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Abstracts

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Applied geophysics

3D geophysical-petrological modelling of the lithospheric structure from Pannonian basin to Trans-European suture zone

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We have analysed the thermochemical structure of the mantle in Central Europe, a complex area with a highly heterogeneous lithospheric structure reflecting the interplay of contraction, strike slip, subduction, and extension tectonics. Our modelling is based on an integrative 3-D approach (LitMod) that combines in a self-consistent manner concepts and data from thermodynamics, mineral physics, geochemistry, petrology, and solid Earth geophysics. This approach minimizes uncertainties of the estimates derived from modelling of various data sets separately. To further constrain our 3-D model we have made use of the vast geophysical and geological data (2-D and 3-D, shallow/crustal versus deep lithospheric experiments) based on experiments performed in Central Europe in the past decades. Given the amount and the different nature/resolution of the available constraints, one of the most challenging tasks of this study was to consistently combine them finding a trade-off between all local and regional data sets available in a way that (a) preserves as many structural details as possible and (b) summarizes those data sets into a single robust regional model. The resulting P/T-dependent mantle densities are in LitMod 3-D calculated based on a given mineralogical composition. They therefore provide more reliable estimates compared to pure gravity models, which enhance modelling of the crustal structures. Our results clearly indicate presence of several lithospheric domains characterized by distinct features, Pannonian Basin being one of the most outstanding ones. It has the thinnest crust and lithosphere in the area modelled, characterized by relatively fertile composition.

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Research impact velocities of seismic waves on optimization of blasting effects in the quarry Trebejov

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Unwanted or harmful effect seismic blasting is an important factor that limits the general and reasonable tendency to magnify the extent of blasting. Technically unjustified high seismic safety leads to narrowing charges and blasting, reducing the efficiency of disintegration and conquest. On the contrary, underestimation of seismic effects can cause great material damage. Currently, the identification of these harmful effects and determine the seismic safety of current problems. The article described a method that allows for the interpreted results, determine the velocity of propagation of seismic waves in the quarry Trebejov. Knowing the speed of propagation of seismic waves in the rock environment allows optimizing the refractive millisecond timing blasting, so it is possible to increase the attenuation of seismic waves to the receptor and to ensure seismic safety of blasting.

Case study of shalow seismic tomography from South-West slopes in Malé Karpaty Mts. (Western Carpathians).

Príkladová štúdia plytkej seizmickej tomografie z oblasti JZ svahov Malých Karpát (Západné Karpaty).

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Príkladová štúdia je venovaná stanoveniu hĺbky a priebehu skalného podložia v oblasti SZ svahov Malých Karpát vo vysokoškolskom areáli Mlynská Dolina pri FIIT v Bratislave. Skalný podklad je v tejto časti tvorený granitoidnými horninami. V niektorých častiach sú na granitoch neogénne sedimenty zastúpené rôznymi druhmi siltov, piesčitých a ílovitých siltov a hlinitých pieskov. Vekovo sa zaraďujú do panónu (neskorý miocén). Kvartérny pokryv leží jednak priamo na granitoch a jednak prekrýva všetky neogénne horniny. Najvýraznejšie sú strednozrnné štrkové terasové lavice (mocnosť 4 -8 m). Medziterasové svahy a časti terás sú zaviate piesčitými sprašami a eolitickými pieskami. Stupňovitý charakter svahov je zamaskovaný deluviálnymi ílovitými hlinami. (Nemčok, 1966).

Záujmový profil je lokalizovaný medzi sondami hĺbenými pre inžiniersko geologický posudok staveniska vysokoškolského areálu v roku 1966. Kryštalinikum bolo zachytené len sondami v dolných častiach svahu. Sondy v blízkosti profilu zachytili iba neogénne a kvartérne sedimenty. Refrakčné seizmické meranie sa realizovalo na profile s dĺžkou 120 m. Použitá bola 24 kanálová aparatúra DMT s 10 Hz vertikálnymi geofómni a ako zdroj slúžilo kladivo. Namerané dáta boli spracované v programe Reflexw Version 8.0 (by K.J. Sandmeier). Výsledkom je rýchlostný model prostredia. Vo jeho vrchnej časti je nízkorýchlostná vrstva s rýchlosťami šírenia sa P vĺn do 500 m/s a pod ňou približne 15 m hrubá vrstva s rýchlosťami cca 1100 - 1300 m/s, zodpovedajúca neogénnym sedimentom zachyteným najbližšou vŕtanou sondou. V podloží tejto vrstvy, v hĺbke cca 20 – 25 m pod povrchom, bolo interpretované granitoidné podložie (priemerná rýchlosť vo vrstve 3060 m/s). Seizmické meranie prinieslo požadované výsledky a v rámci ďalšieho prieskumu bude doplnené aj o ERT meranie. Prezentovaný seizmický profil je prvým z plánovaných profilov, ktoré by mali upresniť hĺbku a priebeh granitoidného podložia hlavne vo vrchných častiach svahov v skúmanej oblasti.

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Examples of application for seismic methods in practice

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Seismic methods allow a wide range of uses. We can apply them across all geological disciplines, solving environmental problems, building and specially deploying certain types of solutions. This poster shows only a brief overview of the great use of seismic methods. Individual images capture the specific use of a typical seismic method for a given problem and its solution. For example, in sedimentology, seismic can provide valuable information for the overall interpretation of the sedimentary basins. In landslide areas, seismic refraction can draw a more accurate picture of the position and size body of the landslide. Seismic reflection at large depths allows for a good view of the tectonic and structural structure of the geological structures of the measured section. Appropriate use of seismic methods is for geological exploration of highways or rail tunnels.

Monitoring of Electromagnetic Emisions on active landslide in Ruská Nová Ves village

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The Electromagnetic Emission (EME) method is based on the generation of electromagnetic waves by mechanical stress on solid materials. In geological disciplines, this method is gradually applied to the tectonic research and also penetrates into the solution of slope deformations. In this paper, we want to point out the possible use of this method in the monitoring of landslides areas. The results of the three-hole EME field monitoring on the Ruská Nová Ves (Eastern Slovakia) site are confronted with the results of the inclinometric measurements. The obtained results point to an increased generation of the EME field in the area over the shear zones in the gravelly deluvial sediments. On the other hand, no anomaly EME values are recorded near the shear zones in the clay sediments. The time changes of the EME field in various parts of the slope deformation provide a new view of the dynamics of the stress-strain state in the landslide body.

Georadar images of road construction

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One of the gratifying objects for georadar measurement application are road constructions. The density of the information they provide is fully satisfactory for assessing the state of road construction. The assessment of the condition of the road construction elements from the results of the georadar measurement is possible based on the analysis of the results of real measurements, physical modeling and mathematical modeling. This paper presents the results of real georadar measurements with 150 MHz and 1 GHz antennas on road constructions. Radargrams present different design elements according to available project documentation on asphalt and concrete roads. They are mainly interfaces of structural layers, bridges, faults due to the sliding processes, sewerage, etc.

New CBA map interpretation in wider region of Bratislava

Interpretácia novej mapy ÚBA širšieho okolia Bratislavy

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Po viac ako desiatich rokoch bola opäť prepočítaná a vylepšená mapa Úplných Bouguerových anomálií (ÚBA) územia SR. Do existujúcej regionálnej gravimetrickej databázy boli začlenené aj doteraz nevyužité hodnoty detailnej databázy zo súkromného sektora. Súčasťou novej mapy ÚBA územia SR (Pašteka et al., 2017) bolo aj územie širšieho okolia Bratislavy, ktoré zaznamenalo nárast oproti doterajšej mape ÚBA z 1611 bodov (Kubeš et al., 2001) na 8923 bodov. Nárast o viac ako 450% sa oblasti širšieho okolia premietol do mimoriadne vysokej hustoty bodov až 24-25 bodov na km^2. Taktiež bol využitý nový softvér pre výpočet terénnych korekcií Toposk (Marušiak a Mikuška, 2012). Z dôvodu významnému nárastu hustoty bodov, skvalitnenia výpočtu terénnych korekcií ako aj ďalšej gravimetrickej interpretácie bola potreba osobitne vypočítať mapu ÚBA pre územie širšieho okolia Bratislavy. Interpretačnými postupmi boli metódy 3D modelovania, gravimetrického odkrývania a výpočet regularizovaných derivácií. Vypočítaný gravitačný účinok sedimentárnej výplne širšieho okolia Bratislavy bol odpočítaný od mapy ÚBA za vzniku odkrytej tiažovej mapy predterciérneho podložia. Gravimetrické odkrývanie je jedným z najpoužívanejších gravimetrických interpretačných postupov v Západných Karpatoch. Pre odkrytú tiažovú mapu boli vypočítané aj jej regularizované derivácie, konkrétne horizontálny gradient, ktorý bol úspešne aplikovaný na území Západných Karpát pri vyhľadávaní a overovaní tektonických línií. Nová mapa ÚBA pre širšie okolie Bratislavy má veľmi podobný charakter poľa ako jej predchádzajúca verzia, s tým rozdielom že nová mapa ÚBA v sebe nesie oveľa viac detailov. Amplitúda gravitačného účinku modelovanej kvartérnej a neogénnej sedimentárnej výplne spravidla reflektuje jej hrúbku. Odkrytá tiažová mapa reprezentuje anomálne hustotné prejavy predterciérneho podložia vzhľadom na referenčnú hustotu 2,67 $g.cm^{-3}$, ktoré z najmä v oblasti Malých Karpát prislúchajú odozvám jednotlivých geologických jednotiek. Prínosom mapy horizontálneho gradientu predmetného územia je predovšetkým spresnenie priebehu malokarpatského zlomu.

