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# EASTERN SILESIAN GEODYNAMIC GPS NETWORK-PRELIMINARY RESULTS OF THE CAMPAIGN 2003-2004*

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ABSTRACT
Geodynamic GPS network has been established in the area limited by four permanent GPS stations – KRAW (Kraków), ZYWI (Żywiec), KATO (Katowice), LELO (Lelów). It is an extention of geodynamical network of the vicinity of Krakow into Eastern Part of Upper Silesian Coal Basin(USCB). One of the basic problems occuring in this area which is subject to particularly significant deformations resulting from intensive mining is the current updating of its geodetic frames. Present state of the Geodynamic GPS network linked to the above nearest permanent GPS stations, POLREF system and levelling network GIGANT are presented. Proposals of inspection method of classical levelling network in mines area by means of GPS measurement are also given. Special attention has been paid to the method of ground deformation monitoring in mine areas.

**KEYWORDS:** Upper Silesian Coal Basin, permanent GPS stations, geodynamic network, deformation monitoring

## 1. BRIEF PRESENTATION OF THE PROJECT AND ITS SCIENTIFIC PURPOSES

In the recent years GPS has been extensively used for deformation monitoring. The advantages of using the GPS for deformation monitoring can be amplified when the area coverage is large.The main output from processing of GPS observations are coordinates. The differences of this coordinates in time and space are used for monitoring of ground deformations. In 2002 a team of scientists from Department of Geodesy and Cartography and Department of Mine Surveiyng of the Faculty of Mining Surveying and Environmental Engineering, AGH-UST, initiated research within the project named "Research geodynamic network linked to the levelling network GIGANT and Active Geodetic Network (ASG-PL)" (Goral, 2002). The geodynamic network is situated within the area between Kraków and Katowice. The network covers the eastern part of the USCB in Poland (Fig. 1). The major purpose of the project is establishing a precise GPS network and its integration with levelling network GIGANT and determining geoid undulations. The combination of GPS measurements and levelling yields information on the inclination of the quasi-geoid/geoid relative to the WGS84 ellipsoid (deflection of the vertical). Once the inclination components of the quasi- geoid are known for an area of operation the GPS derived ellipsoidal height differences can be transformed into normal height differences. The work is oriented to application of results obtained from GPS permanent and epoch observations to monitoring surface deformations within the area of mining activities. There are several reasons for initiating this kind of a research project. The USCB area is the most man transformed area in Poland due to mining and other industry. A comprehensive look at the range of the influence is an urgent need to modernization of classical geodetic network in the area of USCB in Poland. Studies and testing of new measuring technologies and software. Comparative studies of classical and modern methods of determining the geoidal heights. Studies of precise height determination and atmospheric effects. One of the tasks realized in the framework of the created geodynamic network is to create a model of a local sub-centimeter quasi-geoid and geoid.

## 2. LEVELLING NETWORK GIGANT AND ASG-PL NETWORK

Large-scale observations of the surface subsidence in the Polish part of USCB area were achieved by the second order-levelling network called GIGANT (Banasik et al. 2000, 2002). This network has been established systematically since 1968. Its goal was to find the changes in the initial state of the surface of the area and the rock mass, connected to mining activities. GIGANT was established to make the bases for the reference of observation lines of particular mines. This goal was achieved by repeated observations in sequences of total length 1370 km.

