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Contents

4

Foreword

The third Slovak National Report to IUGG provides a concise review of results achieved in geophysics and geodesy in the Slovak Republic in the period of 2003-2006. As in the previous two national reports, partial reports to five associations are included – reports to IAG, IAGA, IAHS, IAMAS and IASPEI. The report also comprises basic information on geophysical/geodetic research and teaching institutions, international conferences held in Slovakia, international projects in which Slovak researchers participated, scientific journals published by the Slovak institutions, defended PhD theses, and members of the Slovak National Committee for IUGG.

Broader and closer cooperation with foreign partner institutions, larger involvement in international grant projects as well as more intensive collaboration with individual foreign researchers is obvious from the report almost in all research topics compared to the past. This is a positive, encouraging and necessary aspect of the geophysical and geodetic research in Slovakia.

The Slovak National Committee believes that the presented report will be a useful reference for all who are interested in the geophysical and geodetic research in Slovakia.

Peter Moczo
President
Slovak National Committee
for IUGG

Report to IAG

Ladislav Brimich
IAG National Correspondent

Positioning and applications

The astronomical positioning at more than 30 points using the portable Circumzenithal 50/500 instrument was applied for geoid determination in Poland. Observations and their analysis were performed within the Polish – Slovak cooperation (*Bogusz et al.,* 2005).

Methods of integration of terrestrial and satellite geodetic observations are analyzed in (*Gerhátová and Hefty,* 2003) yielding the complex 3D network with gravity field parameters determined. The integration of heterogeneous GPS networks in unique model is studied in (*Hefty,* 2004; *Hefty, Kováč and Igondová,* 2004).

Determination of relative GPS antenna phase centres and the resulting coordinate drifts and variations are investigated in (*Hefty and Plánovský,* 2002*; Hefty*, 2004). The influence of extreme catastrophic environmental phenomena on permanent GPS observations is investigated in (*Igondová and Hefty*, 2005).

General theory and methodology
Development of new techniques for inversion and interpretation of gravity data

We are developing a new gravity data interpretation technique, the "Truncation Filtering Methodology" (TFM), based on data enhancement and pattern recognition. The TFM is based on filtering the gravity data by means of integral transforms – convolution integrals – with various kernels and one free parameter. Such filtering produces animated sequences of 3D surfaces of the post-filter quantities, in which dynamic patterns are observed. The patterns and their onsets are associated with features of geological formations. The determination of the features and estimates of depth to a feature are based on pattern recognition and on onsets of the dynamic patterns. The knowledge of patterns and their onsets is acquired by means of synthetic modeling and case studies. Currently we model and study salt domes embedded in sedimentary

layers. In the future we want to study faults and other geological scenarios relevant to geophysical exploration for mineral and hydrocarbon resources. This work is partially supported by VEGA and APVT national grants.

The "Harmonic Inversion Method" for solving the inverse gravimetric problem has been successively improved. The first substantial improvement consists in ability to calculate the shape and dimensions of any number of anomalous subsurface bodies at once. The second improvement further advances the reliability of the resulting solution by using a different information function in the first step of the two-step inversion procedure. The third improvement (which is now in the stage of development) will allow to solve the inverse problem for the real situation - ellipsoidal shape of the Earth surface (the previous variants were constructed for the flat surface) and the real terrain. This task requires the development of the suitable tools: the first one is the construction of the maximally regular net on the surface of the sphere and rotational ellipsoid. Such a net substantially improves the numerical integration of any given quantity over the surface of the Earth what is the basic requirement for the use of the inversion method. This work was partially supported by VEGA and APVT national grants.

Compilation procedures for precise gravity data for the gravimetric inverse problem:

Several aspects of defining, compiling, and correcting the gravity data that become input data in solving the inverse problem of gravimetry have been revisited with the outcome, that some procedures of compiling such data need to be refind in order to comply with current accuracy and precision requirements. By analytical derivations and numerical simulations several improvements were demonstrated to be needed, and improved procedures were proposed (publications listed below), such as proper treatment of the computation of normal gravity at the observation points, the computation of topographic correction, especially regarding the choice of the lower boundary of topographic masses, the computation of atmospheric correction, the argument for replacing the topo-corrected gravity anomaly with the topo-corrected gravity disturbance was justified, and several systematic errors, such as the geophysical indirect effect, and the secondary indirect effects were numerically assessed. This work was carried out under (non-financed) international cooperation with European and Canadian academic institutions, namely the University of New Brunswick, Canada (Prof. Vaníček), University of Vienna, Austria (Dr. Meurers), Delft University of Technology, Netherlands

(Dr. Tenzer), Newcastle University, UK (Dr. Moore), Tallinn University of Technology, Estonia (Dr. Ellmann), Research Institute of Geodesy, Topography and Cartography, Czech Republic (Dr. Novák), University of Western Bohemia, Czech Republic (Dr. Novák). This work was partially supported by VEGA and APVT national grants.

Geodynamics

Earth rotation

Geokinematics of Central European region was investigated on the basis of long-term GPS observations in several projects. The site velocities from permanent stations are evaluated and analysed in (*Hefty, Gerhátová, Igondová and Kováč,* 2004; *Hefty, Igondová and Hrčka,* 2005), kinematics from epoch stations is subject of papers (*Hefty et al.,* 2005; *Hefty and Gerhátová,* 2006). The relatively stable Central Carpathians, northward oriented drifts of Adriatic part and Dinarides and southward oriented motion of East Balkan are outputs of CEGRN monitoring (*Hefty,* 2005b; *Hefty et al.,* 2005). The homogenized velocity field and subsequent deformation analyses based on horizontal velocities in Central Europe are subject of papers (*Hefty and Ďuračiová,* 2003; *Hefty,* 2005b; *Hefty,* 2005c).

Periodic site coordinate variations in diurnal and sub-diurnal bands are evaluated and analysed on the basis of permanent GPS networks. The results summarized in (*Hefty,* 2002; *Hefty et al.,* 2004; *Hrčka and Hefty,* 2006) proves the existence of slight high-frequency variations in majority of GPS stations and points on some deficiencies in modelling of reference frames, ocean loading and locally induced site variations.

Reference frames

The reference frames issues are studied in Slovak Republic at various levels – continental, regional and national. Slovak University of Technology act as the EUREF Local Analysis Center (LAC SUT). The sub-network analysed consists of 40 stations distributed mainly in Central Europe and partially in other regions of Europe (West Europe, North-East Europe and Mediterranean). The standard products of LAC SUT as well as some other specific products like coordinate series with subdaily resolution are summarized in (*Hefty and Igondová,* 2004; *Hefty,* 2002 and *Hrčka and Hefty,* 2006). The denser network of about 40 permanent GPS stations concentrated in Central Europe is analysed at SUT in framework of the CERGOP-2/Environment EU project.

9

Analysis method, coordinate time series and evaluation of stability of network stations is described in (*Hefty, Kártiková and Kováč,* 2003; *Hefty, Gerhátová, Igondová and Kováč,* 2004; *Hefty*, 2005a). The history of GPS epoch observations in Central Europe starts from 1994 when first campaign of Central Europe Geodynamic Reference Network (CEGRN) was performed. The analysis of all CEGRN campaigns until 2006 resulting to coordinates and velocities for more than 50 stations is in (*Hefty and Gerhátová,* 2006; *Hefty et al.*, 2005; *Hefty,* 2005b; *Hefty*, 2005c). Problems of effective combination of permanent and epoch-wise GPS observations are investigated in (*Hefty,* 2004; *Hefty, Kováč and Igondová,* 2004). The Slovak national GPS networks and levelling networks of 1st order are analysed in (*Hefty and Vanko,* 2005).

Interpretation of temporal gravity changes and surface deformations

Measurable temporal changes of gravity and deformations of earth's surface are indicators of dynamic processes inside the earth, such as those associated with movements of magma and volcanic eruptions. The observation, analysis and interpretation of surface gravity changes and vertical displacements contribute to understanding the physics of magma reservoirs and the processes associated with volcanic activity such as eruptions. Active volcanism is experienced all over the globe. Millions of people live in a close vicinity of active volcanoes that pose a real threat to human lives. Understanding the processes leading to eruptions, hazard assessment, mitigation, and early warning leading to evacuation of inhabitants are vital. The precursors to an eruption are very complex and depend on many conditions that may be respective to the given region or the given volcano. We have participated in developing methods for interpreting gravity changes and surface vertical displacements linked with magma processes inside a volcano in terms of modelling these processes using point sources of heat and pressure. Also the TFM methodology was tested for its potential in interpreting gravity changes. Case studies were performed for two volcanoes, Mayon in Philippines, and Merapi in Indonesia. This research was carried out under (non-financed) European cooperation with colleagues from the University of Madrid, Spain, from FSU Jena, Germany, and TU Darmstadt, Germany. Observed data from the two volcanoes were provided to us by the German colleagues. This work was partially supported by VEGA national grants.

Earth tides research

The research activities in this area focused on the finite element (FE) modelling of the displacement field and associated gravity change due to a deep heat source with its volcanological motivation, FE modelling of tidal deformation of an underground gallery with the aim to quantify the cavity effect on the tilt measurements, FE modelling of gravitational and inertial loading of speleothems, which is of strong paleoseismological interest. In parallel, analytical reference solutions of simple boundary value problems (rectangular linearly elastic body deformed by its own weight) were sought for. With regard to the applications in 2D plane strain/stress problems, the rock strenght criteria were examined in more detail. Dr. Kohút defended recently his PhD. thesis "Modelling of the cavity effect influence on tidal tilt measurements". This work was partially supported by VEGA and APVT national grants.

Modernization of the Vyhne tidal station was realized in 3 stages. In the first stage in the year 1996 the capacitive transducer constructed at the Geophysical and Geodetical Institute of the Hungarian Academy of Sciences in Sopron were installed, *Mentes* (1986, 1995, 1998). In the second stage in the year 2001 the datalogger CR 10X from Campbell Scientific, inc. were installed and in the third stage in the year 2005 online connection of the tidal station in Vyhne with the Geophysical Institute SAS in Bratislava was built.

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Report   to   IAGA

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This report was developed on the basis of scientific activities of geophysical institutions mainly:

I. Geophysical Institute of Slovak Academy of Sciences, Bratislava, including Geomagnetic Observatory Hurbanovo.

II. Department of Astronomy, Physics of the Earth and Meteorology, Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava, including AGO Modra (Astronomical and Geophysical Observatory Modra). In 2004 this new Department (in comparison with the 1999 – 2002 period) was developed from 2 former departments – Department of Physics of the Earth and Planets, and Department of Meteorology and Climatology, further on from the Faculty Astronomical Institute, as well as, some persons from other departments of the Faculty were included.

III. Moreover, scientific activities of other institutions are also important, see e.g. Solar Terestrial Physics Studies Section where contributions from Astronomical Institute of Slovak Academy of Sciences, Tatranská Lomnica and Institute of Experimental Physics of Slovak Academy of Sciences, Košice (including observatories in Stará Lesná, Skalnaté Pleso, Lomnický Peak) are also included.

The report consists of a number of Sections (in brackets are [corresponding subeditors – including individual contributors]): (1) Theories of geomagnetic field generation [Brestenský – Guba, Ševčík, Šoltis], (2) Ground based geomagnetic observations [Valach – Váczyová, Dolinský], (3) Magnetotelluric and magnetovariational studies and theoretical EM modelling [Hvoždara – Vozár], (4) Paleomagnetism and magnetism of rocks [Túnyi – Orlický, Klučiarová, Gregorová], (5) Ionosphere [Ondrášková – Ševčík], and (6) Solar terrestrial physics studies [Prigancová – Rybák, Sýkora, Slivka, Dzifčáková, Masarik, et al.].

Theories of geomagnetic field generation

Due to successful geodynamo computer simulations of many teams and the improvement of coordance of these simulations with better understanding of physical processes in the Earth'core there is a great progress in the problem of geomagnetic field generation in the last years. Furthermore, in many laboratories the experiments with hydromagnetic dynamos have been successfully started and great hopes are given to special geomagnetic satellites which significantly enrich the knowledge on geomagnetic secular variations in details and, in particular, on a soft structure and time development of the magnetic field in the Earth's core surface.

However, there are many open problems, e.g. how to explain the coordance of geodynamo computer simulations with the main observed features of geomagnetic field, if due to limitations of the most modern computers in memory and computational time the used values of diffusive coefficients are too high, e.g. the used eddy viscosity is of two orders greater than the value to be supposed in the Earth's core. Many phenomena bond e.g. to the core/mantle interface or to inner/outer core interface or to the region of tangent cylinder, i.e. the cylinder coaxial with the axis of rotation and tightly surrounding the inner core need better physical understanding and in more details. Therefore, development of models, significantly simplified from many points of view, but specially focused on understanding of the physics which determines the chosen phenomena, is extraordinary necessary.

Rotating magnetoconvection

(*Brestenský et al*., 2003abc, 2004ab, 2005ab, 2006ab; *Šimkanin et al.,* 2003; *Šoltis,* 2004; *Šoltis et al.*, 2004, 2005abc, 2006ab; *Tagare et al*., 2003, 2006; *Marsenić and Ševčík,* 2006)

Rotating magnetoconvection; diffusive instabilities

The study of diffusive processes influence in the problems of rotating magnetoconvection is very needful, because they modify the basic balance of forces due to distinct weakening of various forces by various diffusions. Thus in many cases commonly negligible diffusive forces can strongly modify the dynamics of diffusive systems. The attention was focused on diffusive instabilities in planar horizontal layer rotating around vertical axis and permeated by (1) basic azimuthal magnetic field (with corresponding homogeneous vertical current density) or by (2) vertical homogeneous

magnetic field. Due to the simplest boundary conditions and analytical tractability many properties of arising instabilities were explained. In (*Brestenský et al.*, 2001) magnetically driven instabilities of MC waves type, propagating westward and arising only in viscous fluid, were revealed. *Šoltis et al.* (2004) analytically proved that these MC(W) modes arise due to transformation of MAC modes. The conditions for the transformations MAC → MC and reversally were studied in details.

Weakly non-linear analysis was applied on rotating thermohaline convection models with the Soret effect included by *Tagare et al.* (2003, 2006).

Rotating magnetoconvection at anisotropic diffusive coefficients

Anisotropic diffusive coefficients were introduced into the problem of rotating magnetoconvection. The main motivation for it is the streamline to understand why geodynamo computer simulations are successful at non – realistic values of diffusive coefficients. The paper (*Braginsky and Meytlis,* 1990) devoted to the turbulence study in the Earth's core was our main inspiration to introduce the anisotropy of diffusive coefficients into the fluid layer. However, due to mathematical tractability of the problem (the separability of partial differential equations) other cases of anisotropies were studied than the one studied by *Braginsky and Meytlis* (1990).

The anisotropy was introduced in the sense of various values of diffusive coefficients in vertical direction and in horizontal directions (keeping isotropy in horizontal directions). We distinguish the anisotropy of type *a* and type *o*. In *a*-anisotropy diffusive coefficients are greater in vertical than in horizontal directions, and in *o*-anisotropy it is opposite. With both types of the basic magnetic field (azimuthal and vertical one) there were combined three types of the fluid layer stratification, i.e. the unstable, stable and the neutral one.

The most important influence of anisotropy on rotating convection in both considered cases of the basic magnetic field is, that the *a*-anisotropy facilitates the convection and convective cells are more elongated in vertical direction than in horizontal one, while the *o*-anisotropy inhibits convection to arise and the cells are elongated in horizontal directions. In the case of the vertical magnetic field, which is analytically well tractable, it is interesting that the strong *a*-anisotropy can suppress the inhibiting role of rotation or of magnetic field to arise convection. The intention to present non-standard explanation of the Earth's core torsional oscillations related to decadal geomagnetic secular variations due to special anisotropy of diffusive coefficients and only with

vertical magnetic field with zero radial magnetic component, which is decisive in standard explanation, failed.

The influence of both *o* and *a* anisotropies was studied also in cases of magnetically driven instabilities either of MAC waves type or MC(W) viscous modes. It must be the *o*-anisotropy which gives the chance to arise these modes, propagating in the direction of basic azimuthal magnetic field, for geophysically more realistic conditions.

Rotating magnetoconvection; the basic magnetic field of dipole parity

A model of a horizontal stratified plane between $z=\pm d/2$ layer filled by electrically conducting Boussinesq fluid rotating with a constant angular velocity under a vertical gravitational field and a non uniform magnetic field $\boldsymbol{B_0}$ was investigated. Imposed magnetic field in the form $\boldsymbol{B_0} = B_0(z-z_0)\hat{\boldsymbol{y}}$, where B_0 is a magnitude of the field and $\hat{\boldsymbol{y}}$ is unit vector in Cartesian geometry, had a zero point inside the layer by what the condition of existence of a critical level has been satisfied. The critical level in the middle of the domain corresponds to the purely antisymmetric field which is of so called dipolar parity. It was supposed that such fields are less stable than the ones of quadrupole parity (symmetric with respect to the central plane of the layer). An influence of shifted critical level on the onset of an instability was studied. Linear stability was examined for onset of stationary convection in the form oblique rolls to the imposed basic magnetic field. Thermally and magnetically driven sinuous and varicose modes were found (*Marsenić and Ševčík*, 2006).

Mushy layer at the outer/inner core interface

(*Guba and Worster*, 2006ab)

When a binary alloy solidifies directionally, a planar interface between the liquid and solid regions can become morphologically unstable owing to constitutional supercooling. As a consequence of this supercooling, regions of coexisting liquid and solid phases, referred to as mushy regions, are often formed. Mushy regions are prevalent in a number of industrial and environmental contexts, including metallurgy, the Earth's core, silicate magma chambers and sea ice.

Guba and Worster (2006a) studied the problem of nonlinear development of oscillatory convective instability in a two-dimensional mushy layer during solidification of a binary mixture. They considered a distinguished limit of large Stefan number, which allowed a destabilization of the system to an oscillatory mode of convection. They found that either travelling or standing

waves could be supercritically stable, depending strongly on the sensitivity of mushy-layer permeability to variations in the local solid fraction. Furthermore, the decrease in permeability was found to promote the subcritical primary oscillatory states. In addition to mapping out the location of different stable oscillatory patterns in the available parameter space, they gave the detailed spatio-temporal structure of the corresponding thermal, flow and solid-fraction fields within the mushy layer, as well as the local bulk composition in the resulting eutectic solid.

Guba and Worster (2006b) performed an analysis of the lateral solidification of a semi-infinite mushy region influenced by the buoyancy-driven convection of the residual interstitial melt. They considered a parameter regime in which the flow was steady on the time scale of the transient evolution of the mushy region. Their idealized model predicts patterns of macrosegregation consistent with earlier experimental studies and sheds light on the mechanisms involved.

Ground-based geomagnetic observations

The geomagnetic observations for the Slovak Republic territory are performed on a continuous regime at the Hurbanovo geomagnetic observatory ($\varphi=47.87°$, $\lambda=18.18°$, $\Phi=46.89°$, $\Lambda=101.12°$). This observatory is the detached work-place of the Geophysical Institute of the Slovak Academy of Science. It operates at the same place since the year 1893 (with some interruptions due to first and second World wars and since the year 1998 it is reliable member of the world-wide network of geomagnetic observatories IMO (in a frame of INTERMAGNET project). Main equipment of the observatory includes: digital variometer station TPM made in Belsk Observatory (Poland) and magnetoregistration device DI-fluxgate Magson gained on the co-operation basis with GeoForschungsZentrum Potsdam and Volkswagen Stiftung (Germany). For the absolute geomagnetic measurements there are used mainly DI-fluxgate magnetometer, proton magnetometer ELSEC, QD declinometer. The magnetovariational data in one minute sampling interval are supplied via internet to the INTERMAGNET centre in Edinburgh and Paris. The hourly mean data of X,Y,Z geomagnetic component are also published in the CD-ROM prepared according to INTERMAGNET rules (*Váczyová,* 2003, 2004, 2005, 2006).

The members of the Hurbanovo Observatory staff regularly perform the field absolute geomagnetic measurements at the secular point network (they

were selected 6 points according to the rules of MagNetE). These measurements were used also for analysis of the secular changes of GMF at the Slovak territory during the last 100 years, and there was revealed that the declination increases about 5-6 ′/year, and total field intensity increases by 22 nT/year (*Valach, Váczyová, Dolinský*, 2004, 2006a, 2006b). These changes are in agreement with secular changes of GMF in the Central Europe. In the years 2003-2004 the members of Hurbanovo observatory staff took part in the field campaign of magnetotelluric and magnetovariational sounding of the Slovakia territory. In the year 2006 there was started also the geomagnetic survey of Slovakia in a network of about 130 points – this project is supported mainly by the Slovak APVV grant agency and will be finished in the year 2008.

Data contribution of GO Hurbanovo to the Data CD-ROMs (For GO Hurbanovo edited by Váczyová M.):

INTERMAGNET 2002 CD-ROM, published in 2003
INTERMAGNET 2003 CD-ROM, published in 2004
INTERMAGNET 2004 CD-ROM, published in 2005
INTERMAGNET 2005 CD-ROM, published in 2006

Magnetotelluric and magnetovariational studies and theoretical EM modelling

The magnetotelluric investigations of the Košice Basin were applied for more detailed assessment of depth/lateral extension of the reservoir of geothermal water (*Vozár, Hvoždara, Köhler*, 2003). During the years 2003-2004 there were performed magnetotelluric (MT) sounding measurements along 6 profiles running close to the seismic CELEBRATION profiles on the territory of Slovakia and 11 sites of deep MT soundings. The 1-D and 2-D inversion techniques applied to the measured data revealed various interesting differences in depth & lateral distribution of electrical conductivity of the Earth's crust and upper mantle on the territory of Slovakia, namely:

- The results from 1D OCCAM and D+ inversions estimate the litosphere thickness from 100km to 160km for investigated region of western Slovakia.