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ERTmod – an in-house electrical resistivity tomography inversion software

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Presented work deals with aspects of electrical resistivity inverse software package ERTMOD, based on the minimal structure inversion, producing models with minimal structure and sharp boundaries. Results of forward modeling and inversion of synthetic and field ERT data inversion are presented.

The main core of the forward modeling code is based on the 3D finite differences modeling principle adopted from Dey and Morrisson (1979), where several improvements has been made. Singularity removal technique seems to be most significant improvement to the final results. An up to date numerical techniques, like parallelization and modified preconditioning speed up the solution. These techniques enables us to employ 3D geometry concept to calculate very accurate 2D and 2.5D structures as well with comparable time requirements to the 2D algorithms, which makes the forward modeling code very versatile. As a precision benchmark of electric potential distribution calculation a Boundary Integral Equation method (Hvoždara, 1995) was adopted. The inverse problem in ERT method is non-linear problem, therefore it has to be solved iteratively. The inversion core of the ERTMOD is based on a Gauss-Newton inverse scheme, which was applied to reformulate non-linear inverse problem into a linear one. Local regularization scheme of the system is based on the IRLS method (Farquharson, 2008), which adaptively adjusts data weights during the inversion on the most non-fitting data during each iteration and significantly improves output resistivity models. The objective function to be minimized in this case follows:

$$\Phi = \phi_d + \lambda \phi_m ,$$

where index *d* and *m* represent data and model misfits respectively and λ is dumping factor, which is decreasing during the inversion. For minimum structure and sharp models the l_1 norm is mostly used to evaluate the misfit function. Final resistivity models are compared with broadly established commercial software RES2DINV.

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Areas of geothermal waters location detection and mapping by the frequency-resonance method of the remote sensing data processing and interpretation (Eastgate, UK)

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The results of the frequency-resonance technology of remote sensing (RS) data processing application for the areas of geothermal sources searching and mapping are analyzed. The experimental studies have been conducted in the area of “Eastgate” deep geothermal well location in Weardale (UK). At the initial stage within the surveyed area the zone of tectonic fractures were detected and traced. As a result of the subsequent processing within the surveyed area seven anomalous zones of the "geothermal water" type were found and mapped. Within the contours of the individual anomalies the local area with the highest estimates of water temperature were highlighted. Zones with a maximum water temperature are located mainly in the areas of the faults intersection. The results have been showed that the "Eastgate" well is located on the edge of one of the detected anomalous zones. A site with a higher water temperature is in the opposite, south-eastern part of this anomaly in the zone of the faults intersection. Not far from the "Eastgate" well and in the area of the maximum temperature of the water a detailed vertical scanning of satellite data were conducted. According to the scanning, the depths and thicknesses of the various aquifers (water intervals), as well as the temperature in them have been identified. This kind of detailed studies was carried out for the first time.

In general, the results of experimental research in the region of “Eastgate” deep geothermal well and the multiyear practical experience of mobile geophysical technologies application for water prospecting allows to state that the frequency-resonance method of RS data processing and interpretation allows detect and map the zones of water and geothermal waters location. The maximal temperatures of the geothermal water in separate points of mapped anomalies can be also estimated.

Deep geothermal sources for electricity production in Slovakia: thermal conditions

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The region of Slovakia belongs to promising areas for the exploitation of geothermal energy in the form of hydrothermal sources and also as the hot dry/wet rock sources. The region is characterized by complicated tectonic evolution and resultant structure with relatively high thermal activity.

Our contribution presents the results of geothermic interpretation approaches applied to measured geothermal data and is aimed to determination of thermal conditions for the application of EGS technologies in the region of Slovakia and adjacent areas. Primarily, the heat flow data and the temperature distribution measurements in boreholes were interpreted by classic 1D interpolation and extrapolation methods. New terrestrial heat flow density (THFD) map for studied area was constructed using the values determined in boreholes, their interpretation, newest outcomes of geothermal modelling methods based both on steady-state and transient heat transfer approaches, and on other recently gained geoscientific knowledge.

THFD varies typically within the interval of 50-120 mW/m² with some extremal values outside of this range. Heat flow density values in localities suitable for geothermal energy exploitation from the thermal and technical point of view are usually higher than 90 mW/m².

From the constructed maps of temperature field distribution at selected depths of up to 6000 m below the surface we have made the final map of the isothermal surface depths for the reservoir temperature of 160 °C. This map serves for the appraisal of the effective application of the binary cycle power plant technology in Slovakia in term of the thermal conditions.

The promising regions for both classic hydrothermal source types and petrothermal sources with 160 °C deep source temperature existing at the depth up to 5000 m include the substantial part of the Slovakia.

The East Slovakian Basin with the flanking Prešov Depression is the most promising area in the region of Slovakia regarding the thermal conditions. In the prevailing part of this structure the temperature of 160 °C is reachable at depths of up to 4000 meters. In the central part of the Trebišov depression the depths of the considered temperature isoplane would be less than 3500 m. Furthermore, in the SE part of the Trebišov Depression the isosurface depth is supposed to be as low as 3000 m. The temperature of 160 °C is reachable at the depth of 4000 m or less also in the central part of the Danube Basin both in Slovakia and Hungary. It is necessary to mention also other regions: central part of the Vienna Basin, central area of the Central Slovakian Volcanics together with Žiar Depression, and the partial areas along the axis of the Carpathian Conductivity Zone in the most Eastern part of the Outer Carpathian Flysch.

Flysch belt, Klippen belt and Inner Western Carpathian Paleogene basin relation in the NE Slovakia by magnetotelluric imaging.

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Our contribution deals with the interpretation of magnetotelluric measurements carried out on the profile directed NE-SW in the wider surroundings of Stará Ľubovňa. The profile arises from Flysch Belt units (northerly from Hraničné), crosses the Pieniny Klippen Belt (PKB) near Jarabina and continues in WSW direction toward Inner Carpathian Paleogene sediments as far as Ružbachy block with its Mesozoic carbonate complexes of Fatricum arising to the surface.

The measurements were carried out almost equidistantly at seven points. The results of measurements were processed by standard robust methods (software Mapros) and primarily interpreted by multidimensional magnetotelluric inversion modelling approaches.

In the northern part of our profile there are apparent more conductive flysch complexes lying on nonconductive, probably Oravic, basement inclined northerly. The contact between Outer flysch units and PKB forms subvertical system of faults. The Klippen belt is characterized by higher conductivities up to the depths of 1 – 1.5 km. Under these depths the conductivity distribution corresponds to higher content of dry carbonates. In the first hundreds meters there were determined high-conductivity anomalies caused by hydrogeological factors. Some of them indicate also possible spatial structure of deeper aquifers. On the southwest PKB is separated from Inner Carpathian Paleogene by the Podhale fault. It has also almost vertical direction. In the depths of about 500 m from the surface there is higher conductivity obtained from model data and it is likely related to the presence of water at the contact of fault lines.

Along the profile toward the west there are displayed higher conductive Inner Carpathian flysch sediments situated on less conductive basement formed by Mesozoic carbonates as well as by the crystalline complex below. This basement is broken into crustal blocks along faults. Depth of basement varies from 1 km in the middle part up to 1.5-2 km at the structure edges. Near the Ružbachy Mesozoic block the estimation of basement depths is more difficult due to lateral influences of high conductive water-saturated limestones occurred here. Inner Carpathian Paleogene around Kamienka exhibits high conductivities of near-surface layers. This is caused by big amount of water filled in.

The results of interpretation of magnetotelluric measurements provide new knowledge about geological and geoelectrical structures in both NE part of PKB and surrounding units. Further they will be utilized for the interpretation of the distribution of both temperature field and surface heat flow density along south border of PKB. This has a great importance also in the determination of geothermal energy sources parameters.

Airborne gamma-ray spectrometry survey – an overview of procedures

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The airborne gamma-ray spectrometry survey is one of the most effective and costless types of geophysical exploration usually applied for lithological and soil mapping, radioelement and mineral reconnaissance and environmental purposes. The primary advantage of an airborne gamma-ray survey is that a large amount of data on the radioelement concentrations of the exploration area can be obtained in a short period of time. Systematic airborne reconnaissance for natural and artificial radioelements is based on the use of digital data recording followed by computer processing with the use of statistical methods to reduce noise in multichannel spectra. The process of converting a series of airborne gamma-spectrometric data into equivalent radioelement concentrations at ground level requires a succession of precise procedures that guarantee the right result. Almost exclusively the airborne gamma-ray survey is combined together with aero-magnetic measurements.

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Glacifluvial sediments and their resistivity in Belá river (Liptov basin)

Glacifluviálne sedimenty a ich rezistivita na rieke Belá (Liptovská kotlina)

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Elektrická rezistivita je parameter, ktorý citlivo odráža materiálové, zrnitostné a pórovitostné zmeny geologických materiálov. Z uvedených dôvodov bolo vykonané mapovanie priestorových zmien elektrickej rezistivity pre účely geomorfologického výskumu histórie a vývoja glacifluviálnych sedimentov v povodí rieky Belá. Pri mapovaní bola použitá geoelektrická metóda (VES) (Gajdoš, 2013).

Z analýzy vertikálnych rezistivitných rezov vedených pozdĺž toku rieky Belá vyplýva, že materiál podložného paleogénu (íly, ílovce, pieskovce) sa hodnotami elektrickej rezistivity výrazne odlišuje (sú v zásade nižšie) od materiálu kvartérnych uložení (piesky, štrkopiesky, štrky, balvanité štrky), čo umožňuje pomerne dobre sledovať rozhranie kvartér – paleogén. Podobne kvartérne uloženiny netvoria homogénne teleso, ale sa miestne diferencujú a vytvárajú lokálne telesá v podobe subhorizontálnych dosiek, odlišujúcich sa od seba charakterom horninového materiálu.

