

**17<sup>th</sup> Czech-Polish Workshop**

**ON RECENT GEODYNAMICS  
OF THE SUDETEN  
AND THE ADJACENT AREAS**

**ABSTRACTS**

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(Editors)

Ramzová, Czech Republic  
October 20 - 22, 2016

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2016

ISBN 978-80-86433-63-9

**Organizing Committee  
of the 17<sup>th</sup> Czech-Polish Workshop**

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# IMPACT OF HYDROLOGICAL FACTORS AND NON-TIDAL OCEAN LOADING ON CHANGES OF GNSS COORDINATE TIME SERIES FOR SELECTED STATIONS

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## ABSTRACT

The aim of analysis is determine impact of hydrological factors and non-tidal ocean loading on changes GNSS coordinate time series for North, East and Up component. For this purpose used data model from GGFC (Global Geophysical Fluid Center) and the coordinate time series of IGS stations (CODE Repro2013).

**Keywords:** *GNSS time series, correlation signals, non-tidal ocean loading, hydrology.*

# **POSSIBILITY OF THE SEISMIC HAZARD PREDICTION IN THE MIDDLE-ODRA FAULT ZONE ON THE BASIS OF THE OBSERVATIONS OF THE SWIEBODZICE DEPRESSION KINEMATIC ACTIVITY**

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## **ABSTRACT**

Variations of kinematic activity of rocky blocks of Swiebodzice Depression massif are produced by changes of the sub-continental scale field of tectonic stresses. Irregular in the time approaches of the field of tectonic stresses to Swiebodzice Depression are observed by instruments of the Książ Geodynamic Laboratory of SRC PAS. The fields of tectonic stresses cause changes of kinematic activity of massif which are registered by water tubes tiltmeters (WT) as huge variations of water levels in hydrodynamic systems of instruments. During the epochs of high tectonic activity signals registered by WT are one or more orders higher than the tidal signals. The signals registered by WT are interpreted as tiltings of foundation and vertical displacements of rocky blocks. Both signals, i.e. tiltings and vertical motions are, superposed by the WT registration system. The resultant signal was defined by us as tectonic activity function. Variations of the tectonic activity function were compared with the seismic activity in Fore-Sudetic Monocline. We observed correlation between locations of extremes and inflection points of the first derivative of the tectonic activity function and the seismic events on the Middle-Odra system faults in the Fore-Sudetic Monocline. Good correlation concerns only the strong earthquakes the energies of which were large than 4 Mj.

In the years from 2005 to 2015 almost all high energy seismic events take place when the tectonic activity function reach minima, maxima or inflection points and generally the function of first derivative was close to zero. In the epochs when function of tectonic activity was steep, i.e. tectonic activity of Swiebodzice Depression was strong, the high energy earthquakes almost never happened. In the case of the earthquakes of lower than 4 Mj energy this rule was not fulfilled. This observation indicates that the origin of the earthquakes of low and high energy is different. The high energy earthquakes are produced by natural tectonic activity, while the low energy earthquakes are associated with the mining industry activity.

Taking into attention above conclusion only high energetic earthquakes are suitable for discussion of dependences between positions of extremes as well as the inflection points of tectonic activity function and occurrences of seismic events. More detailed analyses show us that for evaluation of the level of seismic hazard not only positions of zero of the first derivative are important but also important are variations of trend of tectonic function preceding these earthquakes. We observed that specially high probability of occurrence of strong seismic events takes place just at the ends of long lasting trends of tectonic function several hours or single days after the change of trends.

***Keywords:*** *geodynamics, tectonics of the Sudetic Mountains region, tectonic and seismic activity, mine surveying, geodetic and geophysical measuring systems*

# **DETERMINATION OF HORIZONTAL VELOCITIES OF GNSS STATIONS AND INTERPRETATION OF TECTONIC SIGNALS REGISTERED BY WATER-TUBE TILTMETERS ON THE BASIS OF ESTIMATION OF CRUSTAL STRAIN**

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## **ABSTRACT**

Non-tidal effects are observed as episodic and strong signals (one order of magnitude or more greater than tidal signals), and registered in Książ Geodynamic Laboratory (LGK) since 1975 by horizontal pendulums (HP) and also by water-tube tiltmeters (WT), since 2003. The measurements of WT tiltmeters are several orders more precise than HP and based on different observing technique. Discussion the results from both types of instruments and studies the geological data provide us to the thesis that we are dealing with the tectonic effects. The main driving force of kinematic activity of the Świebodzice Depression are horizontal crustal movements. Lack of instruments in the laboratory, which are able to measure horizontal component of the rocky blocks movements caused, that we decided to complete underground measurements in the immediate vicinity of the laboratory through the establishment of two permanent GPS stations: station KSIA (in November 2010) and station KSII (on May 2013). Station KSIA, situated directly above the LGK underground corridors, was used for determination of the station velocity vector, which was compared with the velocity vectors of the neighboring and regional permanent GNSS stations. Station KSII is established in 400 m distance from station KSIA and is situated on the



opposite to the station KSIA wing of the 'main fault' in surroundings of the laboratory. This fault is situated on the southern side of the laboratory and is well marked in morphological form of Pełcznica river valley. Both stations were applied to determine relative motions of the wings of this fault. The results and analysis of daily solutions of GPS/GNSS observations in form of the time series of their horizontal components, stations velocity vectors and seasonal signals were presented for both our stations as well as for the neighbouring and regional GPS/GNSS stations. Obtained results were compared with the other available solutions and with chosen geodetic and geodynamic velocity field models. For crustal strain estimations we applied algorithm for computing strain rate between non-colinear GPS/GNSS stations, based on their horizontal components of velocity vectors. These results were also compared and discussed with the results obtained from water-tube tiltmeters (WT) measurements.

***Keywords:*** *GNSS technique, station velocity vector, geodetic and geophysical measuring systems, geodynamics, tectonic activity, tectonic faults, Sudeten tectonic activity.*

# THE MOVEMENTS OF ASG EUPOS STATIONS IN THE POLISH CARPATHIANS AND ADJACENT AREAS IN VIEW OF GEOLOGICAL BACKGROUND

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## ABSTRACT

Neotectonic studies in Poland concern usually areas of the Sudetes as the Carpathians, where manifestations of recent tectonic movements was studied extensively in the scope of geomorphic studies. Evaluated from the studies rates of recent vertical crustal movements change from -1 to +2 mm/yr. Additionally, many authors provided examples proving that young tectonic deformations are manifestation of forces resulted from the relaxation of remnant horizontal stresses of Neogene thrusting. Geodetic measurements are still insufficient in the area of the Polish Carpathians. Long time observations are limited usually to the Pieniny Klippen Belt and Tatra Mts. and there are some studies on deformation in contact zone separating the Carpathians and their forefield in Bochnia and Wieliczka. No displacement field was evaluated in the Polish Flysch Carpathians and this is happening as a result of the lack of geodetic test fields there.

Several years of permanent observations within ASG EUPOS gives reason for determination of displacement vectors for the area of the Polish Carpathians and adjacent area. Although the result are ambiguous there are some relation between evaluated position changes and tectonic setting. The author discuss result of the changes, which he identifies in some examples with movements caused by tectonic stress.

**Keywords:** *GNSS surveying, neotectonics, horizontal and vertical displacements, tectonic stress.*

# **CURRENT SEISMOLOGICAL OBSERVATIONS IN THE MORAVO-SILESIAN REGION**

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## **ABSTRACT**

Current seismological activities in the Moravo-Silesian region pursued by staff of the Institute of Geonics of CAS (IGN) represent monitoring of regional seismic activity, identification of seismic events and their detailed analysis. The basic seismic station Ostrava – Krásné Pole (OKC) presents part of the Czech Regional Seismological Network and it is operated by the IGN and other institutions. Another solitary seismic stations of the IGN, namely Zlaté Hory (ZLHC), Klokočov (KLOK) and Stěbořice (STEB), represent virtual seismic network. Data from other seismic stations operated by Institute of Physics of the Earth (Masaryk University) and Geophysical Institute of CAS are also used to evaluate seismic loading in the region under study.

This paper deals with description of current virtual seismic network operated by the IGN and of project of this network innovation. Current seismological observations are also presented. Generally, three types of seismic events are detected: local and regional earthquakes, mining induced seismic events (from Czech Republic and Poland), and technical/anthropogenic vibrations. Natural seismic activity of the area is very low. Due to complex tectonic pattern of the given area, definition of seismic active faults is very problematic.

# CONTRIBUTION OF GEODESY TO EARTHQUAKE PREDICTION STUDIES

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## ABSTRACT

In the last decades it is more and more obvious that satellite geodetic techniques can significantly contribute to earthquake prediction studies. They allow site position changes to be continuously monitored over a relatively extensive area and by this way to detect regional long-term surface deformations that in most cases reflect recent dynamic processes going on in the Earth's crust. A history of some joint geodetic and seismological investigations carried out in selected earthquake active areas exhibit their mutual beneficial research contributions. At present the GNSS/GPS data are able to monitor fairly precisely site horizontal movements and if they are correlated with geological structures, they can detect active fault zones and their possible seismogenic potentials.

A few examples of professional benefits in geodesy and seismology known from the world that substantially influenced some their joint investigations since the 2nd part of the 19th centuries up to now will be presented. Besides, some geodetic contributions attained with respect to recent seismoactive processes that have been monitored and detected in the West Bohemian area in the last decade will be presented together with an informative revealing of local vertical structural motions evaluated by the interferometric synthetic aperture radar technique which is one of the remote sensing space-to-Earth satellite geodetic methods.

# QUATERNARY TECTONIC ACTIVITY ON THE MARIÁNSKÉ LÁZNĚ FAULT IN THE CHEB BASIN, WEST BOHEMIA

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## ABSTRACT

The NNW-SSE trending Mariánské Lázně Fault (MLF) zone is situated in the western part of the Bohemian Massif (Czech Republic). It is morphologically very pronounced and limits the Tertiary Cheb basin on the SE. A trenching survey was combined with shallow geophysics to study the late Quaternary activity of the MLF. Trenching revealed repeated movements along the several faults of various ages within the MLF on the Cheb basin limit. The youngest fault displaced and deformed Holocene deposits of the age interval 5.3 - 1.1 ka BP, which is the youngest proved surface faulting in central Europe reported so far. The extensive geophysical survey enabled to extrapolate geological information from the trenches and to trace the fault laterally and to the depth.