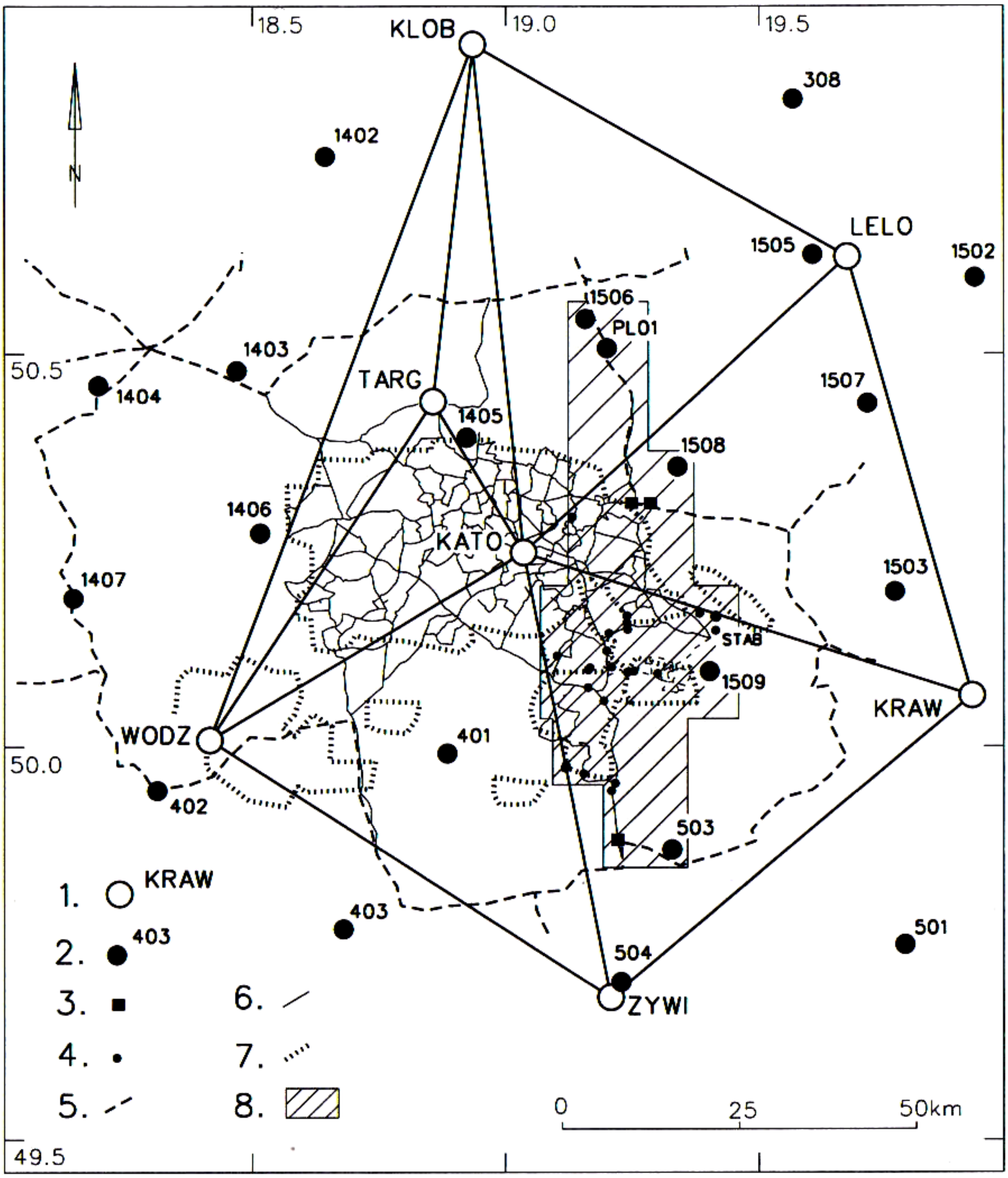


**Fig. 1** Location of the research geodynamic network.
1 - permanent GPS station; 2 – point of POLREF network; 3 – initial fundamental levelling benchmark GIGANT; 4 – GPS points; 5 – Polish first order levelling network; 6 – GIGANT (second order levelling network); 7 - mines area; 8 - area of the research geodynamic network

**Table 1** Geodetic coordinates of the permanent GPS stations

| Site | B [° ′ ″] | L [° ′ ″] | h [m] |
|---|---|---|---|
| KRAW | 50 03 58.10463 | 19 55 13.70889 | 267.165 |
| KATO | 50 15 11.76522 | 19 02 08.27285 | 332.938 |
| ZYWI | 49 41 12.07769 | 19 12 21.42221 | 412.832 |
| LELO | 50 40 58.38170 | 19 37 43.95508 | 306.347 |
| WODZ | 50 00 00.57511 | 18 27 30.32345 | 298.848 |
| KLOB | 50 54 19.87444 | 18 56 12.81917 | 301.672 |