Získané výsledky boli využité na posúdenie zmien hrúbky kvartérnych sedimentov, na vymedzenie jednotlivých litologických typov kvartérnych sedimentov a ich priestorové rozmiestnenie a na spresnenie prítomnosti a polohy tektonických porúch, ktoré podmieňujú vývoj kvartérnych sedimentov.

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High resolution Slovak Bouguer gravity anomaly map and its enhanced derivative transformations: new possibilities for interpretation of anomalous gravity fields

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This contribution deals with the revision and enrichment of the present gravimetric database of the Slovak Republic. The output of this process is a new version of the complete Bouguer anomaly (CBA) field on our territory. Thanks to the taking into account of more accurate terrain corrections, this field has significantly higher quality and higher resolution capabilities. The excellent features of this map will allow us to re-evaluate and improve the qualitative interpretation of the gravity field in the research of the structural and tectonic geology of the Western Carpathian lithosphere. In the contribution we also analyze the field of the new CBA based on the properties of various transformed fields - in particular the horizontal gradient, which by its local maximums define an important density boundaries in the lateral direction. All original and new transformed maps make a significant contribution to improving the geological interpretation of the CBA field. Except for the horizontal gradient field, we are also interested in a new special transformation of TDXAS (product of so called balanced horizontal gradient and analytical signal functions), which in an excellent way separates various detected anomalies of gravity field and improves their lateral delimitation.
New enhanced derivatives maps can also contribute to the research of the sedimentary basement structure and the detection of areas, which are suitable for a prognosis of the hot dry rock energy sources. This process is still developing and is being discussed. In spite of that the results represent exclusive geophysical interpretative materials for a study of the Western Carpathian geology. Grids of presented transformed fields (GS Surfer format) are available for scientific community and can be downloaded from the server of the Department of applied and environmental geophysics.

Radon monitoring in the Važecká cave, Slovakia

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The Važecká karst cave is developed in the Middle Triasic dark-grey Gutenstein limestone of the Biely Váh Series of the Choč Nappe, by ancient ponor waters of the Biely Váh side branch. Continual radon (^{222}Rn) monitoring in the Važecká karst cave started in June 2012 at the station Gallery and is still being carried out. Since November 2015, monitoring is performed at three stations: Entrance Hall, Lake Hall and Gallery. Radon is registered using the Barasol detector based on alpha particle detection. Besides radon, also CO_2 concentration, internal air temperature and relative humidity are continually measured at each station. The Važecká cave is also equipped with the external meteorological station. The aim of the research is to determine the values of ^{222}Rn activity concentration in the cave atmosphere and evaluate the influence of microclimatic and external meteorological parameters on the variation of ^{222}Rn activity concentration. A temporal variability of radon and environmental parameters measured inside and outside the cave is analyzed. Radon activity concentration in the cave atmosphere exhibited seasonal, non-periodic short-term and periodic daily variations. Radon reached its maximum in summer months, from June to September. Multi day radon variations lasting up to 15 days were observed at all three stations. Most of them were registered simultaneously at the Lake Hall and the Gallery station and they coincided with CO_2 multi day variations. The spatial differences in radon activities among stations were confirmed. The highest radon levels were found in the Gallery, the most distant station from the cave entrance. The radon research in the Važecká cave was supported by the Agency VEGA No. 02/0135/12, 01/0143/14 and 02/0083/15.

Gemeric granites of the Western Carpathians: 3D density modelling

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The Gemeric granites play one of the most important roles in the frame of the tectonic evolution of the Gemeric Superunit. Moreover, these granites are particularly interesting in terms of their mineralogy, petrology and ages. A new and original 3D density model of the Gemeric granites was created by using the interactive geophysical program IGMAS. The results show clearly that the Gemeric granites represent the most significant upper crustal anomalous low-density body in the structure of the Gemeric Superunit. Its average thickness varies in the range of 5–8 km. The upper boundary of the Gemeric granites is much more rugged in comparison with the lower boundary. There are areas, where the granite body outcrops and/or is very close to the surface and places in which its upper boundary is deeper (on average 1 km in the north and 4-5 km in the south). While the depth of the lower boundary varies from 5-7 km in the north to 9-10 km in the south. The northern boundary of the Gemeric granites along the tectonic contact with Rakovec and Klátov Groups (North Gemeric Units) was interpreted as very steep (almost vertical). The results of the 3D modelling show that the whole structure of the Gemeric Unit, not only the Gemeric granite itself, has an Alpine north-vergent nappe structure. Also, the model suggests the Silicicum-Turnaicum and Meliaticum nappe units to be overthrusted on the Golčatov Group.

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Determination of rock densities and integrated geophysical modelling of the continental lithospheric structure in the Western Carpathians and Pannonian Basin

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One of the most important goal of the CELEBRATION 2000 project was to research the structure and the dynamics of the lithosphere in the Carpathian-Pannonian region. In addition, the goal was to broaden the knowledge of deep-seated structures and the geodynamics of the complex continental lithosphere and to study the relationships between the main tectonic units of Central Europe.

The aim of this contribution is to determine and analyze densities of rocks in the Carpathian-Pannonian lithosphere. We present a density analysis based on the seismic interpretation along suitable seismic refraction profiles of the CELEBRATION 2000: CEL01, CEL04, CEL05, CEL06, CEL09, CEL11 and CEL12. To these profiles we applied transformation of seismic P-wave velocity v_p to densities ρ by using Sobolev and Babeyko's (1994) and Christensen and Moony's (1995) formulas for crustal rocks, and Lachenbruch and Morgen's (1990) formulas for the lower lithospheric rocks. This contribution presents the determined densities in different depth, which depend on the pressure and temperature conditions in the crust and lower lithosphere. These results are shown for seismic refraction profiles CEL01, CEL04, CEL05, CEL06, CEL09, CEL11 and CEL12 crossing tectonic units of the Pannonian Basin, Transdanubian Range, Central Western Carpathians, Outer Carpathian Flysch, Carpathian Foredeep, Paleozoic Platform including the Lysogóry and Malopolská Unites, East European Craton with Lublin Trough, and Bohemian Massif. Seeing that some of the seismic refraction profiles cross the same tectonic units, we were able to create graphical display range of depth and densities in the upper and lower crust, and lower lithosphere in individual tectonic units. These results provide significant input data for the density modelling of the Carpathian-Pannonian lithosphere.

Furthermore, we present two-dimensional models CEL01, CEL04 and CEL05 based on integrated geophysical method linking heat flow, gravity, absolute topographic elevation and geoid data.

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Some thoughts about the origin of the Tatra Mountains

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The Tatra mountains form the highest mountain horst of the West Carpathians. The Tatra Mts. are only 53 km long and 15 km wide. On all sides except the SW, they are surrounded by thick sedimentary complexes of inverted Central Carpathian Paleogene basin (CCPB). The Tatra Mts. are part of elevated Central Slovakia and Polish Central Carpathians. The uplifted area is 150 km long and 60 km wide in the triangle area of Považská Bystrica – Brezno – Stará Lubovňa. Thick crust there is isostatically compensated according to an excellent old study by Josef Popelář. The convergence of both plates is still going on. Steady state uplift and erosion have been compensated by arrival of the material from the area of Adriatic collision in the SW and its collisional amalgamation above the sharply bent European plate. Geodynamic development of the Tatra Mts. in their recent form started already with cessation of the sedimentation of the CCPB some 17 Ma ago. The first 6 Ma until early Pannonian (11 Ma) were coeval with oceanic subduction in the Ukrainian and Romanian Carpathians and were dominated by some erosion of the collisional area and possibly also by some orogen parallel extension. Strong collision, uplift and erosion of the whole area within the mentioned above triangle started in the early Pannonian 11,2 Ma ago. Differential uplift of the Tatra Mts. against the CCPB has started also at that time. The formation of the Tatra megafold was accompanied by syngenetic formation of the Orava basin syncline. Before Quaternary, all area of crustal thickening was a high plateau with relatively steady state quite significant erosion. The Orava basin was pronounced by pre-Quaternary sediments of pelitic nature. Uplift rate in the very center of the thickening area was measured precisely by AFT method in deep borehole Bukowina Tatrzańska PIG-1 by Aneta Anckiewicz and others. Their result was a 400 m/Ma erosion rate between 10 Ma to 6 Ma. Similar erosion rate was estimated by S. Králiková and others in the High Tatras but corresponding ages have about 1500 m height difference. About 4 km of material was removed during the last 11 Ma from the Podhale basin and the High Tatras. The Late Pliocene and Quaternary cold climate and mainly last 900 ky of seven severe ice ages shaped Tatras to recent face that is very different from previous post-Sarmatian to late Pliocene times. Extreme erosional exhumation due to the cold climate and glaciations gave rise to 2 km high rugged mountains and different, gravels dominated sedimentation. Already partially exhumed Tatra Mts. were completely stripped of CCP sediments and, beacause of cold climate, very rugged mountaineous relief has been formed.

Previous studies of the origin of the Tatras were based on the assumption of the Subtatra fault as a steep thrust fault (see papers by Dimitrij Andrusov and others). This thrust fault, however, does not exist as we see from two seismic lines crossing the fault. The line 513/87 + 1T crossed the fault in Jamnícka dolina locality. It revealed that the Liptov basin filled by sediments of the CCP is a syncline and that the Paleogene sediments did not dip under the Tatras, just vice versa. The line 753/93 reached the Subtatra fault near to Tatranská Kotlina village. All reflections are dipping ESE, therefore from the fault and not beneath it. Moreover, the line 513/87 passes deeply beneath the West Tatra in Jamnícka dolina and shows clear image of doming reflections in the upper 3 s of TWT. The Tatras have developed a real dome and the whole structure today is a post Sarmatian brachyanticline with broken flexure in the S.