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# PRELIMINARY RESULTS FROM INTERCONNECTION OF THE EPOCH GPS GEODYNAMIC NETWORKS IN CENTRAL MORAVIA

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## ABSTRACT

Several geodynamic GPS networks have been established within the Moravia territory in last three decades for the purpose of recent crustal movements monitoring. These networks were established by various institutions that are using them for their own particular local investigations. During the same period there have been established five networks of permanent stations, operated again by various public and private subjects.

New measurements on selected points of the MORAVA, EAST SUDETEN and HIGHLANDS epoch geodynamic networks affirm previous assumptions about recent activity along the Diendorf -Čebín tectonic zone (DCTZ). Complex evaluation of satellite data together with geophysical and geological knowledge confirm that also the northern part of the Boskovice Furrow is active, with seismic manifestations and noticeable morphotectonic signs perceptible in SRTM and InSar data. The main active risk area is delimited by recently active Konice-Nectava fault system. To this system are tied the post-alpine grabens – Blansko, Moravská Třebová – Lanškroun. The part of the Boskovice Furrow that is connected to the graben structures north of Boskovice represents the most risky area accompanied by recent earthquakes of magnitudes up to M3 with depths to 18 km. Southern limitation of the area constitutes the morphotectonically distinctive zone of the Železné hory – Tišnov tectonic system.

Reliable evaluation of neotectonic and recent deformation tendencies at areas of civil engineering interest could serve to better assessment of the associated geodynamic risk. Interconnection of the epoch networks and their integrated evaluation brings better homogeneity of results and their interpretation. To completion of the kinematic model of the Moravia territory contribute also the measurement results on another GPS/GNSS networks.

The contribution was elaborated with support of Grant No. BD 12600034 of Brno University of Technology.

# **CURRENT PERSPECTIVE ON THE PROBLEM: LEGITIMACY OF RESEARCH ON MOVEMENTS OF THE ROCK MASS IN THE AREA OF THE JASKINIA NIEDŹWIEDZIA IN KLETNO**

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## **ABSTRACT**

The study of displacements and deformations of the rock mass in addition to being used for scientific purposes, have also practical significance. They are particularly important in areas where intense tourist traffic occurs. Safety of visitors is particularly important in places, where as a result of unexpected events, human life may be in danger. Such places are for example the natural objects, especially when they are located in mountainous areas.

The study is an attempt to assume an attitude to the validity of movements of the rock mass research, in the region of Śnieżnik Massif, especially on this part of the Jaskinia Niedźwiedzia, where intensive tourism activities are present.

The presented study relate to establish necessary frequency of making control geodetic measurements, their accuracy and problem of referring measurements to areas relatively stable.

**Keywords:** *rock mass movements, leveling, vertical movements*



# NEW DETERMINATION OF THE PERIOD AND QUALITY FACTOR OF FREE CORE NUTATION

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## ABSTRACT

Traditionally, the period  $T$  and quality factor  $Q$  of the Free Core Nutation (FCN) are derived from VLBI-based celestial pole offsets (CPO). To this end, either the direct analysis of the observed values of CPO, or indirect method consisting in studying resonant effects of nutation terms with frequencies close to FCN, are used. The latter method is usually preferred, since it yields more accurate results. Here we propose a new method, based on combination of both. We integrate numerically the part of CPO that is due to geophysical excitations for different combinations of  $T$ ,  $Q$ , using Brzezinski's broad-band Liouville equations, and compare the results with the observed values of CPO. The values yielding the best fit are then estimated. The observed CPO, however, must be first corrected for the change of nutation that is caused by the  $T$ ,  $Q$  values different from those used to calculate IAU 2000 model of nutation. To this end, we are using Mathews-Herring-Buffet transfer function and apply it to the five most influenced terms of nutation (with periods 365.26, 182.62, 121.75, 27.55 and 13.66 days). The results, obtained from the data in the interval 1986.0—2016.0, will be presented in two variants: with only atmospheric/oceanic excitations, and with impulse-like excitations due to geomagnetic jerks added.

# DECADAL CYCLES OF EARTH ROTATION, MSL AND CLIMATE EXCITED BY SOLAR ACTIVITY

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## ABSTRACT

The solar activity affects all surface geosystems, including weather and climate indices, winds, rains, snow covers, mean sea level, river streamflows and other hydrological cycles. The mean sea level and polar ice changes cause common variations of the principal moments of inertia and Earth rotation with decadal, centennial and millennial periods. The mean sea level, Earth rotation and climate indices have also some oscillations with periods below 40 years, whose origin is not connected with the known tidal and solar effects. The shape of solar cycles is rather different from sinusoidal form, so they affect geosystems by many short-term harmonics. A possible solar origin of decadal variations of Earth rotation, mean sea level and climate indices is investigated by the harmonics of Jose, de Vries and Suess cycles with centennial periods of 178.7, 208 and 231 years. The common decadal cycles of solar-terrestrial influences are investigated by long time series of Length of Day (LOD), Mean Sea Level (MSL) variations at Stockholm, temperature and precipitation over Eastern Europe, Total Solar Irradiance (TSI), Wolf's Numbers  $W_n$  and North-South solar asymmetry. A good agreement exists between the decadal cycles of LOD, MSL, climate and solar indices whose periods are between 12-13, 14-16, 16-18 and 28-33 years. The new linear models of the decadal common Earth and solar cycles may help long term forecasts of many global and local changes.

# **EPOS-PL – THE POLISH EARTH SCIENCE INFRASTRUCTURE INTEGRATED WITH THE EPOS PROGRAMME**

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## **ABSTRACT**

On 30 June 2016 the Polish National Information Processing Institute (OPI) has published the result of the first call in the framework of Action 4.2: “Development of modern research infrastructure of the science sector” under the Operational Programme of Intelligent Development (POIR). Funding was recommended for the project EPOS – European Plate Observing System. The main aim of this project is the cooperation of geophysics and geodesy community to create a multi-layer, multi-disciplinary and interoperable research infrastructure EPOS-PL. The proposed infrastructure will be designed to collect data from the observing networks as well as to develop, standardize and integrate data (meta data) in the databases. The data and results of analyses will be available for end users through the website. The infrastructure built in the EPOS-PL project is closely linked with the European EPOS research infrastructure. The EPOS program is the largest European infrastructure project in the Earth sciences. The general objectives of the project are presented with particular focusing on the development of the gravimetric, magnetic and GNSS infrastructure and on the integration of GGOS-PL network with the EPOS-PL infrastructure.

# FILTRATION OF INCOMPLETE GNSS TIME SERIES WITH PROBABILISTIC PCA

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## ABSTRACT

It has been already proven, that any geodynamic investigations using position time series from Global Navigation Satellite System (GNSS) should be preceded by spatiotemporal filtration to remove a common mode error (CME). CME may be a joint effect of mismodelling of: satellite orbits, the Earth Orientation Parameters (EOP) or unmodelling of large-scale atmospheric and hydrospheric effects, as well as small scale crust deformations. Many physical and artificial sources contribute to data gaps in GNSS time series. Multivariate statistical methods used for CME extraction require interpolation of missing coordinates beforehand or iteratively. Probabilistic Principal Component Analysis (pPCA) provides additional benefits over traditional PCA, such as a fast EM (Expectation-Maximization) learning procedure and profitable way of handling missing coordinates in time series.

In this research we used daily sampled position time series from 15 stations situated in the area of Central Europe. The time series were distributed by International GNSS Service (IGS), and all of them were contributed to the newest realization of the International Terrestrial Reference Frame (ITRF2014). We computed relative errors of extracted common signal from residual coordinate time series, when different percentages of missing data were simulated. The ability of pPCA based filtration method to compute CME for incomplete data has been compared to previously used PCA methods (Dong et al., 2006; Shen et al., 2013). The largest relative errors of extracted CME for incomplete time series were 7.3, 8.1 and 5.2% for the North, East and Up, while our new proposed method allowed to reduce relative errors to 4.9, 5.1 and 3.8%, respectively. The accuracy of station velocity was also discussed in the context of missing data handling method adopted for time series filtering.

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# **THE BENEFIT OF NEW GPS SIGNALS AND IGS-RTS CORRECTIONS TO SINGLE POINT POSITIONING**

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## **ABSTRACT**

GNSS single-point positioning (SPP) is a well-known technique used in location and navigation. It is based on code ranges from a single GNSS receiver. One advantage of SPP is obtaining instant position in real-time, another one is less complicated data processing comparing to differential positioning or Precise Point Positioning (PPP). But SPP also has some disadvantages. The most noticeable one is relatively low accuracy of a few meters. For this reason SPP is not used in, e.g., Geographic Information System (GIS) applications. However, current GPS modernization opens new possibilities for improvement of SPP positioning accuracy. One possibility may be the application of new and modernized GPS signals, and the second one, employing of the International GNSS Service - Real-Time Service (IGS-RTS) corrections. In our work these two possibilities are explored and their benefit to SPP positioning is evaluated.

# MUTUAL VALIDATION OF GNSS-DERIVED AND RADIOMETRIC IWV MEASUREMENTS

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## ABSTRACT

Nowadays GNSS has become an important source of valuable meteorological data. Among other parameters, GNSS can provide estimates of the Integrated Water Vapor (IWV) that is one of the most important factors in weather forecasts. GNSS allows for IWV estimation with a high temporal and spatial resolution, but its accuracy and reliability still have to be investigated and improved. Another well-established instrumentation for IWV determination are Microwave Radiometers. The advantage of radiometers is that they allow for direct IWV measurements. However, previous research has showed that the radiometers also have their disadvantages and the reliability of the received IWV information has to be tested. Therefore, this research focused on IWV determination using both techniques mentioned above, and on their mutual validation. In our contribution, the IWV estimates were investigated for two neighboring GNSS stations: POTS and POTM, and two collocated microwave radiometers. The two GNSS stations and two radiometers provide an unique observational set-up that allows for robust testing and crossvalidation of both techniques. The GNSS data was processed with G-Nut/Tefnut software in Precise Point Positioning mode using IGS ultra-rapid orbit information to simulate near real-time scenario. The test results confirm high accuracy and reliability of GNSS-derived IWV that allows for their applicability of weather forecasts.

# IDENTIFICATION OF PSEUDO-NODAL POINTS ON THE BASIS OF PRECISE LEVELLING CAMPAIGNS DATA AND GNSS

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## ABSTRACT

Four campaigns of precise leveling has been carried out in Poland, and for several years there is a functioning system of permanent GNSS stations determining the height of network points. On the basis of these data, several variants of vertical crustal movements models have been developed. In order to develop a kinematic model of vertical movements, one of the possibilities is an alignment of the network formed simultaneously with the leveling data and GNSS data. The main problem is a need to identify common points between the data sets, and their correct connection. This problem can be solved by creation of coherent database containing attributes of both types of data and automatization of the joint points identification process. The article shows the results of such identification process, depending on the amount of data, on the example of the area of Upper Silesia.