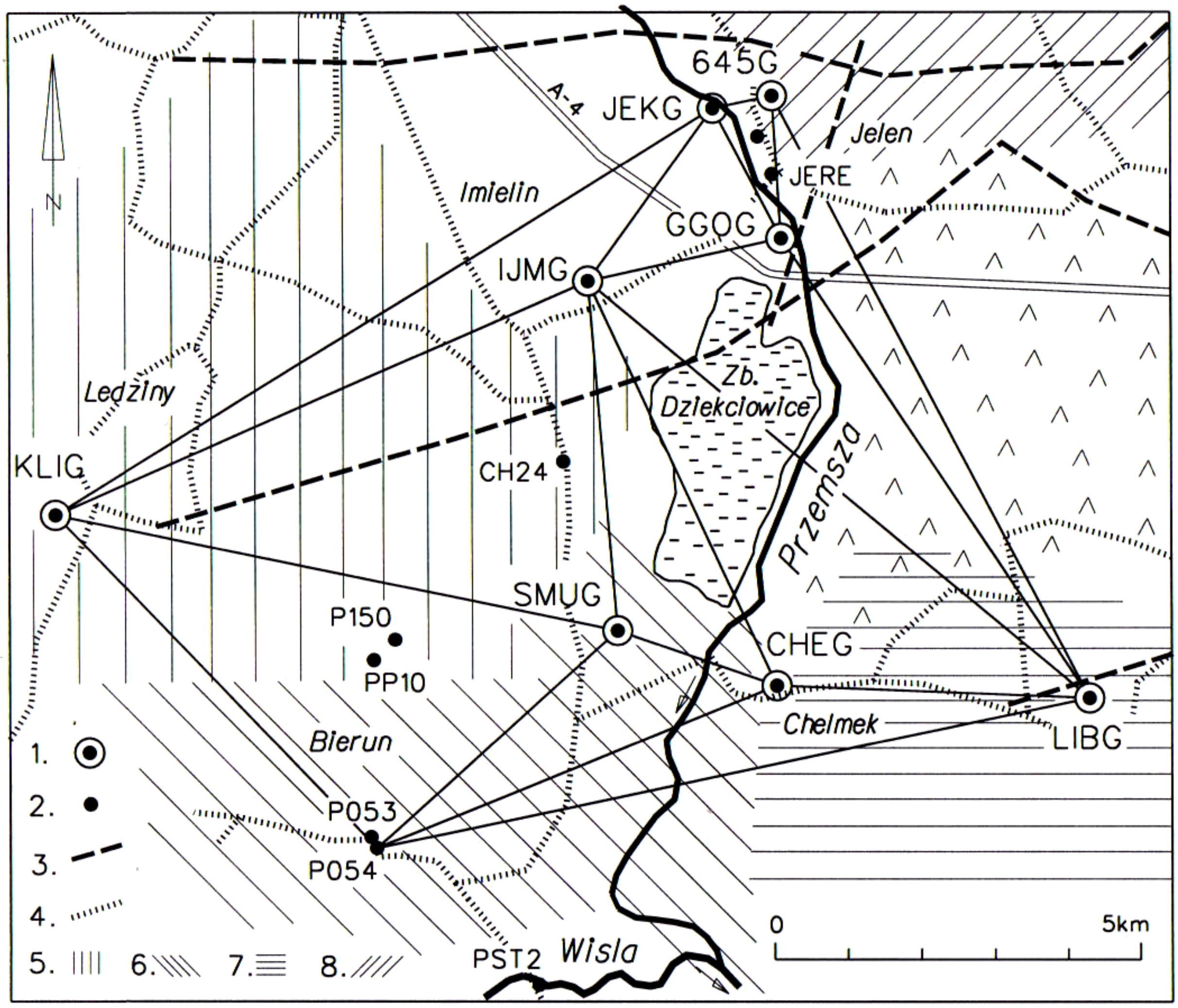


**Fig. 2** The research geodynamic network along the "Przemsza" river
1 - geodynamic network points (GPS, gravimetry, levelling); 2 – GPS monitoring points;
3 – tectonic faults; 4 – fragment of the levelling network GIGANT;
5,6,7,8 – areas of the following mines: "Ziemowit", "Piast", "Janina", "Jaworzno".