Geodesy, Gravimetry and Geodynamics

Extensometric observation of Earth tides and local tectonic processes at the Vyhne station, Slovakia

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The Vyhne Tidal Station of the Earth Science Institute of the Slovak Academy of Sciences is located in the former mining gallery of St. Anthony of Padua in the Vyhne valley, Štiavnické vrchy Mts., Central Slovakia. It is equipped with a 20.5 metre long quartz-tube extensometer measuring Earth's tides, and long-term tectonic deformations of the Earth's crust. Data between 2001 and 2015 with some diverse gaps were digitally collected processed and analysed. The effect of the local conditions, such as structure of the observatory, cavity effect, topography and geologic features of the surrounding rocks, was investigated in detail and these effects were taken into consideration during the interpretation of the results of the data analysis. Tidal analysis of the extensometric data between 2005 and 2015 revealed that the measured tidal amplitudes are close to the theoretical values. The tidal transfer of the observatory was also investigated by coherence analysis between the theoretical and the measured extensometric data. The coherence is better than 0.9 both in the diurnal and semidiurnal band. The effect of the free core nutation resonance was also investigated in the case of the K1 and P1 tidal components. Since the K1/O1 ratio was about the theoretical value 0.8, than the P1/O1 was between 1.0 and 1.15 instead the theoretical value of 0.9. The rate of the long-term strain rate was also investigated and the obtained –0.05 μstr/y shows a good agreement with the strain rate inferred from GPS measurements in the Central European GPS Reference Network.

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Creation of the new reference frame of the Baltic vertical system after adjustment

Tvorba novej realizácie výškového referenčného systému Bpv

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Národný výškový systém Baltský po vyrovnaní a jeho realizácia z vyrovnania z roku 1957 reprezentuje výškové základy v súčasnosti stále záväzné na území Slovenskej republiky. Pôvod tejto realizácie siaha ešte do doby povojnového Československa, kedy bolo vykonané prvé súborné vyrovnanie vtedajších štátov socialistického bloku. Na základe jeho výsledkov bola do roku 1962 prevedená celá Československá jednotná nivelačná sieť (ČSJNS) do Baltského výškového systému po vyrovnaní a v ňom je udržiavaná dodnes. Dlhoročné integrovanie novo vykonaných nivelačných meraní, ktoré je spojené s početnými ťahovými prevyrovnaniami jednotlivých úsekov, zapríčiňuje nehomogenitu siete ako celku, ktoré je možné vyriešiť iba úplne novým vyrovnaním celej siete. V minulosti bolo uskutočnených viacero pokusov o vykonanie nového vyrovnania, ale jeho nasadenie vždy narazilo na úskalia tej ktorej doby. V súčasnosti, v zmysle koncepčných zámerov rezortu ÚGKK SR na roky 2016-2020, prebiehajú práce na vytvorení novej realizácie Bpv, ktorá by mala nahradiť súčasnú, z roku 1957. Tvorba novej realizácie má niekoľko etáp, ktoré sú v krátkosti popísané v príspevku. Okrem popisu nivelačných meraní je príspevok venovaný aj spôsobu určovania a získavania hodnôt tiažového zrýchlenia na bodoch Štátnej nivelačnej siete (nástupcu ČSJNS na území SR), ktoré je nevyhnutné pri výpočtoch fyzikálnych výšok. Príspevok je podrobnejšie zameraný aj na analýzu vplyvu neistoty polohy bodov ŠNS na získavanie hodnôt tiažového zrýchlenia. V závere je zhodnotený stav plnenia jednotlivých etáp k dnešnému dňu aj s náčrtom plánov na najbližšie obdobie.

Ground Stability Monitoring of the Sub-Tatra Basin by Means of Sentinel-1 Multi-Temporal InSAR

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Multi-temporal synthetic aperture radar (SAR) interferometry techniques (MT-InSAR) are nowadays a well-developed remote sensing tool for ground stability monitoring. Employing the long time series of SAR images, they identify radar targets, which do not change their backscattering characteristic over time (referred to as persistent scatterers). For such points, temporal evolution of deformation can be retrieved, thus forming a natural, opportunistic geodetic network to monitor seismic and tectonic activity, landslides, cities, or even individual structures. MT-InSAR is comparable to conventional geodetic monitoring techniques in terms of accuracy, yet maintains vast spatial coverage at low-cost merit. This application capability has recently been emphasized by the Sentinel-1 satellite mission, providing freely available SAR images of the entire Earth's landmass within a 6-day repeat cycle.

We perform MT-InSAR ground stability analysis over the wider, geologically notable region of Poprad basin and eastern part of High Tatra Mts., utilizing 127 Sentinel-1 images, which cover the time period since the end of 2014 until the beginning of 2017. We incorporate processing chain based solely on open-source tools, addressing the technology's feasibility at this sparsely urbanized and mountainous study area, affected by severe atmospheric perturbations. This is the first such initiative in Slovakia to study the geodynamics via MT-InSAR at large spatial scale.

Our study's results are deformation maps providing a global outlook on the relative movements in the area of interest. Several millimetre level ground motion processes have been revealed: the long spatial wavelength uplift of Štrbský horst, accompanied by the slight eastward tilting of Svit municipality – a possible indicators of recent tectonic activity, as well as small-area urban subsidence or slope failures at the High Tatras. Deformation time series, corresponding accuracy, interpretation and GNSS cross-validation are all subject to discussion. We enclose our study with remarks concerning the further Sentinel-1 MT-InSAR applicability within the Slovakia territory, especially regarding the free and guaranteed Sentinel-1 data.

High-resolution modelling of the static gravity field from the GOCE gravity gradients in spatial domain

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Meshless boundary collocation techniques like the method of fundamental solutions (MFS) or singular boundary method (SBM) can be efficiently used to model the static gravity field purely from the GOCE gravity gradients. On the contrary to classical approaches based on spherical harmonics (SH), these numerical methods allow to solve the problem in spatial domain while using the fundamental solution of the Laplace equation as basis functions. Hence, the system matrix is created by the second radial derivatives of the fundamental solution that depend solely on geometrical parameters, i.e. on 3D positions and direct distances between the GOCE observations and source points located on the Earth's surface. Such a configuration is free of singularities and MFS can be applied to derive unknown coefficients in the source points. From these coefficients the disturbing potential and gravity disturbances can be evaluated in any point above the Earth's surface. To obtain their values directly on the Earth's surface, e.g. at the source points, SBM can be applied. The key idea of SBM is to isolate singularities of the fundamental solution and its derivatives using some appropriate regularization techniques.

The numerical experiments present results of processing several datasets of the GOCE measurements, namely 8 datasets for different semi-annual periods and 1 dataset for 2-years period. To obtain "cm-level" precision, the source points are regularly distributed over the Earth's surface with the high-resolution of 0.05 deg (12,960,002 points). For every dataset the disturbing gravity gradients as input data are filtered using the nonlinear diffusion filtering. Large-scale parallel computations are performed on the cluster with 1.2 TB of the distributed memory. Numerical solutions obtained for different datasets/periods yield the static gravity field models that are compared with the SH-based satellite-only geopotential models like GO_CONS_GCF_2_DIR_R5. Finally, the geopotential evaluated on the DTU15 mean sea surface model is used to derive velocities of the ocean geostrophic surface currents.

History and the current status of the gravimetric baselines on the territory of Slovakia

História a súčasný stav gravimetrických základníc vybudovaných na území Slovenska

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V gravimetrii a v odvetviach kde sú využívané relatívne gravimetre je z pohľadu metrológie potrebné a požadované pravidelne vykonávať kontrolu a overenie správnosti týchto prístrojov. Na kontrolu, preskúšanie správnej funkčnosti, ale napríklad aj určenie kalibračnej konštanty relatívnych gravimetrov slúžia gravimetrické základnice. Gravimetrické základnice pozostávajú z bezproblémovo dostupných stabilizovaných bodov, ktoré majú mať dostatočne presne určené hodnoty tiažového zrýchlenia, a ktoré majú mať medzi jednotlivými bodmi dostatočne veľký a presne určený tiažový rozdiel. Na voľbu a orientáciu bodov základníc, s cieľom získania dostatočného tiažového rozdielu, sa využívajú fyzikálne zákonitosti, t.j. body základníc sa volia buď v oblastiach s veľkým prevýšením, alebo sa body volia približne v smere poludníkov. Podľa toho, ktorý s týchto faktorov prevláda sa základnice označujú za výškové (vertikálne) alebo šírkové. Prvé gravimetrické základnice sa začali zriaďovať na územiach štátov, ktoré začali budovať gravimetrické siete relatívnymi gravimetrami. Na našom území to bolo od konca päťdesiatych rokov, kedy sa začala budovať celoštátna československá gravimetrická sieť I. a II. rádu. Gravimetrické základnice slúžili na pravidelné kontroly a nastavenia konštánt relatívnych gravimetrov využívaných pri meraní siete, čím vlastne udržiavali aj jej mierku. Neskôr, s rozvojom využívania absolútnych gravimetrov, začala byť mierka gravimetrických sietí udržiavaná pomocou tzv. absolútnych bodov, t.j. bodov, ktorých tiažové zrýchlenie bolo určené absolútnym gravimetrom a gravimetrické základnice už slúžili iba na kontrolu a kalibráciu relatívnych prístrojov. Aby nebolo potrebné parametre resp. rozmer gravimetrických základníc určovať vyrovnaním vykonaných meraní relatívnymi gravimetrami, alebo ich dokonca odvodzovať od použitých prístrojov, prípadne ich určovať prenášaním rozmeru inej základnice, je najvhodnejšie určiť všetky jej body priamym meraním absolútnymi gravimetrami. Touto filozofiou sa vybral aj Geodetický a kartografický ústav Bratislava, výsledkom čoho sú jeho v posledných rokoch vykonávané aktivity pri budovaní novej vertikálnej gravimetrickej základnice v lokalite Vysokých Tatier medzi Gánovcami a Lomnickým štítom pozostávajúce z merania všetkých jej bodov absolútnymi gravimetrami. Základnica bude zaradená medzi ďalšie základnice plánovaného rezortného metrologického pracoviska budovaného v rámci rezortu ÚGKK SR a bude k dispozícii širokému okruhu záujemcov využívajúcich relatívne gravimetrické prístroje.