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# APPLICATION OF MULTICHANNEL SINGULAR SPECTRUM ANALYSIS TO GNSS POSITION TIME SERIES

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## ABSTRACT

Mathematical model of GNSS time series is composed of initial value, linear trend, seasonal signals and stochastic part. The main aim of our research was to estimate the common seasonal signals for neighbouring stations which can arise from real and spurious effects. For this purpose, we used the MSSA approach. MSSA is an extension of the classical Karhunen–Loève method and it is a special case of the SSA method for multivariate time series (Ghil et al., 2002). MSSA is a data adoptive approach that allows decomposition of continuous time series on nonlinear trend, time-varying seasonal signal and noise. In this study, we used simulated time series and time series taken from 30 stations located in Central Europe. Daily time series of chosen stations were derived from the International GNSS Service (IGS). Additionally, these stations contributed to the second realization of the International Terrestrial Reference Frame (ITRF2014). Before modelling annual and semi-annual oscillations, we discussed the influence of some parameters in the MSSA, like the windows length. For this purpose, we used simulations with different approaches.

In this research, we showed the capability of the MSSA approach to extract annual and semi-annual oscillations with regard to IGS stations from GNSS-derived time series of position changes. This method has an advantage over the traditional modelling of seasonal signal by least-squares estimation approach because it can extract time-varying and common seasonal oscillations for stations located in the selected area.

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# **CARRIER PHASE BIAS ESTIMATION OF GEOMETRY-FREE LINEAR COMBINATION OF GNSS SIGNALS**

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## **ABSTRACT**

The ionosphere is an important accuracy limiting factor in GNSS applications in geosciences, and in geodynamics in particular. On the other hand, the ionosphere can be modelled and studied using dual-frequency GNSS signals and their geometry-free linear combination. Therefore, a number of GNSS-derived ionosphere models were developed and applied in a broad range of applications. However, due to complexity of estimating of carrier phase ambiguities, most of these models are based on low accuracy carrier phase-smoothed pseudorange data. This, in turn, critically limits their accuracy and applicability. In this contribution we present a methodology of carrier phase bias estimation of geometry-free linear combination of GNSS signals. This methodology is suitable for ionosphere modelling at regional/continental scale. In addition, we present its evaluation under varying ionospheric conditions. The test results show that the carrier phase bias can be estimated with a very high accuracy, what consequently allows for ionospheric TEC calculation with low uncertainty of 0.5 TECU. This high accuracy makes the resulting ionosphere model suitable for improving GNSS positioning for high-precision applications in geodynamics.

# THE REAL IMPACT OF APPLYING MULTI-CONSTELLATION GNSS RECEIVER ON FIXES ACCURACY IN MOUNTAIN AREAS

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## ABSTRACT

GNSS fixes accuracy depends on three main factors: method of measurement, time of observation and geometry of tracked satellites, described by DOP (Dilution Of Precision) coefficients. As far as we talk about observations performing in unobstructed environment (open flat area or top of the mountain or hill), even GPS alone constellation provides sufficient number of satellites to ensure high fixes accuracy. Nevertheless, GPS alone could not be enough during observations in obstructed environment, when satellites with lower elevations can be covered by hills and mountains. In consequence, DOP values will be higher and fixes accuracy lower. On the first sight, the use of multi-constellation receiver should be remedy for this disadvantage – but is it really so? It is true that multi-constellation GNSS receiver will allow to track greater number of satellites, but on the other hand all of them will still have elevations greater than elevations of surrounding mountains and hills. It may be that greater number of tracking satellites does not guarantee significant improvement of DOPs values (especially Horizontal DOP) and in consequence higher accuracy of positioning.

In the paper results of extensive numerical experiments are presented. The main aim of the experiments was to check hypothesis that the use of multi-constellation GNSS receiver will significantly improve fixes accuracy during observations in mountain areas. Software simulator of GNSS measurements and DTM (Digital Terrain Model) were used to perform numerical experiments. Simulations of one year measurements were conducted. Locations of the simulated measurements were change, but every time the horizon was partly covered by surrounding hills and mountains. Number of tracked satellites, DOPs values and fixes availability for defined maximum DOP thresholds were analysed. Performances of GPS, GLONASS, GALILEO and BEIDOU systems were compared and their different

combinations, too. As a result, the answer allowing accept or reject the hypothesis was obtained.

In the first part of the paper were presented theoretical considerations concerning influence of mountain area on GNSS fixes accuracy. In the next section, the numerical experiment, and used methodology of research were described. The presentation of the software simulator of GNSS measurements and used DTM is included in the third part. Next, the results of the experiment are presented. Conclusions of the experiments can be found in the final section.

# VALLEY EVOLUTION OF THE BIALA ŁĄDECKA DRAINAGE NETWORK DURING LATE CENOZOIC, LOWER SILESIA, POLAND

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## ABSTRACT

Biala Łądecka (Biala Kłodzka) river is located in Lower Silesia (Poland) and its valley separates Góry Żłote Mts. (Rychlebské hory Mts.) on the northeast from Góry Bialskie Mts. on the southwest. We investigated geomorphology research of the Biala Łądecka river basin, in order to determine if Quaternary tectonic activity at the Sudetic Marginal Fault is contributing to the river's asymmetry. Previous research provided in adjacent area by L. Finckh and G. Götzinger (1931), W. Walczak (1954) and A. Ivan (1966), Biala Łądecka river used to flow across the Góry Żłote Mts. directly to Oderská nížina Lowland during Pliocene; currently it flows to Nysa Kłodzka Basin. Our research was focused on analysis of all available cartographic materials (geological and topographic maps), available literature and own detail geomorphological mapping of selected landforms. Spatial distribution of these landforms such as gullies, erosion trenches, dellens, alluvial plains, alluvial fans, springs, swamps, river terraces, could potentially indicate recent tectonic activity in the studied area. Moreover, stream network parameters (measured using DEM data) such as changes in erosion intensity indicated in longitudinal and cross-section profiles, slope gradient and morphometric indexes, e.g. Stream Length (SL) index (Hack 1973), for Biala Łądecka river basin were analysed. In selected places geophysical measures were used was also performed to discover locations of sediments of the Biala Łądecka paleoriver.

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# COMPARISON AND EVALUATION OF DIGITAL SURFACE MODELS CREATED BY MEANS OF UNMANNED AERIAL SYSTEMS

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## ABSTRACT

Digital Surface Model (DSM) as a tool for describing Earth's topography is widely used in geodynamics investigations in global, regional as well as local scale. Different data sources can be used to generate DSM. In the last decade airborne laser scanning (ALS) has been established as a dominant technology for DSM data acquisition in the regional and local scale. Since ALS is relatively expensive technology in local application, Unmanned Aerial Systems (UASs) are increasingly used as an alternative technology for data acquisition.

The objective of this study is to evaluate the quality of different DSMs created from UAS data acquired with different sensors and processed according to various schemes. The data was acquired with: Nikon D800 RGB camera, Optris PI Lightweight 450 thermal camera and Velodyne HDL-32E laser scanner. The processing of imagery data was executed in two stages: data georeferencing and point cloud creation. In the first stage the aero triangulation (AT) of the image block was performed according to 3 schemes based on: ground control points (GCPs) acquired with GNSS-RTK, air control points (ACPs) acquired with GNSS-RTK and ACPs obtained by GNSS/IMU navigational solution. In the second stage the dense image matching was applied to create point clouds from images. In the case of laser scanner, typical processing scheme was used, i.e. the point cloud was georeferenced based on GNSS/IMU reconstructed trajectory.

Obtained results showed that all tested sensors can be used to generate local scale DSMs, however, their accuracies depends on many factors. The highest accuracy of DSM was obtained for the Nikon images where georeferencing was based on GCPs. Slightly worse accuracy was obtained for Velodyne data where the most affecting factor was the quality of navigational solution, especially the orientation of the platform. DSMs obtained from imagery data that was adjusted based on the ACPs are of good internal accuracy but the absolute height of DSM were shifted. The worst DSMs were obtained for thermal camera. It could be explained by very low resolution and poor geometrical quality of the camera.

# **ASSESSMENT OF GEOPHYSICAL PHENOMENA IMPACT ON THE BALTIC SEA LEVEL CHANGES USING THE SATELLITE ALTIMETRY AND GRACE OBSERVATIONS – THE FIRST STEP**

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## **ABSTRACT**

The mean sea level fluctuations are the resultant of a number of geophysical phenomena. Temperature and salinity changes cause seawater density variations resulting in steric sea level changes. These changes are dependent on different time scales, and so, the geographical coordinates.

The aim of the paper is to elaborate the geophysical phenomena impact on the changes in the Baltic Sea. The authors used to study the data from the satellite altimetry and GRACE observations, the combination of data allows for a comprehensive research of sea level changes. The average and maximum changes in sea level are calculated, in which periods are observed.

The result is a comparison between the effect of the mass changes and the sea level. Although, the spatial distribution of the data is different, the research can bring valuable information about aspects in sea level changes and the impact of geophysical phenomena.



# GEODETIC INVESTIGATION ON BARDO- JANOWIEC LANDSLIDE

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## ABSTRACT

In July 1997 after heavy rains near the Village Janowiec in Bardo district a new landslide occurred. In next few years it was forgotten because most researchers and local people have not seen changes in shape of ground. From this point most opinion was that mass-movements stops.

In 2009 researchers from Wrocław University of Science and Technology started geodetic monitoring of this landslide. From year to year the control network was growing. On beginning authors used tachymetry, precise levelling, next GPS, airborne and terrestrial laser scanning, UAV photogrammetry technics. Most significant change occur in 2014 when one inclinometric and two piezometric columns has been installed. Its allow to connect surface and subsurface movement measurements.

In the paper authors present results of their work carryout during this years which shows that the landslide is still active.

# FAULT SLIPS DEVELOPMENT RECORDED ON MAJOR LUGICUM FAULTS

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## ABSTRACT

Based on results of 3D monitoring of fault slip within the Rasovna and Západní caves developed in zones of major LUGICUM faults as Lusatian Fault and Sudetic Marginal Fault a comparison of fault movement development along Lusatian Fault and Sudetic Marginal Fault is presented. Fault slips are recorded in three dimensions using specially designed optical-mechanical crack gauges known as TM-71s as a part of the EU-TecNet monitoring network. Network was established about fifteen years ago to record fault displacements across selected tectonic structures in the shallow crust. The network comprises more than one hundred fifty sites, most of which are situated underground, spread across the globe ([www.tecnet.cz](http://www.tecnet.cz)). Regular monitoring is supported by research infrastructure programme CzechGeo.