GIGANT nowadays contains 1656 benchmarks, including 23 reference points. The measurements of the network were performed in two or three years series. The network covered entire area of Polish part USCB area and is linked to the first order levelling network (Fig. 1).

At the end of 2002 the GPS permanent station KRAW started in Kraków. The station is located on the roof of the building of our Faculty. At the end of January 2003 it was included into the EPN. Since February 2003 in Vojevodeship Slaskie the so called Active Geodetic Network(ASG-PL), consisting of six permanent GPS reference stations, has been in operation. The ASG-PL network with KRAW station also covers entire area of USCB (Fig. 1). Silesian active GPS stations as well as KRAW station are equipped with the same receivers - Ashtech μZ – CGRS (Continuous Geodetic Reference Station ) and Ashtech choke ring antenna with radome. Currently stations KRAW, KATO and ZYWI are included into the EUREF Permanent Network (EPN). From these stations hourly and daily observation files are transmitted to Data Center in BKG. The operation of the above stations stimulate research of increasing accuracy, reliability and efficiency of positioning with the use of GPS permanent stations.

Refering GIGANT network to ASG-PL makes building of a uniform, precise geodetic system resistant to local mining caused deformations possible. It will modernize the existing geodetic surveying networks in USCB area allowing the monitoring of technogenic and natural dislocations of selected points. The results of the observations of the network will simplify distinguishing the sources of deformations. Used reference frame is defined by the stations the coordinates of which (latitude, longitude and ellipsoidal height in the system ETRF'89) are taken from: www.asg-pl.pl and are given in Table 1.

### 3. "EASTERN SILESIAN" GEODYNAMIC RESEARCH NETWORK

The Eastern Silesian Geodynamic Research Network (ESGRN) is located in the area enclosed by four permanent GPS stations: KRAW, ZYWI, KATO, LELO (Fig. 1). The research network covers the area over 1000 km$^2$ and its length is ca. 50 km in meridian direction and about 15 – 20 km in E–W direction. Six mines are located in the research area: "Brzeszcze","Ziemowit", "Piast", "Janina", "Jaworzno" (Fig. 2), and "Trzebionka". Currently the network consists of 40 points measured in period 2003 –2004 by GPS techniques. The GPS sites were selected after detailed geological and geodetic analysis. Research network points were set up in places suitable for GPS observations, often on neighbouring points of the state triangulation network. Points have mostly been stabilized directly on triassic outcrops. Only point SMUG have been monumentated with blocks of concrete with heads for forced centring. Research points have been concentrated on the triassic outcrops along the valley of Przemsza river, between the Jelen and Chelmek- points: 645G, JEKA, IJMG, GGOG, CHEG, LIBG, SMUG - (Fig. 2). Gravity and gravity vertical gradients observations have been accomplished in cooperation with the Department of Geophysics AGH-UST on twenty points, using SCINTREX CG-3M instrument. Twenty points of the GPS network were also tied by precise levelling to the neighbouring points of second order levelling network GIGANT and state first order levelling network.

### 4. MEASUREMENTS, DATA ANALYSIS AND PRELIMINARY RESULTS

Static satellite GPS measurements were carried out in 3÷10 h sessions with data registered every 15 s. Measurements were taken with Z-Survey receiver with the antenna type of ASH701008.01B (3 sets). The presented results are based on the processed GPS measurements from DOY 309, 2003, obtained on the stations: KRAW, ZYWI, KATO, 645G, IJMG. The preliminary processing of GPS observations was made with the help of GPPS 5.2 Ashtech Software with the following default values: 20° temperature, 50% humidity (48.5% only for KRAW in sessions A and B), and 1010 hPa pressure, 12° elevation cut-off angle. Ionosphere was eliminated by the ionospheric free linear combination. In first step the appropriate phase center offsets and elevation dependent corrections patterns, taken from NGS, were introduced to the GPS observations with the help of our software (Goral et al., 1999). In the next step, for comparative studies of the strategy applied, the observations from stations KRAW, ZYWI and KATO were processed. The obtained differences between computed coordinates B, L, h and its "true" values – given in Table 1 - and the associated standard deviations for points ZYWI, KATO and KRAW are presented in Table 2. The same is presented for points 645G and IJMG in Table 3, which coordinates are obtained as a average values from 6 given solutions.