Príspevok popisuje históriu gravimetrických základníc vybudovaných a používaných na území Slovenska od päťdesiatych rokov 20. storočia po súčasnosť a detailnejšie sa venuje práve prebiehajúcim aktivitám, ale aj plánom do budúcna.

Nonlinear diffusion filtering methods locally adapted to geodetic data features

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The contribution deals with a nonlinear diffusion filtering methods on a planar surface. These methods represent an extension of the simple linear diffusion filtering by the nonlinear diffusivity coefficient. This coefficient represents a function which depends on data features such as gradient and local or global extrema of data. If we use the nonlinear diffusion filtering influenced by the Laplace operator, local extrema detector function affects the diffusion process. We use a finite-volume method to approximate numerically the nonlinear parabolic partial differential equation on uniform rectangle grid and finite difference method to approximate gradients and Laplacians. Numerical experiments present nonlinear diffusion filtering of real measurements in filtering software with real-time filtered data visualization widget. Real measurements represent GOCE satellite observations and high-resolution altimetry-derived gravity data.

Terrain corrections: example of comparison between scientific and commercial software

Terénne korekcie: príklad porovnania vedeckého a komerčného softvéru

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Terénne korekcie tvoria významnú zložku pri výpočte úplných Bouguerových anomálií a preto je potrebný čo najpresnejší výpočet gravitačného účinku okolitých hmôt. Z tohto dôvodu boli testované na vybranej lokalite, s členitou ale aj rovinatou topografiou, dva rozličné programy určené na výpočet terénnych korekcií. Porovnávaný bol svetovo rozšírený komerčný softvér Geosoft Oasis Montaj (modul Gravity & Terrain Correction) (Geosoft, 2010) a špeciálne pre terénne korekcie vyvinutý vedecký softvér Toposk (Marušiak a Mikuška, 2012). Pri metodike výpočtu terénnych korekcií bolo zaznamenaných hneď niekoľko podstatných rozdiel a to najmä v použití rôznych aproximačných telies, prechodmi medzi zónami, tvarmi horných podstáv aproximačných telies a závislosti veľkosti zón od veľkosti okna gridu digitálneho modelu reliéfu. Kvantitatívna analýza výsledných terénnych korekcií preukázala významné rozdiely už v základných štatistických parametroch akými sú maximum a minimum, ako aj závislosti hodnoty terénnej korekcie od nadmorskej výšky. Kvalitatívne porovnanie dvoch rozdielnych prístupov výpočtu terénnych korekcií umocnilo výsledky kvantitatívnej analýzy. Pokiaľ v rovinatých oblastiach sa rozdiel pohyboval v rozmedzí ±1 mGal, V oblastiach s členitou topografiou, najmä v okolí vrcholov so strmšími priľahlými svahmi táto odchýlka narástla až na viac ako 8 mGal. Takýto markantný rozdiel môže mať za následok významnú deformáciu tiažového poľa Úplných Bouguerových anomálií a následne aj ich nepresnú resp. mylnú interpretáciu.

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Project of a calibration and densification of the gravity data in the Czech Republic

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The data of gravimetric mapping in the scale 1:200 000 (density one point per 4-5 km^2), originated in 1942-1961, is the only one that covers coherently the whole territory of the Czech Republic. Thus, it represents the unique source of gravity information on the areas uncovered with the later, more accurate, detailed gravity mapping 1:25 000 (five points per 1 km^2).

Presented project of gravity data calibration and densification for geodetic purposes brings a complex approach to the original data. It rests on the collection of all currently available data, added with new, relatively sparse, observations. New gravity measurements within this project are used not only for densification (one point per 2-3 km^2), but also for identification of systematic and gross errors in the original data, which are a product of its time. The data and metadata are stored in the relational database, enabling, for instance, a sophisticated approach to semi-automatic corrections of the data by means of data views and action triggers. Many gross errors (in positions, heights and/or gravity) have been already removed. Regarding the systematic effects, the original data will undergo individual transformations with respect to the source information of its author, i.e. instrument used, observation method, method of heights and position determination, etc.

Approximately 70 % of the area of the interest will be finished till the end of 2017. The project of gravity data calibration and densification, alongside with other data sources, such as the airborne LiDAR model of the relief (DMR4 and DMR5 data), will significantly contribute to the solution of the current regional detailed quasigeoid model (QGZÚ-2013).

The study of recent vertical movements using very precise levelling measurements – first results in the central part of Slovakia

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Very precise levelling, as the most precise method for the height determination, offers the opportunity to use it for a study of the recent vertical movements.

Reliability of this method lies in the fact that it is founded on precise measurement methodology and strict criteria for the accuracy. Thanks to this, it can be used also in the areas where the vertical movements are very slightly.

The study of the recent vertical movements is based on the comparison of three or more repeated levelling measurements realized in the different times. The condition for achieving a reliable result is compliance of the accuracy criteria for the very precise levelling, the correct selection of the levelling points, the sufficient time interval and so on.

In the Slovak national levelling network we have data from the 2nd Czechoslovak levelling (1949 – 1957), 1st and 2nd repeated levelling (1961 – 1978) and the latest realization of the 1st order levelling lines (1996 – 2002). The goal of this contribution is to analyse the levelling measurements for the study of recent vertical movements in the central part of Slovakia which are a result of the dynamic tectonic processes in the Earth and also the movements induced by the human activity, for example the mining.

Surface rock density interpretation from detailed gravity measurements based on free-air anomalies and near topographic effects in a terrain with sufficient relative relief

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What is behind the existing concepts of estimating quantity called optimum, representative, suitable or average (correction) gravimetric density, or apparent density of the topographic masses? We suggest that the most important feature in this context is the observed proportionality between free-air anomalies and near topographic effects provided that there are sufficient differences in elevations among the measuring points. Our method of surface rock density interpretation has been based on decoding and exploiting the mentioned proportionality, utilizing the simplest linear approximations of the existing relations between both the original quantities in question (i.e. the free-air anomalies and the near topographic effects calculated for unit density) and their local anomalies. Among other challenges there was the one of interpreting surface rock density along detailed gravity profile(s) measured in mountainous areas. One of the necessary conditions is availability of very detailed and very accurate digital elevation model which is essential when calculating the near topographic effects within the innermost zone up to 250 m from each measuring point.

Although our method is original, there can be found at least three techniques in the literature which have been based on similar principles. Namely, density profiling combined with forward modeling (Anfiloff and Flavelle, 1982), so-called forward modeling the free-air anomaly (Hallinan et al., 2002), and acknowledging the elevation dependence of the surface free-air anomalies combined with suppressing the distorting effect of regional trends (Papp, 2009).

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Monitoring of Earth´s surface deformation in the area of Slovakia

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Monitoring of state, trends and thresholds of the water mass variations contains time series and their fast changes, which serves for purpose of service and protective processes. Information about water mass change in some locality is the important factor for regulation of electric power produce and environmental protection of transport. Water mass variation in certain locality influences on the Earth´s surface, on which there are bounded measured parameters as GPS/GNSS position, gravity and hydrological parameters (soil humidity, surface and underground water, etc.). Earth´s surface hydrological information is completed by satellite hydrological information for complexity of integral solution in form of mathematical model, used for solution of deformation parameters. In present, we established the monitoring network for GNSS, absolute gravity and ground water measurements in the area of Slovakia. It contains 9 points equipped with GNSS receivers and with site on gravity measurement. The experimental analysis of measured results confirmed the effective of used measurement methods for water mass variation determination. The numerical results will be presented at the XII Slovak Geophysical Conference.

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Geodetic and Geophysical monitoring of Koš undermined area

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The territory of the Upper Nitra basin belongs to the Slovak regions heavily affected by geohazards – slope failures and territory subsidence due to undermining. As part of an ongoing research project, we are testing the use of multiple geodetic and geophysical methods to monitor undermined areas. As a pilot monitoring site, we chose the area of Koš municipality in the Hornonitrian basin, where brown coal mining is active up to the present.

At this site, we apply a system of various traditional and modern geodetic and geophysical methods to map current as well as older undermined areas and assess the risk of future urban structure damage. In the paper we present the first results of repeated geodetic and geophysical measurements by precise levelling, RTK GNSS and microgravimetry. The results are also supplemented and compared with the modern aerial and satellite remote sensing methods, like LIDAR, UAV photogrammetry and Persistent Scatterer Satellite Radar Interferometry.

Spectral downward continuation of gravitational curvatures and its implications for future gravity field missions

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Four solutions of the spherical gravitational curvature boundary-value problems can be used to determine the Earth's gravitational potential. We are going to discuss the semi-optimal combination of simulated satellite gravitational curvatures, i.e., components of the third order gravitational tensor, by merging these solutions by the spectral combination method. For this purpose, integral estimators of biased- and unbiased-types will be derived. In numerical studies we investigate the performance of developed models in the context of gravitational field modelling in the area of Central Europe based on simulated satellite measurements. Firstly, we check the correctness of integral estimators for spectral downward continuation in closed-loop test. The closed-loop test shows that estimated errors of combined solution are about 8 orders smaller than those obtained from individual solution. Secondly, we perform a numerical experiment considering Gaussian noise with the standard deviation of 2.5×10^{-16} $m^{-1}s^{-2}$ in input data at the satellite altitude of 250 km above the mean Earth sphere. Superior results with respect to global geopotential model TIM-r5 are obtained by spectral downward continuation of vertical-vertical-vertical component with standard deviation of 4.2 m^2s^{-2} but the global root mean square error was the largest 84.015 m^2s^{-2}. Using the spectral combination of all gravitational curvatures this error is 17 times smaller.

