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THE USE OF PERMANENT AND EPOCH GPS COORDINATE TIME SERIES IN GEODYNAMIC INVESTIGATIONS OF SUDETES AREA - PROPOSAL OF A NEW APPROCH

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ABSTRACT
The future of the global and local geodynamic researches belongs to permanent monitoring. The conception of the semipermanent GPS observations' application in geodynamic research in Sudetes area is presented in this paper. The conception is based on spatial modeling of the disturbing phenomena in the coordinate time series of (semi) permanent stations.
The local interplate movements and their correlation with major European tectonic structures are determined on the strength of coordinate time series of these stations. The problem of epoch integration with semipermanent and permanent (EPN/IGS) observations for local geodynamic monitoring is also investigated.

KEYWORDS: recent tectonic movements, GPS time series, semipermament GPS stations, Sudeten

INTRODUCTION

Geodynamic researches of Sudetes area and its foreland have been conducted since 1996. Within this territory research networks were established and GPS and gravimetric measurements were carried out (1996-2005). The results of measurements that have been performed show contemporary tectonic activity of the area (Cacoń et al., 2003, 2004, 2005; Kontny, 2003; Schenk et al., 2003).

The future for the global and local geodynamic researches will be permanent measurements. Permanent EPN/IGS network stations, which have been used within global, regional and local scope for many years, and namely their time series coordinates changes enable the examination of area's geodynamics (Bock et al., 1997; Hudnut et al., 2002; Herring, 2003).

In Polish conditions starting dense local networks of permanent GPS observations is currently economically unjustified due to enormous costs of establishing such networks. GPS permanent stations' network is too sparse and for this reason GPS periodic observations are applied in geodynamic researches.

In this paper the conception of application of mobile, periodically permanent stations (often called semipermanent) in geodynamic surveys in Sudetes area and its foreland is presented. At these stations continuous measurements will have been taken from 1 up to 2 years. Observations made from these stations and other permanent stations situated in the neighborhood will allow to detect periodic phenomena as well as phenomena which have non-linear structure in time series of GPS points' coordinates changes.

It enables filtering the influence of interference factors from time series of coordinates changes in the case of permanent and epoch stations. The "refined" trends of EPN/IGS permanent stations' positions changes, semipermanent and epoch points' position changes will be the base for the area's kinematics model determination. The model above permits to analyze the correlation of the Earth crust movements with local tectonic structures (Kontny et al., 2004).

GPS POINTS COORDINATES TIME SERIES ANLALYSES

Permanent GPS stations networks of global, regional and local dimension which have been in use for many years brought new quality to geodynamic researches. Coordinates changes time series are more and more often applied as accurate and reliable source of information about surrounding areas geodynamics. On global level time series analysis are made on the base on permanent stations networks - International GNSS Service (IGS). One of IGS' products are network points velocities determined in particular reference system realization, currently ITRF 2000 (Altamimi et al., 2002).

Within regional EUREF Permanent Network – EPN which is a component of global IGS network the specific project entitled „Time Series for

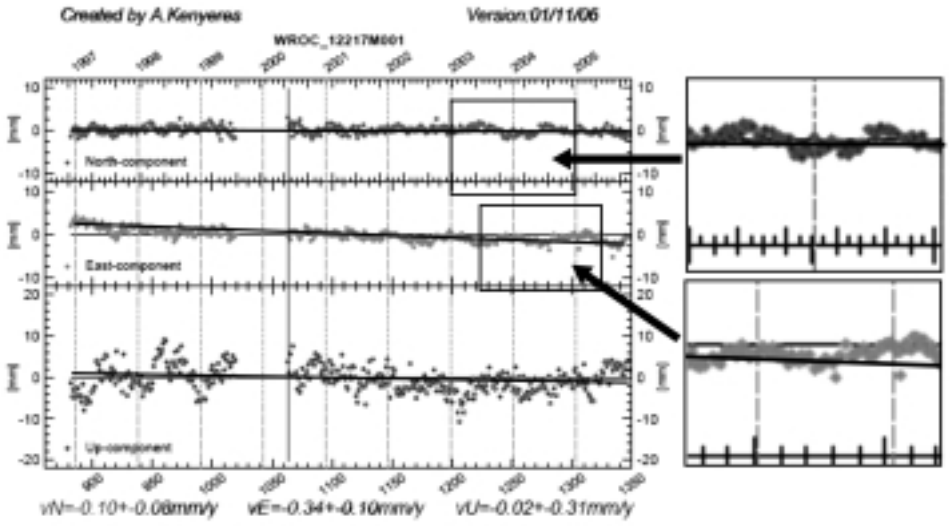

Fig. 1 Velocities components for the WROC station.