The Rasovna Cave is located within the Sudetic Marginal Fault zone approximately 5 km west of Jeseník in north-eastern Bohemia. Extensometer TM-71 was installed across fault  $27^{\circ}/38^{\circ}$  in February 2006.

The Západní Cave is located within the Lusatian Fault zone approximately 15 km west of Liberec, close to the village of Jitrava, in northern Bohemia. It is the largest cave found within the karstic part of Ještěd Ridge. Extensometer TM-71 was installed across fault  $148^{\circ}/90^{\circ}$  in April 2007.

Data obtained during the past decade demonstrate that periods of tectonic quiescence alternate with shorter periods of increased fault activity. The fault displacement monitoring has also shown notable periods of increased geodynamic activity affected both faults, referred to as pressure pulses, in 2008, 2010/2011, and 2013/2014. It has been found that these periods of pressure pulses occur contemporaneously along both major faults. Based on comparison with fault slips recorded on other major faults across the Bohemian Massif these periods are interpreted to reflect the widespread redistribution of stress and strain through the shallow crust. It is possible to

correlate the identified displacement cycles with the strongest earthquakes - swarms which have occurred during the past decade in the Bohemian Massif.

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# STUDY ON THE VARIABILITY OF ACCURACY OF DIGITAL TERRAIN MODEL

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## ABSTRACT

Development of measurement and IT technologies as well as measurement methods result in obtaining more data about measured object/area. Processing and presentation of acquired data depend on the purpose of measurement. It also affects the possibilities and scope of subsequent use of the processed data. One way to visualize the measurement data is to generate digital terrain model (DTM). It is a very popular product that can be a basis for analyses and research in many scientific and economic fields.

One of the aspects that determine the possibility of using the DTM is its accuracy. There are various accuracy measures (e.g.: RMSE, mean height, etc.). Used measure depends, among others, on the source of data acquisition to generate DTM (remote sensing, photogrammetry, laser scanning, GNSS measurement) and the methods used to generate DTM (TIN, GRID). Adopted measure typically refers to the entire area for which DTM is generated. However, a single measure will not be appropriate / significant for the whole area due to the diversity of land. The article presents the results of study on the variability of accuracy of DTM in relation to GRID size and complexity of terrain. DTM was based on data obtained by means of airborne laser scanning (ALS).

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# OPTD METHOD FOR EFFECTIVE 3D MODELING

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## ABSTRACT

Laser scanning is a technology that provides measurement to obtain digital data which faithfully reflect reality with millimeter accuracy. Result of measurement is XYZ coordinates of huge number of points obtained very quickly. The set of coordinates of measured points is a point cloud. Point cloud can be further used for 3D modeling, creating 2D drawings (plans, sections, profiles), and others. 3D modeling is one of the problems with which architects are dealing, especially during the inventory, renovation and maintenance. Solution is e.g. detailed measurements conducted by means of Terrestrial Laser Scanning (TLS). It allows to obtain very accurate “image” of the structure of the building. The paper presents the results of measurements of bas-reliefs located on the historic building with the use of TLS and application of OptD-single method for effective 3D modelling.

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# TRAJECTORY MODELS OF GNSS PERMANENT STATIONS WITH POWER-LAW PROCESS

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## ABSTRACT

The secular trend, periodic oscillations, position displacements due to different sources along with post-seismic decay are all included in a typical trajectory model for a permanent GNSS station. The secular trend is usually assumed to be linear and according to Bevis and Brown (2014) can be called a constant velocity model (CVM). However, not all GNSS position time series follow this simple linear behavior. Among the possible causes of non-linearity are processes associated with the dynamics in subduction and spreading zones or the elastic rebound of the Earth's crust due to rapid ice melt, as has been reported for Greenland and the Antarctic Peninsula. In this research we used position time series from NGL (Nevada Geodetic Laboratory) to investigate whether the trajectory of permanent stations tend to follow a polynomial trend model. We described this model by the linear (1st), quadratic (2nd) and higher (up to 5th) orders and investigated the North, East and Up components of stations where a CVM is not sufficient to check if there occurred an acceleration. We estimated the noise parameters with Maximum Likelihood Estimation (MLE) using the Hector software package for the selected position time series and considered the non-linear term. The noise analysis has shown that a polynomial can be hidden in a power-law process. Moreover, the non-linear model parameters and their associated uncertainties were determined using estimated noise properties.

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# MULTI-TREND APPROACH TO MODEL THE POST-SEISMIC DEFORMATION WITH TEMPORAL CORRELATIONS

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## ABSTRACT

This research is aimed at estimation of velocity of Global Navigation Satellite System (GNSS) stations affected by earthquakes. Up to date, earthquakes in GNSS position time series were modeled with exponential or logarithmic functions or a combination of both mentioned to derive the estimates of velocity that is used to create kinematic reference frames as the latest release of International Terrestrial Reference Frame (ITRF2014). We show a novel multi-trend approach applied together with combined model of logarithmic plus exponential function to estimate velocity of GNSS stations separately for time before and after earthquakes. We prove that it significantly changes comparing these periods. All analyses are performed with assumption of temporally correlated noise, which is known to affect stochastic part of position time series.

To test the multi-trend approach we chose a Tohoku earthquake that occurred in 2011 near the coast of Japan. We used Japanese stations processed by Nevada Geodetic Laboratory (NGL) with time series being 20 years long at maximum (1996-2016). We estimate parameters of combined logarithmic plus exponential function, together with two trends with a break set up at the time of earthquake and other parameters of GNSS time series (seasonal signal and stochastic part) with Maximum Likelihood Estimation.

# GEODETIC STRUCTURAL MONITORING SYSTEM

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## ABSTRACT

Geodetic structural monitoring systems are a very important support for surveyors, both during the construction process, as well as while monitoring of engineering objects. They can be used in monitoring landslides, faults, as well as in monitoring of engineering objects. Utilization of such systems is justified because of the following reasons: reliability; the ability to perform continuous measurements (24 hours a day throughout the year); analysis and presentation of results immediately after the measurements; the versatility of such solutions. Versatility means here the ability to use many types of sensors, which enables observation of the state of the monitored object in wide range. The sensors are as follows: surveying instruments (total stations, GNSS receivers, levels); other instruments – non geodetic ones (variable kinds of inclinometers, meteorological sensors and many others).

Modern geodetic structural monitoring system (Leica GeoMOS) was installed by the Institute of Geodesy and Geoinformatics at the newly built building of the Wrocław University of Environmental And Life Sciences. The system is being actively utilized almost a year now, and gathers information about the building Geo-Info-Hydro.

In the paper, the author presents the results of measurements from the monitoring system, as well as the analysis of the results. The analysis of data from selected sensors (geodetic and non – geodetic) making measurements in the system, along with their development and interpretation of the results. The author presents also a method analyzing and compiling of the results of measurements in an integrated structural monitoring system.

**Keywords:** *geodetic structural monitoring system, sensors.*



# NEW APPROACH IN ISOMETRIC TRANSFORMATION FOR OBLIQUE SYSTEMS PURPOSES

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## ABSTRACT

This article presents the method of determining of the spatial orientation and displacement of the measuring systems. This method is based on isometric space transformation registered in the oblique coordinate system. The approach is based on calculating virtual displacement of the systems and then rotation matrix. The virtual displacement is calculated after moving both coordinate systems to the same point (the temporary center of the systems). This approach, in comparison with the methods known from geodesy and photogrammetry, allows to reduce the points needed to isometric transformation. In this method in calculations can be used the same points for displacement and rotation matrix. The method was verified in laboratory and by field surveying, using displaced and non-levelled tachymetr.

# LASER SCANNING AND MODELING OF UNDERGROUND CITY OSÓWKA

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## ABSTRACT

Project Riese (German for giant) in Owl Mountains, Central Sudetes, is probably the biggest mining and building project of Nazi Germany. The purpose of Riese remains uncertain due to lack of documentation, it is still rather a hypothesis than a fact. Until today six underground structures were discovered in Walim and Głuszycza area. There is a theory that all complexes were supposed to be combined and many kilometres of the underground tunnels are still to be discovered.

In 2015 authors of this report, with the help of students, performed full inventory of Complex Osówka, both underground and ground objects. 1700 meters of underground adits in main part of the complex (Museum of Underground City Osówka) were scanned, together with 130 meters of Sztolnia Wodna (Polish for water adit) and two ground objects: Siłownia and Kasyno. Last two were supposed to be nuclear energy plant and Hitler's headquarters. During measurements laser scanner (Faro, Focus 3D), tachymeter (Topcon, OS103) and GPS receivers (Topcon, HiperPro) for georeferency were used.

Collected material was used to analyze geometrical relations between objects of Osówka complex. Report presents location of objects in relations to each other which was not previously verified in research. The newest service launched for Museum is the virtual tour, which is one of the inventory's results. User can virtually explore the whole complex, including places where visitors are not allowed. Virtual tour also allows to measure selected surface or distance between chosen points and to check coordinates or height in particular spot. User can generate a link to the screen which interests him and upload it on any website.

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# **INTEGRATED MONITORING OF SALT DOMES GEODYNAMICS IN POLAND BY MEANS OF INSAR, CRS AND HISTORICAL DATA ANALYSIS**

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## **ABSTRACT**

The Permian salt diapirs, due to their shallow depth to the earth's surface, are subjected to the mining exploitation in many countries in Europe and also considered as potential structures for storage of hydrocarbons. The later application require detailed and accurate information regarding their geological stability. In central Poland the locations of salt tectonic structures are commonly associated with glaciotectonic deformation in Quaternary and Cenozoic sediment cover. It still remains as an open question whether there are any evidences on contemporary occurring deformations.

Polish Geological Institute – National Research Institute (PGI-NRI) initiated a series of studies to determine the magnitude and extent of the Quaternary and recent dynamics of the terrain surface of the area of salt tectonics in Poland. The study utilize SAR interferometry based on ESA data archive - ERS and Envisat ASAR, TerraSAR-X and Sentinel-1 data. For the specific areas of interest, especially these exhibiting deformation and/or containing sensitive infrastructure a detailed monitoring studies including corner reflector, high-resolution data acquisitions and geodetic measurements will be performed. The areas of interest are also investigated with shallow geophysical methods like Electrical Resistivity Tomography (ERT).