- The 2D modeling in the eastern Slovakia confirmed existence of strong conductive zones represented by the Carphatian Conductivity Anomaly (CCA) and sedimentary basins with strong heat flow. The 3D image of geoelectrical structures from presented profiles show us border between Inner and Outer Carpathians.

22

- Presented measured induction vectors are in agreement with previous works about CCA anomaly. Strong effect of CCA is visible in points close to the anomaly. Following 3D theoretical electromagnetic modelling of CCA shows some geometry effect of CCA bend. Using application *EMI2, Insight* and *mt3dfwd* for 3D modeling enable to compare the results for two types of differential equation solution. The vector integral equation method and finite difference approximation method give practically same results in physical meaning and also quantitative values (*Vozár,* 2005).

The volume integral equation method using the Green's tensor function was used for model calculation of EM induction in the two layered Earth with one or two long 3-D blocks (*Vozár,* 2005). The complex analysis of geophysical, geological, hydrological data and laboratory measurements was applied to the plausible explanation of the CCA nature.

There were found indications for the existence of both graphitic and mineralized water bearing layers below the Western Carpathians bow as the possible cause of the high conductive CCA (*Hvoždara and Vozár*, 2004). For purposes of geothermics in sedimentary basins with partly permeable perturbing body there was solved the 2-D analytical approximation and calculated the surface heat flow anomaly which can cause the increase of the electrical conductivity in such circum- stances (*Hvoždara*, 2005). For purposes of forward problems of magnetometry there were adopted analytical or methods of boundary integral technique for calculations of curves ΔT and ΔI above the 2-D bodies of regular or irregular cross-sections (cylindrical, elliptical, polygonal) (*Hvoždara and Kaplíková*, 2005a,b, 2006).

It is well-known that the results of the deep EM soundings can be distorted by the inhomogeneities of the shallow-surface conducting layer, the conductance of which varies globally from fractions of Siemens (S) inland up to tens thousand of S in the oceans. To demonstrate importance of the non-uniform conductance map for the deep electromagnetic soundings we present map of subsurface conductance (S-map) and the modeling results of Northern, Central and Eastern Europe for the long-period geomagnetic deep soundings (GDS) and magnetotelluric (MT) responses. We put forward a proposal to the geophysical community - to update the global conductance maps by incorporating the existing regional S-maps to it. Recently new regional S-map of the Central, Northern and the Eastern Europe was designed (*Vozár, Semenov,* 2006).

The horizontal spatial gradient method has been evaluated in accordance

with the conventional and modern (including the spatial derivatives of impedances) approaches to compare their efficiency with the deep magnetotelluric (MT) sounding for the study of the heterogeneous media (*Semenov, Vozár and Shuman,* 2007).

Paleomagnetism and magnetism of rocks

Paleomagnetism and magnetism of rocks of Western Carpathians

The rock samples of Paleogene and Neogene age from central part of Western Carpathians were studied. Their interpretation was applied for an assessment of paleorotations of this mountain belt (*Vozárová and Túnyi*, 2003; *Túnyi et al.*, 2003ab, 2004a, 2005abc). The paleomagnetic laboratory analyses were also applied for the study of remanent magnetism of some meteorites (*Hvoždara et al.*, 2003b; *Kapišinský et al.*, 2003; *Funaki et al.*, 2005).

The relations of magnetic properties and a magnetic behavior of Fe-Ti magnetic minerals of volcanic and volcano-sedimentary rocks were studied. Very important statements and suggestions were derived to explain an origin and the source of reversed remanent magnetization of rocks, applying not the field-reversal but the self-reversal hypothesis (See the papers under *Orlický*, 2003 to 2006).

Magnetism of rocks

Magnetism of rocks; study of magnetic fabric of rocks

The main goal of our study of the magnetic fabrics of rocks is to reveal the possible tectonic development and tectonic deformation of the individual geological units in the various Western Carpathians mountains. The basic research tool is the anisotropy of magnetic susceptibility measurement – the very effective method for investigation of magnetic mineral preferred orientation (magnetic fabric) in the rocks.

The hitherto results are based upon the older primary studies from almost all Slovak Western Carpathians core mountains and the new detailed studies till this time carried out in the Malé Karpaty Mountains, Veľká Fatra Mountains and Považský Inovec Mountains. The data comparison between the geological units of the certain mountains, or between different mountains markedly supports to the analysis of the Variscan and Alpine tectonic development of the Western Carpathians. These results were published in the

paper (*Gregorová et al.,* 2003a) and in the proceedings from international conferences, e.g. (*Gregorová et al*., 2003bc, 2004ab, 2005, 2006).

Magnetism of rocks in enviromental applications; magnetic susceptibility of topsoils polluted by heavy metals in the vicinity of Nickel factory dump in the Slovak city of Sereď

The heavy metals are in topsoils predominantly fixed on/in ferro- and ferrimagnetic minerals. Therefore, measurement of the magnetic susceptibility can be employed as a simple and rapid screening method to asses the level of soil pollution. This approach was successfully applied in several European cities, and can be used in all situations, where it is reasonable to assume that magnetic particles and pollutants (mainly metals) coexist. There was tested the applicability of magnetic susceptibility measurement for the detection of industrial soil pollution in the surroundings of a large dump from the (by now closed) nickel factory in the city of Sereď, situated in the south-western region of Slovakia. The environmental load here represents approximately 5.5 mill. tons of material with nickel as the most important pollutant, which was spread by the winds and rain water around the dump . The study locality was a 6 x 6 km square area situated mainly in the southern and south-eastern direction from the dump (including the dump itself). Samples were taken from three horizons (20 cm, 40 cm and 60 cm, respectively), air-dried and measured for the mass susceptibility on the KLY-2 kappabridge. The results show that the topsoils in the studied area are characterized by enhanced magnetic susceptibility κ, with highest values, as expected, directly in the dump. In general, κ decreases with increasing distance from the dump, as well as with increasing depth from the surface. These results are presented in papers *Klučiarová, Gregorová, Túnyi* (2006abc).

Ionosphere

The lower ionosphere

At the Department of Astronomy, Physics of the Earth, and Meteorology, Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava, the height-dependent response of the ionosphere to solar proton events (SPEs) was studied. By means of numerical simulations the effects of the October 19, 1989 and July 14, 2000 SPEs were analysed. Solar proton fluxes measured by satellites "Meteor" were used for calculations of ionisation

rates. GOES 7 1–8Å X-ray fluxes were used as well. Electron density enhancement after the October 1989 SPE was as much as three orders of magnitude at 50–60 km. Simulated response of the lower ionosphere to solar energetic particles in different seasons showed that the increase of electron density was greater for July 2000 SPE than for the October 1989 SPE and this result is in agreement with cosmic noise absorption measurements. Strong contribution of neutral species changes after SPEs seems to be the main factor for seasonal character of the ionospheric response to SPEs. The latter simulations made use of solar proton fluxes and X-rays fluxes measured onboard GOES 8 satellite (*Ondrášková, 2005*).

Simulations showed that during SPE relative abundances of negative ion species change. Concentrations of final ion NO_3^- were found lower than concentrations of CO_3^- and CO_4^- during first two nights of the October 19, 1989 SPE (*Ondrášková and Krivolutsky, 2005*).

Recent simulations of a single SPE showed a difference in summer and winter polar cap response. In summer the increase of electron concentration is lower than in winter likely due to greater pre-SPE concentration in the sun-lit summer polar ionosphere. The duration of the enhancement lasts shorter in the winter polar cap due to differences in chemistry in the absence of light (*Ondrášková et al., 2006*).

Schumann resonances observations

Building of the equipment for the vertical electric field component measurements in the Schumann resonance (SR) frequency band at the Astronomical and Geophysical Observatory of Faculty of Mathematics, Physics and Informatics of Comenius University at Modra-Piesky (AGO) was finished and the time data have been collected and spectra of Schumann resonance eigenmodes have been computed regularly since October 2001. Sporadic measurements of the magnetic field component are performed only from winter 2003/4. Raw spectra can found at http://147.175.143.11/.

The electric field component has been picked up by ball antenna every half an hour, the processed spectra (in the 5–45 Hz range) are written on CD. During most of time (except the periods of heavy rains, wet snow or ice) the first four eigenmodes are clearly distinguishable. For each of these modes, the central frequency, Q-factor and relative amplitude are determined by Lorentzian curve fitting. Data for 2002–2005 have been processed and analysed. Summary of more than 4 years of continuous Schumann resonance

(SR) monitoring of the vertical electric component at Modra Observatory has been published in January 2007 in *Ondrášková et al.* (2007). Principal parameters (peak frequency, amplitude, and quality factor) are determined for resonances from 7 to 30 Hz, i.e. for modes from the first to the fourth. The attention was also concentrated on the less frequently compiled fourth mode. The resonance parameters are computed from 48 daily measurements and represented as the mean monthly values for each time of the detection. Fitting of spectral peaks by Lorentz function is the main method used in the data post-processing. The diurnal, seasonal variations and the indication of inter-annual variations of these parameters (especially peak frequency) are discussed. The results are compared with other observatory measurements. Our observations confirm that the variations of peak frequency of the lower SR eigenmodes can be attributed mainly the to source-observer distance effect.

Measurements of the Schumann resonance frequencies (first 4 modes – at about 7.8, 14, 20 and 26 Hz) at Modra Observatory were analysed with respect to the strong solar energetic proton flux in October 2003. For the determination of the onset of perturbations, satellite data from GOES 11 were used. No significant effect in frequencies nor amplitudes was revealed in our latitudes *(Ondrášková et al.,* 2005*)*.

Anomalously high third SR mode amplitude was observed at AGO in October 2004. Two explanations – the occurrence of multiple return strokes (MRS) or the very special geometrical source-receiver relations – are discussed in *Kostecký et al.* (2005).

During permanent monitoring of SR at AGO, numerous Q-bursts (strong transient ELF signals) were observed. A very strong Q-burst of July 11, 2004 is analysed in *Ševčík et al.* (2005).

In order to relate the observed data with the ionospheric parameters the computer modelling of the Earth-ionosphere resonator is necessary. Various approaches to this task are surveyed and some new insights are suggested in *Kostecký et al.* (2006).

The magnetic field monitoring is – up to now – only in the experimental phase, mostly because of relatively high level of man-made magnetic noise. Nevertheless, at least first two modes have been captured. At present, the experimental endeavour is directed to the increase of search coil sensitivity and the more effective filtering of magnetic component signal. Special hut for the coil has already been built and regular measurements are expected to start soon. It is expected that by means of two orthogonal magnetic sensors, the polarization of SR eigenmodes would be determined.

Some information on Ionosphere studies and Schumann resonances observations is also in the next Section STP studies.

Solar terrestrial physics studies

(A. Prigancová)

In the field of Solar Terrestrial Physics (STP) studies the issue of space weather is investigated on the basis of existing links among physical processes of interaction in the Sun-Earth system. Observations of solar variability (Stará Lesná Observatory and Lomnicky Peak coronal station of the Astronomical Institute SAS), Lomnicky Peak neutron monitor (Institute of Experimental Physics SAS) measurements are carried out on a regular basis. Monitoring of the variable planetary magnetic field at the Hurbanovo Geomagnetic observatory of the Geophysical Institute SAS, that being a member of the INTERMAGNET family, is performed on a continuous basis.

STP studies in Slovakia are realized by a number of institutions and their results are summarized below and allow to follow solar variability and successive response in the interplanetary medium and geospace.

The activities of the *Astronomical Institute of the Slovak Academy of Sciences (AISAS)*, Tatranská Lomnica (http://www.astro.sk) were devoted to the research in solar physics using satellite observations, mainly in the UV, XUV and X-ray spectral regions. That is mainly focused on solar data of the current SOHO mission and TRACE satellite and from previous satellites of the NOAA and GOES series. Other solar studies were focused on relations of the solar corona emission with strength and topology of the large-scale solar magnetic field. Dynamics and energy transfer in the outer layers of the solar atmosphere was studied in a series of papers devoted to quiet solar network and to active events in the supergranular internetwork using data acquired in frame of the SOHO/TRACE joint operation program (JOP078) using the CDS, SUMER, EIT instruments onboard SOHO as well as TRACE. In particular effects of resolution of different instruments were found to be related to phenomenology of the active events (explosive event versus blinker) and relation of plasma in different temperature regimes was investigated (*Gömöry et al.,* 2003a,b; *Rybák et al.*, 2003; *Tomasz et al.,* 2003ab). Mutual relations of the upper layers of the quiet solar atmosphere in/above chromospheric network were studied in order to identify physical mechanisms which control energy transfer to the corona (*Rybák et al.,* 2004; *Gömöry et al.*, 2005ab). In order to

28

proceed in investigation of the outer solar atmosphere a new co-operative program for the SOHO mission was prepared. This program was approved as JOP 171 *Solar network: variability and dynamics of the outer solar atmosphere* - joint observing program of CDS, EIT, MDI (onboard SOHO) and TRACE instruments. The main goal of this program is to study quiet Sun supergranular network using intensities and Doppler shifts of the chromospheric, transition region and coronal emission lines by a team of scientists at AISAS and Institute of Theoretical Astrophysics of Oslo University (Norway). First runs of the JOP 171 were performed within the MEDOC12 campaign in the November 17-19, 2003. Each run took approximately 8 hours. Typical spectra of different spectral lines were obtained by CDS instrument during one JOP 171 run.

Three new runs of the SOHO joint observing program JOP 171 for instruments onboard the SOHO and the TRACE satellites were performed (June 5-9, 2004: MEDOC13 Campaign; July 8-15, 2004: VTT and DOT observing campaign; October 18-31, 2005: SST and DOT observing campaign). These data will be utilized in the near future. In particular very detail observational data have been acquired for a M5.4 solar flare on July 13, 2004 (*Kučera et al*., 2005).

Observations of ten total solar eclipses (1973-1999) enable to describe mutual relations between the white-light and green-line coronal structures and the coronal magnetic fields strength and topology (*Sýkora et al.*, 2003). Archive data of the X-ray flares acquired on the orbit (as well as H alpha measured on the ground) were investigated statistically in order to derive periodicities of their occurrence around the rotational period as well in the interval of the intermediate periods. The intermittent behavior of different periodicities was discovered (*Özguc et al.*, 2003; *Temmer et al.*, 2003a,b). Relation of the cosmic rays periodicities with the interplanetary magnetic field strength and the green coronal index variability were studied in the range of the intermediate periods (*Kudela et al.*, 2003a). Relation of the cosmic rays intensity with the even and odd solar cycle behavior was also investigated (*Storini et al.*, 2003). The International Solar Cycle Study (ISCS) program was adopted by the SCOSTEP to investigate all aspects of the physics of the Sun in the different layers of the solar atmosphere and at various time-scales during the rising phase of Solar Cycle 23. In 2001 the ISCS steering committee accepted invitation of the Slovak National Committee of SCOSTEP to meet at Tatranská Lomnica, Slovak Republic for the final meeting to summarize results of the ISCS program. Twenty-seven invited reviews, thirty-four

contributed oral presentations and one-hundred fourteen posters were presented and published by the European Space Agency (ESA) as the Special Publication No. 535 (2003), ESTEC, Noordwijk, the Netherlands (ed. A. Wilson).

A new archive of prominences observed at the Lomnicky Peak coronal station has been finished and a practical evaluation of the archive has been documented. Archive is used for studies of morphology and time-latitude distribution of prominences as well as for finding a relation between the solar magnetic fields and solar cycle (*Kločok*, 2005).

The short-term periodicities of the flare index are investigated in detail over the epoch of almost 4 cycles (1966-2002). A comparison of the results of the Fourier transform and the time-period wavelet transform of the flare index time series has clarified the importance of different periodicities, whether they are or are not the harmonics of the basic ones, as well as the temporal location of their occurrence. As found, the modulation of the flare index due to the 27-day solar rotation is more pronounced during the declining portion of solar cycle than during the rising portion (*Özguc et al.*, 2004).

Reexamination of the homogeneous coronal data set has been done for the period 1939-1965, using a close correlation between the coronal index of solar activity (CI) and sunspot number (also the 2800 MHz radio flux and the cosmic ray intensity) for the period 1966-2002. New homogeneous coronal data set has been created and a new CI has been recomputed. High correlation between the CI and sunspot number (0.914) has been found. In fact, this method can be used to obtain CI values as far back (1850) as reliable sunspot observations exist (*Rybanský et al.*, 2005).

Archive data of the X-ray flares acquired on the orbit (as well as H alpha obtained on the ground) were investigated statistically in order to derive periodicities of their occurrence around the rotational period as well in the interval of the intermediate periods (*Özguc et al.*, 2004; *Atac et al.*, 2005; *Rybák et al.*, 2005). The 24-day periodicity of the solar flares was explained (*Temmer et al.*, 2005).

Relations of the cosmic rays and the green coronal index variability to the space weather were studied (*Minarovjech et al.*, 2004; *Minarovjech and Kudela*, 2004; *Kudela et al.*, 2005b).

Spectral variation analysis and wavelet analysis of the north-south asymmetry of three solar activity indices (coronal green-line brightness, number and summary area of sunspots, total photospheric magnetic flux has been performed. Long-term variations (increases and decreases) of the N-S

asymmetries of all the three indices occur synchronously and, in addition, they are much better pronounced than the variations in the indices themselves. The N-S asymmetry (NSA) of solar activity is probably a fundamental property of the Sun's body, governing the coupling and degree of coincidence between the magnetic-field-generation mechanism operating in the northern and southern solar hemispheres (*Badalyan et al*., 2005a,e; *Sýkora and Rybák,* 2005). The NSA presents very adequate index for study of the Quasibiennial oscillations (QBOs) of the solar activity (*Badalyan et al.*, 2005b,f). A negative correlation between the power of the QBOs and the asymmetry of A was found (*Badalyan et al.*, 2005c). Phenomenology of the coronal manifestations of the solar activity for the last 60 years is described including the NSA, zonal deviations (equatorial, middle-latitude and polar zones), presence and persistence of the "active longitudes" on the Sun, cyclicity and periodicity of the solar activity (*Badalyan et al.*, 2005f).

Based on sunspot drawings provided by the Kanzelhohe Solar Observatory, Austria, and the Skalnate Pleso Observatory, Slovak Republic, a data catalogue of hemispheric sunspot numbers covering the time span 1945-2004 was prepared. The validated catalogue including daily, monthly-mean, and smoothed-monthly relative sunspot numbers for the northern and southern hemispheres separately is available for scientific use. These data were then investigated with respect to NSA for almost 6 entire solar cycles (Nos. 18-23). For all the cycles studied, it appears that the asymmetry based on the absolute asymmetry index is enhanced near the cycle maximum, which contradicts to previous results that are based on the normalized asymmetry index (*Temmer et al.*, 2006).

Time and spatial variations of the solar corona rotation were quantitatively determined for the period 1939-2001 (using our own database of the coronal green-line brightness) in dependence on the heliographic latitude and on the phase of 11-year solar activity cycle. Comparison of the found results with the recent helio-seismology measurements indicates that the structure of the velocity field in the Sun's convective zone (optically invisible) has similar parameters and it, very probably, governs the velocity distribution in the upper solar atmosphere (*Badalyan et al.,* 2005d, 2006ab; *Badalyan and Sýkora,* 2005, 2006).

The search for sub-structures in the latitude/time distribution of long-lived coronal holes has revealed that they are organized into two populations: (a) numerous coronal holes occurring around the maximum phase of the 11-year solar activity cycle and living for 2-4 years and, (b) two long-living coronal

holes (~18 years) which are unipolar (with opposite polarities) and developing alternatively in the northern and southern solar hemispheres. These (b) holes are clearly related to the long-term evolution of the Sun's global magnetic fields (*Storini et al.*, 2006).

Intermittence of the short-term periodicities (25-35 days) of the flare index is investigated sing the wavelet transform method for the full-disc and for the northern and southern hemispheres of the Sun separately over the epoch since 1966 until 2002. Occurrence of periodicities of flare index power is highly intermittent in time and flaring activity on the solar hemispheres in several time intervals. Correlations of the period-averaged wavelet power of the flare index for the separate hemispheres and for the full-disc reveal significantly stronger relation between the full-disc and the northern hemisphere than between the full-disc and the southern hemisphere (*Rybák et al.*, 2005). The 24-day period in the solar flare occurrence for solar cycles 21 and 22 by means of wavelet power spectra together with the solar flare locations in synoptic magnetic maps was studied. The 24-day peak revealed in the power spectra is just the result of a particular statistical clumping of data points, most probably caused by a characteristic longitudinal separation of about +40 degrees to +50 degrees of activity complexes in successive Carrington rotations (*Temmer et al.,* 2005). Time variations of the flare index, sunspot number and sunspot area (each index arising from different physical conditions) were compared with the solar composite irradiance throughout cycle 23. Rieger-type periodicities in these time series were calculated using Fourier and wavelet transforms (WTs). The peaks of the wavelet power of these periodicities appeared between the years 1999 and 2002. As found, the solar irradiance oscillations are less significant than those in the other indices during this cycle. The irradiance shows non-periodic fluctuations during this time interval. These periodicities appeared intermittently and were not simultaneous in different solar activity indices during the three years of the maximum phase of solar cycle 23 (*Atac et al.*, 2006).