$\Delta T$ denotes durations of the sessions. It can be noted that the geodetic coordinates of the stations: ZYWI, KATO, KRAW obtained by processing GPS observations in two sessions, are in very good agreement with their coordinates given in Table 1. In Table 3 we find an excellent agreement between the results of determined coordinates for stations: 645G and IJMG on the base of three reference stations: KRAW, ZYWI, KATO. Analysis of data presented in Tab. 2 and Tab. 3 indicates that there is a very good compatibility of the obtained results. It was due to very good meteorological conditions. Fig. 3 presents meteorological parameters for station KRAW (2003 DOY 309). To analyse the stability of meteorological conditions, time series of zenith total delay (ZTD) obtained for EPN stations are more favourable. Fig. 4 shows hourly solutions of ZTD (2003, DOY 309) for four Polish EUREF stations. In Fig. 4 one can see that fluctuations of values ZTD for stations: KRAW, ZYWI and KATO are very small (especially for sessions A and B). While the difference of average values of $\Delta$ZTD for baselines: KRAW-ZYWI, KATO-ZYWI, KRAW-KATO - sessions A and B, given in the last column in Table 2 - are practically the same. These relative differences between average values of ZTD for sessions A and B are very good indicators of the stability of meteorological conditions. Data presented in Table 2 and Table 3 prove that the relative stability of meteorological conditions, the ionosphere and others factors, gives solutions of high accuracy.

**Table 2**

| baseline | SESS. | $\Delta B$ [mm] | $\sigma_B$ [mm] | $\Delta L$ [mm] | $\sigma_L$ [mm] | $\Delta h$ [mm] | $\sigma_h$ [mm] | $\Delta b$ [mm] | $\sigma_b$ [mm] | $\Delta T$ [h:m] | $\Delta$ZTD [mm] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| KRAW-ZYWI | A | 4.9 | 3.0 | -0.6 | 2.1 | 0.0 | 5.4 | -2.0 | 3.6 | 4:40 | 42.7 |
| 66479.030 m | B | 4.6 | 3.5 | -0.7 | 2.6 | 0.0 | 6.8 | -2.0 | 4.5 | 3:15 | 43.8 |
| ZYWI-KATO | A | 0.6 | 3.1 | -0.9 | 2.2 | 2.0 | 5.5 | 0.0 | 4.1 | 4:40 | 25.1 |
| 64196.910 m | B | 2.1 | 3.1 | 5.0 | 2.0 | 0.0 | 7.3 | 1.0 | 5.3 | 3:15 | 25.2 |
| KATO-KRAW | A | -1.6 | 2.4 | 1.3 | 1.8 | 0.0 | 4.2 | 3.0 | 2.0 | 4:40 | 17.6 |
| 66569.396 m | B | -1.2 | 3.2 | -1.7 | 2.2 | 0.0 | 5.6 | -1.0 | 2.7 | 3:15 | 18.6 |