Calculation of temperature distribution and rheological properties of the lithosphere along Profile 1 passing through Aswan

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2D integrated geophysical modelling approach has been used to determine the temperature distribution in the lithosphere along the profile passing through the Aswan. Based on the temperature model and the given rheological parameters, we have calculated strength distribution in the lithosphere for the studied profile. The strength envelopes have been calculated for both compressional and extensional regimes. Our results related to the vertically integrated compressional and extensional strength along profile in Aswan show that the strength is constant along the whole length of profile passing through the Nubia plain. Analysis of the yield strength and vertical strength distribution for different lithospheric columns for compressional and extensional deformation, calculated along the Aswan profile, indicates the largest strength can be observed within the upper crust with the maximum (400-500 MPa) on the boundary between the upper and lower crust. That means that in upper crust, rigid deformation is dominant in the whole area. The strength in the lower crust significantly decreases and completely diminishes within the upper mantle. That indicates ductile deformation in this lower part of the lithosphere.

Vertical gradient of gravity on Teide volcano - prediction, verification and significance

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Correct evaluation of the vertical gradient of gravity (VGG) is a subject of interest within the gravimetric networks situated in volcanic areas, especially those affected by vertical deformation (displacement). As we have found, detail calculation of the gravitational effect of the topography based on high-resolution digital elevation models (e.g. derived from LIDAR data) and special developed software Toposk can leads to the reliable prediction of the VGG. Our previous calculations (Vajda et al., 2015) showed a high variability of expected VGG values within the central part of Teide volcano on Tenerife Island. Extreme VGG values (in both senses) are inherent to the extreme terrain features such are peaks, ridges or canyons. Therefore we have focused closely on selected areas of rugged topography to find the places with extreme expected VGGs, which could be subsequently verified by in-situ VGG measurements.

In addition, we focused on existing absolute gravity points as well as the benchmarks of the deformation/microgravity network established on the island. These points are generally not situated in the places with extreme topography. However, several of them showed interesting predicted VGG values and so we also decided to verify those values by in-situ measurements.

During the summer 2016 (thanks to our friends from Instituto Geográfico Nacional, Spain) we realized gravimetric expedition on the Tenerife Island to verify most extreme calculated (predicted) VGG values. We used gravity meter CG-5 in a tower mode, while the spatial coordinates of the measurement points were determined using GNSS method in RTK or post-processing mode. A good agreement between measured and predicted VGG values was achieved at most points (Zahorec et al., 2016). On the other hand, although the mean adopted density of 2200 kg/m^3 for the calculation brings in general successful results, we have shown on two examples that the real density can be even considerably smaller.

We have also discussed two examples when using actual or predicted VGG values vs. so called normal gradient.

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Geomagnetics

News about the Natural Dynamos

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The Geodynamo and Solar Dynamo are important examples of the Natural Dynamos (ND). Dynamo mechanism can explain prevailing majority of Cosmic magnetic fields - various planetary fields, either at existing Dynamos (Mercury, Jupiter, Saturn, Uranus, Neptune, Ganymede,...) or at extinct ones (Mars and Moon, ...). Diversity of the stellar mag. fields in space scales as well as in time scales is yet more profound than of the planetary fields and even the extremally great mag. fields of neutron stars can also correspond to the ND. Galactic mag. fields are unique also in the sense that only their space distribution and time develop-ment can be observed inside the Cosmic objects as details of the ND processes. The revealed magnetism in the asteroid Vesta also indicates that some Cosmic ND can be energetically driven by another way than by generally accepted convection for the majority of the ND.

In the 2nd Conference on Natural Dynamos in Czech Rep, Valtice2017, held in the period 25.6.–1.7. (http://valtice.ig.cas.cz) the newest knowledge on cosmic mag. fields related to the ND was presented. In all contributions, motivation with geophysical or astroph. background was indicated. In the solved models the great variety of physical suppositions with various approximations was used. In math. approaches dominate numerical simulations using the rich spectrum of num. methods – frequently related to spherical geometry. In the simpler geometries (the plane layer, ...) the problems with more complex physics could be presented more transparently, and the related solutions often were in good correspondence in simulations in the spherical geometry, what is very useful in particular in the cases with surprising results or with contraintuitive physical interpretations. Due to asymptotic methods analytic preparation of the num. approaches was often accomplished by the results, indicating that some simulations approached asymp. limits and can approximate promisingly the reality, despite the fact that num. constraints often force to make computations with parameters which are very far from the real values, what is typical e.g. at Geodynamo problems. The correspon-dence paradoxes can be partly explained by experiments which related to the hydromagnetic dynamos were presented as well as the ones related to hydromagnetic instabilities in cosmic connections. The experiments were often realized in the simpler geometries (cylinders ...). Therefore, their theoretical preparation with applications of various math. methods was very effective.

The conference was organized by Geoph. Institute of the CAS in Prague with help of Slovak Institutions, the FMPHI at Comenius University and the Earth Science Institute of the SAS.

Dynamics of convection and solidification in ternary systems

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The modelling and analysis of convection and solidification of multicomponent mixtures play an important role in many natural and industrial systems, including the Earth's inner core. The solidification processes are often associated with the formation of so-called mushy layers, which are regions of an evolving dendritic solid matrix surrounded by the melt phase. The mushy layer that forms during the growth of Earth's inner core plays a key role in the prediction of the solutal flux into the outer core, an important aspect of accurate numerical dynamo models. We review the theoretical models for the solidification and convection in the ternary alloy mushy layers. Scenarios for convective instabilities that may occur in the presence of solutal diffusion are explored.

Dynamo or Gyroscope?

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The process of cosmic magnetic fields generation is presently understood as happening by self-inductive action in liquid, electrically conducting and rotating bodies. This study proposes a different mechanism of magnetic fields' creation. It is based on collective behaviour of conducting electrons in a rotating body. The collective motion relies on weak magnetic properties of the concerned material and on the effect of magnetization by rotation known as Barnett's effect. This behaviour is liken to the gyroscopic motion, to which an angular momentum and therefore also magnetic moment, is attributed. The problem is governed by the equation of motion for the classical electron gas and by the conservation of angular momentum law. The presented conception allows to explain some observed changes in astrophysical magnetic dipole moments.

Geomagnetic activity affected by solar events and solar energetic particle fluxes

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The purpose of this study is to asses the contribution of specific solar energetic events to geomagnetic activity during the period 1996 – 2013, covering the 23rd solar cycle, the solar minimum between the 23rd and 24th solar cycles as well as the ascending part of the current 24th solar cycle. The question is what kind of information is needed to set up an accurate space weather prediction model, relying on available data from solar observations, the satellite data as well as the ground magnetic disturbances records. Short-term forecasts of space weather effects on the Earth in this study use the knowledge of solar activity accompanied with the solar energetic particle (SEP) fluxes. We have shown that adding the input information concerning SEP fluxes to the solar data has the potential to improve forecasts.

Can number of transients/Q-bursts in ELF-band be a suitable criterion for the global thunderstorm activity estimation?

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Schumann resonances (SR) are electromagnetic oscillations in the extremely low frequency (ELF) band (3 Hz–3 kHz) excited in the Earth-ionosphere cavity by the lightning in planetary range. Distinct SR-resonant modes are in the range up to 50 Hz. The response of the lightning strokes activity can be recorded by a capacitive ball antenna measuring of the vertical electric component. The electromagnetic signal radiated by strokes is weakly damped in the ELF-band what gives the possibility to evaluate global lightning activity unlike the VLF/LF-radar and optical satellite measurements giving the local data in time and space. The time records in the ELF-band consist of background signals and ELF transients/Q-bursts superimposed on the background exceeding it by a factor of 5–10. The former are produced by the common worldwide thunderstorm activity (100–120 events per second), the latter origin from individual intense distant lightning discharges (100–120 powerful strokes per hour). A Q-burst is produced by a combination of direct, antipodal and secondary pulses and the decisive factor for its shape follows from the source-to-observer distance. Despite the fact that high frequency measurement (sampling frequency of order kHz) is more useful for the precise determination of the shape of pulses, low frequency measurement with sampling frequency 200 Hz applied in our case is likewise sufficient to identify the transients.

Diurnal/seasonal variations of global thunderstorm activity can be deduced from spectral amplitudes of SR modes. Here we focus on diurnal/seasonal variations of the number of ELF-transients assuming that it is another way of lightning activity estimation. To search for transients, our own code was applied to the SR vertical electric component measured in October 2004 – December 2008 at the Astronomical and Geophysical Observatory of FMPI CU in Modra-Piesok, Slovakia. The width of the primary spike, time difference between primary and the antipodal spike and the amplitude of the primary spike were chosen as criteria for the identification of the burst. Cumulative spectral amplitude of the first three SR modes compared with number of ELF-transients in terms of monthly averaged diurnal variations quite successfully confirmed, that the number of transients can be a suitable criterion for the quantification of global lightning activity.