In the ***Department of Astronomy, Physics of the Earth and Meteorology, Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava,*** some issues of the solar wind composition were studied using the satellite data (e.g. SOHO, TRACE, GOES). The excitation equilibrium of Fe, C and O for the electron kappa-distribution was analysed. It was shown that especially some C IV line intensities are very sensitive to the shape of the distribution (*Dzifčáková and Kulinová*, 2003a). The investigation of the relationship between subphotospheric flows and flaring activity shows the

possibility of the direct connection with strong flows in some depths under the photosphere. These flows were found in the places where active quasi-separatrices are located and where the magnetic field lines change their connectivity during flare. The results are only preliminary and need statistical verification (*Dzifčáková et al.*, 2003; *Dzifčáková and Kulinová,* 2003b).

The SOHO/SUMER observations of EUV bi-directional jets were studied. The phenomenon was observed in chromospheric S III 1251.16 Å and C I 1251.17 Å, transition region N V 1238.8 Å but there was no detectable signature in the coronal line Mg X 625 Å. However, TRACE imager with the 171 Å filter detected the phenomenon clearly. The discrepancy was explained using a non-Maxwellian electron distribution. This could also have implications for other phenomena observed in the TRACE pass-bands, including the transition region `moss' and the 3- and 5-min oscillations (*Doyle et al.*, 2004). The flare accompanied with a surge was analyzed in EUV (TRACE), Hα, radio and HXR (GOES). The observed structure of the flaring active region and its topology was compared with the potential magnetic field model. The start of the surge was accompanied with HXR pulses, type III radio bursts, several slowly negatively drifting features and with huge EUV brightening close to the position where quasi-separatrix layer cuts the photosphere. The magnetic reconnection as a driving mechanism for this surge was discussed (*Kulinová et al.*, 2004). Assuming the presence of non-thermal (power) distribution of electrons during the impulsive phase of a flare, the theoretical line synthetic spectra (X-ray) for Fe XXV were calculated. The series of models were computed for the observed temporal evolution of plasma temperature, density and with the assumption of different temporal evolution of the shape of the distribution function. The results confirmed that under the strongly non-thermal distribution of electrons the ratio of satellite lines to allowed lines increases (*Dzifčáková and Kulinová*, 2004).

Computation of the excitation equilibrium of Fe IX – Fe XV for non-thermal (power) electron distribution shows that at given temperature and electron density the excitation rates increase significantly with the deviation of the distribution function from the Maxwellian one while the de-excitation rates are not influenced so much. As a result, the population of higher levels increases and the emissivities of lines belonging to the transitions starting from these levels also increase. The synthetic spectrum at 180–300 Å was computed for different power distributions, mean energies of distribution and electron densities. (*Dzifčáková and Tóthová,* 2005).

The influence of the electron power distribution on the excitation equilibrium of He-like Si and Ca has been studied. The changes in the excitation equilibrium increase with the increase of the deviation of the distribution shape from Maxwellian one. For strongly non-thermal distribution also the unusual line ratios can be found. The possibilities to diagnose the shape of the distribution from line ratios in solar flare plasma are showed (*Dzifčáková,* 2005).

The possible connection between C IV enhanced emission and non-thermal distribution has been studied. C IV flare intensities vary by factor of 3400 over pre-flare levels. This anomalous intensity enhancement can be explained by the presence of the non-thermal distribution with the enhanced number of particles in high energy tail. The synthetic spectrum for this type of the distribution has been computed. The observed enhanced emission of C IV resonance lines of the transition region (TRACE) is compared with location of magnetic structures (SOHO/MDI) and with the intersection of quasi-separatrix layers with photosphere (*Dzifčáková et al.*, 2005a).

Hα and EUV filaments (Astronomical and Geophysical Observatory, FMFI UK, Slovakia, TRACE 195 Å, respectively) associated with C-class flare have been observed in active region NOAA 10 582 on March 31, 2004. Several shorter threads were lying almost along the inversion line creating the longer filament seeing in absorption. The part of filament interacted with dark loop of near arch filament system during C-class flare. The X-ray images (Solar X-ray Imager) have been used to identify the hottest part of flaring filament. The SOHO/MDI longitudinal photospheric magnetogram has been used for the potential and linear force-free field extrapolation of magnetic field of the active region. The structure of the extrapolated magnetic field has been compared with observed EUV and Hα structures and a possible reconnection scenario has been suggested (*Dzifčáková et al.*, 2005b).

The modification of CHIANTI software and database has been developed for computation and analysis of synthetic spectra for non-thermal distributions (*Dzifčáková*, 2006a).

Computation was done different kinds of non-thermal distributions in the solar corona. New diagnostics of this type of distribution for iron in EUV region (*Dzifčáková,* 2006b; *Tóthová and Dzifčáková*, 2006) and for Si in X-ray region was suggested (*Dzifčáková and Kulinová*, 2006). X-ray diagnostics applied on RESIK flare spectra shows that during rising phase of a flare, large deviations of electron distribution function from the Maxwellian one appear (*Dzifčáková and Kulinová*, 2006). The presence of the non-thermal kappa

distribution can explain the unusual spectral line enhancements and Doppler-shifts of spectral lines in solar transition region (*Doyle et al.*, 2006).

The spectral line emission of coronal loops observed in active regions by SOHO/EIT has been modeled by using of 3-D magnetic field structure obtained from potential and/or linear force-free field extrapolations. Values of temperature and density have been computed using the energy balance equation together with equation of hydrostatic equilibrium. The computed emission in EUV spectral bands of SOHO/EIT filters was compared with observations to test density and temperature model (*Dudík et al*., 2006).

The positions of current kernels obtained from vector magnetograms together with maps of kinetic helicity and vorticity at several depths below the photosphere have been studied. The positions of vertical current kernels do agree with positions of observed flare kernels in UV continuum as it is widely believed. The maxima of kinetic helicity are not located directly below the vertical current kernels but they are still in their vicinity (*Kulinová et al.,* 2006).

The dynamics of cosmic particles with the energies well below those of cosmic rays and well above those of solar wind (from few tens of keV up to several MeV) has been studied by the ***Institute of Experimental Physics, SAS, Košice*** (its Department of Space Physics) in the co-operation with the laboratories abroad, as well as, with the P. J. Šafárik University and Technical University Košice. In addition, the measurements of secondary cosmic rays observed by ground-based facilities were analyzed.

Data from cosmic ray continuous measurements by neutron monitor at Lomnický Štít with 1 min resolution are now available in real time at http://neutronmonitor.ta3.sk. The modulation of cosmic rays in the heliosphere and sensitivity of neutron monitor to galactic cosmic rays was studied. Connections between cosmic rays, solar variability and space weather effects, as well as temporal evolution of quasiperiodicities in cosmic ray records were examined (*Kudela et al.*, 2003ac; *Kudela et al*., 2005b; *Kozlov et al.*, 2003a,b; *Kudela and Storini*, 2003; *Kurilchik et al.*, 2003; *Laštovička et al.,* 2003; *McKenna-Lawlor et al*., 2003; *Miyasaka et al.*, 2003; *Minarovjech et al.*, 2004; *Storini et al.,* 2005; *Spurny et al.*, 2005; *Kudela et al.,* 2005b; *Kudela and Storini,* 2006). The geomagnetic effects on cosmic rays have been checked by methods of trajectory computations in model geomagnetic field (*Bobik et al.*, 2003a,b,c; *Kudela and Usoskin,* 2004). Besides the transmissivity in the disturbed magnetosphere also the estimates of its changes during the past

period using available magnetic field representations were computed for different regions at low orbit (*Bobik et al.*, 2005).

Variation of cut-off rigidity in last two thousand years at the Earth were calculated together with evaluation of global approach of cosmic rays to Earth surface in mentioned period (*Kudela and Bobik*, 2004). Galactic cosmic ray modulation during last five solar cycles was investigated in (*Sabbah and Rybanský,* 2006).

The cosmic-ray time series were compared with the green 530.3 nm coronal emission line intensity over the period 1951–2003. The cross-correlations between the cosmic rays and Wolf sunspot number over the period 1951–2003 were also presented (*Minarovjech et al.*, 2004).

The research was focused on the analysis of the data obtained both from the low altitude and high apogee satellites, as well as on the development and construction of new instruments for the future studies.

Multispacecraft studies using also DOK-2 data (Interball-1) were used to describe the motion of the magnetopause due to the variations of interplanetary magnetic field (*Blecki et al.*, 2005). The detailed energy spectra by DOK-2 instruments on Interball-1 and 2 showed many cases of dispersive velocity events. Those can be used for remote timing and identification of the place of particle injection during geomagnetic disturbances. The dependence of the dispersive events occurrence on altitude, L and magnetic local time was obtained. A case study by DOK-2 during a small substorm when Interball-1 was near the reconnection point in the central magnetotail region, has shown the strong changes of ion flux anisotropy and fast change of energy spectra when the satellite crossed the neutral sheet (*Blecki et al.*, 2003; *Chang et al.*, 2003; *Kecskeméty et al.*, 2003; *Kurilchik et al.*, 2003; *McKenna-Lawlor et al.*, 2003).

Results on the analysis of measurements by CORONAS I satellite were summarized in (*Bučík and Kudela*, 2003). About 40 high energy solar gamma ray emissions were identified from the 2002-2003 data. Large amount of measurements on low altitude polar orbiting satellite CORONAS-F (from August 2001 until December 2005) measuring the energetic particles both electrically charged as well as gamma rays and neutrons was analyzed in cooperation with Skobeltsyn Institute of Nuclear Physics, Moscow State University, Russia. Results using data from the SONG M measuring the energetic gamma rays and neutrons (its electronic part was designed, constructed and tested in the Department) on CORONAS F are presented in (*Bogomolov et al.*, 2003; *Kuznetsov et al.*, 2003a,b; *Kuznetsov et al.*, 2006a;

Ermolaev et al., 2005ab; *Kuznetsov et al.*, 2005b). From the experiment SONG onboard CORONAS-I satellite the fluxes of γ rays and their connection to radiation belt electrons were studied (*Bučík et al.,* 2005a).

The analysis of AMS-01 measurements in order to select secondary particles by the calculation of particles trajectories in the magnetic field was performed (*Bobik et al.*, 2006). The investigation of experimental data of electron fluxes with energies E_e = 30 480 keV at L = 1.2 1.8 in wide altitude interval from 500 up to 1500 km (data from the ACTIVE satellite) was carried out. The comparison with results obtained onboard other satellites reveals that the borders of electron registration zones under the radiation belts of the Earth at middle latitudes coincide (*Grachev et al.*, 2005). Multispacecraft studies using also DOK-2 data on Interball-1 were used to describe the motion of the magnetopause due to the variations of interplanetary magnetic field (*Blecki et al.*, 2005) A case study of Geotail, Interball-1, IMP-8, and Wind observations of density and magnetic field strength cavities excavated by the enhanced pressures associated with bursts of energetic ions in the foreshock was presented. The comparison of conditions upstream from the pre- and post-noon bow shock demonstrates that foreshock cavities introduce perturbations into the oncoming solar wind flow with dimensions smaller than those of the magnetosphere (*Sibeck et al.*, 2004). Statistical study of large amount of upstream ion events by DOK-2 has shown that for the diffusive upstream events observed near the bow shock there is much higher probability of observing high flux of protons for quasi-parallel connections to the model bow shock than for the cases with quasi-perpendicular geometry. The relative importance of the two possible sources of the seed particles, namely those of solar wind ions and particles leaking from magnetosphere was described up to 300 keV on the large data set (*Kudela et al.*, 2005a; *Prech et al.*, 2005ab; *Prech et al.,* 2006). A case study (DOK-2 data) during a small substorm, when Interball-1 was near the reconnection point in the central magnetotail region, had shown the strong changes of ion flux anisotropy and fast change of energy spectra when the satellite crossed the neutral sheet (*Slivka and Kudela,* 2005). Relations of energetic particle fluxes to plasma characteristics (Interball) in the foreshock region as well as in the magnetosheath were examined (*Hayosh et al.*, 2005).

Unusual cases of field-aligned current and their connection to the outer magnetosphere according DOK-2 and IMAP magnetometer data in the north-altitude cusp have been analyzed (*Bochev and Kudela*, 2005).

An intense hard X-ray enhancement associated with lightning flashes in the conjugate hemisphere was explained as a result of electron precipitation into the Earth's atmosphere (*Bučík et al.*, 2006).

Radio bursts in the frequency range 100-1500 kHz and fluxes of energetic electrons recorded onboard Interball-1 satellite during prominent chromospheric flares were studied. The time of propagation of the electrons to the Earth was estimated (*Kurilchik et al.*, 2006). The results of a case study of quasi-periodic ELF/VLF hiss emissions detected on board the Freja and Magion 5 satellites are in (*Pasmanik et al.*, 2004). Examination of electron fluxes during the March-April, 1994 in atmospheric drift loss cone shows that inward radial transport is important in building up of relativistic electrons in the Earth radiation belts (*Bučík et al.*, 2005b). Electron flux formation at middle latitudes was studied in (*Grigoryan et al.*, 2006).

The case study of the wave measurements and gamma rays diagnostic performed on board CORONAS-I shows a possible correlation between enhancements of whistler wave activity and soft gamma rays related to seismic activity (*Rothkaehl et al.*, 2006). Computations of geomagnetic transmissivity for selected periods with different disturbances of the magnetosphere were carried out for different models of the external magnetic field using neutron monitor and satellite measurements (*Kuznetsov et al.*, 2006b).

Emissions of high energy solar gamma rays in late October and in November 2003 (*Kuznetsov et al.,* 2005a; *Veselovsky et al.,* 2004; *Ermolaev et al.,* 2005a; *Watanabe et al.*, 2005). Solar gamma emission with energy 0.05-300 MeV was analyzed using SONG data measurements onboard the CORONAS-F satellite during a solar flare of 20 January 2005. The strong anisotropy of protons enhancements was discussed and a pitch angle distribution of high energy proton fluxes in interplanetary space was estimated (*Kuznetsov et al.*, 2006c).

The investigation of the relativistic electron fluxes dynamics in outer radiation belt using MKL device measurements on CORONAS-F satellite within intervals of 22 strong magnetic storms during years 2001-2004 has revealed that during these magnetic storms the maximum of the electron fluxes shifts earthward in the slot region (*Slivka et al.*, 2006).

The IEP SAS participated in the development and construction of experiments realized by the University of Maynooth, Ireland and STIL Ireland, namely Electrical Supporting System for the mission ESA-ROSETTA and the Ireland's national instrument NUADU (NeUtral Atom Detector Unit) for China's Double Star Polar Mission (Principal Investigator Susan McKenna-

Lawlor) for the polar mission of the project (joint project of ESA and Chinese Acad. Sci.). The objectives (*McKenna-Lawlor et al.*, 2005a) are focused on processes controlling the ring current characteristics and monitoring of space weather effects in the magnetosphere. After the launch the instrument started to work correctly according to the expectations based on tests before the launch. The first examples of events with energetic neutral atom emission indications have been found (*Lu et al.*, 2005; *McKenna-Lawlor et al.*, 2005ab).

At the ***Faculty of Mathematics, Physics and Informatics of the Comenius University, Bratislava (Department of Nuclear Physics and Biophysics)*** the modeling of cosmic-ray induced cosmogenic nuclides and gamma ray production was under way.

A number of meteorites were studied from the point of view of cosmogenic nuclide production. Results of these studies were used for determination of their origin, exposure age, terrestrial age and other characteristics. Relation between Martian atmosphere and regolith composition was studied by investigation of neutron-capture produced cosmogenic nuclides that were used as tracers of exchange processes between surface and atmosphere. For Jupiter moon Europe, we evaluated the production of rare gasses and their possible use for determination of exposure ages of the Europe surface. At present we are involved in preparation of Mars Smart Lander mission experiment measuring in situ production of cosmogenic nuclides (*Kollar et al.*, 2003ab; *Masarik and Wieler*, 2003; *Masarik et al.,* 2003; *Swindle et al*., 2003; *Welten et al.*, 2003ab).

We participated in Mars Odyssey mission experiment with gamma ray and neutron spectrometer. Our contribution was in simulation of expected gamma ray fluxes and comparison of our simulation with obtained experimental data. Based on this, algorithm for deconvolution of measured spectra into chemical composition of surface was developed. For this mission we carried out simulations of gamma ray production and transport from the point of origin to the detector. About two hundred different chemical compositions were supposed and simulated. The results of simulations were used for the study of dependence of production rates of gamma rays on chemical composition, water content and thickness of atmosphere. Results of our simulations are used for physical interpretations of measured fluxes of gamma rays and neutrons escaping from the surface of Mars. For validation and benchmarking our simulations thick target experiment simulating the cosmic ray protons bombardment of martian surface was carried out a few years ago. Finally we

got to the interpretation of this experiment. In collaboration with colleges from LPL in Tucson and from UNM Albuquerque we carried out simulation of production of rare gases at the surface of Europe and carried out study for prospects of in situ chronology (*Swindle et al.*, 2005).

A number of meteorites were studied from the point of view of cosmogenic nuclide production, their exposure histories, and other effects and processes occurring in the parent bodies (*Schersten et al.*, 2005; *Kim et al.*, 2005; *Qin et al.,* 2005). Results of these studies were used for determination of their origin, exposure age, terrestrial age and other characteristics. Relation between Martian atmosphere and regolith composition was studied by investigation of neutron-capture produced cosmogenic nuclides that were used as tracers of exchange processes between surface and atmosphere. For Jupiter moon Europe, we evaluated the production of rare gasses and their possible use for determination of exposure ages of Europe`s surface. At present we are involved in preparation of Mars Smart Lander mission experiment measuring in situ production of cosmogenic nuclides.

Traditionally various aspects of solar-terrestrial physics were studied at the **Geophysical Institute of the Slovak Academy of Sciences.** Recently the study of the Sun-Earth interactions has been carried out from the viewpoint of space weather and its variability.

The plausible association of dynamical characteristics with turbulent processes in solar dynamo was shown (*Vörös et al.*, 2003b). The neural network approach made it possible to distinguish the regularities/irregularities in formation of a magnetospheric disturbance and then to judge the geoefficiency of intermittent fluctuations. The incorporation of the contribution of fluctuations and other singularities into the development of magnetic storms led to an enhanced performance level of prediction schemes applied (*Jankovičová and Vörös*, 2003a). A classification scheme for changing level of space weather disturbances was proposed on the basis of local descriptors of singularities and their global distributions (*Vörös et al.*, 2003a). The multi-scale description of disturbances has proven to be analogous to the regularity/irregularity description of fluctuations, both leading to an enhanced performance level of prediction schemes (*Jankovičová and Vörös*, 2003b). An evaluation of the nonlinear methods for aims of prediction of magnetic storms, including different ANN architectures, outlining their significance in space weather studies was provided (*Jankovičová,* 2003).

The attention was paid to non-linear processes in the Sun-Earth system. The analysis of non-linear characteristics of the magnetic field was carried out and it was shown that interplanetary disturbances with a significant portion of intermittent fluctuations are more geoeffective (*Jankovičová and Vörös,* 2004a). To better understand the relative contribution of intermittence to the efficiency of solar wind–magnetosphere coupling the correlations between the fluctuations and the mean values of some geoeffective parameters were investigated. The kea role of intermittence in the interaction processes between the solar wind and magnetosphere was shown for intervals of enhanced disturbances (*Dorotovič and Vörös,* 2004ab).

The identification of characteristics of nonlinear fluctuations of the studied physical parameters at the Sun, in the solar wind and within the different regions of the Earth's magnetosphere allowed to construct a generic picture of multiscale couplings for the plasma processes in the Sun-Earth system. According to results obtained the primary solar energy is non-homogeneously and intermittently distributed within the solar atmosphere and in the solar wind over magnetohydrodynamic time and spatial scales. On mezo- and microscales, the non-homogeneous distribution of the energy also influences the interaction processes between the solar wind and the Earth's magnetosphere. As to qualitative multiscale and intermittent characteristics, magnetic fluctuations in the polar regions of the Earth and within the magnetotail and fluctuations in the solar wind are similar. However, scaling features typical only for the Earth's magnetosphere are also presented (*Jankovičová, Vörös*, 2004bc).

A new neural network (NN) model for prediction of Kp indices during geomagnetic storms was proposed. The NN model based on the one-hour averages of solar wind parameters Bz, n, and V measured at libration point L1 was proposed. Altogether 34 networks were considered for pairs of values for the number of hidden nodes and length of input vectors as chosen taking into account results of the validation test. Within the final test of the NN model the prediction profiles during three storm intervals on 26–29 August 1998, 18–22 October 1998, and 7–11 November 2004 were performed. The averaged statistical parameters indicate quite good coincidence of observed and modeled Kp values. The comparison with results of modeling based on three-hour averages gives evidence that in case of NN model based on the one-hour averages the more accurate Kp predictions during the selected storm intervals were obtained (*Valach and Prigancová,* 2005; *Valach et al.*, 2006ab).