In this contribution we will elaborate on a design of the monitoring system and results of one of the validation studies – the area of Wapno city. In the wider area of Wapno catastrophic deformation occurred after salt mine collapse that took place in 1977. Due to still unstable hydrogeological balance the area is subjected to subsidence up to 7.5 mm/yr, as recorded from 1997 to 1995. Since 2007 the subsidence is also associated with sinkholes that significantly increase the hazard to urban areas. To monitor the terrain

deformations in Wapno area the existing network for in-situ measurements was supplemented by 10 levelling benchmark and 7 corner reflectors located in key areas. Since July 2015 TerraSAR-X data of Wapno area are systematically acquired including both ascending and descending passes. Independently to TerraSAR-X, and Sentinel-1 data are also routinely acquired over the area since 2014, and are also incorporated into InSAR analysis. We will report on results of historical data processing, present monitoring results of the Wapno area, and put them into a wider geophysical context.

Finally, while some of the details of the presented monitoring concept specifically apply to the case studies in Poland, some general conclusions and recommendations will be derived. Also we will address some of the identified weaknesses and limitations of our concept, and frame an open questions and challenges that grow from our work, and pose them to the community.

# MULTISTATION PRECISE POSITIONING USING MAFA METHOD

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## ABSTRACT

At the present time most popular precise positioning method is LAMBDA method. Alternative for this solution is MAFA (Modified Ambiguity Function Approach) method. Advantage of this method is fact that there is no need to calculate Ambiguity's. In presented research multistation solution is presented, this solution so far has never been used for precision positioning. Goal of this research is to show that this method can be used instead of LAMBDA method for such uses like mountain movements.

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# THE IDEA OF PRECISE 3D LINEAR MEASUREMENTS IN GEODYNAMIC STUDIES

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## ABSTRACT

When performing geodetic measurements on geodynamic objects (eg. Geodynamic Laboratory in Książ, “Szczeliniec Wielki” Massif) very often there is a need for precise situational and height measurements. Usually, when you need precise heights, we use precision digital leveling instrument. In this paper the authors present a prototype prism adapter coupled with precise Leica DNA03 Digital Level. The adapter prism allows the measurement of the horizontal distance between the controlled points on the test object.

For the functional assessment and a precision measurements using the prism adapter on the expansion gap placed two controlled points. The location of controlled points in the space 3D were designated independently by two methods: using the adapter prism and calipers. Measurements were carried out in several series. On the basis carried out of the experimental-research works was determined the accuracy of distance measurements with prism adapter. The proposed measurement method with the using precision digital level equipped with a prototype prism adapter and rod code allows to perform measurements of the distance between controlled points in 3D space with an accuracy of hundredths of a millimeter. The proposed measurement method can be used to measure the horizontal and vertical distances performed in geodynamic studies.

# **CURRENT STATE OF CZECH SENTINEL-1 INTERFEROMETRY SYSTEM FOR MONITORING LAND MOVEMENTS**

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## **ABSTRACT**

Satellite SAR interferometry (InSAR) is an experimental remote sensing method to identify land movements in a very high sensitivity (order of a mm/year). It has found applications in monitoring terrain subsidence due to mining activities or groundwater loss, identification of slow landslide movements, evaluation of deformations at dams and bridges as well as evaluation of earthquake characteristics or movements at tectonic zones. With the arrival of Sentinel-1 satellite in 2014, the method became on disposal for observation of practically any area in Europe and in the world.

This contribution will summarize briefly few Czech (or collaborative) projects where Sentinel-1 InSAR was successfully applied, in order to raise awareness and understand its potential for space-based observation of land movement. Just an example, subsidence of undermined areas in Czech Silesian region has been observed, evaluating movements not only at known subsidence troughs, but also identifying decay subsidence over Karvina city and borders of subsidence trough overlapping activated landslide of Doubrava hill.

Currently the research turned from building algorithms used to process data and analyse results into the automation of processes utilizing Big Sentinel-1 Data in supercomputing environment. The current state of Czech system will be presented together with dissemination of its practical usage possibilities for interested, especially non-commercial, Czech-Polish institutes.

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# RECORD OF POST-LATE CRETACEOUS KINEMATIC ACTIVITY OF THE LUSATIAN FAULT AS REVEALED FROM ITS FAULT-BELT ARCHITECTURE

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## ABSTRACT

The analysis of fault-slip data from the Lusatian Fault Belt, limiting the Lusatian Block of the Bohemian Massif in the SW, yielded parameters of eight successive paleostress patterns Late Cretaceous to Plio-Pleistocene in age. Superposition of these patterns was inferred from fault-belt architecture, and the related paleostress fields were dated on geological basis (occasionally also with the use of geochronologically dated volcanics). During the effect of each paleostress pattern, a new population of striae was imposed on sets of activated fault-slip ruptures. The orientations of the striae were controlled by the acting stress. Moreover, some of these paleostress patterns were linked with the formation of specific structures permitting a straightforward identification of the respective pattern. All this information is useful in the reconstruction of paleostress patterns using the paleostress analysis.

Paleostress pattern group  $\alpha$  represents stress fields transmitted from the Alpine Orogen to the Alpine foreland. Several stages can be distinguished differing in the parameters of the acting paleostress tensors: (1)  $\alpha_1$ , NE- to NNE-directed compression in a reverse fault regime ( $\sigma_3$  vertical), associated with major thrusting and the formation of a broad, impressive drag zone along the fault in the latest Cretaceous, preceded by pre-drag origin of deformation bands  $\alpha_0$ ; (2)  $\alpha\beta_{1-2}$ , NNE-directed compression compensated by WNW-directed extension (so-called dilation), associated with the emplacement of polzenite-group volcanics ( $\approx 80-61$  Ma) and the influx of hydrothermal fluids; (3)  $\alpha_2$ , N-directed compression in a reverse fault regime, probably Paleocene in age, associated with thrusting and intensive shear faulting in adjacent parts

of blocks; (4)  $\alpha_3$ , NNW-directed compression, probably Eocene to Early Oligocene in age, associated with the activation of transverse/oblique faults of the fault belt; (5)  $\alpha\beta_3$ , Middle to Late Oligocene W- to WNW-directed extension in a regime of strike-slip faulting ( $\sigma_2$  vertical), probably connected with the emplacement of phonolitic magmas and influx of hydrothermal fluids.

The Alpine Orogen continued to be compressed in the Early Miocene. In contrast, the Bohemian Massif was affected by a specific (6) paleostress pattern group  $\beta$ , associated with multi-stage N- to NE-directed extension in a normal fault regime. This pattern was responsible for the origin of many types of tensile structures, emplacement of basaltic magmas and downfaulting of the hangingwall block of the Lusatian Fault. Much like in other regions of the Alpine foreland in Central Europe, the Lusatian Fault Belt displays prominent structures reactivated by (7)  $\gamma$ , Mid to Late Miocene NE-directed compression in a reverse fault regime. This pattern was associated with the second activation of the main fault as a thrust fault. Faults of near orientations were activated as oblique strike-slips. The youngest paleostress pattern (8) is reflected by striated faults cutting Pliocene lava flows of Kozákov Hill. Paleostress analysis revealed  $\delta$ , NW- to NNW-directed compression in a strike-slip regime. This paleostress is also associated with reactivated transverse faulting at many places within the fault belt. The inferred stress parameters correspond to those presumed for the present-day stress field.

# HUMAN- OR STRUCTURALLY-INDUCED LANDSLIDE? AN EXAMPLE FROM CZERWONY WĄWÓZ (WLEŃ GRABEN, SUDETES)

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## ABSTRACT

On 16th July, 2016, after heavy rainfalls in Sudetes, a landslide with an area of ca. 880 m<sup>2</sup> occurred above the renovated pension in Wleń town (Lower Silesia, Izerskie Foothills). The landslide affected the western, steeply inclined slope of the Bóbr River Valley (the Czerwony Wąwóz area). Despite the relatively small territory affecting by mass movements, the landslide destroyed already-built infrastructure and led to significant material damages. Author's geological investigations focused on structural and sedimentological analysis in the Wleń Graben which were carried out a few months before, suggest that mass movements in the study area were predictable. The main causes of the landslide were: (i) human-induced destabilisation of the slope; (ii) heavy rainfalls and (iii) geological structure of the area.

Czerwony Wąwóz is about 40 m deep, hanging valley formed in the Permian (Upper Rotliegendes) and the Triassic (Buntsandstein) sedimentary rocks that infill the Wleń Graben (Northsudetic Synclinorium). The Wleń Graben constitutes NW-SE trending, elongated morphological and structural depression, which is bounded by high-angle normal and strike – slip faults. In the vicinity of Nielestno and Wleń towns, the Bóbr river created antecedent, steep walled gorge that cuts the middle part of the graben. Orientation of the valley is transverse to the graben axis. In this part of the gorge, a numerous, mostly structurally-controlled landslides have been recognized (Kowalski, 2016). The landslide in Czerwony Wąwóz is located ca. 500 m to the north-east of another landslides identified in the Wleń Graben – the Świerkowa Dolina and Gniazdo landslides.

The landslide in Czerwony Wąwóz is a consequence of undercutting a steep valley slope by human activities. Terraced slope has been additionally overloaded by blocks and walking paths in the vicinity of the pension. A retaining wall of about 5 m height with drainage systems were built in 2015, to stabilize the slope. In March of 2016, a number of fissures and tensile cracks

were developed above the north-eastern part of the retaining wall. The concrete wall began to crack and incline. Tensile cracks have been expanded upward to the upper part of a slope. In May of 2016, about 15 m above the crown of the retaining wall, a distinctive scarp of approx. 1 m height were formed. The height of the scarp has been gradually increasing. In July of 2016, a sudden landslide occurred. The northern part of the retaining wall was completely destroyed. The head scarp of the landslide is up to 4 m high and shows an inclination of 45-80°. Within the main scarp occur outcrops of heterolithic, fluvial deposits of the Upper Rotliegendes (sandstones, mudstones and claystones). Landslide colluvium comprises well-developed minor scarps, benches and steps which finally pass downward to landslide toes.

Apart from human activities, a lithological variety of the Permian rocks and NE-SW trending strike-slip faults were an important factors that increased mass movements activity in the area. In addition, a heavy rainfalls influenced liquefaction of silty soils developed above the Permian rocks. The landslide in Czerwony Wąwóz is an example of interplaying a several anthropological and natural factors which resulted in initiation of a mass movements.