**Table 3**

| distance | SESS. | ΔB [mm] | $\sigma_B$ [mm] | ΔL [mm] | $\sigma_L$ [mm] | Δh [mm] | $\sigma_h$ [mm] | Δb [mm] | $\sigma_b$ [mm] | ΔT [h:m] |
|---|---|---|---|---|---|---|---|---|---|---|
| **645G:** B=50°10′19.91347″±0.00013″, L=19°14′22.99007″±0.00009″, h=323.674m±0.003m | | | | | | | | | | |
| **KRAW - 645G** | A | 0.9 | 3.5 | -1.3 | 2.8 | 3 | 6.8 | 0 | 3.0 | 2:55 |
| b=50097.376 m | B | 6.8 | 3.8 | 1.3 | 2.7 | -2 | 7.4 | -1 | 3.5 | 2:49 |
| **ZYWI - 645G** | A | -5.6 | 4.1 | 0.6 | 3.2 | 6 | 7.8 | -4 | 6.1 | 2:55 |
| b=54059.594 m | B | 1.5 | 4.2 | 2.6 | 3.0 | -3 | 8.1 | 3 | 6.2 | 2:49 |
| **KATO - 645G** | A | -3.7 | 4.0 | 0.2 | 3.1 | 1 | 7.6 | 2 | 3.7 | 2:55 |
| b=17133.667 m | B | -0.6 | 4.3 | -3.0 | 3.1 | -4 | 8.2 | -2 | 4.1 | 2:49 |
| **IJMG:** B=50°08′58.25264″±0.00014″, L=19°12′14.54299″±0.00009″, h=347.267m±0.001m | | | | | | | | | | |
| **KRAW - IJMG** | A | -0.9 | 3.2 | -1.8 | 2.3 | 0 | 5.9 | 1 | 2.7 | 4:19 |
| b=52084.874 m | B | 7.7 | 4.0 | 2.0 | 2.9 | 1 | 7.7 | -1 | 3.6 | 3:00 |
| **ZYWI - IJMG** | A | -5.2 | 3.4 | 0.0 | 2.4 | 0 | 6.3 | -4 | 4.8 | 4:19 |
| b=51482.169 m | B | 2.8 | 4.1 | 2.6 | 2.9 | 0 | 7.8 | 4 | 5.9 | 3:00 |
| **KATO - IJMG** | A | -4.9 | 3.5 | -0.4 | 2.5 | 2 | 6.4 | 2 | 3.7 | 4:19 |
| b=16666.967 m | B | 0.3 | 4.0 | -2.2 | 2.9 | 0 | 7.8 | -3 | 4.4 | 3:00 |

