics of the non-dipolar part of the vector geomagnetic field has been studied (Kasyanenko et al., 2000, 2001).

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