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# **ASSESS THE USEFULNESS OF THE VIDEO MONITORING SYSTEM FOR INVENTORY OF HOUSING AND REINFORCEMENT OF MINE SHAFT**

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## **ABSTRACT**

The paper presents the <System of video monitoring of the housing and shaft reinforcement condition during sealing the rock mass around the mine shaft "Kosciuszko"> made for Salt Mine „Wieliczka”. It was used during the monitoring of sealing the rock around the mine shaft "Kosciuszko" and now it serves for periodic visual inspection. Due to the fact that ongoing work injection may lead to deformation of the shaft lining and its reinforcement, the system that allowed real-time monitoring of the shaft was built. The processing of data obtained from recorded movies and photos gives also possibilities to generate numerical model of the shaft in the form of a three-dimensional point cloud. In order to determine the accuracy of the 3D model the comparative analysis of a cloud of points obtained from laser scanning was made. Multistage accuracy analysis showed a high correlation between the models in the analyzed portion of the shaft. The mean square error of the model was calculated which amounted  $\pm 33\text{mm}$ . Precision of the spatial model demonstrates the usefulness of the system for acquiring 3D data in vertical mine excavations. The acquired experience allows for continuous improvement of the system and increasing the accuracy of the data obtained by this method.

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# TELEMETRY MEASUREMENTS OF MINING SHAFT INFLUENCED BY SEALING OF THE HOUSING

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## ABSTRACT

The paper presents deformation of the housing and shaft reinforcement surveyed within the telemetry deformation monitoring system. The leaking into Kościuszko shaft posed a serious threat to the Salt Mine Wieliczka Museum. It has been decided to seal the housing with Jet-grouting method. Due to boreholes which were designed very close to the shaft, the material injected under considerable pressure could damage the reinforcement and cause critical failures of the shaft. In order to prevent such situations, mobile system for continuous monitoring of the shaft's structure condition was constructed. Its indications allowed to define the value of temporary changes occurring in the shaft, depending on the pressure, depth or speed of the injection. Operator can modify the course and range of injection works thanks to the chart and numerous data delivered by the system at the present time. Analysis of received results shows a slight deformation of the shaft housing during the injection, it also demonstrates the advantages of the monitoring system and a novel method of high-pressure injections.

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# INTEGRATED MONITORING OF SALT DOMES GEODYNAMICS IN POLAND BY MEANS OF INSAR, CRS AND HISTORICAL DATA ANALYSIS

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## ABSTRACT

The Permian salt diapirs, due to their shallow depth to the earth's surface, are subjected to the mining exploitation in many countries in Europe and also considered as potential structures for storage of hydrocarbons. The later application require detailed and accurate information regarding their geological stability. In central Poland the locations of salt tectonic structures are commonly associated with glaciotectonic deformation in Quaternary and Cenozoic sediment cover. It still remains as an open question whether there are any evidences on contemporary occurring deformations.

Polish Geological Institute – National Research Institute (PGI-NRI) initiated a series of studies to determine the magnitude and extent of the Quaternary and recent dynamics of the terrain surface of the area of salt tectonics in Poland. The study utilize SAR interferometry based on ESA data archive - ERS and Envisat ASAR, TerraSAR-X and Sentinel-1 data. For the specific areas of interest, especially these exhibiting deformation and/or containing sensitive infrastructure a detailed monitoring studies including corner reflector, high-resolution data acquisitions and geodetic measurements will be performed. The areas of interest are also investigated with shallow geophysical methods like Electrical Resistivity Tomography (ERT).

In this contribution we will elaborate on a design of the monitoring system and results of one of the validation studies – the area of Wapno city. In the wider area of Wapno catastrophic deformation occurred after salt mine collapse that took place in 1977. Due to still unstable hydrogeological balance the area is subjected to subsidence up to 7.5 mm/yr, as recorded from 1997 to 1995. Since 2007 the subsidence is also associated with sinkholes that significantly increase the hazard to urban areas. To monitor the terrain

deformations in Wapno area the existing network for in-situ measurements was supplemented by 10 levelling benchmark and 7 corner reflectors located in key areas. Since July 2015 TerraSAR-X data of Wapno area are systematically acquired including both ascending and descending passes. Independently to TerraSAR-X, and Sentinel-1 data are also routinely acquired over the area since 2014, and are also incorporated into InSAR analysis. We will report on results of historical data processing, present monitoring results of the Wapno area, and put them into a wider geophysical context.

Finally, while some of the details of the presented monitoring concept specifically apply to the case studies in Poland, some general conclusions and recommendations will be derived. Also we will address some of the identified weaknesses and limitations of our concept, and frame an open questions and challenges that grow from our work, and pose them to the community.

# EXTRACTING OF TOPOGRAPHIC FEATURES WITHIN RIVER AREA BY INTEGRATION OF AIRBORNE AND TERRESTRIAL LASER SCANNING

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## ABSTRACT

In the studies related to the river area, the aspect of relief in the vicinity of the river is very important, therefore reliable data representing the physical surface of study area is essential characterized by appropriate accuracy and the relatively short time of acquisition. Digital terrain model (DTM) generated on the basis of data from airborne laser scanning (ALS) was integrated with DTM derived from data acquired by means of terrestrial laser scanning (TLS). It was carried out according following scheme: comparing test data - DTMs generation; searching planar feature: PCA calculation; establishing matching criteria (distance and angle); surface matching (Least Squares 3D Surface Matching - LS3D). In the article the main emphasis is on the assessment of the accuracy of terrain features in relation to data integration method. Both sets of data (from ALS and TLS) were compared. The analysis estimating the size of difference area was also performed. Indicators of relief classification and roughness were here applied.

**Keywords:** *data fusion, laser scanning, terrain feature, relief classification*

# **DAMAGES OF ARCHITECTURE OF KSIĄŻ CASTLE COMPLEX IN THE LIGHT OF NEW INFORMATIONS ON THE STRUCTURE AND TECTONIC ACTIVITY IN KSIĄŻ AREA**

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First informations about the aspects of recent tectonic activity in Książ area come from indications of horizontal pendulums (HP), launched in 1974 in Książ (Chojnicki and Blum, 1996). Over 40-years long series of observation have provided informations about the periods when it came to a sudden change of WP's measuring azimuths. This phenomenon has been interpreted as the result of tilting of rock blocks on which HPs are installed. Recent tectonic activity was confirmed by water-tube tiltmeters (WT) which have recorded episodically appeared events of tiltings of foundation and vertical movements (Kaczorowski, 2009). The consequences of strike-slip movements in Książ area are reflected both in the structure of the Świebodzice Basin (e.g. displacements of geological formations, deformations of the geometry of the Pełcznica River valley) as well as damages of architectural elements of the Książ Castle, where the underground Geodynamic Laboratory of Space Research Centre of Polish Academy of Sciences is located (GL SRC PAS; Kaczorowski and Wojewoda, 2011, 2012; Kasza et al., 2014).

Tectonic phenomena recorded by both types of tiltmeters (HP and WT) are observed in forms of tilting of foundation and vertical movements. The cause of these effects are horizontal strike-slip movements on the surface of discontinuities (faults) in the Książ massif (Kaczorowski and Wojewoda, 2011). From the mechanical point of view faults are the nodes of distribution for these movements. Because of the faults orientation in relation to the main direction of tectonic displacement GL's measuring instruments show transformation of the horizontal component of the movement to vertical movements and tiltings of foundation.

Geological and geodetic works carried out in the Książ area allowed for identification and measurement of faults visible in underground corridors of GL. Analysis of the direction parameters of identified surface of discontinuities allowed to build a model of the structure of Książ massif. Created model contains 12 interpreted main zones of dislocation. Determined routes of fault zones correspond with the general direction of zones of discontinuity in Książ area based on analysis of

geological data for the surroundings of Książ Castle (Kaczorowski and Wojewoda, 2011).

Research lead to the conclusion that the manifestations of recent tectonic activity are part of the threat to the stability of the architectural elements of the Książ Castle, causing its numerous damages. Based on created model of the structure of castle's hill there were designated approximate routes of faults on the surface. These routes confirm that part of the interpreted major-active nowadays zones of discontinuity is located directly below the castle's architectural elements and corresponds with the observed damage zones. Taking into account the observed value of the vertical component of tectonic deformation during a single event (~1000 micrometers) likely mechanism explaining the formation of damages is the cumulative effect of vertical deformations formed in the subsequent tectonic events that after many epochs produce deformations of orogen sufficient to generate cracks and damages of architectural elements located in area of zones of discontinuity.

**Keywords:** *recent tectonic activity, water-tube tiltmeters, faults, Świebodzice Depression, Książ Castle*

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# APPLICATION OF MULTIFRACTAL ANALYSIS IN STRUCTURAL GEOLOGY: EXAMPLES

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Fractals are of rough or fragmented geometric shape that can be subdivided in parts, each of which is (at least approximately) a reduced copy of the whole (Zmeškal et al. 2001). Fractal analysis is a collection of mathematical procedures used to determine fractal dimension or set of fractal dimensions (in the case of multifractals) with the smallest error (Mandelbrot, 1983; Brown & Liebovitch, 2010). It consists of several methods to assign a fractal dimension and other fractal characteristics to a dataset which may be a theoretical dataset or a pattern or signal extracted from phenomena including natural geometric objects. A multifractal system is a generalization of a fractal system in which a single exponent is not enough to describe its dynamics; instead, a continuous spectrum of exponents is generally needed. Multifractal systems are common in nature, especially in geophysics, solid mechanics and engineering geology (fracture mechanics). There are three ways of applying a force to enable a crack to propagate: opening mode (a tensile stress normal to the plane of the crack), sliding mode (a shear stress acting parallel to the plane of the crack and perpendicular to the crack front), and tearing mode (a shear stress acting parallel to the plane of the crack and parallel to the crack front). The last two cases can be analyzed using fractal vector analysis in relation to a simple shear systems at different scales, off a sample of rock to the regional scale, and in the case of transformation of the rotational motion into the linear one.

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# ROBUST NETWORK ADJUSTMENT OF VERTICAL CRUSTAL MOVEMENTS WITH GNSS DATA

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## ABSTRACT

Long operation periods of GNSS stations gives a possibility to use their data in vertical crustal movements elaboration with accuracy better then  $\pm 0.5$  mm/y. During the elaboration the reliability must be considered. This involves the choice of the adjustment method. In most cases the models are designed as absolute and related to the ellipsoid. The other options are differential, relative models. In this case GNSS stations are connected and vertical movements are calculated between them. In the next stage the network of vertical crustal movements is adjusted and the accuracy is asessed. The goal of this article is to calculate the unadjusted trend on the basis of GNSS time series and their adjustment in the Central Europe territory. The article presents the robust adjustment method with the appropriate weighting scheme. Obtained results are showing that the accuracy of vertical crustal movements model of 0.5 mm/y can be obtained from the GNSS observation processing. Also the benefits coming from the application of robust adjustment method are emphasised.