Geokinematics" is realized (Kenyeres et al., 2002). Nowdays for each EPN station points velocities are determined on the base on EPN networks week solutions in ITRF 2000 system implementation *(http://www.epncb.oma.be/_dataproducts/timeseries/index.html)*. These values are exemplified by WROC station in Figure 1.

The exemplar of permanent stations network on the local level is Southern California Integrated GPS Network – SCIGN (Bock et al., 1997), in which time series analysis for geodynamic purposes are carried out by a few institutions in the USA, inter alia, JPL, Massachussets Institute of Technology – MIT (Hudnut et al., 2002; Herring, 2003) and Scripps Orbit and Permanent Array Center – SOPAC (Nikolaidis, 2002). In Europe, time series analysis in permanent stations networks, which have local character, for the geodynamic researches needs are carried out, inter alia, on the Apennine peninsula (Vespe et al., 2001) and in Scandinavia (Poutanen et al., 2001). Quality and quantity analyses of vectors components short – term changes determined from GPS observations are described in the work (Kryński and Zaniemonskiy, 2003).

The method of reference stations selection for local geodynamic networks on the base on time series coordinate changes of those networks is also depicted in this work.

Estimated movements parameters for permanent stations, e.g. EPN, have mostly global character; they are determined for long time intervals and they may be free of the plates movements by means of geokinematic models. In shorter time intervals these values are biased by different periodic components of time series (compare Fig. 1). For local geodynamic parameters estimation (resulting from local phenomena) periodic components of global and regional type should be eliminated.

Figure 2 presents spectral density of BOGO station's coordinates vertical component changes for series of weekly solutions. In this series two dominant components may be recognized: a year-period component and approximately 3.5-year-period component. In the case of daily and hourly coordinates changes series short-term components will be also seen. They will often have non–stationary character. To investigate this type of series non–stationary wavelet analysis is recommended (Keller, 2004). First trials in this discipline have already been taken but in limited range by Bruyinx and Yseboodt (2002). Ding et al. (2002) applied wavelet analysis to periodic components identification in GPS observations series at permanent stations in Pacific Ocean region.

EPOCH OBSERVATIONS

In 1996 the local geodynamic network GEOSUD was established (fig. 3) covering the area of Eastern Sudetes and Fore – Sudetic Block (Cacoń et al., 1998; Cacoń and Dyjor, 1999). In 2000 the successive points were incorporated into this network in the western part of the investigated area (Cacoń and Dyjor, 1999). In 1997 the selected points of GEOSUD network were included in POLISH – CZECH regional geodynamic network SUDETY (Schenk et al., 1999) which is attached to GPS permanent stations that belongs to IGS/EPN network

Since 1997 in SUDETY and GEOSUD networks annual, two-day-observation campaigns have been performed. The particular strategy of local GPS network processing for the networks connected to IGS/EPN stations was designed (Bosy and Kontny 1998, Bosy et al., 2003, Bosy, 2005). The strategy optimizes data coming from epoch campaigns and allows to gain accuracy comparable to IGS/EPN permanent networks processing results. The model of