The analysis of the magnetic storm development was realized within the multilateral co-operation on the ISSI (International Space Science Institute,

Bern) project *How to quantify the solar wind-magnetosphere coupling*. The various aspects of modeling of the magnetospheric magnetic field during magnetic storms were discussed. The satellite data of monitoring the geomagnetic field (GOES data) and space measurements of particle precipitation (DMPS data) were used for the modeling of global magnetic disturbances. Within the frame of international co-operation the 24–26 September 1998 intense magnetic storm was analyzed in detail. Its modeled profile replicates the storm development in a better way when the significant contribution of the magnetotail current to the Dst variation is taken into account. Its enhanced magnetic effect can be explained by the tail current sheet shifting to deep L shells (up to ~4 R_E) during the storm main phase (*Feldstein et al.*, 2005, 2006a).

The new approaches were stated to be needed to describe magnetic fields in the magnetosphere more precisely. Their calculation on the basis of the so-called paraboloid model with its time-dependent input parameters is a way to estimate the contribution of individual magnetospheric current systems to the Dst variation (*Prigancová and Feldstein,* 2003).

To quantify the magnetospheric response during the magnetic storms the analysis of two high-speed solar wind streams from solar ejecta (interplanetary ejecta CMEs) with regard to the development of storm variations with depressions of –85 nT and –205 nT was carried out. The high time resolution data on solar wind parameters (CDA Web WIND database) and on Sym-H (WDC for Geomagnetism, Kyoto) were used. As shown, the internally generated current systems are an integral part of the solar wind-magnetosphere interaction and the magnetospheric response cannot be accurately represented without their inclusion (*Feldstein et al.*, 2003).

The study of dynamics of plasma precipitation boundaries location at ionospheric altitudes improves our understanding of the magnetospheric magnetic field variability and promotes its more adequate modeling. Empirical relationships to calculate the plasma precipitation boundary location are representative for both magneto-quiet and disturbed conditions. The results reported can be used for aims of space weather forecasting (*Prigancová et al.,* 2005).

The cause-and-effect links regarding the formation of a global magnetospheric disturbance due to variability of the sun (geoeffective solar wind and interplanetary magnetic field parameters) were considered. The dynamics of current systems (polar, westward and eastward electrojets as well as field-aligned currents) at high latitudes was studied on the basis of ground-

based and satellite data. Results of the analysis of variations in the location and intensity of the auroral electrojets during magnetic storms and substorms were obtained using a numerical method for estimating the equivalent ionospheric currents based on data from meridian chains of magnetic observatories. It is shown that the westward electrojet adjoins to the polar electrojet located at cusp latitudes in the dayside sector. The association of electrojets with the field-aligned currents (FACs), namely Region 1 FAC and Region 2 FAC is considered. During intense disturbances a Region 3 FAC (accompanied by diffuse electron precipitation from the plasma sheet boundary layer) with the downward current was identified. The analysis of observational data is summarized in terms of 2D time-space distribution of electrojets at ionospheric altitudes. The magnetic field sawtooth variations generated during the storm main and early recovery phases are also discussed. To follow 3D currents in the magnetosphere-ionosphere system a clarified view of interrelated 3D currents and magnetospheric plasma domains is presented (*Feldstein et al., 2006bc*).

   Using measurements of the geomagnetic field variations along three meridian magnetometer chains at spanned longitudes, the location of polar, eastward, and westward electrojets at high latitudes of the Northern hemisphere was determined during intervals of magnetic disturbances. Based on a regularization method to solve an underdetermined system of linear equations for densities of currents flowing across a chain, the intensities of equivalent ionospheric currents were calculated. If polar coordinates CGL-LMT (corrected geomagnetic latitude – local magnetic time) are used, the westward and eastward electrojets are located along three truncated spirals. The westward electrojet flows along the morning and night spirals, and the postnoon-evening spiral corresponds to the eastward one. The westward electrojet spirals are located nearby the auroral oval. The postnoon-evening spiral is located in the region of diffuse auroral precipitation. The new features in location of spirals are revealed and discussed. It is shown that magnetic disturbances along the postnoon-evening spiral are attributed not only to processes in the inner magnetosphere since during midday hours this spiral is mapped on the magnetopause. The night and morning spirals do not construct the closed oval. Between prenoon and postnoon hours, there is a gap between spirals at latitudes of the daytime cusp. In this time sector the polar electrojet is located just at these latitudes. In addition, the spiral distribution of most intense magnetic disturbances in daily variations of geomagnetic activity are

considered and compared with that of high-latitude electrojets (*Prigancová et al.,* 2006).

The results of the extensive analysis of changes of most known meteorological characteristics (air temperature T and precipitation totals P) from the chosen sets from the world-wide network of meteorological stations were summarized. As shown, the modulation of the T and P profiles by solar forcing on the time scale of cyclic and secular changes appears to be apparent in spite of some irregularities can be indicated. Due to non-linearity of the climatic system these irregularities can be explained in terms of its limiting behavior which allows the transition from a regular regime to chaotic oscillations by means of the Feingenbaum mechanism (*Prigancová,* 2004).

In the ***Department of Astronomy, Physics of the Earth and Meteorology, Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava,*** the analysis of the height-dependent response of the ionosphere was continued. By means of numerical simulations the effects of the Solar Proton Events (SPE) in October 1989 were studied. It has been shown that the relative abundance of cluster ions (composition parameter f^+) as well as the recombination parameter is reduced for about two weeks after SPE. Calculated values of recombination parameter for the October 1989 SPE support the idea that the effect of SPE depends on season (*Ondrášková et al*., 2003). The height-dependent response of the ionosphere was analyzed with regard to solar cosmic rays variability. Data on solar proton fluxes measured by satellites "Meteor" were used for calculations of ionization rates. GOES 7 1–8 Å X-ray fluxes were used as well as electron density enhancement after the October 1989 SPE was as much as three orders of magnitude at 50–60 km. Simulated response of the lower ionosphere to solar energetic particles for different seasons showed that the increase of electron density was greater for July 2000 SPE than for the October 1989 SPE. This result is in agreement with cosmic noise absorption measurements. Strong contribution of neutral species changes after SPEs seems to be the main factor for seasonal character of the ionospheric response to SPEs. The model simulations of the D-region ion composition and electron density response to strong solar proton events were based on measurements (GOES 8 satellite) of SPE fluxes and X-rays fluxes (*Ondrášková and Krivolutsky*, 2003; *Ondrášková*, 2005). Simulations showed that during SPE relative abundances of negative ion species change. Concentrations of final ion NO_3^- were found lower than concentrations of CO_3^- and CO_4^- during first two nights of the October 19 1989 SPE (*Ondrášková and*

Krivolutsky, 2005). Recent simulations of a single SPE showed a difference in summer and winter polar cap response. In summer the increase of electron concentration is lower than in the winter likely due to greater pre-SPE concentration in the sun-lit summer polar cap. The enhancement lasts shorter in the winter polar cape due to different chemistry in the absence of light (*Ondrášková et al.,* 2006).

Measurements of the Schumann resonance frequencies (first 4 modes at about 7.8, 14, 20 and 26 Hz) at Modra Observatory were analyzed with respect to the strong solar energetic proton flux in October 2003. For the determination of the onset of perturbations, satellite data from GOES 11 were used. No significant effect on frequencies or amplitudes was revealed (*Ondrášková et al.*, 2005).

In summary, STP studies reported contribute to our understanding of the space-time dynamics of solar activity and the corresponding magnetospheric response. The deeper insight in these links is of immense importance for adequate forecasting of the space weather influencing the high-tech society activities.

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Report to IAHS

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Catchment and river processes: experimental research and mathematical modeling

Attempts to increase the understanding of hydrological processes on various scales have been the focus of the international scientific community in recent years. Studying hydrological processes on small as well as large temporal and spatial scales, understanding land-atmosphere interactions, studying the impact of land use and climate change on the hydrological cycle and water resources, etc., have been centers of interest. International and interdisciplinary co-operation was seen as one of the prerequisites for success in this development. This report reviews the response of hydrologic research in Slovakia to these trends. The results of the main research programs in hydrology from 2003 to 2006 are reviewed and references provided.

Problems in the dynamics of water balance, material and nutrient transport in the atmosphere – plant canopy – soil aeration zone – groundwater system

Estimation of the components of the water balance in lowland forests and agricultural ecosystems, the interpretation of infiltration, evaporation, transpiration, capillary inflow and the seepage of water into lower horizons by means of monitoring and mathematical modeling resulted in an advanced quantitative analysis of the water balance equation. The methodical aspects were tested and verified under the conditions of the Ray Island (Žitný ostrov) and the East Slovakian Lowlands. Evapotranspiration from agricultural canopies and its distribution over the territory of Slovakia were analyzed and modeled. The relationship between transpiration and nutrient uptake dynamics in plant canopies, which is applicable to the modeling of the soil's chemical balance, was studied. The spatial and temporal variability of the soil's hydraulic conductivity was studied as a function of the percentage of effective pores (i.e., pores through which water and solute are transported), and the

bypassing ratio was estimated during the whole growing season in order to predict the transport of agrochemicals or pollutants in surface-vented macropores in the course or after a heavy rainstorm. Laboratory and field research on the shrinking and swelling processes in heavy soils was conducted on the East Slovak Lowlands. Relationships between the volume changes in these soils and the soil water content, fractions of various soil particle sizes, and density were derived. These can be used to estimate crack porosity, the net formation of cracks, subsidence of the soil's surface, and the potential for linear extensibility (*Novák,* 2003; *Novák and Vidovič,* 2003; *Novák, Hurtalová and Matejka,* 2005; *Novák and Havrila,* 2006; *Mikulec and Stehlová,* 2006; *Skalová,* 2005; *Skalová, Šútor and Štekauerová,* 2003; *Skalová, Štekauerová and Šútor,* 2004; *Štekauerová, Šútor and Farkaš,* 2003; *Štekauerová and Šútor,* 2004; *Štekauerová,* 2004; *Štekauerová, Šútor and Mikulec,* 2005; *Štekauerová and Nagy* 2006; *Šútor and Gomboš,* 2006).

The distribution of groundwater salinity characteristics (electrical conductivity and the sodium adsorption ratio) were studied in the southeast Danube Lowlands, which are classified as bearing highly mineralized waters with the consequence of a high degree of salinization of the subsurface environment. The spatial variability of the salinity and sodicity in the shallow mineralized groundwater was also assessed by kriging and visualised in the form of maps on a regional scale (*Burger and Čelková,* 2003a,b).

Radioactive tracer techniques for estimating the share of cadmium adsorbed on soil particles smaller than <0.01 mm and a modified Tessier sequential analysis were used in studies of the soils from several sites. It was determined, that in the first phase of the cadmium–soil contact, a very rapid sorption of cadmium on small particles with a higher content of clay minerals and humic substances takes place, which is predominantly electrostatic and reversible. In the next phase of the process, a much slower fixation of cadmium takes place in the coarse-grained fractions of soils with a simultaneous desorption of cadmium from reversible, exchangeable sites on the surface of fine-grained particles. This sorption is irreversible and leads to immobilization of the cadmium in the soils. Numerical modelling was used to analyze the transport of cadmium in soils from an extreme rainfall event. It was demonstrated that cadmium may percolate below the root zone within a short period of time ((*Lichner et al.,* 2006a; *Dušek et al.,* 2006).

Soil water repellency was studied at several sites on actual soils. It was demonstrated, that microscopic soil fungi can only create a small (sub-critical) degree of soil water repellency with their hyphae and exudates, because the

soils also include constituents alleviating the water repellency (e.g., kaolinite and calcite). But in pure sand, some microscopic soil fungi (e.g. *Penicillium expansum*) and the addition of heat can result in extreme water repellency with a water drop penetration time longer than 3600 s. It was also found from an analysis of the results obtained after a cycle of wetting and drying at 50ºC, as well as incubation at 50, 100, 150, 200, 250 and 300ºC, that the addition of kaolinite and Na-montmorillonite resulted in a drop in the persistence of the water repellency of the model material (sand covered with stearic acid), but the addition of illite and Ca-montmorillonite resulted in an increase in the persistence of the water repellency (*Ďugová et al.,* 2005; *Dlapa et al.,* 2004; *Lichner et al.,* 2006b).

The groundwater research was mainly oriented on the influence of human activities on the natural groundwater regime and surface-groundwater interactions in the lowland areas of Slovakia. Several studies were concerned with the interrelationship between the surface waters and the groundwater under withdrawal. Numerical groundwater models were used for the analysis, prediction and control of groundwater levels on several water structures in Slovakia in order to suggest technical measures that could be used to improve the groundwater regime even in extreme hydrologic conditions. (*Fendeková et al.,* 2005; *Fendeková and Nemethy,* 2005; *Gavurník, 2006; Krčmář,* 2005; *Šoltész,* 2006; *Šoltész and Baroková,* 2006a,b,c; *Baroková,* 2006; *Baroková and Šoltész,* 2006).

The quantitative aspects of groundwater formation and regimes were also studied in several regions. Transboundary flow modeling was applied in the Morava river catchment. Utilisation of geothermal resources in the Slovak Republic for the period 2000-2004 was catalogued. Estimates of usable geothermal water amounts in the locality of Oravice were established *(Fendek and Fendeková,* 2005a,b; *Fendek et al.,* 2005*)*.

River processes and sediment transport

Qualitative and quantitative investigations of the effect of river morphology on ichthyological fauna in both natural and regulated segments of selected rivers were conducted. The composition of fish species, the diversity of species, the abundance and biomass of particular species, the mean individual weight and the ichthyomass were monitored during the spring and autumn seasons. Factors affecting the density of a fish population were specified. It was observed that in a natural stream segment, the number and diversity of

species and the equitability indices were higher than in regulated ones (*Macura and Ivančo,* 2003; *Macura and Škrinár*, 2003a,b, 2004, 2005, 2006).

Several projects focused on the study of river and floodplain processes (flow regimes, development of river channels and floodplains, sediment transport). Special focus was placed on the lower Morava River, where by means of numerical and physical models, the negative impacts of river regulation and other human interventions on the environmental quality of the river and the adjacent protected landscape area were analysed. The studies were also aimed at evaluating the effect of previous river training and the efficiency of recently implemented river restoration measures. Morphologically stable and environmentally sensitive river training measures were proposed with the aim of supporting the creation of a natural range of instream and bankside habitats for fisheries, flora and fauna, and protecting the wetland ecosystem of the lower Morava river against continuing degradation and for sustainable flood protection (*Holubová and Lisický,* 2003; *Holubová, Hey and Lisický,* 2005; *Koníček, Miklánek and Pekárová,* 2004).

River process and sediment transport studies on the Danube River based on extended field measurements and surveys were focused at the identification of changes in the sediment transport regime resulting from the operation of the Freudenau and Gabčíkovo hydropower schemes. The impact of river training, dredging and other human interventions on the riverbed of the Danube were also analysed with regard to the possible morphological development of the riverbed in the future (*Holubová, Capeková and Szolgay,* 2006; *Holubová,* 2006; *Holubová and Capeková,* 2006; *Majerčáková et al.,* 2006; *Turbek et al.,* 2006).

The flood protection and forecasting research included re-evaluation of the probabilities of flood occurrences on the Danube and Morava Rivers in Slovakia with respect to anthropogenic influences, and the development of new hydrological flood routing models and flood routing model comparisons. The changes in flood travel times on the Danube and Morava Rivers were also studied with respect to the flow regime (*Lukáč et al.,* 2004, 2006; *Mitková et al.,* 2005; *Szolgay,* 2004a,b; *Szolgay, Danáčová and Papánková*, 2006a,b).

Regionalization and mapping of hydrological phenomena and variables

The creation of an extensive GIS-based database of physiographic characteristics of the small basins of Slovakia permitted a number of new and comprehensive hydrogeographical and hydrological regionalization studies.

Various approaches in the application of regional regression equations in hydrogeography and hydrology were analyzed. Data from 129 catchments in Slovakia were used to derive the relationships among mean annual runoff, precipitation and air temperature. The relationships were subsequently used to delineate seven homogenous regions. Six regional types of the long-term hydrological balance were identified using the mean annual precipitation and mean altitude of the basins as differentiating factors (*Holko et al.,* 2004; *Solín,* 2003, 2004).

The identification of hydrometeorological and hydrological regional classes from the point of view of the definition of the basic spatial units, the formulation of the regional taxonomic problems and an evaluation of the hydrological response of the regional classes using the rules of regional taxonomy was systematized. The growing number of stream-gauging stations and rain gauges in small basins and the extension of data records made it possible to examine how some of the new concepts of regional homogeneity reported in the literature perform in the regional frequency analysis of floods and extreme rainfall and in the estimation of their respective design values for engineering purposes. Also, regional and at site approaches to frequency analysis were compared in these studies (*Mitková, Kohnová and Pekárová,* 2004; *Pekárová et al.,* 2006). In particular, annual and seasonal maximum one-to-10 day precipitation depths in several regions were studied. N-year values of the maximum precipitation depths were estimated at-site and regionally by using several distribution functions. Although the number of statistically acceptable distribution functions was found to be rather high in the region, a comparison of the resulting design precipitation values estimated from these distribution functions showed that these did not exhibit any significant differences. (*Kohnová, Szolgay and Gaál,* 2004; *Kohnová et al*., 2005; *Kohnová et al.,* 2006).

The subjective division of Slovakia's population of small basins into four regional types for regional frequency analysis, identified in the space of basin characteristics by logical principles, was proposed. Regional approaches based on the Hosking and Wallis methodology were also applied to annual and seasonal maximum flood data from more than 260 basins in Slovakia. Other studies dealt with the regional frequency analysis of one-to-five days' maximum annual and seasonal precipitation.

Various physiographic properties of basins, rainfall and flood runoff characteristics were used as factors for the differentiation of homogeneous regions and regional types (pooling groups). Several methods for the definition

of homogeneous regions and regional types were tested. Aspects under which the concept of regional homogeneity can be used in the regional frequency analysis of floods and extreme rainfall under the rather heterogeneous runoff-generating conditions in Slovakia were studied and discussed (*Kohnová and Szolgay,* 2003; *Kriegerová and Kohnová,* 2005; *Solín,* 2005a,b). The results of this research were also summarised in the monograph *Kohnová, Szolgay, Solín and Hlavčová* (2006).

Estimation of the spatial patterns of hydrological processes is particularly difficult in mountain regions, where data are sparse and the spatial variability of the governing processes and properties of the hydrological environment is high. *Pecušová et al.* (2004, 2005) used manual fitting of semivariograms to calculate the areal precipitation of a large mountain basin by means of kriging with external drift. A spherical semivariogram was the most frequent theoretical model, and the spatial correlation among the 65 stations typically existed within a distance of 40-60 km. *Petrovič et al.* (2006) presented the results of work on the water balance of the Danube basin, including maps of the mean water balance components (mean annual precipitation, runoff and actual evapotranspiration during the period 1961-1990).

Methods for transferring model parameters from gauged to ungauged catchments are needed in water resources modelling studies in poorly gauged regions. Although a great deal of experience has been gained from using parameter estimation methods for ungauged catchments, there is a continuing need to upgrade these methods and test them against practical requirements, since the problem of regional parameter estimation still constitutes the largest obstacle to the successful application of models in ungauged catchments. Rainfall-runoff model parameter regionalization was attempted in *Szolgay et al.* (2003); *Kohnová, Zvolenský and Jazudek* (2004); results from several studies were summarized in *Kohnová, Szolgay, Solín and Hlavčová* (2006).

Several studies were aimed at the development of methodologies for the spatial interpolation of hydro-meteorological data for hydrological mapping and rainfall runoff modeling and design discharge computations (e.g., *Danihlík and Hlavčová*, 2004; *Szabo, Kalaš and de Roo*, 2004; *Szolgay, Parajka and Hlavčová*, 2005; *Kohnová, Hlavčová and Parajka,* 2006; *Kohnová, Szolgay, Solín and Hlavčová,* 2006).

Catchment processes, water quality and land use impacts on runoff

Snow hydrology research was mostly oriented towards distributed simulation of snow accumulation and melt using both energy-based and temperature-index approaches. A comparative study by *Holko et al.* (2003) showed that both approaches provided similar results in the mountain catchment studied. Model parameterization was more important than the basic approach to snow accumulation and melt modeling. The model which considered the effect of a forest on radiation reduction and snow drift performed better in the forested areas.

Point simulations of snow accumulation and melt were used to test two parameter optimization methods – PEST and genetic algorithms (*Holko et al.,* 2003). Genetic algorithms showed an existence of equifinality in the snow cover modeling. The multi-objective MOSCEM techniques were used in a follow-up study to account for the uncertainty of the simulation by providing the "lowest" and "highest" estimates of snow water equivalent (*Holko and Parajka*, 2004). In the same study, measured snow temperatures were used to constrain the parameters of the snow model.

Spatial and temporal variations of snow water equivalent in a large mountain catchment over 40 hydrological years were analyzed by *Pecušová et al.* (2004) and *Lapin and Faško* (2005). A follow-up study (*Holko et al.,* 2005) assessed the impact of climate change on the snow water equivalent in the same catchment and catchments that form the headwaters of the main Slovak rivers.

A spatially distributed hydrological model was used to estimate the impact of severe forest damage on snow accumulation and melt and the hydrological response of mountain catchments of varying scales (*Kostka et al.,* 2005). The study did not confirm any significant changes in the snow water equivalent in deforested areas.

The validation of snow models by means of satellite images was tested by *Holko et al.* (2005). Due to very frequent cloudiness, long series of images are necessary to test the performance of a snow model in even relatively large (1767 km^2) mountain catchments.