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# IS NEOTECTONIC REJUVENATION OF FAULTS RESPONSIBLE FOR SOME LANDSLIDE PHENOMENA IN THE BARDZKIE MTS (SUDETES, SW POLAND)?

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## ABSTRACT

A number of elongated morphological escarpments can be perceived over the area of the Bardo Mts on the LiDAR-based digital elevation models. Their analysis on the background of the existing geological maps (e.g. Oberc et al. 1994) and preliminary field studies (Sikora and Piotrowski 2016; Sikora et al. 2016) point to their relationships with the tectonic structure of the bedrock. These observations, complemented with data from neotectonic (Krzyszczkowski et al. 2000, Badura et al. 2003) and geophysical (Aleksandrowski and Ostrowski 2016) studies, allow for delineation of probable fault reactivation zones, affecting details of the morphology in the Bardo Mts. The rejuvenation of some fault zones have brought about local landslide activity in the area. Such faults control the geometry, structure and surficial morphology of the related landslides, while the outcropping bedrock nearby make it possible to undertake mesostructural studies of the latter. At present, our research work is focused on the antecedent gorge of the Nysa Kłodzka river and is hoped to result in refining our understanding of the neotectonic factors that influenced its formation and evolution.

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# TESTING CORRELATION BETWEEN VERTICAL CRUSTAL MOVEMENTS AND GEOID UPLIFT FOR SUDETEN AREA

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## ABSTRACT

Long time span of observations from GNSS permanent stations can be used in the development of models of vertical crustal movements. The absolute vertical crustal movement related to the ellipsoid consists of the observed movement with relation to the mean sea level, the eustatic movement and the geoid uplift. The geoid uplift can be determined from GRACE and GOCE satellite missions observations. The calculated parameters can be compared with the theoretical ones.

The aim of this study is to check the correlation between vertical crustal movements and a geoid uplift determined from satellite data. Moreover, results allow for a preliminary verification of the assumptions concerning these values published e.g. by Lisitzin (1974), Sjöberg (1982) or Ekman (1986). GNSS data and satellite observations for Sudeten area were used as a case study. GNSS data were obtained from permanent stations of ASG-EUPOS, SAPOS, CZEPOS and SKPOS systems, which are the Polish, German, Czech and Slovak multifunctional systems respectively. Changes of the ellipsoidal heights from more than 5 years of observations were used as input data. Temporal variations of geoid were calculated based on the geopotential models from satellite observations. The obtained results give an overview of a possibility of the proposed method usage.

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# VERIFICATION OF THE GNSS TIME SERIES DISCONTINUITY DETECTION ALGORITHM FOR THE VERTICAL CRUSTAL MOVEMENTS ELABORATION

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## ABSTRACT

Vertical crustal movements can be outlined on the basis of GNSS data taken directly on permanent stations (the absolute motion) as well as on vectors between the stations (the relative motion). The time series, which are created in both cases, include, apart from the information about height, measurement noise and they are burdened with the influence of factors that are difficult to identify. The factors make momentary or long-term changes in height in due time. The explicit places of momentary changes in height (jumps) are difficult to determine. In order to set the velocity of changes of height, the jumps should be identified on the basis of the determination of the place of a jump and its value. The authors of the article created an algorithm that supports the process of creating the models of vertical crustal movements from GNSS data. The solutions used in the algorithm allow for determining the place of a jump and estimating the velocity of changes of height. The aim of the article is to verify the algorithm on the basis of height changes in adjacent stations of ASG-EUPOS networks and to set proper algorithm parameters. The parameters value that are essential for proper use of the algorithm were determined. Additionally, the results received on the basis of the algorithm were evaluated and compared with the velocity counted manually from the same time series, the velocity and parameters with values adjacent to complex parameters, information in .log files and the loop misclosure values. The estimated results indicate on the proper functioning of the algorithm and its usefulness in supporting the creation of models of vertical crustal movements from GNSS data.

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# ABSTRAKTY K POSTERUM

## AN ATTEMPT TO DETERMINE CONTEMPORARY HEIGHT CHANGES IN WROCLAW

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### ABSTRACT

For the large cities, where a lot of various objects (including those which can cause a threat to the safety of the residents) are located, there is a need to determine the contemporary height changes of terrain surface, which can affect the stability of those objects. It is particularly important for areas with a high risk of incidental tectonic phenomena occurrence. Also on non - seismic areas, disadvantageous changes of the stability of the soil, caused by torrential rains, floods and anthropogenic factors can occur.

The study will present the results of terrain height changes research, made for area of Wrocław. Data was obtained from studies of satellite data and periodically measured vertical displacements of city network benchmarks as well as benchmarks dedicated to monitoring of selected buildings and engineering objects.

**Keywords:** *ground surface deformations, displacements, Wrocław*

# **THE STUDY OF VERTICAL DISPLACEMENTS OF GEO-INFO-HYDRO BUILDING**

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## **ABSTRACT**

Didactic building Geo-Info-Hydro belonging to the Wrocław University of Environmental and Life Sciences, located at Grunwaldzka Street was founded in 2012 and it was put into service in October 2015. The building is built on a foundation slab and it is surrounded by other engineering structures - among other buildings belonging to the campus of the Wrocław University of Environmental and Life Sciences.

For monitoring stability as well as for educational purposes, on the building and surrounding objects monitoring system sensors are installed. System automatically register any movements or changes of building. An integrated geodetic monitoring system operates on the building, and it consists set of sensors: geodetic and non – geodetic ones, as well as software, which are monitoring the state of an object in real time.

To measure vertical displacements inside the building leveling network was established, controlling the stability of the structure of the object. Benchmarks of the network were established mainly on supporting poles carrying the weight of the structure to the foundation. They are located on level -1 of the building. The study presents the measurement network and the results of the first control measurements.

# OPTIMIZATION OF TOPOGRAFIC LANDSLIDE TRIGGERING FACTORS FOR LANDSLIDE SUSCEPTIBILITY ASSESMENT IN THE REGION OF ROŻNÓW LAKE, POLAND

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## ABSTRACT

Landslides are natural hazard that causes many damages to the environment in the world. Landslide can destroy or damage buildings, as well as agricultural and forest areas. Generally, landslides have negative impact on the environment. The increasing awareness of the socio-economic landslide significance motivates for deep studies on landslide susceptibility assessment.

Landslide susceptibility assessment is the preliminary step for hazard and risk prediction. However, landslide susceptibility mapping is the challenging task. It requires taking into consideration specific landslide triggering factors (LTFs). Different factors can be considered as the LTFs, wherein the terrain topography is one of the most important LTF. Therefore, the selection of the appropriate topographic factors is very important. Some researchers assume that the accuracy of the created susceptibility map increases proportionally with the quantity of landslide triggering factors. Other scientists state that a small number of landslide controlling factors are satisfactory to produce landslide susceptibility maps with a reasonable quality. Therefore, no specific rule exists, that defines how many conditioning factors are sufficient for the susceptibility analysis on a given study area

The objective of this research is to understand which topographical LTFs are the most appropriate parameters for landslide susceptibility analysis. For this reason, wide analyses of topographic information provided by digital elevation model (DEM) were made. Topographic LTFs were created from DEM delivered by airborne laser scanning data. Among them we can distinguish: elevation, slope, aspect, multiple shaded relief, topographic position index, topographic wetness index, gradient of the slope, area solar radiation, and stream power index. Principal Component Analysis (PCA) and likelihood model was applied in order to evaluate the most significant factors.

Afterwards it was possible to eliminate factors which were not significant for landslide susceptibility mapping, eg. topographic position index, stream power index. Presented approach was tested on study area in the eastern part of Rożnów Lake in Poland. The landslide density within the study area is 25% which cause this area very prone for landslide activity.

**Keywords:** *landslide, landslide susceptibility mapping, landslide controlling factors, principal component analysis*

# **GEOLOGICAL AND GEOPHYSICAL SURVEYS ON BARDO-JANOWIEC LANDSLIDE**

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## **ABSTRACT**

The majority of landslides in Poland are located in the Carpathian and are made of Flysch. This region is well recognized, but other part of Poland not. This was the reason to undertake the research of verifying methods used there but in the area of the Sudeten, where diversity of structure from magma rocks through the metamorphic and sedimentary deposits build small tectonic units, separated and divided by faults, create a geological mosaic structure.

The aim of the research was to test the suitability of various geophysical methods in the diagnosis a landslide on the slopes of the Bardo Mountains (Sudeten, Poland). Within the project was made electrical resistivity sounding and tomography (SGE, ERT), shallow seismic and GPR survey. To recognize the range of the landslide were also used a laser scanning. Also was made a boreholes down to bedrock allowed to verify the geophysical surveys and to determine the hydrogeological conditions.

Geophysical surveys confirmed the hypothesis of the landslide Janowiec position in the zone of fault stair system formed on the northern slope of a deep valley of the Nysa Klodzka. Bedrock in this part of the slope is characterized by a strong cracking and high rate of gaps.

The research revealed that the landslide is still active and pose a threat to residential, industrial buildings and infrastructure in the western part of Bardo and adjacent areas.



# **OPTIMAL GEOSTATISTICAL METHODS FOR DISTURBED IONOSPHERE INTERPOLATION: A CASE STUDY DURING SAINT PATRICK STORM**

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## **ABSTRACT**

Geostatistical Analyst is a set of advanced tools for analysing spatial data and generating surface models with the use of statistical and deterministic methods. It enables the interpolation of models on the basis of data measured at chosen points. Geostatistical Analyst enables analyses of data variability, setting data limits and checking global trends, as well as creating forecast maps, estimating standard error and probability, making various surface visualisations including contour lines (isolines) and analysing spatial autocorrelation and correlation between multiple data sets. Data can be interpolated using deterministic methods providing surface continuity, and also by determining the most probable value estimation, while the kriging techniques, based on a statistical model considering data autocorrelation, evaluate the expected error. These properties of Geostatistical Analyst make it a valuable tool for Earth's ionosphere modelling and analysis. Hence, our research aim at testing its applicability for studying the ionosphere, and ionospheric disturbances in particular. This paper compares ionosphere models developed using various interpolation methods by means of validation, which aims at calibrating and determining the stability of a model. The indicators that can be compared are the statistical characteristics of interpolation error, such as: Mean Prediction Error, Root Mean Square Prediction Error, Average Standard Error, Mean Standardised Prediction Error, Root Mean Square Standardised Prediction Error. Here we present analysis of the modelling results for different states of the ionosphere: on the St Patrick's Day geomagnetic storm of 2015, one day before the storm and one day after. Finally, the optimal interpolation method is presented.