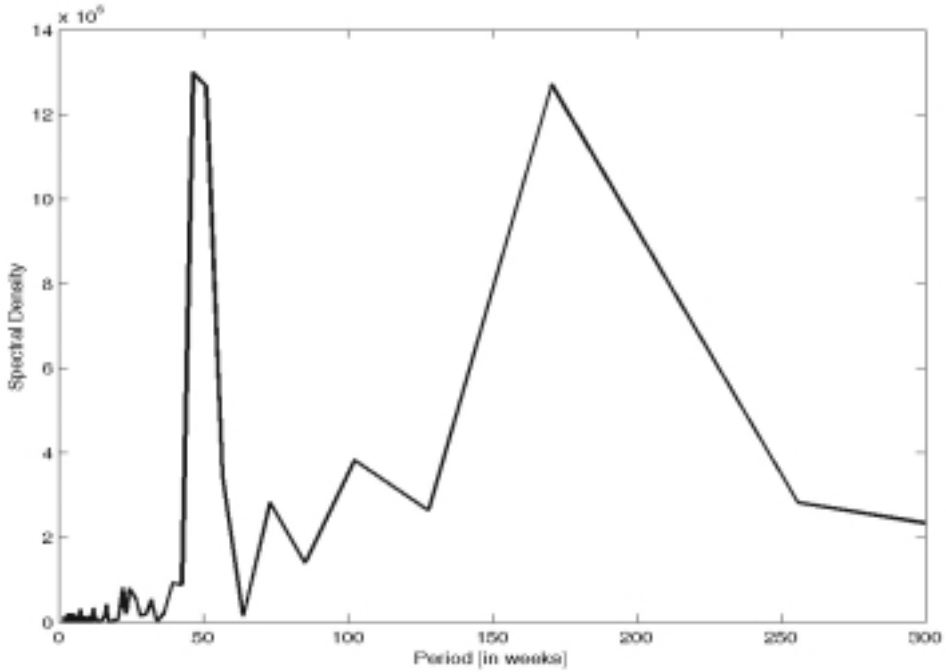

Fig. 2 Spectral density for the BOGO EPN-station from weekly solutions.

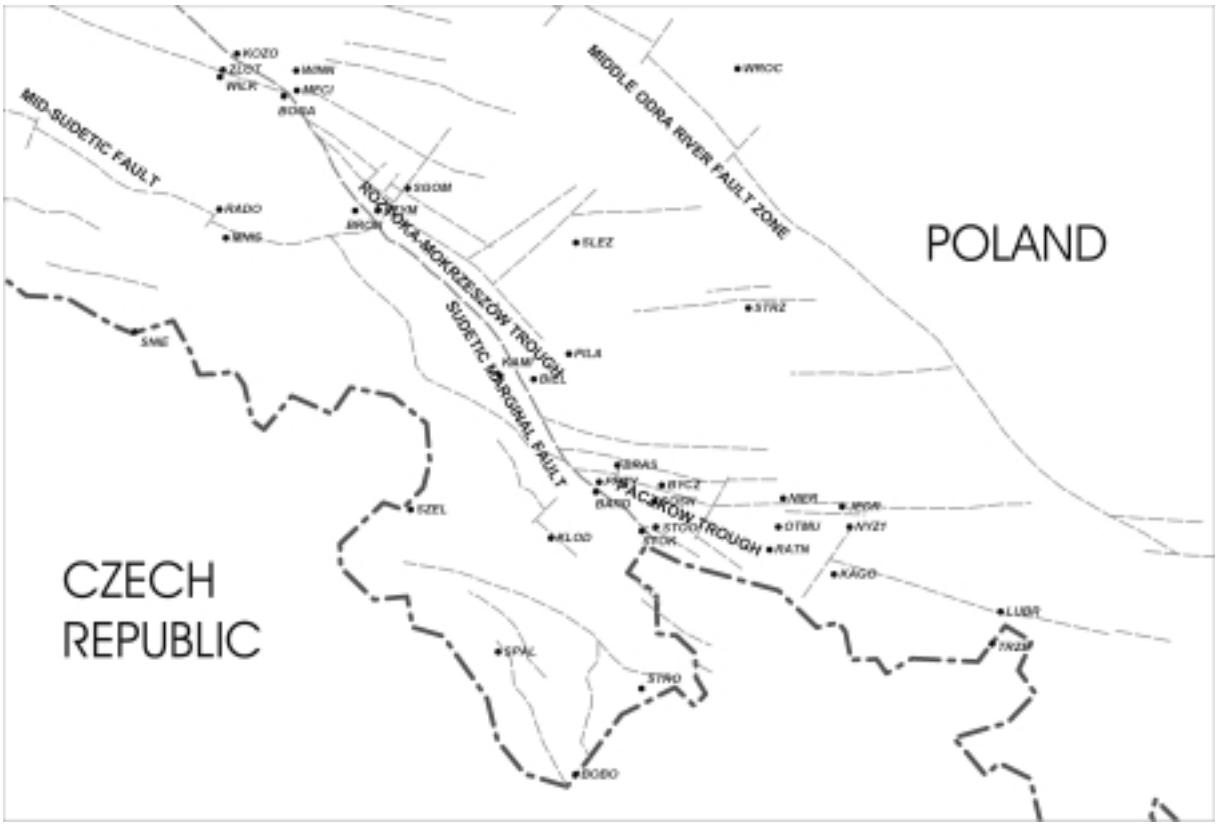

Fig. 3 Local geodynamic network GEOSUD.