Kostka et al. (2005) presented the results of a study focused on the development of snow cover in the forest. *Kyselová et al.* (2006) informed about the snow hydrology activities in operational hydrology.

Kostka and Holko (2003) analysed daily-to-10-minute rainfall-runoff data from a small mountain catchment during the period 1989-2001. The analysis

proved the rapid response of catchment runoff to rainfall. The spatial distribution of precipitation did not seem to affect the response. Rainfall amounts were the most important factor influencing the response. On the other hand, pre–event saturation of the catchment was not strongly related to runoff response. The analysis indicated the existence of a threshold of about 40 mm of rainfall initiating the runoff response.

Holko et al. (2006) reported on the results of monitoring nitrates in a mountain catchment (October 2003-April 2005). Water samples collected at the outlet of the mountain part (almost no human activities) had lower concentrations of nitrates than samples collected downstream in the rural area. The differences were smaller during the warm period of the year. The highest concentrations of nitrates and the highest differences among the uninhabited and inhabited areas were observed at the time of snowmelt. Samples collected along the creek in March and April 2005 showed increasing concentrations with an increasing population. Concentrations of nitrates measured during the springs of 1992, 2004 and 2005 were in a similar range.

Continuous observation programs in experimental basins in the mountains and research plots along the Danube floodplain permitted an analysis of the diurnal and seasonal courses of several components of the hydrological cycle. Relationships, which allowed for the estimation of the transpiration rates, evapotranspiration, interception and sediment transport indirectly from the meteorological measurements and physiographic data, were studied and determined (*Halmová, Miklánek and Pekárová,* 2006a,b; *Halmová, Pekárová and Miklánek,* 2006; *Liu et al.,* 2005; *Miklánek et al.,* 2004; *Miklánek* and *Mészároš,* 2006; *Miklánek and Pekárová,* 2006).

Long-term changes in the water balance, including sediment and nutrient transport, in the experimental catchments of the Institute of Hydrology of the Slovak Academy of Sciences were investigated with respect to land use and societal changes. The balance of nitrates in the water cycle was evaluated for the Rybárik agricultural experimental basin and the forested Lesný experimental basin in several studies. The variability of suspended sediment loads was studied in the Rybárik basin in detail. The nitrate balance, defined as the difference between the input from atmospheric water (precipitation) and the output of the basin (runoff), showed typically positive values in the agricultural basin, while negative values were found to occur in the forested basin as of 1989. These results indicate that a forested basin may have purifying effects on surface water. The data on insoluble matter concentrations during diverse runoff events was used to derive empirical polynomial

relationships between insoluble matter concentrations and specific yields (*Miklánek, Koníček and Pekárová,* 2003, 2005; *Miklánek,* 2006; *Sebíň, Pekárová and Miklánek,* 2006). The results of the water quality research and research estimating land use impact changes in the experimental basins of the Institute of Hydrology of the Slovak Academy of Sciences were summarized in a monograph by *Pekárová, Koníček and Miklánek* (2005).

The impact of land use on stream water quality was analyzed using the observed water quality data from the regular network of the Slovak Hydrometeorological Institute and from experimental basins. A higher frequency sampling of the data (daily, for a duration of several years) was used for a more precise estimation of the pollutant loads and their temporal variations in surface streams. Empirical relationships and long-term trends were derived for the estimation of the concentrations and loads for several water quality constituents, which will serve the purpose of the implementation of the EU WFD in Slovakia (*Miklánek and Pekárová*, 2005; *Pekárová et al.,* 2004; *Pekárová, Pekár and Miklánek,* 2006).

The prototype for an affordable system for monitoring water pollution was constructed in the EC 5th Framework Program Project "System for European Water Monitoring" SEWING (http://www.sewing.mixdes.org). It is based on new types of Ion Selective Field-Effect Transistors which are selectively sensitive to various polluting ions. A large variety of non-organic polluting ions can be detected with a broad range of sensitivity to ion concentrations. This makes the sensors suitable for various types of water resources (*Holko et al.,* 2005, 2006; *Lichner et al.,* 2004).

A very high number of large flash floods caused by extreme precipitation have occurred in recent years in Slovakia. These events were individually investigated, and the formation of the floods in ungauged basins was reconstructed using data from at site hydrological surveillance and available data from the hydrological and meteorological network together with radar and satellite data. An assessment of the historical floods in the rivers of the Bodrog River Basin in East Slovakia was preformed. (*Lapin and Hlavčová,* 2003; *Lapin, Hlavčová* and *Petrovič,* 2003; *Miklánek, Halmová and Pekárová,* 2003; *Šťastný and Majerčáková*, 2003; *Pekárová, Halmová and Mitková,* 2005).

Recent extreme flood events in Europe have also stimulated public discussion on the issue of whether the frequency and severity of floods have been increasing and if such changes could be attributed to anthropogenic influence. The effect of deforestation on runoff is another important issue, which is frequently discussed between environmentalists, hydrologists and

77

water resources managers. In several studies the question has arisen as to how distributed parameter models are suited to predict the hydrological effect of land use change and if their parameters and structure can have an adequate physical interpretation, since the availability of a spatially distributed data such as digital elevation model, land use, and soil information makes the use of distributed models convenient. The impact of the historical (potential) natural vegetation on runoff formation was estimated; in particular, changes in the long-term mean annual runoff and its components, mean monthly discharges and changes in maximal mean daily discharges were analyzed. Strategies for the estimation of rainfall-runoff model parameters were discussed. Simulated runoff changes were confronted with expert judgments and estimates from the literature. Limitations in the use of distributed models for estimating land use change impacts were discussed (*Bahremand et al.,* 2005a,b; *Hlavčová et al.,* 2004, 2005, 2006; *Kalaš, Feyen and Vrugt,* 2006; *Kohnová and Zvolenský*, 2004).

As a consequence of some devastating floods, the performance of several current flood-forecasting methods was also evaluated. A pressing need to increase the standard of forecasts in cases of floods striking larger territories, rivers with regulated flows and local flood events (flash floods) has been identified. In response, the Government of the Slovak Republic in 2001 approved a national program for flood protection, which will run till 2010. As a part of this program the "Flood Warning and Forecasting System of Slovakia (POVAPSYS)" project, which is aimed at considerable innovations in flood warning and forecasting practices, started in 2003. Within this framework a number of recent studies dealt with the development forecasting models (*Babiaková et al.,* 2005; *Babiaková and Lešková,* 2005; *Hlavčová et al.,* 2004; *Kalaš et al.,* 2004; *Ramos et al.,* 2006; *Szabo, Kalaš and de Roo*, 2004; *Szolgay,* 2004a,b; *Majerčáková et al.,* 2004b; *Mitková et al.,* 2005; *Szolgay, Danáčová and Papánková*, 2006a,b).

Runoff fluctuations and research on the impact of climate change

The expected impact of climate change in general, vulnerability assessments and adaptation measures for Slovakia were summarized in the Fourth National Communication on Climate Change (*Balajka et al.,* 2006; *Szemešová et al.,* 2006); an overview of the impacts on climate-related sectors of the hydrosphere and biosphere are given in *Pekárová* (2004).

Time series of precipitation and runoff were analyzed in several studies in order to detect climate change signals in the data series. The precipitation totals and air temperature series were analyzed using statistical methods. Their long-term variability and also that of the runoff series of Slovak rivers as well as rivers in the temperate zone of the Northern Hemisphere and the sub-tropic and equatorial zones were also analyzed with the aim of estimating the main cycles of the series. The analysis detected a time shift in the occurrence of runoff extremes in the regions of the world studied. Special attention was paid to the detection of teleconnections in the region of Central Europe and the modeling of time series (*Auer et al.,* 2007; *Komorníková et al.,* 2006; *Lapin and Hlavčová,* 2003; *Lapin,* 2004; *Lapin et al.,* 2005; *Pekárová,* 2003; *Pekárová, Miklánek, and Pekár,* 2003; *Pekárová and Miklánek*, 2004; *Pekárová, Miklánek and Pekár,* 2006; *Pekárová and Pekár,* 2006). *Holko et al.* (2006) analysed the long-term daily runoff data (1962-2001) from three mountain catchments in central Europe. The analysis did not confirm the hypothesis on the increasing frequency of high flows.

Local and regional hydrological droughts and the water balance of sensitive areas such as agricultural land and wetlands was studied in this respect in several papers (*Juráková and Klementová,* 2003, 2004; *Klementová, Lischtmann and Látečka,* 2003; *Klementová and Lischmann,* 2004a,b; *Litschman and Klementová,* 2004; *Majerčáková et al.,* 2004a; *Pekárová and Miklánek,* 2004). As a result of the EU FP5 project "Analysis, Synthesis and Transfer of Knowledge and Tools on Hydrological Drought Assessment through a European Network" (ASTHyDA) a textbook was edited by *Tallaksen and van Lanen* (2004) with the contribution of Slovak co-author *Fendeková* to chapters 3 and 9.

Several analogous and General Circulation Model (GCM) based climate change scenarios were constructed for the 2010, 2030 and 2075 time frames within the framework of the Slovak National Climate Program. The construction of physically plausible scenarios of monthly and annual time series for air temperature, precipitation and air humidity was also attempted. The outputs of CCC M1, CCC M2 and GISS98 GCMs with coupled systems of atmospheric and ocean circulation were downscaled to the territory of Slovakia. Attempts to design scenarios of extreme monthly and daily precipitation totals for selected time frames (2010, 2030, 2075) began (*Lapin et al.,* 2003; *Lapin and Melo,* 2004; *Lapin et al.,* 2006a,b)

According to these scenarios, a significant increase in annual temperature (2-4°C), small changes in long-term precipitation totals, and a remarkable

increase in short-term precipitation extremes (20-50%) are expected in Slovakia in the warm half-years up to the 2075 time frame. On the other hand, more frequent and longer periods of drought will occur, mainly in the Slovak lowlands. Higher precipitation and a warmer climate in winter will significantly affect the winter runoff and snow regime on most of the territory of Slovakia.

The Turc model has been selected for determining the impact of climate change on mean annual flows. Grid maps of the long-term average precipitation, temperature evapotranspiration and runoff yields have been constructed based on this model for the whole territory of Slovakia. Map algebra methods in a GIS environment were employed to compute the areal averages of expected changes in runoff for the climate change scenarios. Regions with different degrees of climate change risk were defined (*Danihlík et al.,* 2004; *Hlavčová et al.,* 2006).

Several spatially lumped conceptual hydrological rainfall-runoff models were also used in the climate change impact studies. The models were calibrated under a variety of different hydrologic situations in a number of catchments, which represent a wide spectrum of runoff regimes. Scenario-driven simulated runoff from different models exhibits a similar character of expected changes in the seasonal distribution of mean monthly flows.

According to the results of these studies, mean monthly discharges should increase in the winter low-flow period; spring flows could (partly substantially) decrease in the northern parts of Slovakia. Flow regimes in the summer and autumn will show stationary behaviour with moderate decreases in runoff. The extremity of the decrease in mean monthly flows accelerates with the widening time horizon of the scenarios. In the southern areas the scenarios show a tendency towards the creation of a stable dry period with low flows substantially below the values from the baseline time series. September remains the month with the lowest mean monthly discharges, despite the slight increase in flows in this month. The whole territory of Slovakia could become more vulnerable to drought in the summer and the autumn (*Szolgay et al.,* 2003; *Danihlík et al.,* 2004; *Danihlík and Trizna,* 2005; *Hlavčová et al.,* 2006).

Basic strategies for the adaptation processes in water resources management in order to account for climate change impacts were suggested. These include a recommendation for transforming natural hydrologic resources into managed resources. Interannual and seasonal redistribution of water and the territorial redistribution of runoff from the north to the south will have to be considered in order to compensate for the expected water shortage in the

south of Slovakia. Revitalization programs for watersheds in order to slow down runoff from the upper parts of basins and restoration projects of existing river training schemes will have to be implemented. Forestation and forest protection in the northern parts of Slovakia will also become increasingly important (*Hlavčová and Kohnová,* 2005; *Hlavčová et al.,* 2006).

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The Slovak National Committee for IAHS

The Slovak Committee for Hydrology (SCH) was established under the leadership of the late Dr. Ľudovít Molnár after the division of the former Czechoslovakia in 1993. It has formed its own bodies, statutes, bye-laws and has been accredited by the Slovak Academy of Sciences (SAS). The SCH is affiliated with the Institute of Hydrology of the SAS. The president of the SCH is Dr. Pavol Miklánek.

The SCH is responsible for all the activities of Slovak hydrologists within the framework of the International Hydrological Program of UNESCO, and it co-ordinates the regional co-operation of the Danubian countries. According to the Statutes of the SCH, it also supports and integrates the activities of Slovak hydrologists in the IAHS serving as a National Committee.

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Report   to   IAMAS

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Comparing the previous Report to IAMAS predominantly the reviewed papers published in Slovak Journals and monographs are presented in this review. We consider that these sources can contribute to spread more effectively national scientific information abroad. It is an advantage that except the textbooks and papers for education all cited contributions have been published in English language.

Weather forecast, modelling of atmosphere processes

This field of meteorology has widely developed in Slovakia mainly since 1990, when new computer technology was installed at the Slovak Hydrometeorological Institute (SHMI), new education subjects have been established at the Comenius University and collaboration with the METEOFRANCE on Aladin Arpege atmospheric models has started. The progress in this field can be clearly seen also from the titles of selected attached references (*Bašták,* 2005; *Derková,* 2005; *Drinka,* 2005; *Gera*, 2004; *Káčer and Káčer,* 2003; *Martíni*, 2003; *Simon et al.,* 2005)

Upper atmosphere meteorology, ozone, UV radiation and aerosols

Many papers on this topic have been presented at conferences and workshops, we selected only five of them published in reviewed meteorological journals. All papers are partly based on dissertations and research results of young scientists (*Bičárová,* 2004; *Kremler and Sojáková*, 2004; *Kremler,* 2005; *Pribulová*, 2005; *Štefánik*, 2004). Ground ozone is regularly measured in Slovakia at about 8 stations only since 1993 (now about 20 stations in Slovakia), presented papers represent the overview of 5-15 year observations and the first attempt in ground level ozone forecast. The Observatory at Stará Lesná and the SHMI branch at Gánovce are specialized

97

also on solar radiation measurements and analyses, including the UV-B fraction (*Pribulová et al.*, 2005).

Climatic changes and variability

Climatic changes and variability can be studied in Slovakia using monthly climatic time series since 1881 (3 air temperature stations, areal precipitation totals and about 20 precipitation stations), series from 203 precipitation stations and other elements from several stations since 1901. Daily precipitation totals and daily temperature means have been edited in computer format series from several stations since 1951, from all stations since 1961 and at the Hurbanovo Observatory from 1871. Detailed studies on precipitation and other climatic elements variability in Slovakia, including daily total extremes and seasonality changes, have been prepared mainly at the Slovak Hydrometeorological Institute and at the Division of Meteorology and Climatology, KAFZM, Comenius University (*Gaál,* 2005; *Faško et al.*, 2003; *Hrvoľ,* 2006; *Lapin et al.,* 2005a; *Lapin,* 2004) and at the SAS Institute of Geophysics (*Ostrožlík,* 2003). It is beneficial that also researchers from other institutions started to study variability of climatic elements and its cross-comparison with other elements (hydrologic at Slovak University of technology, *Kohnová et al.*, 2005; biologic at Forestry Faculty in Zvolen, *Škvarenina et al*., 2004).

Radiative processes in the atmospheric boundary layer

Based on measurements of the diffuse radiation at the Skalnaté Pleso and Stará Lesná Observatories the influence of the atmospheric boundary layer on the diffuse radiation flux density is studied. The suitable position of the both sites enables to investigate the time and vertical variations of the diffuse radiation in average as well as in case of the clear skies and the low clouds. Different altitudes as well as the various topographical conditions at the both localities are manifested in the different diffuse radiation sums (*Ostrožlík,* 2004a; 2004b). Using the experimental data at two high-mountain levels at Skalnaté Pleso and Stará Lesná situated the transformation of the solar radiation in the atmospheric boundary layer is studied. The measurements of the radiation fluxes and sunshine duration, as well as the observations of the cloud amount were completed by the measurements of the air temperature and the air humidity. These data enable to study the radiative heating rate as well as the emissivity of the atmospheric boundary layer caused by absorption of

the direct solar radiation in the investigated layer (*Ostrožlík and Smolen*, 2003, 2005). *Hrvoľ et al.* (2003) present complex elaboration of calculated radiation balance characteristics by original physical model and measurement of other climatic elements from 31 meteorological SHMI stations in Slovakia during the period 1951-2000.

Meteorology of the surface layer of the atmosphere

Results of microclimatic profile measurements carried out above a maize stand were analyzed with aim to quantify the influence of plant canopies on air temperature near the surface. The available experimental data confirmed the theoretical assumptions that changes in the leaf area index and canopy resistance affect the thermal stratification in the surface layer of the atmosphere. The impact of expected climate change on the structure of the energy balance of a spruce forest were estimated using an experimentally verified mathematical model simulating the exchange of heat and water vapor between the spruce forest and the atmosphere. Results of performed model simulations indicated that the physiological control of transpiration can play an important role as a factor with stabilizing effect on energy balance of forests and consequently on their microclimate. The aerodynamic characteristics of the atmospheric surface sublayer above selected field crops were determined, simultaneously with corresponding surface resistances. Changes in the roughness length and zero plane displacement with wind speed were analyzed. Detail results of such research were presented in the previous IAMAS Report. Now we contribute to this topic by five selected papers (*Hurtalová et al.,* 2005; *Matejka et al.*, 2003ab; 2004ab). These papers represent the prolongation of mentioned research and summarize the results from international experiments, mainly with the Czech colleagues. Comparable activities have been carried out also at the Forestry Faculty and the Forest Research Institute in Zvolen (*Tužinský et al.,* 2004).

Snow in mountainous environment

Requirements of regular snow cover information have been applied mainly from selected ski centers, hydrology resorts and avalanche precaution centre. Snow cover depth is regularly measured at the Slovak climatological/precipitation stations since 1921. At the SHMI a continual completion and quality control of series from about 500 stations is realized since 1991. That is why nearly every year some preliminary or final results are

published. Now just two papers are cited (*Lapin et al.,* 2005b; *Vojtek et al.,* 2003), at conferences and proceedings several other results published by these authors can be found. *Ostrožlík* (2005) opened relatively new topic – icing formation analysis in Slovak mountains. Such analysis was not published in Slovakia several decades. Also the avalanche conditions research can be considered as relatively new at the Comenius University (*Vojtek*, 2005). This research contributes to the knowledge how the snow cover depth acts with respect to meteorological elements especially in the late winter season, this could be useful mainly for hydrologists, sport activities (tourism) and for avalanche control.

Air pollution

The monitoring of regional air pollution and precipitation quality in the Slovak Republic under the two international programmes ECE EMEP and WMO GAW started in 1977. Five background monitoring stations were put in operation. A very evident drop in concentrations of sulphur compounds in air as well as in precipitation was recorded. A clear decrease in heavy metal concentration in aerosols, particularly lead, was monitored. An annual average increase in ground level ozone in Slovakia about 1 $\mu g.m^{-3}.yr^{-1}$ was observed for a period 1969 – 1992, but no trend was identified in the 1990s. On the other hand a decrease in ozone extremes was recorded in the last decade. Downward trends of the most regional air pollution indicators correspond well to the Slovak and European emission reductions. The sensitivity of the air pollution model for car traffic was introduced. Obtained results have shown that the input parameters of the model: the height of the built-up area around the street, the width of the street canyon, and the wind speed, should be given as exact as possible. The constant emission factors, independent of the speed of cars are use at the contemporary Slovak methodology of the air pollution calculation from the road traffic. Presented selected papers represent a brief overview from many papers on these topics. The selection was made with respect to cover all problematic – mercury (*Brežná et al.*, 2003), lead (*Szabo*, 2004), radioactivity (*Sojáková,* 2003; *Melicherová,* 2006; *Závodský,* 2006), polycyclic aromatic hydrocarbons (*Szabóová,* 2003) and other pollutants (*Kazakovič et al.*, 2004; *Spišáková et al.*, 2003; *Szabo*, 2003, 2006).

Methods of measurements and data quality control

Meteorological and other elements measurements and observations in mostly provided by the SHMI (Slovak Hydrometeorological Institute, *Chvíla*, 2003; *Novanská et al.*, 2005; *Zahumenský*, 2006), some activities have been carried out also within international collaboration with the Central European countries (*Auer et al.*, 2007). *Lišková* (2006) started relatively new problematic as young scientist and obtained very valuable results on hail measurements by radar.

Regional climatic studies

Except the Climatic changes and variability some research have been carried out also in the field of regional climatic studies. Selection of four papers does not cover all results. *Kohnová et al.* (2004) published new method of 5-day precipitation total elaboration for hydrologic use. *Snopková* (2003) analyzed within her dissertation air temperature characteristics in important hollow in Central Slovakia. *Szolgay et al*. (2005) applied the GIS method on annual evapotranspiration evaluation in any region in Slovakia. *Tomlain* (2004) regularly contribute to water balance characteristics evaluation in Slovakia, now the humid conditions (soil moisture) are presented.