# TO AN INTERPRETATION OF A SURFACE HORIZONTAL DEFORMATION MODEL OF THE SUDETEN AREA BASED ON THE GPS DATA

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## ABSTRACT

The recent permanent GNSS observations together with periodical GPS data recorded in the 1997–2013 period at regional geodynamic networks were reprocessed by the Bernese 5.2 software. The reprocessing had been done within a standardized reference frame applying new absolute models of antenna phase centers, the latest models of the rotary motion of the Earth and the atmosphere models. The site horizontal movement vectors obtained by this aggregated and integrated processing became an input for a modeling of the intraplate horizontal velocity and deformation fields of the upper Earth's crust. The model fields were created by the GRID-based interpolation methods and then subjected to geodetic (geometrical) and structure geological interpretations. An attempt to explain the deformation model was undertaken using the concept of gravitational collapse developed by tectonicists to explain the behaviour of uplifted mountain ranges. The horizontal linear deformations along selected cross-sections were joined with the altitudes of the *Shuttle Radar Topography Mission* model of 90 m resolutions. Then we with geologists and geophysicists analyzed them with crustal structures and the Bouguer's gravity anomalies together. The thickness of the Earth's crust was

acquired from geophysical interpretative models resulting from the CELEBRATION 2000 and SUDETES 2003 deep seismic projects. Gravity anomalies were taken from the Gravimetric Atlas of Poland. The primary results of the interpretative analyses show the compliance of the GPS data with the assumptions of the gravitational collapse model only along some segments of the studied profiles. Therefore, a more complete understanding of causes of the measured horizontal deformations in the Sudeten requires further research.

# EVALUATION AND ANALYSIS OF GROUND WATER LEVEL CHANGES AND WATER BUDGET IN THE AREA OF SUDETY MOUNTAINS

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## ABSTRACT

Water is one of the most important component of the environment, having a direct effect on the maintenance of life on Earth. Monitoring resources and quality of water is necessary to ensure public safety. Both excess and lack of water are dangerous. Groundwater is an important component of water resources, and currently in many areas, including Poland, the declining groundwater level has been observed (Barlik et al., 2007; National Water Management, Annex 1 to the draft national water policy 2030, 2010).

In this paper, the analyses of changes of groundwater level (GWL), water budget and all the parameters included in these quantities, were performed, on the area of Sudety Mountains, in the period of 2003 – 2016.

The ground water level changes were computed on the basis of the mean Terrestrial Water Storage (TWS) values determined from GRACE observations, completed with data acquired from the Global Land Data Assimilation System (GLDAS). TWS data have spatial resolution of one degree, and temporal resolution of one month, therefore the calculated changes of GWL do also refer to such resolution.

The water budget values are calculated usually for checking the quality of the GLDAS data referring to a chosen area. These values were computed in both one degree and a quarter of degree resolution, to study whether the better resolution would provide substantially increased accuracy.

The results obtained were analyzed both graphically and statistically, for the whole Sudety Mountains area.

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# EXTRACTING OF TOPOGRAPHIC FEATURES WITHIN RIVER AREA BY INTEGRATION OF AIRBORNE AND TERRESTRIAL LASER SCANNING

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## ABSTRACT

In the studies related to the river area, the aspect of relief in the vicinity of the river is very important, therefore reliable data representing the physical surface of study area is essential characterized by appropriate accuracy and the relatively short time of acquisition. Digital terrain model (DTM) generated on the basis of data from airborne laser scanning (ALS) was integrated with DTM derived from data acquired by means of terrestrial laser scanning (TLS). It was carried out according following scheme: comparing test data - DTMs generation; searching planar feature: PCA calculation; establishing matching criteria (distance and angle); surface matching (Least Squares 3D Surface Matching - LS3D). In the article the main emphasis is on the assessment of the accuracy of terrain features in relation to data integration method. Both sets of data (from ALS and TLS) were compared. The analysis estimating the size of difference area was also performed. Indicators of relief classification and roughness were here applied

***Keywords:*** *data fusion, laser scanning, terrain feature, relief classification*

# POSSIBILITY OF USING UAS IN LANDSLIDE RESEARCH

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## ABSTRACT

One of the first visible signs of landslide occurrence are changes in microrelief and shape of the slope. In the classical survey to determine the range of the landslide will be used tachymetry, GNSS survey or remote sensing techniques.

To get quickly and accurate actual information of the object also can be used airborne low-level photogrammetry from UAS (unmanned aerial systems). Pictures taken by unmanned aerial vehicles (airplane or multicopter) have a ground resolution of the pixel on the level of single centimetres. Beside simple RGB pictures also can be obtain multispectral information, which allow to calculate e.g. Normalized Difference Water Index (NDWI) which gave information of humidity of soil on the slope of landslide. A high resolution orthophoto map as well as a point cloud, which can be filtered to develop a digital terrain model (DTM) can be developed after processing acquired data from UAS..

This type of material developed in short time allows to specify the landslides range, as well as to predict risk for surrounding area in its further movement.

In paper authors presents results concerning of using UAS in landslide research. Also the data acquired by UAS are compared to other techniques: GNSS, terrestrial laser scanning (TLS), ALS data (numerical terrain data – acquired by airborne laser scanning), time-domain reflectometry (TDR).



# **ANALYSIS OF THE SELECTED ELEMENTS OF THE GRAVITY ACCELERATION CHANGES IN THE ŚNIEŻNIK GEODYNAMIC NETWORK**

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## **ABSTRACT**

Geodynamic network in the Massif Śnieżnik (Sudety Mts, SW Poland) was founded in 1992 by a team of Institute of Geodesy and Geoinformatics Wrocław University of Environmental and Life Sciences. 27 measurement stations (concrete pillars) have been fixed in the Polish and Czech parts of the massif. Network point locations have been correlated with geological conditions, topography and tectonics of the Śnieżnik metamorphic. Measurements were taken by relative spring gravimeters Scintrex Autograv CG3M and Lacoste&Romberg. In each campaign, the observations of relative acceleration were performed by the profile method according to the scheme A, 1, 2, 3, ..., A. All measurements were made in reference to the Primary Gravimetric Network of Poland (POGK). The reference point of observation in the Śnieżnik Massif was a point of the absolute measurement  $g$ , founded in the basement of the pension "Emilia" in Bolesławów. Previously, it was a relative observation reference point at the church in Bolesławów. This solution ensured the highest possible accuracy. Determination of the absolute acceleration  $g$  value was performed using ballistic gravimeter FG-5 No 230. The relative profile observations and determine the absolute values of  $g$  were made in cooperation with the Warsaw University of Technology. The paper presents the variability of the gravitational acceleration in the Massif Śnieżnik (Polish Part) based on the analysis of a observational data series from the period 1996-2010. This work was supported by Polish Ministry of Science and Higher Education, Project NN 526 223335 „Geodetic monitoring of the Waliszów-Morawa tectonic zone recent activity”.

# GRAVIMETRIC MEASUREMENTS ANALYSIS IN THE WILKANÓW FAULT AREA WITH RESPECT TO THE GEOLOGICAL STRUCTURE

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## ABSTRACT

Wilkanów fault (Sudety Mts., SW Poland) is a natural border between Upper Nysa Kłodzka Graben and the Śnieżnik Massif. Due to that two research gravimetric profiles, intersecting Wilkanów fault, were designed. In the northern part of the fault the profile Idzików was located, whereas -the profile Wilkanów-Międzygórze was located in the southern part of this fault. All observations were implemented method of single measurements profile according to the scheme A, 1,2, ..., A. Detailed gravimetric profiling were performed with quartz gravimeter Autograv Scintrex CG-5. Measuring points in the both profiles set at approx. 100 m. Points were positioned by a RTK GNSS technique. Due to the nature of the object, a separate reference point was fixed for each profile. The described research was performed in cooperation with Institute of Geodesy and Geoinformatics Wrocław University of Environmental and Life Sciences and Department of Geophysics of the AGH University of Science and Technology in Kraków. Analysis of processed results of observation, taking into account geological data enabled the determination of distributions Bouguer anomaly profile along Idzików and Wilkanów-Międzygórze. The amplitude of the gravity changes in the profile of the South is larger and amounts to approx. 4 mGal. Schedules Bouguer anomalies in both profiles, in the western and central part, are similar in character, but their progress is incompatible with the distribution density of the rock formations. They accepted them on the basis of cartographic and a literature study the geological structure of the area. In the eastern part a varied course is visible. According to these assumptions the force of gravity should increase from west to east, that is, from the lower density (Upper Cretaceous sedimentary rocks) toward higher densities (gneisses). The decrease in the force of gravity within, built of gneiss Międzygórze unit indicates the existence of the track with a density lower in this region. Since gneiss appear on the surface of high density, it seems probable existence of a low density

track directly under gneisses. The shapes of both curves suggest a contact the density in the vicinity of both profiles, consistent with geological maps shown in the course of the fault. This problem needs additional observations in the new research profile Szklary, in the central part of the study area and to achieve a better distribution of surface gravity. This work was supported by Polish Ministry of Science and Higher Education, Project NN 526 223335 „Geodetic monitoring of the Waliszów-Morawa tectonic zone recent activity”.



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**17<sup>th</sup> Czech-Polish Workshop**

**ON RECENT GEODYNAMICS  
OF THE SUDETEN  
AND THE ADJACENT AREAS**

Lubomil Pospíšil and Alena Berková  
(Editors)



Vydal

ECON publishing, s.r.o.  
Pod Nemocnicí 590/23, 625 00 Brno  
e-mail: [econ@atlas.cz](mailto:econ@atlas.cz)  
tel.: 602 755 541  
[www.econ.cz](http://www.econ.cz)

v roce 2016 jako svoji 74. publikaci v systému ISBN.

Vydání první.

*Redakce:* prof. Ing. Otakar Švábenský, CSc., doc. Ing. Lubomil Pospíšil, CSc.

*Grafické zpracování:* doc. Ing. Lubomil Pospíšil, CSc., Ing. Alena Berková

*Tisk:* FAST VUT

ISBN: 978-80-86433-63-9