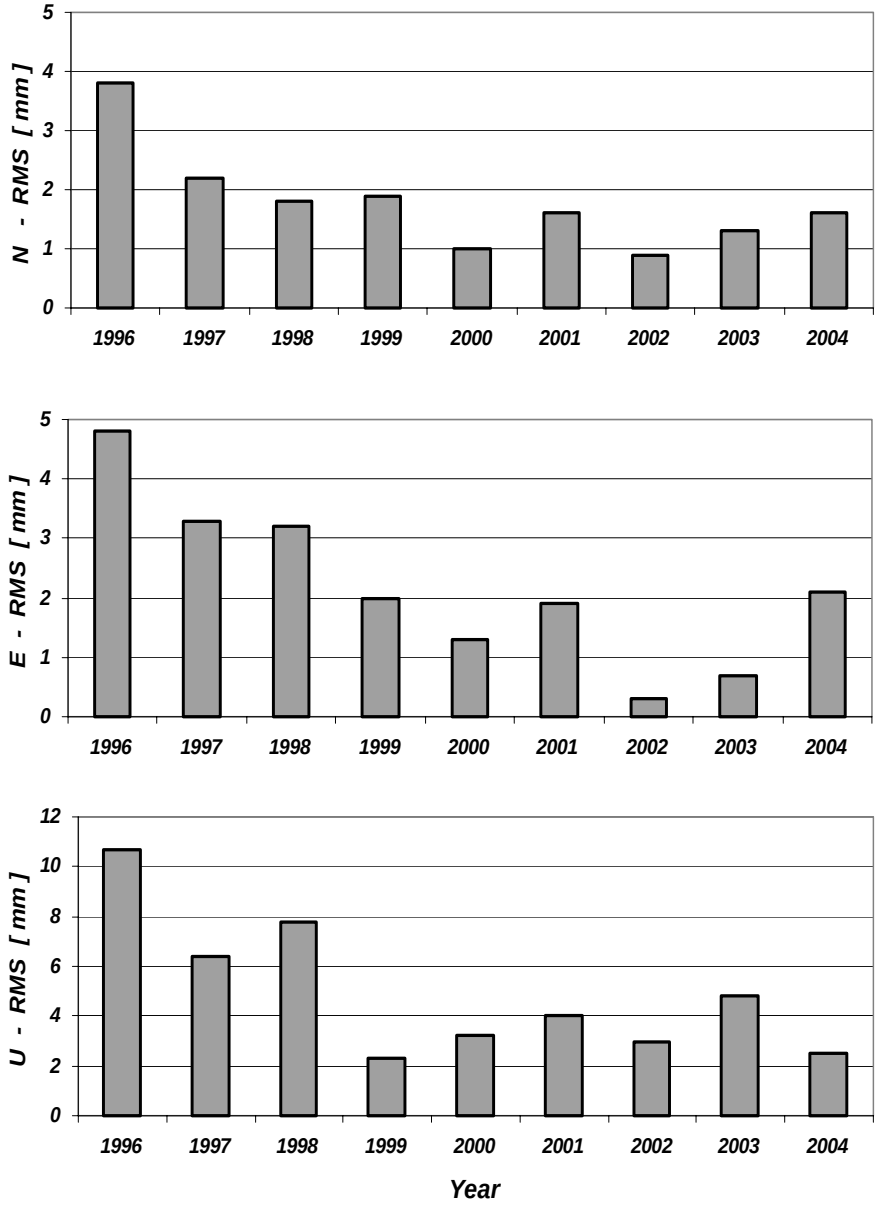

Fig. 4 Estimation of the accuracy of GPS observations in the GEOSUD network in period 1996-2004 (unweighted RMS values with respect to the combined solution in mm).

local ionosphere WUTE–L and local troposphere model, based on meteorological observations by tropospheric delay estimation, were applied in this strategy.

In Fig. 4 collective accuracy characteristics for GEOSUD network in form of RMS errors computed from residues for each observation campaign are presented.