Thunderstorm activity is mainly concentrated in the equatorial tropical landscape regions during afternoon hours of local time. African source dominates at 14–16h UT and it is more active in comparison with Asian source which dominates at 5–8h UT. America's source would be most active at 20–21h UT but its response is quite slight. Very high resolution lightning climatology derived from 16 years of satellite observations indicates that the great/greatest activity in South America's hotspots occurs during nocturnal hours of local time (at 0–2h LT), i.e. at 5–7h UT. Therefore strong South America's activity could coincide in time with Asian afternoon source activity at 5–8h UT.

Measurements of the total field at the Hurbanovo Geomagnetic Observatory

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The first measurements of the total field (F) at the Geomagnetic Observatory Hurbanovo (HRB) were provided in year 1973, when the observatory obtained 2 proton magnetometers for the absolute measurements:

1. ELSEC 592/480 (from GB)
2. PZHTM (from RSSR)

Before that the total field values were calculated only from scalar values H, D and Z or D, H and I of the geomagnetic field, which were registered in the observatory.

Other proton magnetometers were purchased in: 1986 - ELSEC 820 M2

1994 - EDA

2006 - PMG.

With these magnetometers we controlled the basic values of the variation devices. Since 2016 the magnetometer PMG has been continuously registering a total field. In this work we analyzed the accuracy of this instrument from the comparative measurements what we carried out at Dourbes Observatory (2016) and at Tihany Observatory (2017) and also we compared the differences on the Observatory Hurbanovo between the ELSEC 820 M2 and EDA proton magnetometers, as well as the final field values calculated from the component X, Y and Z.

The results show, that the registered field values with magnetometer PMG in the quiet days (K-index up to 4+) are usable as an observatorial standard for component F, but for the disturbed days this values are not sufficiently reliable.

Acknowledgments

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The magnetic superstorm on 17 November 1848 as a possible 'Carrington-like' event

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Recently, the space weather researchers have raised their interest in extreme geomagnetic storms. One of the practical reasons for the increased attention to these phenomena is vulnerability of some modern technological systems to rapid changes in the geomagnetic field. Examples of the consequences of such phenomena are outages of electric power grids with major economic damages. In our contribution we first deal with the strongest of the up to now observed geomagnetic storms, the so-called Carrington storm, that occurred on September 2, 1859 [1]. Some of the features of this exceptional phenomenon are not perfectly in line with present-day concept for the mechanism of the ordinary geomagnetic storms [2, 3]. Our paper then contribute to the debate about whether the Carrington storm was really as unique event as the scientists have hitherto thought. The superstorm which occurred on November 17, 1848, is presented here as a likely example of another 'Carrington-like' storm of the 19th century.

Acknowledgements

This research was supported in part by the Slovak Research and Development Agency under the contract no. APVV-0662-12 and by the grant of the Ministry of Education, Youth and Sport of the Czech Republic no. LM2015079.

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Geophysical 3D joint inversion applied on sedimentary basin with geothermal potential

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The Permo-Triassic Lough Neagh Basin, situated in the southeastern part of Northern Ireland, exhibits elevated geothermal gradient in the exploratory drilled boreholes and indicates good geothermal exploitation potential in the Sherwood Sandstone aquifer. We have used a 3-D joint inversion framework for modelling the magnetotelluric (MT) and gravity data collected to the north of the Lough Neagh to derive robust subsurface geological models in the frame of the IRETHERM project. Comprehensive supporting geophysical and geological data (e.g. borehole logs, reflection seismic images, and Tellus Project airborne EM data to constrain MT data and the uppermost part of MT models) have been used in order to analyse and model the MT and gravity data.

The 3-D joint inversion modelling reveals that the Sherwood Sandstone Group and the Permian Sandstone Formation are imaged as a conductive zone at the depth range of 500 m to 2000 m with laterally varying thickness, depth, and conductance. The conductive target sediments become shallower and thinner to the north and they are laterally continuous. The layer is thickening and deepening in south-east direction. The conductivities vary from 0.1 to 6 S/m, which indicates high concentration of fluids.

To obtain better characterization of thermal transport properties of the investigated area we used porosity and resistivity data from the boreholes Annaghmore, Ballynamullan, and Ballymacilroy to estimate relation between the porosity/permeability and electrical conductivity. We are presenting porosity studies and results for Upper Sherwood Sandstones lithology for Annaghmore and Ballymacilroy Borehole. The 3D resistivity model exhibits very good correlations with borehole log information. The formulas are based on generalized Archie's law for multiple phases. The program randomly calculates the parameters of the Generalized Archie's law between ranges defined at the inputs of the program (Campanya et al., 2014). We do not have direct estimations of interstitial fluids in the boreholes, that’s the reason why we allow to fit freely this parameter. This results in high conductivity estimations of fluids with expected cementation factor between 1.8 and 2 for sandstones lithology. If we force the lower fluids conductivity in modelling it results in lower cementation factor estimations.

Seismology

Temperature dependence of inconsistency of the complex viscoelastic shear modulus of basaltic lavas witnessed by their relaxation time spectra

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The viscoelastic storage shear modulus $G'(\omega)$ is consistent with the viscoelastic loss shear modulus $G''(\omega)$ when they satisfy the Kramers-Kronig relationships. Or, alternatively, when they yield the same relaxation time spectrum. In experimental practice, consistency is rarely encountered. The relaxation time spectra can serve as suitable indicators of the inconsistency and provide interesting insights into its variations with temperature. We demonstrate it on the viscoelastic datasets of basaltic lavas (James et al., 2004).

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Earthquakes in Slovakia in the period 2015-2016

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One of the main tasks of the Geophysical division of the Earth Science Institute of the Slovak Academy of Sciences is monitoring and analysing of seismic activity on the territory of Slovakia. The Department of Seismology operates the National Network of Seismic Stations that consists of 13 seismic stations. The seismic stations are deployed with the intention to determine seismic source zones on the Slovak territory more precisely and to allow to record and localize any earthquake on the territory of Slovakia and adjacent region with possible macroseismic effects. Data from seismic stations are transmitted to the data center in Bratislava in real-time and processed in two steps – an automatic processing with real-time first localizations, and a detailed manual interpretation on daily basis.

The Department of Astronomy, Physics of the Earth and Meteorology of the Faculty of Mathematics, Physics and Informatics, Comenius University operates the Local Seismic Network of Eastern Slovakia. The local network consists of 6 seismic stations with real-time data transmission to the data center in Bratislava. The seismic stations are deployed with intention to better monitor and understand the seismic regime of this region. There is a close cooperation between both research institutions.

The Department of Seismology of the Slovak Academy of Sciences also cooperates with the Progseis company that operates the local networks of seismic stations deployed around nuclear power plants Mochovce and Jaslovské Bohunice. These data are particularly usefull for studying the Malé Karpaty source zone.

For more detailed monitoring of this source zone three additional seismic stations were established. These stations have been built and are operated in cooperation between former Geophysical institute of Slovak Academy of Sciences, the Progseis company and the Institute of Rock Structure and Mechanics of the Academy of Sciences of the Czech Republic, Prague.

Using seismic data mainly from the National Network of Seismic Stations and the Local Seismic Network of Eastern Slovakia about 156 earthquakes with epicenter on the territory of Slovakia were seismometrically localized in the period 2015-2016. During this period, 11 earthquakes with macroseismic effects were observed on the terrirory of Slovakia - 6 of them with epicenter in Slovakia (2 earthquakes in the Vihorlatské vrchy region, 1 earthquake in the Horehronie near Predajná, 1 earthquake in the Rajecká dolina, 1 earthquake in the Veporské vrchy and 1 earthquake in the Malé Karpaty source zone). Except these earthquakes, 5 earthquakes with epicenter in neighbouring countries were macroseismically observed on the territory of Slovakia too - Hungary (4 earthquakes) and Austria (1 earthquake). During the given period, the highest reported macroseismic intensity was 5-6° EMS 98 for the earthquake with epicenter in the Horehronie near Predajná (3.11.2015). For this earthquake some damage to buildings was reported too and the earthquake was observed in 77 localities on the territory of Slovakia.

Tectonic stress regime in the 2003-2004 and 2012-2015 earthquake swarms in the Ubaye Valley, French Alps

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We study two earthquake swarms that occurred in the Ubaye Valley, French Alps within the last decade: the 2003-2004 earthquake swarm with the strongest shock of magnitude ML=2.7, and the 2012-2015 earthquake swarm with the strongest shock of magnitude ML=4.3. The 2003-2004 seismic activity clustered along a 9 km long rupture zone at depth between 3 and 8 km. The 2012-2015 activity occurred a few kilometers to the northwest from the previous one. We applied the iterative joint inversion for stress and fault orientations to 74 events of the swarm 2003-2004 and to 13 strongest events of the swarm 2012-2015. The stress regime is consistent for both seismic activities. The σ3 axis is nearly horizontal with azimuth of 103°. The σ1 and σ2 principal axes are inclined and their stress magnitudes are similar. The major active fault is well oriented for shearing with respect to tectonic stress and significantly differs from faults geologically mapped in the region. The estimated low value of coefficient of static friction 0.2-0.3 supports an idea of seismic activity triggered or strongly affected by presence of fluids.

Numerical testing of a new discrete representation of a poroelastic interface – the first results

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Development of numerical modelling of seismic wave propagation and earthquake ground motion based on the finite-difference method by Bratislava team has been for years focused on complex heterogeneous viscoelastic medium (see the book by Moczo et al. 2014 and the most recent article by Kristek et al. 2017). Very recently the team has extended its modelling to viscoelastoplastic and poroelastic media. The viscoelastoplastic and poroelastic rheologies pose specific non-trivial challenges if realistic models are to be properly accounted for.