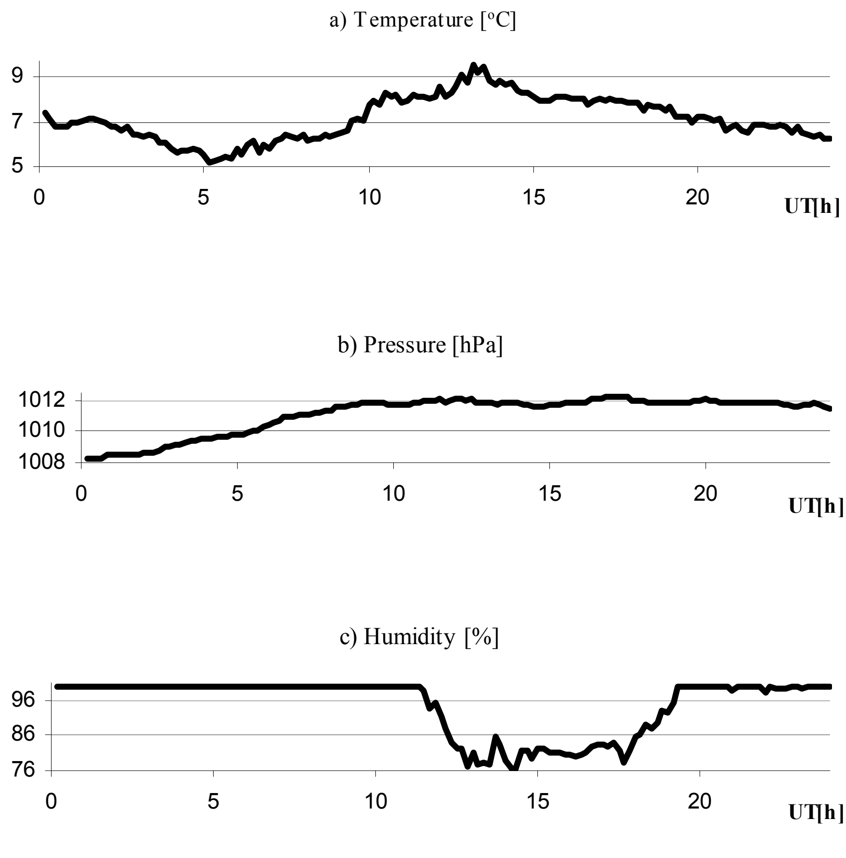


**Fig. 3** KRAW 2003 DOY 309, a) temperature, b) pressure, c) humidity

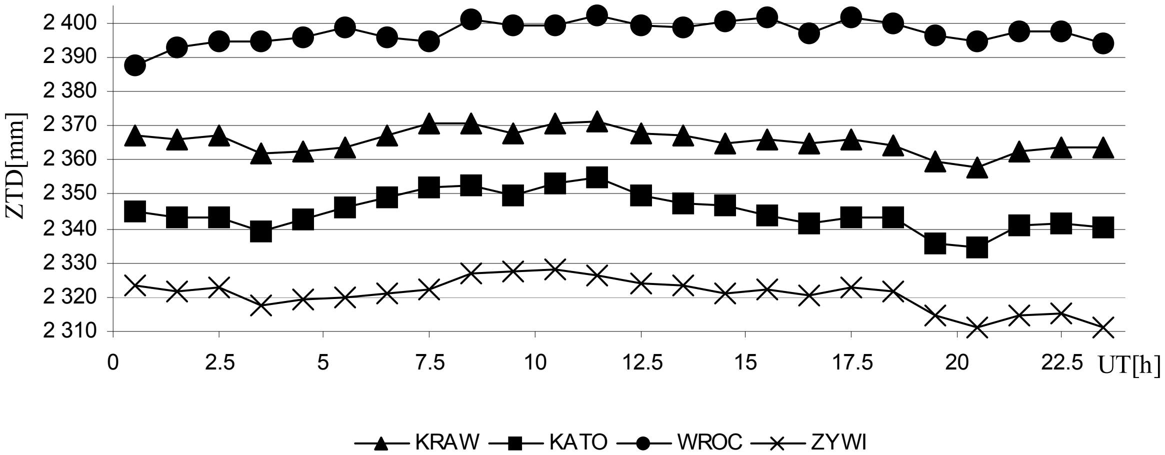


**Fig. 4** Zenith total delay (ZTD), 2003 DOY 309, [05 Nov.]

## 5. CONCLUSIONS

GPS technology proved its convenience for long term monitoring of spatial displacements of points caused by different factors. Properly used GPS technology can give the positions of points in a fixed coordinate frame with accuracy of few millimeters. Recently the establishment of the permanent GPS stations in the South of Poland, using GPS technology has become an important means in the mine surveying work. GPS can also be used to collect, update and modify data for mine geographic information system. With the GPS technology one can survey and modify ground control network for mine area, and survey the observation station of surface movement. The permanent ASG-PL + KRAW network will provide valuable data for understanding and modeling the GPS error spectrum over a wide range of spatial and temporal scales, and enables characterization and understanding of distribution and time dependence of deformations within USCB in Poland.

## REFERENCES

Ashtech XII GPPS$^{TM}$: 1993, The GPS Postprocessing System Manual Version 5.0.

Góral, W., Kudrys, J. and Maciaszek,, J: 1999, Precise measurements of differences in height by means ofGPS in environment of terrain obstructions. Scientific Bulletins of the University of Mining and Metallurgy, Geodesy, Vol.5, No.2, Cracow, 207-218, (in Polish).

Banasik, P., Góral, W., Maciaszek, J. and Szewczyk, J.: 2000, Monitoring of large-area surface changes in Upper Silesia Industrial area (GOP) with application of modern measurement technologies. 11 th International Congress of International Society for Mine Surveying, Vol.1, Cracow, 2000, Poland.

Banasik, P., Góral, W., Maciaszek, J.and Szewczyk, J.: 2004, Silesian Active Geodetic Network in supporting high precision positioning in the region of intensive mining, 12 th International Congress of International Society for Mine Surveying, Vol.1, Fuxin-Beijing, 2004, China, 524-527.

Góral, W.: 2002, A concept of research geodynamical network in the area limited by Silesian Active Geodetic Network and permanent station KRAK. Scientific Bulletins of the University of Mining and Metallurgy, Geodesy, Vol.8, No.1, Cracow, 19-25, (in Polish).