Climate change scenarios, impacts and adaptive options

The first climate change scenarios for Slovakia were prepared within the Slovak National Climate Program (NCP) and the Country Studies Program (CS) projects in 1991-1997. In 1998 a new stage of such activities started at the Division of Meteorology and Climatology (Comenius University in Bratislava) under collaboration with the Slovak Hydrometeorological Institute adopting outputs of new General Circulation Models (GCMs) with coupled systems of atmospheric and ocean circulation (coupled GCMs) that offer output of monthly data (each year months starting January 1900) for 46 climatic elements at the Canadian GCM CCCM1997 and CCCM2000 and for 59 elements at the U.S. GCM GISS98, but only for individual years and monthly means for decades starting January 1990. Climate change scenarios have been calculated taking into account 4 closest GCM gridpoints round Slovakia and measured data at a set of stations in Slovakia in the reference period 1901-1990 or 1951-1980. For precipitation totals different scenarios for individual stations were designed using weighting interpolation method. At all other climatic elements only one scenario for the center of Slovakia was

preferred, because of negligible areal differences (up to 0.2°C at temperature). More details can be found in papers and the chapters of the NCP monographs in 1994 to 2001. Now a representative selection of 11 papers from many other papers and contributions is presented. *Balajka et al*. (2005) present in this monograph a comprehensive review from the climate change research since 2001 when the 3rd Slovak National Communication on Climate Change was issued. This report was sent also to the UN FCCC centre and is available in the FCCC web site. *Lapin et al.* (2003ab, 2004, 2006ab) present in selected papers the results on climate change scenarios design in Slovakia, including heavy rains scenarios assessment. *Szolgay et al*. (2003), *Pekárová et al.* (2005) and *Škvarenina et al*. (2004ab) analyze in their papers possible impacts of climate change on different socio-economic sectors in Slovakia up to the year 2100. *Szemesová* (2004) presents some more information on greenhouse gases emission inventory in Slovakia compared to the 4th Slovak National Communication on Climate Change.

Phenology and climate

The first study on phenology phases and climatic elements correlation in Slovakia has been presented in 2000. Since that several papers have been published, some also on possible impacts of supposed climate change. In this review we included only two selected papers. *Gomoryová* (2004) tries to identify impacts of topographic and climatic factors change on Norway spruce stands. *Špánik et al.* (2004) continue their research on climate change scenarios apply on the shift of phenologic phases, now at grapevines.

Education in meteorology and climatology

In Slovakia about 200 meteorologists and climatologists work in different branches at present, mainly at the SHMI. Beside them several hundreds of students and other specialists are interested in meteorology and climatology because of their profession or hobby. That is why every year several papers and textbooks are issued for education purpose, nearly all only in Slovak language. In this selection just three of them are shown. *Gaál* (2003) presented a procedure how to obtain scientific information on meteorology and Climatology from libraries via Internet, *Lapin* (2005) informs in details on the Earth's climate system theory by the method understandable also by non physically educated people (this paper is available also in web site) and *Špánik et al.* (2004) published comprehensive textbook on Bioclimatology for students

in Slovak Agricultural University (this textbook is acceptable also for students in forestry or other technical branches).

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Report to IASPEI

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Numerical modeling of seismic wave propagation and earthquake ground motion

Equivalence of the GZB and GMB-EK rheological models for eismic wave attenuation

After publications by *Emmerich and Korn* (1987) and *Carcione et al.* (1988a,b) authors who implemented realistic attenuation in the time-domain methods decided for either of two rheological models – generalized Maxwell body (GMB, classical Maxwell bodies plus one Hooke body connected in parallel - as defined by Emmerich and Korn) or generalized Zener body (GZB, classical Zener bodies connected in parallel). Two parallel sets of papers and mathematical formalisms developed during the years. *Moczo and Kristek* (2005) have found no explicit comment in tens of published articles on the other rheology. Therefore, they review both models and show that, in fact, they are strictly equivalent. One implication is that the two parallel streams of papers and development of incorporation of the realistic attenuation into the time-domain methods should be reviewed and compared in terms of unifying and simplifying the whole relevant theory, including curve-fitting procedures.

Moczo and Kristek (2005) have not found in the reviewed publication except Carcione (2001) the correct relaxation function for the GZB. A likely explanation is that authors simply took the wrong formula the work of *Liu et al.* (1976). It may be a good idea that the authors check their implementations of the GZB.

Moczo and Kristek (2005) also derived new – material-independent – viscoelastic functions (memory variables) which are necessary if the coarse spatial sampling of the viscoelastic functions is applied in order to reduce additional memory requirements due to incorporation of the attenuation.

Comparison of the conventional, staggered-grid and optimally-accurate finite-difference schemes

Kristek and Moczo (2006) presented a heterogeneous FD scheme, Doptm2, based on the application of the optimally accurate operators developed by *Geller and Takeuchi* (1998) to the heterogeneous strong formulation of the equation of motion developed by *Moczo et al.* (2002) for the 1D problem. They numerically compared Doptm2 with two other schemes - Dconv2 based on the application of standard conventional 2nd-order FD operators to the heterogeneous strong displacement formulation of the equation of motion for the 1D problem, and DSstag4 based on the application of the staggered-grid 4th-order operators to the heterogeneous strong displacement-stress formulation of the equation of motion for the 1D problem.

The numerical comparisons were performed for three types of models – homogeneous space, two halfspaces in contact, and an interior layer with a strong velocity gradient. The accuracy of the numerical solutions was quantified by evaluating the envelope and phase misfits (*Kristeková et al.*, 2006) with respect to the exact analytical solutions.

The main conclusions may be summarized as follows:

Error of the FD schemes due to the grid dispersion in a homogeneous medium:

The error of Dconv2 (or, equivalently, DSstag2) considerably increases with distance due to the grid dispersion (except for the stability ratio $p = 1$ for which the scheme is accurate); the error can be reduced by drastic increase of the number of grid spacings per wavelength (N) and using the maximum possible stability ratio.

The error of DSstag4 grows considerably with distance for N and large p ; for a chosen N the error can be reduced by using sufficiently small p for which the sum of the envelope and phase misfits takes the minimum value.

The error of Doptm2 is negligible compared to those of Dconv2 and DSstag4. Despite the formal 4th-order accuracy of DSstag4, for $p = 0.95$ the errors of both DSstag4 and Dconv2 as functions of N have the same convergence rate, -2, whereas that of Doptm2 is -4.

While adjustment of the stability ratio p value in DSstag4 is possible in the homogeneous medium (at a price of a small fraction of the maximum possible time step), it is not possible in general in the heterogeneous medium.

Error at the interface:

The error is primarily controlled by the boundary condition and its numerical approximation.

The error weakly grows with the velocity contrast.

The 4th-order of DSstag4 does not improve the accuracy compared to the 2nd-order schemes.

The arithmetic averaging of elastic moduli yields significantly lower accuracy compared to the harmonic averaging.

Error away from the interface:

For a given N the error of DSstag4 can be reduced by using an adjusted small value of the stability ratio p (and consequently small fraction of the maximum possible time step) only in the case of sufficiently small velocity contrast; in the case of moderate or large velocity contrast the error can be reduced only using sufficiently small spatial grid spacing.

Despite the formal 4th-order accuracy of DSstag4, the spatial sampling criterion cannot be weaker than that of the formally 2nd-order accurate Doptm2.

Error inside the strong velocity gradient layer:

The errors of Dconv2 and Doptm2 are comparable, the error of DSstag4 is larger mainly for small N (i.e., larger grid spacings) likely due to the relative large spatial extent of the operator (large stencil).

The general conclusion is that Doptm2, that is the scheme applying *Geller and Takeuchi's* (1998) 2nd-order optimally accurate operators to the strong heterogeneous formulation of 1D equation of motion of *Moczo et al*. (2002), is significantly more accurate than the schemes based on the application of the conventional 2nd-order and staggered-grid 4th-order operators.

Fundamental formulations, FD targets, and optimally-accurate finite-difference schemes

Moczo et al. (2007a) developed alternative formulations for the 3D canonical problem with a welded material interface - strong formulation, weak formulation, integral strong formulation, and discontinuous strong formulation. Then they specified the alternative formulations for the 1D canonical problem with a welded material interface. They applied the formulations to the free surface and welded material interface, and obtained corresponding finite-difference (FD) targets. The alternative formulations led, in principle, to two basic types of FD targets. They compared FD approximations to the two types of the targets and showed why it is advantageous to FD approximate the second type.

Moczo et al. (2007a) found conventional FD approximations which are 2nd-order accurate at the grid point at the free surface and material interface. They

defined criteria for deriving 2nd-order optimally accurate FD approximations to the obtained FD targets, and found corresponding 2nd-order approximations.

Moczo et al. (2007a) numerically investigated the effect of the same order of approximation applied at grid points at and away from the interface using four FD schemes - Dconv2 (conventional, 2nd-order in the homogeneous medium, 1st-order at the interface), Dconv2i2 (conventional, 2nd-order in the homogeneous medium, 2nd-order at the interface), Doptm2 (optimally accurate, 2nd-order in the homogeneous medium, 1st-order at the interface), and Doptm2i2 (optimally accurate, 2nd-order in the homogeneous medium, 2nd-order at the interface). They compared the obtained FD solutions against exact solutions using the time-frequency-analysis based envelope and phase misfits. The numerical comparison showed that the application of the 2nd-order of approximation also for the grid point at the interface clearly reduced error at the interface compared to the schemes which are only 1st-order accurate at the interface.

The 2nd-order finite-element and 4th-order staggered-grid finite-difference implementation of the TSN method for dynamic rupture propagation

Kristek et al. (2006) and *Moczo et al*. (2007a) developed four implementations of the TSN method (Traction-at-Split-Node method) for simulation of the rupture propagation: three implementations in the staggered-grid (SG) velocity-stress FD scheme and one implementation in the FE method.

In all three SG FD implementations 4th-order centered approximations are used for spatial derivatives at grid points at distances equal or larger than $3h/2$ from the fault plane. The three implementations differ from each other by approximations used for spatial derivatives at grid points close to the fault plane and grid points directly on the fault plane. These differences are indicated by the acronyms we will use for the implementations:

SG FD 2nd-order:

 2nd-order at grid points close to the fault plane and grid points on the fault plane,

SG FD mixed 2nd-order -- 4th-order:

 2nd-order at grid points close to the fault plane and 4th-order at grid points on the fault plane,

SG FD 4th-order:

 4th-order at all grid points.

FE 2nd-order:

The FE implementation is the 2nd-order accurate everywhere.

Kristek et al. (2006) and *Moczo et al*. (2007a) performed a series of numerical simulations of spontaneous rupture propagation on a planar fault in a homogeneous unbounded elastic medium. In order to have a reference solution they followed *Dalguer and Day* (2007) who used Version 3 of the Southern California Earthquake Center (SCEC) benchmark problem *Harris et al.* (2004).

Simulations differed in values of the used spatial grid spacing and time steps. The goal was to see an effect of the spatial sampling on the level of accuracy of the simulations. The DFM0.05 solution by *Day et al.* (2005) was taken as the reference solution. DFM means Day's implementation of the TSN method in the partly-staggered grid, 0.05 means 50 m large grid spacing. Individual solutions are graphically compared. For each our numerical simulation the root-mean-square (RMS) misfit between the rupture-propagation times in the obtained solutions and the rupture-propagation times in the DFM0.05 solution over the whole ruptured area was evaluated. The comparison of the RMS misfits for the four implementations of the TSN method lead to conclusion that the FE 2nd-order implementation of the TSN method has the highest rate of convergence while the rate of convergence of the SG FD 4th-order implementation is the lowest. It has to be noted that the performed comparison does not really compare the relative accuracy of the individual implementations. This is because the chosen reference solution DFM0.05 cannot be a priori taken as the most accurate solution. Thus only the convergence rates for the particular choice of the reference solution are in fact compared. At the same time it is likely that DFM0.05 is a reasonably accurate solution.

The 3D finite-difference – finite-element hybrid modeling

The FE method more easily incorporates boundary conditions at the free surface and material interfaces compared to the FD method. This is especially true about non-planar surfaces and interfaces. From this point of view the FE method is better suited for simulation of the traction-free condition and rupture propagation. On the other hand, the 4th-order staggered-grid FD scheme is computationally more efficient if the seismic wave produced, e.g., by the dynamically rupturing fault, are to be propagated away from the fault. It is therefore very natural to think of a hybrid combination of the two methods if we want to comprise both the dynamic earthquake source and the wave propagation in the complex heterogeneous medium. *Moczo et al*. (1997)

combined 2nd-order conventional FD scheme with the 2nd-order FE method for the 2D P-SV modeling of seismic motion in the near-surface sedimentary/topographic structure. *Ma et al*. (2004) combined the 4th-order velocity-stress staggered-grid scheme with the 2nd-order FE method for the 2D P-SV modeling.

Moczo et al. (2007a) combined the 4th-order velocity-stress staggered-grid scheme with the 2nd-order FE method for the 3D modeling of earthquake motion in the heterogeneous viscoelastic medium with the free-surface topography and with, optionally, kinematic (point or finite) or dynamic earthquake source. A part of the computational domain with the free-surface topography or dynamically rupturing fault can be covered by the finite elements. In principle the whole computational domain can involve several FE regions. Obviously, the FE region should be as small as possible. The rest of the computational domain is covered by the FD grid.

The interiors of the FE and FD regions are updated independently by the FE and FD schemes, respectively. The FE and FD regions communicate at each time level at the contacts of the regions, that is, in the FD-FE transitions zones. The transition zone is the region where the FD and FE grids overlap. The FD-FE transition zone consists of three distinct parts - the FE Dirichlet boundary, averaging zone, and FD Dirichlet zone. The local thickness and (staircase) shape of the FD Dirichlet zone is determined by requirement that the particle-velocity at the grid interface between the averaging zone and FD Dirichlet zone be calculated using the 4th-order velocity-stress staggered-grid FD scheme for an interior grid point.

Clearly, the question is how thick the averaging zone should be. This was estimated using extensive numerical tests of behavior of the FD-FE transition zone. The numerical test showed that the smallest possible thickness of the averaging zone, one grid spacing, considerably improves accuracy compared to the algorithmically minimal transition zone (without averaging zone) and yields sufficiently accurate results.

The behavior of the transition zone was also investigated for the case of presence of a material interface crossing the zone, and for a possible numerical interaction with a dynamically rupturing fault.

The developed 3D FD-FE hybrid method seems to be a powerful tool for numerical modeling of earthquake motion in complex viscoelastic heterogeneous media due to dynamically rupturing fault.

Numerical simulations of seismic motion in the Volvi basin, Thessaloniki, Greece

Numerical simulations of seismic wave propagation were performed for the preliminary 3D model and several hypothetical local earthquakes for the area of the Volvi basin near Thessaloniki, Greece. Simulations indicate considerable 3D effects in the basin which has been considered as a 2D structure by previous researchers. The northern sources with the S-wave radiation in the north-south direction generate slow Love waves that propagate in the east-west direction. The Love waves dominate the wavefield in the sediments in later times that was also confirmed by the Time Frequency Analysis (TFA) applied to all numerically simulated wavefields. The generation and propagation of the surface waves in the basin seems to be quite robust phenomenon whose intensity mainly depends on the focal mechanism.

Standard spectral ratios (sediment-to-bedrock reference site) were calculated for previous 2D simulations along the Profitis-Stivos profile and 3D simulations. The Profitis site was used as a reference site. Spectral ratios for east-west and north-south components of displacement, as well as for arithmetically and geometrically averaged horizontal components of displacement were determined. The spectral ratios show considerable differences between the 2D and 3D simulated motions. As anticipated, the largest differences were obtained for the NS component – the one on which energetic slow Love waves were found in the 3D simulations.

The 3D effect indicates that 2D simulations for the Volvi basin cross-sections may have very limited meaning.

Real records from an artificial explosion performed in 2003 at the BRG site were compared with the synthetic seismograms from numerical simulation of the explosion. The comparison showed that the preliminary 3D model gives considerably earlier arrivals of the S and surface waves. This means that at least the S-wave velocity in the homogenous-sediment model is considerably overestimated. Likely this is true mainly for the upper part of the sediments. The partial conclusion was that it is necessary to modify the velocity model of the sediments.

The modification of the model is based on the available map of the fundamental frequencies in the H/V spectral ratios obtained by analysis of the seismic noise recordings, and map of the sediment-bedrock interface (that is, in the computational model, sediment thickness). Under the assumption that the H/V dominant frequencies correspond to the frequencies of the fundamental mode of the local 1D vertical resonance, the local value of the frequency and

thickness can give the local S-wave velocity distribution. Given the uncertainty and scatter of the data, only one S-wave velocity distribution with depth was determined for the whole basin using all data. The least-square-method was used to fit the set of values in the frequency-depth plane. The vertical S-wave velocity distribution in the sediments was assumed in the form $V_S(z) = V_0 + \alpha (z/z_0)^\beta$, where z is the depth of sediments and V_0, α, β, z_0 are parameters. In addition to the whole-basin S-wave distribution, 4 other distributions were determined for the northern, southern, eastern and western parts of the basin. For each of these distributions only data from the corresponding parts of the basin were used. The best level of agreement was found between the whole-basin distribution and that in the central part of the previously found 2D velocity distribution along the Profitis-Stivos profile.

Indicative 2D finite-difference modeling for the BRG explosion profile shows much better agreement between arrival times in real records in numerical synthetics for the modified model with a S-wave velocity gradient. A 3D modeling has to be performed to properly check the possibility to use the modified model for the further earthquake motion modeling.

Time-frequency misfit criteria for comparison of seismograms

Kristeková et al. (2006) have developed and numerically tested quantitative misfit criteria for comparison of seismograms. The misfit criteria are based on the time-frequency representation of the seismograms obtained as the continuous wavelet transform with the analyzing Morlet wavelet. The misfit criteria include time-frequency envelope and phase misfits, time-dependent envelope and phase misfits, frequency-dependent envelope and phase misfits, and single-valued envelope and phase misfits.

Properties of the misfit criteria were tested using canonical signals and also relatively complicated synthetics obtained by several numerical methods. The canonical signals, taken as the reference signals, were specifically amplitude, phase-shift, time-shift, and frequency modified in order to demonstrate the ability of the misfit criteria to properly quantify and recognize the character and cause of the misfit between the reference and modified signal.

The numerical tests for pure amplitude modification imply the following conclusions:
- the maximum values of the envelope misfits are proportional to the level of the modification; they exactly equal the percentage of the modification if the entire signal in the time domain is multiplied by some (constant) coefficient,

116

- in the latter case, the all phase misfits are zero because there is no phase modification of the reference signal,
- the misfit exactly equals the single-valued envelope misfit.

The numerical tests for pure phase-shift modification imply the following conclusions:
- the maximum values of the phase misfits are proportional to the level of the phase-shift modification; they exactly equal the percentage of the modification if the time-dependent phase of the analytical signal is shifted by the same value at each time,
- in the latter case, the all envelope misfits are zero because there is no amplitude modification of the reference signal,
- the misfit is approximately three times larger than the single-valued phase misfit.

The misfits were also calculated between the reference signals and modified signals obtained by simple shifting along the time axis or by a small change of the signal's dominant frequency. In all cases the misfit criteria properly quantified and characterized misfits between the reference and modified signals.

The application of the time-frequency misfit criteria to the SCEC test problem LOH.3 (single layer over halfspace with attenuation) demonstrated that the single-valued envelope and phase misfit criteria successfully capture and quantify the principal visible discrepancies between the numerical solutions and the FK reference solution. By putting phase and amplitude differences, respectively, on a quantitative basis, the proposed single-valued misfit metrics provide a scheme for rating different numerical methods according to their relative suitability for specific applications. Furthermore, the time-frequency-dependent, time-dependent and frequency-dependent misfit functions provide valuable additional descriptions of the discrepancies, together with insights into their origins. In particular, these misfit functions clearly exhibit bandwidth limitations on phase and amplitude accuracy, sign changes in the phase misfits between different numerical solutions, and spectral biases due to approximations to the constant-Q attenuation operator, all of which can be traced to the characteristics of the respective numerical solution methods.

The performed numerical tests confirmed that he standard RMS misfit matches the single-valued envelope misfit (EM) only in the case of a pure amplitude modification of the signal. In all other cases, RMS considerably overestimates misfits compared with EM and PM. In contrast with RMS, the

more precise and complete characterization provided by EM and PM makes the latter more effective for assessing the applicability of numerical solution methods to specific applications. Suitability for phase-sensitive applications such as surface-wave dispersion or travel-time studies, for example, can be assessed by giving higher weight to PM than to EM, whereas suitability for amplitude-sensitive applications such as strong motion simulation might be better assessed by giving higher weight to EM than to PM.

The Fortran95 program package TF-MISFITS is available at
http://www.nuquake.eu/Computer_Codes/.

SPICE code validation

Within the FP6 project SPICE (Seismic Wave Propagation and Imaging in Complex media: a European network) coordinated by Heiner Igel (LMU Munich, Germany), a considerable effort The Southern California Earthquake Center (SCEC) organized the 3D Numerical Simulation Code Validation Project for wave propagation in the past years. Recently, SCEC organizes an earthquake source physics code validation/comparison exercise. The goal of both efforts is to validate 3D earthquake simulation methods and foster their application by engineering community. One set of computational models includes simple models of a homogeneous halfspace and layer over halfspace, as well as complex model of the San Fernando Valley / Los Angeles Basin region. The earthquake source validation set will similarly cover models starting from relatively simple ones up to complex real events.