One of the most important aspects of numerical modelling in realistically complex models is a discrete representation of smooth and discontinuous heterogeneities. Specifically, in order to have the finite-difference modelling sufficiently accurate and computationally efficient, it is necessary to properly represent an arbitrary and arbitrarily located material interface in a uniform spatial grid. The Bratislava team has developed original efficient and accurate representations for elastic and viscoelastic media.

Recently we are developing a new discrete representation for an interface between two poroelastic media. In this contribution we present preliminary results of numerical testing of the potential new discrete representation of an interface between two poroelastic media.

For testing accuracy of the finite-difference modelling it is necessary to have a sufficiently accurate independent solution. Diaz & Ezziani (2008) developed an exact 2D solution for two homogeneous halfspaces with a planar contact for a wavefield generated by a linear explosive source perpendicular to the plane of propagation. We use the code by Diaz & Ezziani for testing our representation.

Here we demonstrate accuracy of our modelling in two canonical configurations. One comprises 5 different positions of planar interface within one grid spacing. Though parallel with the grid line, these positions is impossible to account for without properly evaluated effective grid material parameters. The other configuration has a planar interface in an oblique position in the uniform grid.

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Analysis of 3D simulated seismic wavefields in the media modified by the underground nuclear explosion – the first results

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The international agreement Comprehensive Nuclear-Test-Ban Treaty (CTBT) bans nuclear explosions worldwide. The CTBT has a unique and comprehensive verification regime to make sure that no nuclear explosion goes undetected. One of the important pillars of this regime are On-site inspections (OSI). Following indications of a nuclear explosion obtained on the basis of the international monitoring network, further evidence needs to be sought at the location of the suspicious event in order to confirm violation of the CTBT. Therefore the Treaty lists several techniques that can be carried out by the inspection team during OSI at a possible nuclear test site, from the seismic ones, e.g., aftershock monitoring, active seismic surveys and a group of methods labelled as "resonance seismometry". All these techniques are focused on the detection of changes in the media and environment due to the underground nuclear explosion (UNE). The detection is complicated due to several factors, including the large size of the area to be searched and relatively large depth together with small dimensions of the region with UNE-induced changes.

Within our contract with CTBT Organisation we investigate possibilities of resonance seismometry using 3D modelling of seismic wave fields in realistic models of the media after an UNE. We have developed a set of structural models for the vertical emplacement considering a) two yields of the UNE (1 kt and 10 kt), b) four different material parameters of the pre-shot geological environment (tuff, alluvium, granite, rock salt), c) two extreme cases of the depth of burial (minimal and 2-times minimal). We estimated geometrical and material parameters of the models based on extensive review of the available literature. We estimated geometrical parameters with uncertainties quantified by standard deviations. This makes it possible to consider a variety of models. The models include cavity, chimney with apical void, rubble zone, crushed zone, fractured zone and free surface.

For the developed set of the models we have performed an extensive numerical study of seismic wavefields due to plane-wave excitation using forward 3D finite-difference simulations.

We present the preliminary results of the analysis of 3-component seismic waveforms simulated at the large set of receivers. We analysed the simulated waveforms in the time, frequency and time-frequency domains with the aim of identifying those characteristics of seismic ground motion that could be related to resonance phenomena caused by cavity, chimney and surrounding underground structure changed after UNE.

Adjoint-tomography of Local Surface Sedimentary Structures

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The local surface sedimentary basins and valleys are often responsible for anomalous earthquake ground motions and corresponding damage in earthquakes. In many cases only relatively small number of records of a few local earthquakes is available for a site of interest. Consequently, prediction of earthquake ground motion at the site has to include numerical modelling for a realistic model of the local structure.

In recent international exercises on numerical prediction of earthquake ground motion (EGM) in local surface sedimentary structures teams with the most advanced numerical-modelling methods reached very good level of agreement among different methods. The synthetics, however, were not sufficiently close to earthquake records. It was concluded that the structural model must be improved.

Here we apply adjoint tomography to 2D local surface sedimentary structures aiming to find a model for which EGM characteristics will be sufficiently close to those determined from records. This is an important difference compared to traditional structural inversions. The methodology developed in the exploration/regional/global scales cannot be directly applied due to relatively small amount of data, relatively large initial waveform misfit, and low frequencies with respect to the size of the structure. We have elaborated an inversion procedure specific for the local structures.

We present a verification blind test that is closer to real-data inversion than the standard synthetic inversions. A third party provided a) seismograms numerically simulated for an undisclosed true structure, b) source parameters and c) a homogeneous halfspace as the initial model. We demonstrate quality of the inverted model up to the target frequency 4.5 Hz using seismograms, waveform misfits, waveform goodness-of-fit, and mainly goodness-of-fit for important EGM characteristic.

Re-evaluation of macroseismic intensities for 1941 Strážske, 1967 Dobrá Voda and 1988 Trenčianske Teplice earthquakes

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The Slovak macroseismic earthquake catalogue (SLOVMEC, version 2015) is a catalogue of earthquakes with macroseismic effects observed on territory of Slovakia. The catalogue includes 760 earthquakes for the period 1034 - 2014. For each earthquake in the catalogue, a set of Macroseismic Data Points (MDPs) is available.

The territory of Slovakia is characterized as a region with low-to-moderate seismic activity. The second half of the 20th century was a relatively quiet seismic period with several earthquakes up to magnitude 5 and epicentral macroseismic intensity up to 7. Because of the existence of the nuclear power plant (NPP) sites Jaslovské Bohunice and Mochovce, an earthquake catalogue needs to be regularly checked and updated by all available instrumental and macroseismic data.

The macroseismic archive for the territory of Slovakia is administered by the Earth Science Institute of the Slovak Academy of Sciences (ESI SAS) and includes collection of macroseismic questionnaires, official reports and hand-written letters for the period 1941 - 2016. From the 1940s up to the 1970s the macroseismic effects were originally evaluated in the MCS scale, in the 1980s in the MSK scale for the purpose of Procházkova & Kárník isoseismal maps these intensities were converted to MSK scale. However, the methodology used for the conversion between MSK scale and MCS scale is not clear. Therefore we decided to re-evaluate the macroseismic questionnaires, official reports and letters in the EMS-98 scale. We present the preliminary results for three case studies: 1941, June 5th Strážske earthquake (I_0 = 7, 5 MDPs), 1967, December 3rd Dobrá Voda earthquake (I_0 = 6-7, 38 MDPs) and 1988, April 28th Trenčianske Teplice earthquake (I_0 = 6, 67 MDPs).

The effect of small-scale random heterogeneities in local sedimentary structures on earthquake ground motion

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Within the international project SIGMA – SeIsmic Ground Motion Assessment – organized jointly by EDF, AREVA, CEA and ENEL in 2011-2015, we performed an extensive numerical study of site effects for a set of 6 real local sedimentary structures. The goal of our study was to investigate the potential of typical 2D and 3D structures to produce significant amplification effects by a) identifying the key structural parameters responsible for these effects, b) identifying key characteristics of earthquake ground motion, and c) quantifying impact of the key parameters on the key characteristics. The selected sites include the shallow sediment-filled Mygdonian basin in Greece, the typical deep Alpine valley beneath Grenoble in France, and 4 other typical sediment-filled valleys – two small, one mid-sized and one relatively large. In addition to these 6 "nominal models" with a given geometry and a given set of mechanical parameters (velocities, density, attenuation) we also defined modifications of the nominal models in order to investigate sensitivity of the ground motion characteristics to impedance contrast, attenuation, velocity gradient and geometry. For all models we first performed direct ground motion simulations using the finite-difference method. Then we calculated amplification factors, and 2D/1D and 3D/2D aggravation factors for 10 earthquake-engineering ground-motion characteristics. We accounted for an input motion variability by considering a set of selected representative recorded accelerograms.

Recently we have supplemented the sensitivity investigation by including small-scale random heterogeneities in sediments. We considered random media with 3 different autocorrelation functions – Gaussian, exponential and von-Kármán. These media differ in the spectral fall-off of their velocity fluctuations. We considered 3 different standard deviations (5%, 10% and 20%) and fixed values of correlation lengths with a vertical-to-horizontal ratio 1:10. One numerical simulation of seismic wave propagation in random medium means only one possible realization of a random process. Therefore we performed several realizations for each of the 9 combinations of the autocorrelation function and standard deviation for the selected nominal models.

Based on the statistical analysis of the calculated earthquake ground motion characteristics for thousands of receivers, we quantified the impact of inclusion of random heterogeneities on amplification and aggravation factors.

The homogenized macroseismic catalogue for the Slovak national seismic hazard map in terms of macroseismic intensity

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The territory of Slovakia is a region with low-to-moderate seismic activity. The probabilistic seismic hazard maps for the Slovak territory need to be regularly revised and updated due to the critical national infrastructure (e. g. nuclear power plants, dams) and emergency planning. The previous probabilistic seismic hazard analysis (PSHA) for the territory of Slovakia in terms of macroseismic intensity for the 475-year return period was prepared within the GSHAP project more than fifteen years ago.

First part in each PSHA procedure is the compilation of the earthquake catalogue. The area of interest includes the territory of Slovakia and neighbouring parts of Austria, Hungary, Czech Republic, Poland and Romania. The catalogue is based on data from five national earthquake catalogues and two regional catalogues (ACORN, EMEC). We compiled the so called preliminary catalogue by merging national and regional catalogues. We checked the preliminary catalogue for duplicities and excluded them. We also excluded the events outside the area of the seismotectonic model SK2011. We homogenized the catalogue for the epicentral macroseismic intensity and for the moment magnitude. We applied the declustering procedure and distinguished the earthquakes as foreshocks, mainshocks and aftershocks. We investigated the time completeness based on different macroseismic intensity classes. The final unified and homogenized macroseismic catalogue consist of 4122 earthquakes with epicentral intensities between II and IX-X for the time period 456 - 2011.

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