As results from Fig. 4, from the year of 2000 show, the accuracy of points coordinates determination reached the steady value of 2 mm for horizontal components and under 5 mm for vertical component.

On the basis of epoch measurements' results (discrete changes of coordinates) points' kinematic parameters were designated in form of velocities components. Details related to the way of velocity determination were presented in the work (Kontny, 2003) and horizontal velocity vectors estimated from the data of the period of 1996 – 2004 are presented in Fig. 5.

Fig. 5 Horizontal velocities of GEOSUD network points (1996-2004).

CONCEPTION OF COMBINATION OF EPOCH AND SEMIPERMANENT OBSERVATIONS

The proposed conception of semipermanent stations consist in application of local research networks of continuous observations in selected points (mobile GPS networks), performed in finite time interval, e.g. 1-2years, whereas in the remaining points epoch measurements are realized. After 2-year-measurement period, which is long enough to determine sufficiently accurate parameters of points movements, semipermanent stations may be moved to other network points.

On the strength of coordinates time series analysis of permanent EPN/IGS stations and semipermanent stations obtained from weekly or daily solutions and by EPN products application (ionosphere model, Tropospheric Zenith Delay TZD) periodic signals are detected together with their influence on the station's coordinates (signal's amplitude and phase). Spatial distribution of periodic signals parameters and their correlation with atmospheric factors changes and other geophysical factors allow to identify potential interfering sources as well as to compile spatial model of their influence (correlation model for epoch solutions). The periodically observed points coordinates received from epoch solutions are rectified by corrections resulting from the model. Released from periodic influences, coordinates time series of semipermanent and epoch stations, constitute data for movement parameters determination and compilation of researched area kinematics model. The pattern for permanent and epoch observations compilation is presented in Figure 6.

In the investigated area 3 permanent EPN stations exist: WROC, SNEZ and BISK (Schenk et al., 2002). It is recommended to install at least 2 additional semipermanent stations. Permanent stations location and proposed semipermanent stations location in the investigated area is shown in Figure 7.

It is proposed to locate mobile stations in pairs, on the both sides of the main tectonic fault zone so as to determine parameters of its kinematics.

CONCLUSIONS

The major scientific effect of proposed conception is methodological proposal for determination of GPS points kinematic parameters. On the basis of those parameters the kinematics parameters of the area tectonic structures may be determined in the way which enables interfering factors influence filtering. The most important advantages of the proposed approach, which is the combination of permanent and epoch networks, are as follows:

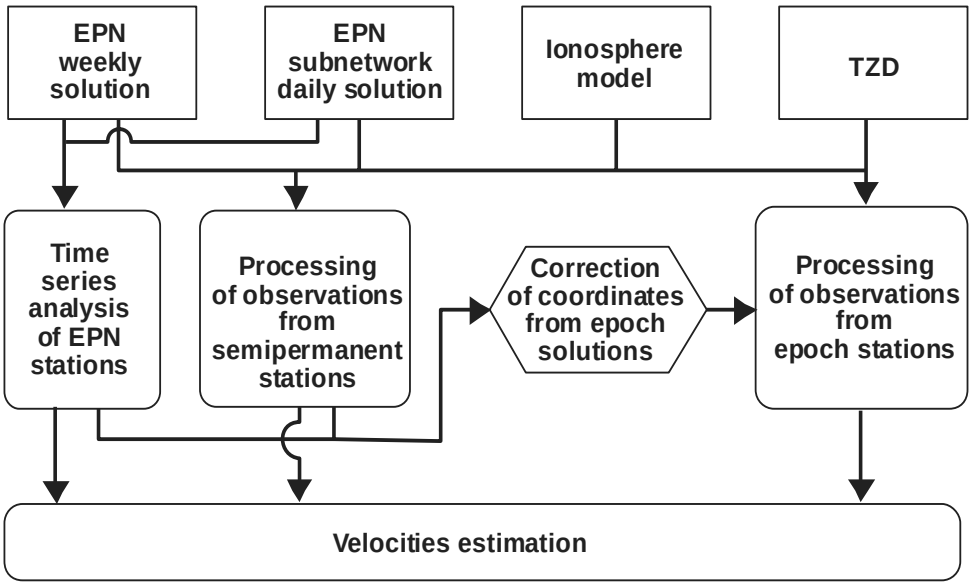

Fig. 6 Diagram of GPS data processing strategy for combine epoch permanent and semipermanent observations.