Development of the earthquake motion numerical simulation methods is one of the primary goals of the Seismic Wave Propagation and Imaging in Complex Media: a European Network (SPICE), the EU FP6 project coordinated by Heiner Igel (LMU Munich, Germany). SPICE provides a reasonable platform for a code validation effort in Europe. This effort led to establishment of the SPICE Code Validation. The intention is to create a long-term basis for possible tests/comparisons/validation of numerical methods and codes for the earthquake motion simulation. The basis should serve even after the SPICE project is completed. The wave propagation subsets of models include a) simplest canonical models designed to test accuracy of the methods with respect to individual factors/features of the models including absorbing boundary conditions, b) canonical models combining two or more basic structural features, and c) realistic models. The source dynamics subsets of models are organized in a similar way. The models should account for different configurations of (visco)elastic parameters, friction laws, initial stress,

nucleation and fault geometries. The model sets should reflect the recent development of the numerical methods as well as anticipated progress in a near future. Therefore, the plan also includes models for which reference solutions are not yet available and whose computational parameters will be specified in correspondence with the methodology development. The SPICE Code Validation is coordinated by the SPICE team in Bratislava, Slovakia. Technically, the code validation process is facilitated using the web-based interface http://www.nuquake.eu/SPICECVal/.

Monitoring of earthquakes

The National Network of Seismic Stations

The Geophysical Institute of Slovak Academy of Sciences (GPI SAS) operates the National Network of Seismic Stations (NNSS), and analyzes instrumental and macroseismic data for earthquakes from territory of Slovakia. The seismic stations of NNSS 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 with possible macroseismic effects and with epicenter on the Slovak territory. Map of the NNSS seismic stations is shown in Fig. 1.

This status was achieved by completing project of Modernization and Extension of NNSS that was realized in a period of 2001-2004. In the scope of this project seven new seismic stations (CRVS, KECS, KOLS, LIKS, SRO1, SRO2 and STHS) were built, four existing seismic stations (MODS, SRO, VYHS and ZST) were modernized. Real-time connection between data center in Bratislava and all seismic stations was established. A comparison of the main characteristics of NNSS in years 2000 and 2006 shows improvement achieved in the scope of the project (Tab. 1).

Data collection, processing and analysis

A data center of the national network is located in the GPI SAS, Bratislava. It collects waveforms from all stations of NNSS and from selected seismic stations of some other institutions from Central and Southeastern European countries. Data are collected in real or near-real time using the SeisComp/SeedLink *(Hanka et al*., 2000; *Van Eck et al*., 2004; *Hanka and Saul*, 2006) or SEMS SeedLink software, respectively. The miniSeed format is used for both data collection and data exchange. In total, data from 75 seismic

stations are collected. These stations create Regional Virtual Seismic Network at the GPI SAS (Fig. 2). Live seismograms from the national network are available at the http://ww.seismology.sk web page. Live seismograms are archived for 30 days.
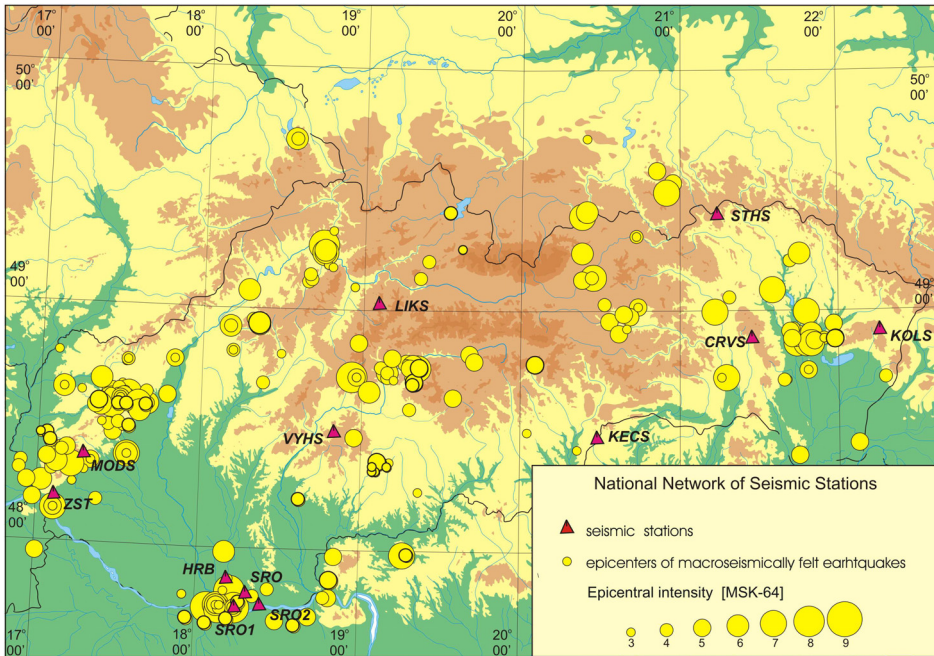

Fig. 1. The National Network of Seismic Stations.

Seismic waveforms are exchanged with all institutions which supply data to the data center in Bratislava. In addition, the seismic waveforms are sent also to the Orfeus Data Center, De Bilt, Netherlands.

A two-step analysis of seismic waveforms is performed - automatic analysis and localization of earthquakes and manual analysis and localization.

The automatic analysis is performed by AutoLoc package of GFZ Potsdam (*Hanka and Saul*, 2006). A first automatic localization is available until 10 minutes after seismic waves` arrival. If the alert criteria are met, information is sent to the Civil Protection and other relevant authorities. Results of automatic localization of events are also available at the http://www.seismology.sk web page.

120

Tab. 1. Comparison of main characteristics of NNSS in the years 2000 and 2006

Item	Status in 2000	Status in 2006
Total number of stations in the national network	6	12
Number of BB stations	1	5
Number of SP stations	5	7
Number of stations with real-time data transmission in the national network	1	12
Total number of stations received in real-time (including foreign stations)	1	75
Automatic localization of earthquakes	no	Yes
Automatic e-mail messages with earthquake parameters	no	yes
Automatic generation of web pages with localizations	no	yes
Live seismograms on web page	no	yes
Archiving facilities	magnetic tapes	HDD DVD
Archived streams	event oriented	continuous streams
Approx. capacity of archiving facilities	10 GB	4 400 GB

The manual analysis is performed on daily basis using the Seismic Handler package since October 2003 (*Stammler*, 1993). The results of waveform interpretation and earthquake localization are stored in a database which is in operation since 1996. Fig. 3 shows an example of an event interpretation for the May 20, 2003, M_L=3.7 earthquake in the Eastern Slovakia.

Besides seismometric data, the GPI SAS collects and analyzes macroseismic data. In case of an earthquake with possible macroseismic

effects on the territory of Slovakia, the GPI SAS issues public information and request for people to contact the institute if they observed macroseismic effects of the earthquake. Then macroseismic questionnaires are sent to people or people can download them from the http://www.seismology.sk web page. If there is a possibility of exceeding intensity 6^0 EMS-98 in some localities, an on-site macroseismic survey is performed. Macroseismic intensity is then estimated for each locality with available macroseismic observations. The macroseismic intensity is estimated in degrees of a macroseismic scale EMS 98 (*Grünthal, ed.,* 1998).

Seismic activity on the territory of Slovakia in the period 2003-2006

The seismic activity on the territory of Slovakia for the period 2003-2006 is briefly characterized in Tab. 2 and illustrated in Fig. 4. Clear increase of localized microearthquakes is obvious for years 2004-2006. Especially in years 2005 and 2006, practically all the seismic stations of NNSS were in operation.
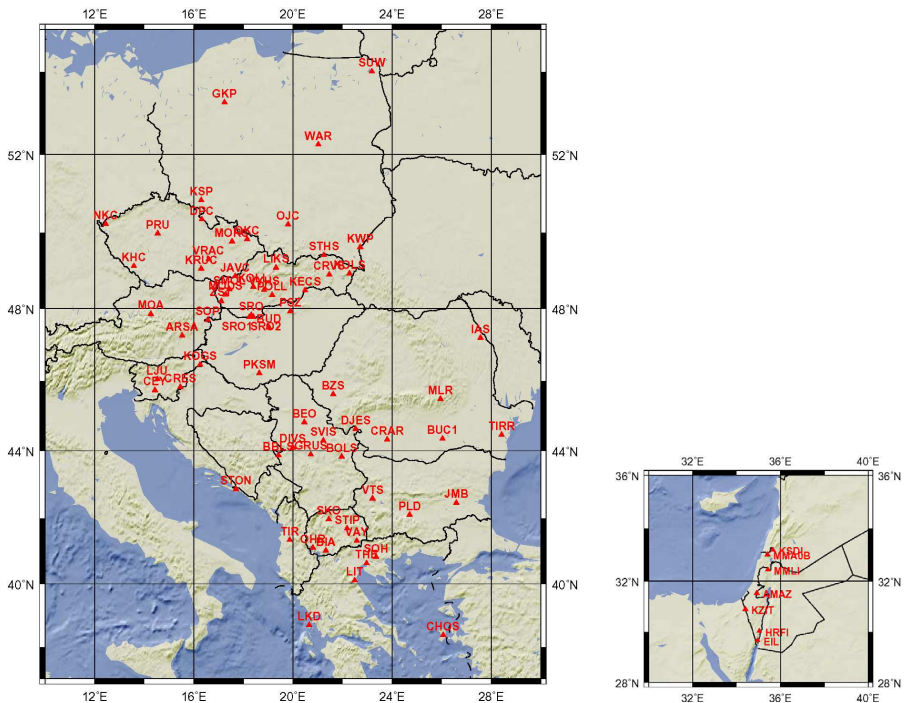

Fig. 2. Virtual Regional Seismic Network in the Geophysical Institute, Slovak Academy of Sciences, Bratislava.
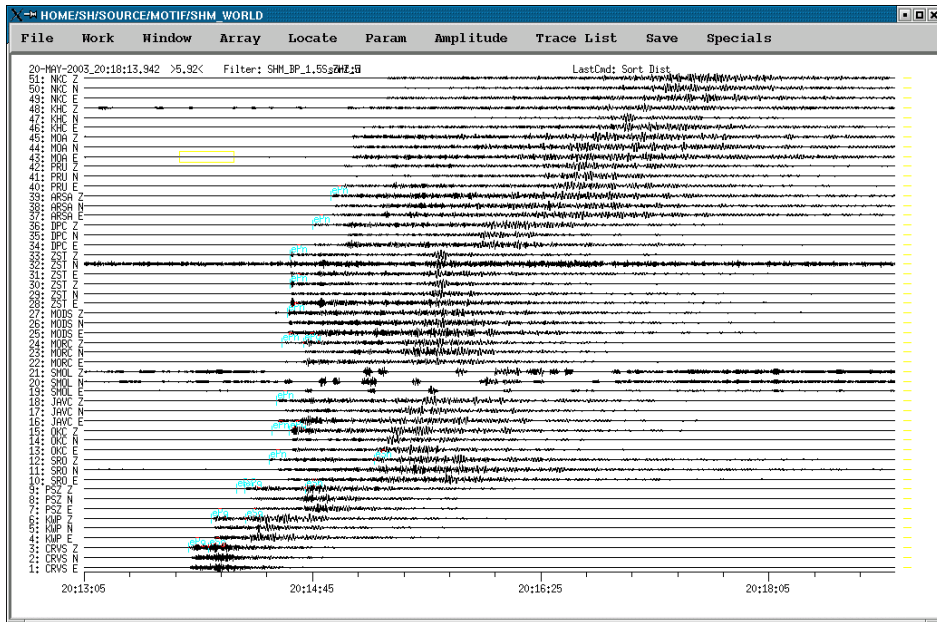
Fig. 3. An example of manual event interpretation using the Seismic Handler package. Displayed traces are from the Virtual Regional Seismic Network in the GPI SAS Bratislava for the May 20, 2003, M_L=3.7 earthquake in the Eastern Slovakia.

Using data from the seismic stations of NNSS, 98 earthquakes without macroseismic observations (microearthquakes) were localized with epicenter on the territory of Slovakia or border areas in the years 2003-2006. Microearthquakes occurred in all known seismic source zones. A Polish-Slovak border area seems quite active during the period 2003-2006. Although in most cases the epicenters are located on the Polish site, a big earthquake in the area would also affect the Slovak territory. In the Eastern Slovakia, three source zones are indicated by data - Spiš, Slanské vrchy and Vihorlat.

During the period 2003-2006, 22 earthquakes were macroseismically observed on the territory of Slovakia. The biggest ones were the earthquake in Eastern Slovakia - Vihorlat area (20.5.2003) and the earthquake in Poland (30.11.2004). The earthquake in Eastern Slovakia - Vihorlat area was felt in 86 localities in the Eastern Slovakia. The earthquake in Poland was felt in 160 localities mainly in the Northern Slovakia but also in the central and Eastern Slovakia. This earthquake was followed by three weaker macroseismically observed earthquakes in the same area in few days.

123

Tab. 2. Seismic activity on the territory of Slovakia in the period 2003-2006

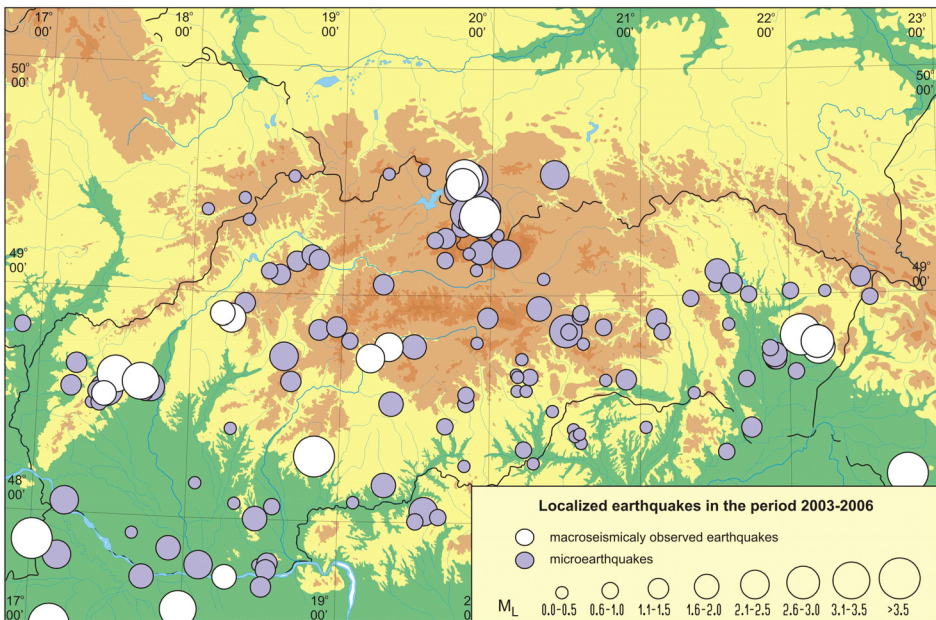| Year	Microearthquakes	Macroseismically observed earthquakes (epicenter in SK)	Macroseismically observed earthquakes (epicenter outside SK)
2003	6	4	1
2004	25	5	6
2005	50	1	0
2006	52	4	1

Fig. 4. Seismic activity on the territory of Slovakia in the period 2003-2006.

Geophysical study of the Carpathian-Pannonian lithosphere

Integrated geophysical modelling and interpretations

The structure of the Western Carpathian lithosphere with specific physical and rheological properties is a result of a complicated geodynamic development of the orogen. Geophysical methods are important tools for the investigation of these complicated structure and geodynamic development of the lithosphere.

Based on the critical analysis of earlier geophysical and geological models in the Western Carpathians and determination of the new map of the lithosphere thickness and the map of crustal thickness in the Carpathian-Pannonian Basin Region, the qualitatively interpretation of the seismic reflection profiles in Slovakia was done (*Bielik, Šefara, Kováč, Bezák and Plašienka,* 2004*).* In this study, it was particularly described: the structures of (1) Late Alpine collision and the Neogene back arc basin development (deep seated contact of colliding plates, slab detachment zone, compressional accretionary wedge of the Outer Western Carpathians-Flysch Belt, extensional structures as a result of retreating subduction and asthenosphere updoming), (2) the Early Alpine structures related to the Cretaceous thrust-stacking, subhorizontal reflection packages interpreted as extensional structures of various generations, the underplated intra-Penninic (Oravic) continental ribbon and the traces of the Meliatic oceanic suture, as well as (3) remnants of north-dipping reflectors, which are interpreted as boundaries of the Hercynian lithotectonic units with opposite vergency to the Alpine units.

The deep reflection seismic profiling also enabled to specify the position and shape of the MOHO discontinuity. Note that the map of crustal thickness reflects the youngest deep-seated processes in the orogenic collision zone and high thermal stage of the Pannonian Basin system.

The crustal thickness in the Western Carpathians (*Bielik, Šefara, Kováč, Hók, Vozár and Zeyen,* 2004 and *Bielik, Šefara and Vozár,* 2004) ranges among 27–35 km. The central Western Carpathians are characterized by thicker crust (30–55 km) in comparison with thinner crust (25–30 km) in the Pannonian Basin System. This feature is probably the result of the youngest lithosphere processes from the Middle Miocene. The Moho discontinuity was established in the hinterland of the Western Carpathians (Danube and East Slovak Basins) in a much higher position than earlier. This feature probably resulted from the youngest extension of the crust, which is related to the oblique collision between the European plate and the ALCAPA block and an

increase of the asthenospheric updoming from the Middle Miocene onward.

A unique method of 2D integrated modeling that combines interpretation of surface heat flow, gravity and topography (local isostasy) was used for calculation of the lithospheric thickness in the Pannonian-Carpathian basin region (*Dérerová, Bielik and Dudášová,* 2005 and *Dérerová, Zeyen, Bielik and Salman* (2006). Based on the obtained results, a new map of lithospheric thickness has been created for the area. The map indicates a new phenomenon of the lithosphere thickness in the studied area. Important differences in lithospheric thickness across the chain as well as along-strike of the Carpathian arc exist. The central and eastern parts of the Western Carpathians (*Bielik, Šefara, Kováč, Hók, Vozár and Zeyen,* 2004 and *Bielik, Šefara and Vozár,* 2004) are bordered in the north by a thicker and stronger lithosphere of the European platform (100–150 km), which is underthrust (about of 50 km) beneath the margin of the overriding Carpathian orogen. In the Eastern Carpathians, the lithosphere increases in thickness to a maximum of 240 km in the foreland. The thickening of the lithosphere in these areas has not been suggested in the former interpretations. This thickening is interpreted as remnants of subducted slabs. In contrast, the "thin" lithosphere at the western margin of the Western Carpathians can be considered as a result of oblique collision along a deep-seated transform zone between the platform and orogenic lithosphere. Beneath the Pannonian Basin, the lithosphere-asthenosphere boundary is located in our models at 80-110 km, underneath the Transylvanian Basin at 100-130 km, and at 90-130 km underneath the Apuseni Mountains.

Neo-Alpine "soft" collision and retreating subduction of this orogen can also be discovered by means of quantitative interpretation of observed gravity field (*Szalaiová, Zahorec, Stanková, Katona, Bielik and Šefara,* 2006; *Katona, Szalaiová, Vozár and Bielik,* 2005*; Dérerová, Zeyen, Bielik and Salman,* 2006; *Bielik, Šefara, Kováč, Hók, Vozár and Zeyen,* 2004 and *Bielik, Šefara, Vozár and Zeyen,* 2004).

The 2D integrated modelling combining the interpretation of surface heat flow data, gravity data and topography and was also applied along the Vrancea geotransect in the Eastern Carpathian-Transylvanian-Apuseni-Pannonian region (*Dérerová and Bielik,* 2003).

Solution of 3D forward gravimetric problem

Bielik, Makarenko, Legostaeva, Starostenko, Dérerová and Šefara (2004) made the first attempt of a calculation of the stripped gravity map from the

whole Carpathian-Pannonian basin region in order to demonstrate the gravity anomalies due to the density inhomogeneities located beneath the pre-Tertiary basement. The stripped gravity map is a result of removing density contrast of known surface density inhomogeneities from the map of Bouguer gravity anomalies.

In the Carpathian-Pannonian basin region the surface density disturbance masses are represented by the Tertiary-Quaternally sediments of the Pannonian and Transylvanian basins, the Outer Carpathians Molassic Foredeep and the Outer Carpathians Flysch zone. 3D total gravity effect of these sedimentary layers has been calculated by means of the automatic program system. The shallowing of the Moho is a main reason of the long wavelength Pannonian gravity high in the stripped gravity map. The relief of the pre-Tertiary basement and the intra-crustal inhomogeneities originate the short wavelength relative both positive and negative gravity anomalies in this long wavelength Pannonian gravity high. It is suggested that the Carpathian gravity low is a result of superposition of both gravity effects of sediments and deep-seated density inhomogeneities as well. A thicker crust could represent it.