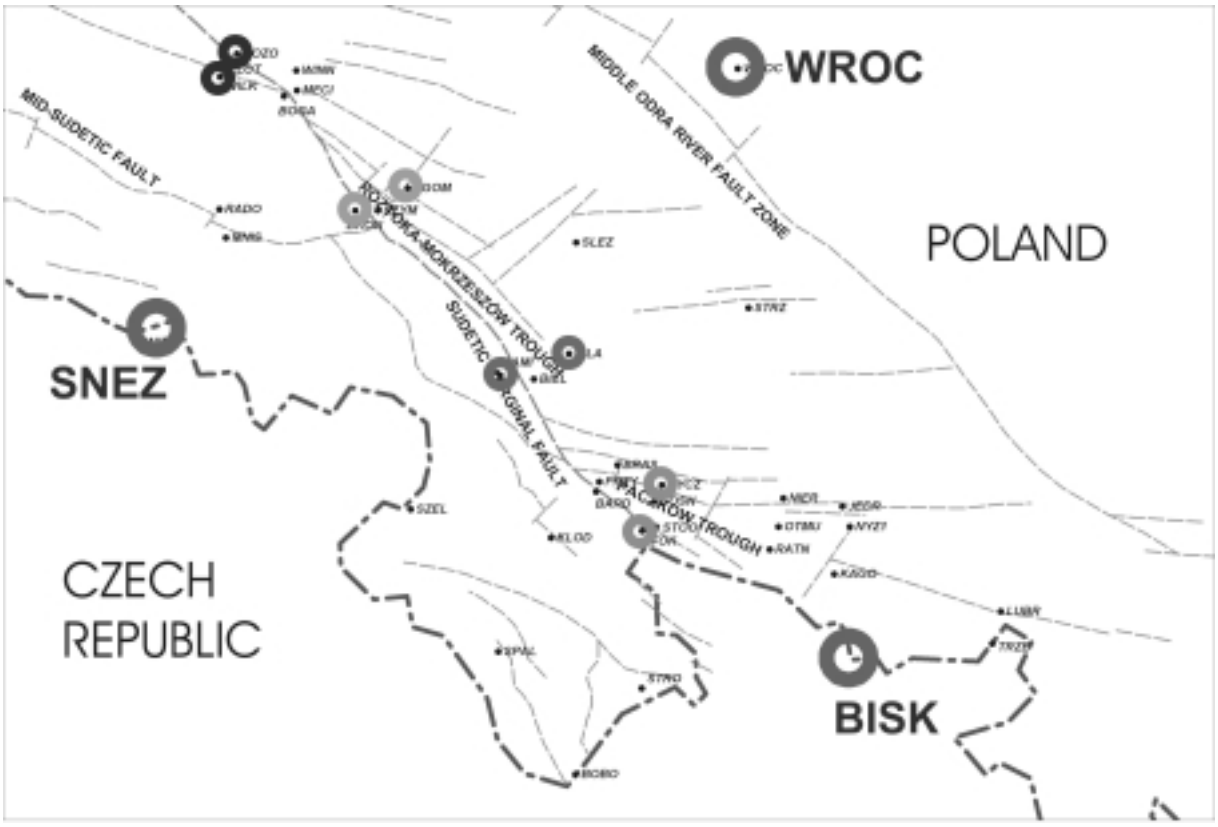

Fig. 7 Location of permanent and semipermanent GPS stations – proposal.

- possibility to connect epoch measurements to permanent EPN stations and EPN products application (ionosphere and troposphere) in local network solution
- possibility to determine periodic variations in time series of local network points coordinates being under the interfering factors influence (geophysical and atmospheric) and considering their influence in epoch measurements results
- possibility to determine precise linear movement velocities (linear trends) of selected network points in relatively shorter time period than in the case of epoch measurement, what is particularly important for engineering objects danger evaluation
- possibility to detect episodic relocations (eg caused by tectonic and mining upheavals or technogenic factors) in time series at semipermanent stations
- possibility to detect non – linear character of points movement

Application of this approach will enable more reliable danger evaluation for engineering – technical objects in the research area resulting from natural, contemporary earth crusts movements. It mainly refers to dams situated in the area of active tectonic faults (e.g. Dams in Nysa and Dobromierz).

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