New results related to the thickness of the sedimentary cover of the European platform and new study and analysis of the densities of the sediments in the Carpathian-Pannonian region result in the re-construction of the density models presented in the paper of (*Bielik, Makarenko, Legostaeva, Starostenko, Dérerová and Šefara,* 2004*).* Based on these new models the 3D gravity effects of the sediments in the Pannonian Basin, the Carpathian Molassic Foredeep and the Outer Carpathian Flysch zone were re-calculated *Bielik, Makarenko, Starostenko, Legostaeva, Dérerová, Šefara and Pašteka,* (2004). The largest gravity effect (up to -85 mGal) comes from the sediments of Outer Carpathians Flysch and cover of the European platform. Maximum gravity effects of the Pannonian and Transylvanian basin sediments and Carpathian Molassic Foredeep are lower (up to -55 mGal). It was found out that the gravity effects of the sediments in the Eastern and Southern Carpathians still do not reach the amplitudes of the Carpathian gravity minimum. The results indicate that the Carpathian gravity minimum in these parts of Carpathians belt must be explain not only by gravity effect of low density sediments but also by additional gravity effects some other deep-seated crustal (and/or uppermost part of the upper mantle?) density anomalous bodies. Contrary in the Eastern and Southern Carpathians, the amplitude of the Carpathian gravity minimum was overreached by gravity effect of the sediments of Outer Carpathian Flysch in the Western Carpathians and Eastern

Carpathians junction.

Density models of the whole lithosphere play an important role during the forming of the geodynamic models and lithosphere evolution. *Šefara and Bielik* (2004) suggest that it is necessary to implement additional inhomogeneities into the former conception of the isostatic equilibrium, which is crucial for the gravitational instability of the lithosphere-asthenosphere system. This leads to more complex and complicated relationships between the model and its gravitational representation. The techniques and implementation of the independent data into the models must be performed according to their credibility, some of which are uniquely defined, some partially, others arbitrarily chosen density anomalous masses.

Seismic activity and neotectonic character of the Western Carpathians

Study of the seismic activity and neotectonic character of the Western Carpathians in this period was concentrated mostly on the Mochovce nuclear power plant area (*Hók, Šujan, Bielik and Nagy,* 2005; *Bielik and Moczo,* 2005; *Bielik, Kováč, Hók, Šujan, Labák, Moczo, Šefara, Plašienka and Dérerová,* 2005). The results obtained from analysis of the geophysical fields yielded data served an important tool to defined tectonic disturbance of the near region and the site vicinity of the Mochovce nuclear power plant. Interpretation of geophysical fields in compliance with the geological structure and geodynamics EMO far region (*Bielik, Hók, Šujan, Nagy, Kováč, Plašienka and Šefara* (2006) contributes significantly to development of seismo-tectonic model. The model represents the correlation between seismic activity and geological-tectonic setting. The achieved seismo-tectonic model in fact reasons all recorded seismic events in the area and points out to a seismic activity decrease towards the Danube Basin center, thereof, there being situated the EMO locality.

Application of light geophysical methods during exploration of the sources of geothermal waters was presented in the paper of *Maďar, Grand, Džuppa, Šefara, Remšík, Komoň, Pašteka, Bielik and Weis* (2005).

Rheological properties of the Western Carpathian lithosphere (*Bielik, Šefara, Kováč, Bezák and Plašienka,* 2004) show that the mechanical strengths decrease within the whole lithosphere from the area of the European platform via the Western Carpathians to the Pannonian basin. The most remarkable and important first-order tectonic structures (seismo-tectonic zones) in the Western Carpathians are the zones of the Pieniny Klippen Belt, the Mur-Mürz-Leitha

fault zone, the Čertovica fault zone and the Hurbanovo line. Map of neo-Alpine fault systems and neotectonic regions (blocks) of Slovakia was defined.

Interpretation of potential fields in frame of Seismic refraction experiment CELEBRATION 2000

The interpretation of the gravity field in the 2D and 3D space requires an accurate Bouguer gravity anomaly map. This requirement is of particular importance, when different techniques, instrumentation and data processing methods have been used in different parts of the area of interest. The first and original unified Bouguer gravity anomaly map of the CELEBRATION 2000 countries (Austria, Czech Republic, Hungary, Poland and Slovak Republic) was published (*Bielik, Kloska, Meurers, Švancara and CELEBRATION 2000 Potential Field Working Group,* 2006). The gravity map will serve as basis for 2D and 3D modelling of the gravity field in the CELEBRATION 2000 region. Due to different average station density of gravity measurements in the countries (Austria - 1 station/9 km2, Czech Republic - 1 station/2.6 km², Hungary - 4 stations/km2, Poland - 2.74 stations/km² and Slovak Republic –5 stations/km2) the gravity data were interpolated to grids by using different spacing and projection in each country. In the entire CELEBRATION area the average station density is approximately 2.4 stations/km² and the gravity data set contains more than 1 620 000 measurement points. Additionally, the most important regional gravity anomaly patterns of the map are presented with commentary. To avoid truncation problems in the quantitative interpretation, the map area was also expanded far from mentioned five states. The expanded region has the coordinates 45° – 54° latitude and 12° – 24° longitude.

The paper *Bielik, Grabovska, Bojdys, Csiscay, Šefara and Speváková* (2006) deals with density modelling along the seismic refraction Profile CEL01 and finding out a possibility of application of special formulae for transformation of the P-velocities to densities. Three variants of the resulting density models were presented. In general, good agreement between the seismic and gravity interpretations of the lithosphere was acquired. The largest disagreement between the seismic and gravity interpretations is observed beneath the Trans European Suture Zone (TESZ). To obtain good fit between data and model predictions it was necessary to increase densities and to adjust the geometry of the anomalous bodies of the lower part of the upper crust and the lower crust. The lithospheric structure is the most complicated in the TESZ and the European platform (EEP) junction. The large anomalous bodies of the upper crust [km of the profile: 460–640 (and 640–740) with density of 2.68

gcm^{-3} (2.62 gcm^{-3})] and lower crust (km of the profile: 640–710 with density large than 3.05 gcm^{-3}) was modelled. The high-density body within the lower crust (km of the profile: 640–710) was interpreted by both the seismic and gravity interpretations. The large differences can be observed in the crustal thicknesses of the EEP and the microplate ALCAPA. The EEP crustal thickness (43 km on average) is larger in comparison with the ALCAPA crustal thickness (32 km on average). In the Western Carpathians the largest thickness (37 km) is indicated beneath the Pieniny Klippen Belt and Outer Western Carpathians Flysch zone junction (around of 400 km of profile). The Pannonian Basin is characterized by thin crust (28 km on average only). The thickness of the lower crust beneath the Pannonian Basin is also very thin (8-10 km). The lower part of the lower crust of the TESZ and EEP with the seismic velocities $v_P = 6.85\text{-}7.05$ kms^{-1} and density $\rho \geq 3.00$ gcm^{-3} does not exist beneath the Pannonian Basin. The interpretation indicates that the thickness of the crust beneath the TESZ and EEP is thinner than it was suggested in the former seismic interpretation.

Other achieved results are documented in the publications listed below.

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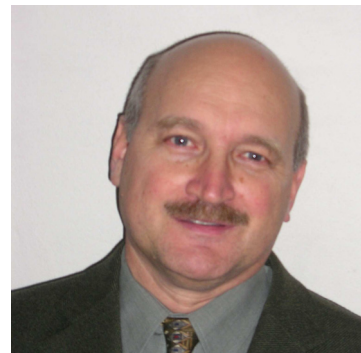Slovak University of Technology
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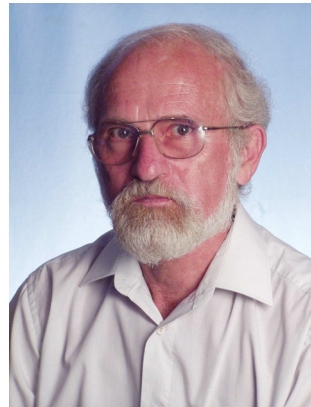
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Selected Journals

Contributions to Geophysics & Geodesy
ISSN 1335-2806, 4 volumes per year
Since: 1969
Publishing Institutions / house: Geophysical Institute Slovak Academy of Sciences
Address of the Editorial office:
Geophysical Institute Slovak Academy of Sciences
Dúbravská cesta 9
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                cgg@savba.sk

Meteorological Journal
ISSN 1335-339X, 4 volumes per year
Since: 1998

Publishing Institutions / house: Slovak Hydrometeorological Institute
Address of the Editorial office:
Slovak Hydrometeorological Institute
Jeséniova 17
833 15 Bratislava
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Phone :   + 421-2-5477 5670
Fax :   + 421-2-5477 5670
E-mail :   zavodsky@shmu.sk
http://www.shmu.sk

Acta Meteorologica Universitatis Comenianae
ISSN 0231-8881, 1 volume per year
Since: 1972
Publishing Institutions / house: Comenius University Bratislava
Address of the Editorial office:
Division of Meteorology and Climatology, KAFZM, FMFI UK
Mlynská dolina, F1
842 48 Bratislava
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Acta astronomia et geophysica Universitatis Comenianae
Since 1975
University Press
Address of the Editorial office:
Department of Astronomy, Physics of the Earth, and Meteorology
Faculty of Mathematics, Physics and Informatics, Comenius University,
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Contributions of the Astronomical Observatory Skalnaté Pleso (CAOSP):
    1. ISSN 1336-0337 (online edition)
    2. ISSN 1335-1842 (printed edition), three times a year
    3. CODEN CAOPF8
    4. Web: http://www.astro.sk/caosp.html
Since: 1955
Publishing Institutions/house: Astronomical Institute of the Slovak Academy of Sciences
Address of the Editorial office:
059 60 Tatranská Lomnica
Slovak Republic
Phone: +421/52/7879111
Fax: +421 /52/4467656
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http://www.ta3.sk/

International Research/grant projects

COST-726
Long-term changes and climatology of UV radiation over Europe
since 2004
National coordinator – Anna Pribullová
United calibration network of broadband UV-meters, involving instruments operating at the meteorological observatories of the GPI SAS, was established in cooperation with the Slovak Hydrometeorological Institute (SHMI). Reconstruction of solar UV radiation time-series has been performed at different localities in Slovakia.

COST-727
Measuring and forecasting atmospheric icing on structures
since 2004
National coordinator – Marián Ostrožlík
The purpose of the project is to concentrate and analyze data of atmospheric icing in the Slovak territory. Atmospheric icing in the high-mountain positions represents an important contribution to the atmospheric regime.

TAQI
Transnational Air Quality Improvement: A Management Tool for Regional Planning
Timing: 07/2004 – 09/2007
Project coordinator: AEEG, AT
Subproject coordinator for Slovak Republic – Jozef Lengyel
Participating institutions from: AT, CZ, HU, SK

FLOODMED
Monitoring, forecasting and best practices for FLOOD mitigation and prevention in the CADSES region
Timing: 03/2006 – 04/2008
Project coordinator – M. Mimikou, National Technical University of Athens
Subproject coordinator for Slovak Republic – J. Vivoda
Participating institutions from: BG, DE, GR, HU, IT, PL, RO, Serbia, SK

HYDROCARE
Hydrological Cycle in CADSES Region
Timing: 01/2006 – 12/2007
Project coordinator – V. Lucarini, CINFAI, Italy
Subproject coordinator for Slovak Republic – L. Blaškovičová
Participating institutions from: DE, GR, IT, PL, RO, SK

OPERA 3
Operational Programme for the Exchange of weather RAdar information
Timing: 01/2007 – 12/2010
Project coordinator – I, Holleman, KNMI, NL
Subproject coordinator for Slovak Republic – D. Kotláriková
Participating institutions from: 23 European countries

H- SAF
Support to Operational Hydrology and Water Management
Timing: 09/2005 – 08/2010
Project coordinator – R. Sorani, Dipartimente Protezione Civile, Rome, IT
Subproject coordinator for Slovak Republic – J. Kaňák
Participating institutions from: BE, ECMWF, DE, HI, HU, IT, PL, RO, SK, TR

FLASH
Timing: 06/2005 – 06/2007
Project coordinator – Pasi Rosenquist, Vaisala, FI
Subproject coordinator for Slovak Republic – M. Jurášek
Participating institutions from: AT, FI, HU,SK

The ISSI (International Space Science Institute, Bern) project
How to quantify the solar wind-magnetosphere coupling
2003–2005
Project coordinator: Y. I. Feldstein, IZMIRAN, Russia
Local coordinator: Alina Prigancová, GPI SAS, Bratislava, Slovakia
Participating institutions: Brazilia, Germany, Russia, Slovakia, USA

COST 724
Developing the basis for monitoring, modelling, and predicting
Space Weather
2003–2007
Local coordinator: Fridrich Valach, GPI SAS, Bratislava, Slovakia
Participating institutions: multilateral

INTERMAGNET–First order world network of geomagnetic
observatories
From 2003
Local coordinator: Magdaléna Váczyová, GPI SAS, Bratislava, Slovakia
Participating institutions: multilateral

EC 5th FRAMEWORK PROGRAM Grant Project EVG1-CT-2000-00026
(SESAME)
Site effect studies using ambient excitations
May 2001-April 2004
National coordinator – Peter Moczo (Pierre-Yves Bard - coordinator)
France, Belgium, Germany, Greece, Italy, Norway, Portugal, Slovak Republic,
Switzerland

EC 5th FRAMEWORK PROGRAM Grant Project EVG1-CT-2001-00040
(EUROSEISRISK)
Seismic hazard assessment, site effects and soil structure interaction
studies in an instrumented basin

2002-2004
National coordinator – Peter Moczo (Kyriazis Pitilakis - coordinator)
Greece, France, Germany, Japan, Italy, Slovak Republic, Spain

EC 5th FRAMEWORK PROGRAM Grant Project EVRI-CT-2000-40007
(MEREDIAN)
**Developing Existing Earthquake Data Infrastructures Towards
a Mediterranean-European Rapid Earthquake Data Information
and Archiving Network**
2002-2005
National coordinator – Peter Labák (Torild van Eck – coordinator)
The Netherlands, Slovenia, Spain, Italy, Greece, Germany, France, Austria,
Switzerland, Norway, Romania, Poland, Bulgaria, Malta, Estonia, Hungary,
Czech Republic, Slovak Republic

EC 6th FRAMEWORK PROGRAM Grant Project MRTN-CT-2003-504267
(SPICE)
**Seismic Wave Propagation nad Imaging in Complex Media: a European
Network**
2004-2007
National coordinator – Peter Moczo (Heiner Igel – coordinator)
Czech Republic, France, Germany, Great Britain, Holland, Ireland, Italy,
Norway, Slovak Republic, Switzerland

ITALIAN – SLOVAK Bilateral Project
**Hybrid Finite-element – Finite-difference Modeling of Earthquake Source
Dynamics**
2004-2007
Coordinators – Massimo Cocco and Peter Moczo

GREEK – SLOVAK Bilateral Project
**Numerical Simulation and Analysis of the Earthquake Ground Motion for
the Test Site in Mygdonian Basin in Greece**
2005-2006
Coordinators – Costas Papazachos and Peter Moczo

Slovak MFA/UNDP Trust Fund Project ACU/2003/01/UZ/17   (LAMP)
Landslide Monitoring Program

2004-2006
Coordinator – Peter Labák
Slovak Republic, Uzbekistan

Slovak ODA Bratislava-Belgrade Fund Project NPOA/G10/2004   (DIRECTE)
Development of Infrastructure for Rapid Earthquake Data Collection and Exchange
2004-2006
Coordinator – Peter Labák
Slovak Republic, Serbia

Slovak MFA/UNDP Trust Fund Project ACU/2004/02/MK/02   (DIRECTE2)
Development of Infrastructure for Rapid Earthquake Data Collection and Exchange – Part 2
2004-2006
Coordinator – Peter Labák
Slovak Republic, Macedonia

INDO – SLOVAK Bilateral Project
Thermohaline Magnetoconvection Related to the Earth's Core
2001-2004
Coordinators – Suhas G. Tagare and Jozef Brestenský

EC 5th Framework Program
CERGOP-2/Environment, a multipurpose and interdisciplinary sensor array for environmental research in Central Europe
April 2003-August 2007
National coordinator: Marcel Mojzeš
Coordinator – Peter Pesec
Participating institutions from Austria, Bulgaria, Bosnia & Herzegovina, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Italy, Romania, Slovakia, Slovenia and Ukraine.

Grant of Polish Grant Agency
Determination of astro-geodetic geoid on the territory of Poland
Januar 2005 - December 2006
National coordinator – Jan Hefty
Coordinator: Jerzy Rogowski

Participating institutions from Poland and Slovakia

Scientific-Technological Projects :

Ministry of Education of the Slovak Republic
Modernization and extension of the National network of seismic stations
March 2001-February 2004
Coordinator Peter Moczo

Ministry of Education of the Slovak Republic
Local Seismic Network Eastern Slovakia
2004- 2007
Coordinator Peter Moczo

Defended PhD Theses

Institution:	Slovak University of Technology, Bratislava, Slovak Republic
Title:	Determination of characteristics of Earth's surface deformations based on GPS observations (in Slovak)
Student:	Renata Ďuračiová
Supervisor:	Ján Hefty
Year of defense:	2003

Institution:	Slovak University of Technology, Bratislava, Slovak Republic
Title:	Use of permanent GPS networks for troposphere and ionosphere modeling (in Slovak)
Student:	Miroslava Igondová
Supervisor:	Ján Hefty
Year of defense:	2006

Institution:	Slovak University of Technology, Bratislava, Slovak Republic
Title:	Software modeling of combination of various geodetic observations (in Slovak)
Student:	Marián Kováč

Supervisor: Ján Hefty
Year of defense: 2005

Institution: Geophysical Institute, Slovak Academy of Sciences
Title: Nonlinear methods of magnetic storm prediction (in Slovak)
Student: Dana Jankovičová
Supervisor: Alina Prigancová
Year of defense: 2003

Institution: Geophysical Institute, Slovak Academy of Sciences
Title: Two dimensional integrated modeling and three dimensional density modeling of lithosphere in the Carpathian – Pannonian area (in Slovak)
Student: Jana Dérerová
Supervisor: Miroslav Bielik
Year of defense: 2005

Institution: Geophysical Institute, Slovak Academy of Sciences
Title: Modelling of the cavity effect influence on the tidal tilt measurements (in Slovak)
Student: Igor Kohút
Supervisor: Ladislav Brimich
Year of defense: 2007

Institution: Geophysical Institute, Slovak Academy of Sciences
Title: Mathematical modeling of dispersion of chemicals released by open burning of household waste and the health risks associated with their transfer through environmental media (in English)
Student: Janka Krajčovičová
Supervisor: Ferdinand Hesek
Year of defense: 2007

Institution: Geophysical Institute, Slovak academy of Sciences
Title: Time-frequency analysis of seismic signals (in Slovak)
Student: Miriam Kristeková
Supervisor: Peter Moczo

Year of defense: 2006

Institution: FMFI, Comenius University, Bratislava, Slovak Republic
Title: Study of Precipitation Tine Series in Slovakia and Iran
Student: Mohammad Reza Pishvaei (Iran)
Supervisor: Milan Lapin
Year of defense: 2003

Institution: FMFI, Comenius University, Bratislava, Slovak Republic
Title: Importance of radiosonde drift in modeling of atmosphere
                 processes (in Slovak)
Student: Martin Benko
Supervisor: Eva Hrouzková
Year of defense: 2004

Institution: FMFI, Comenius University, Bratislava, Slovak Republic
Title: Critical loads and levels (in Slovak)
Student: Martin Kremler
Supervisor: Dušan Závodský
Year of defense: 2006

Institution: FMFI, Comenius University, Bratislava, Slovak Republic
Title: Extreme precipitation design values statistical analysis (in
                 Slovak)
Student: Ladislav Gaál
Supervisor: Milan Lapin
Year of defense: 2007

International Conferences

NMESD 2003
Workshop on Numerical Modeling of Earthquake Source Dynamics
September 1- 3, 2003, Smolenice Castle, Slovak Republic
Organizer: Faculty of Mathematics, Physics and Informatics, Comenius
            University, Bratislava
            Geophysical Institute, Slovak Academy of Sciences
http://www.nuquake.eu/NMESD2003

General Workshop of the FP5 SESAME Project
Site Effects Assessment using Ambient Excitations
September 22 – 24, 2003, Smolenice Castle, Slovak Republic
Organizer: Geophysical Institute, Slovak Academy of Sciences
http://www.nuquake.eu/Sem&Conf/SESAME2003.pdf

ČSSD 2004
Czech – Slovak Seismological Days
June 1 – 4, 2004, Smolenice Castle, Slovak Republic
Organizer: Geophysical Institute, Slovak Academy of Sciences
                      Faculty of Mathematics, Physics and Informatics, Comenius
                      University, Bratislava
                      Geophysical Institute, Academy of Sciences of the Czech
                      Republic, Prague
                      Faculty of Mathematics and Physics, Charles University, Prague
http://www.seismology.sk/Conferences/CSSD2004/CSSD2004.html

SPICE R&T Workshop II
Seismic Wave Propagation and Imaging in Complex Media: a European
Network
September 4 – 10, 2005, Smolenice Castle, Slovak Republic
Organizer: Faculty of Mathematics, Physics and Informatics, Comenius
                      University, Bratislava
                      Geophysical Institute, Slovak Academy of Sciences
http://www.seismology.sk/Conferences/Spice2005/spice_2005.html

STSDLS 2005
Science and Technology for Safe Development of Life Line Systems. Natural
risks: Earthquakes and co-seismic associated risks, neotectonics and seismic
hazard assessment in the CEI Area
October 24-25, 2005, Bratislava, Slovak Republic
Organizer: Faculty of Natural Sciences, Comenius University, Bratislava
                      Geophysical Institute, Slovak Academy of Sciences

ČSSD 2006
Czech – Slovak Seismological Days
May 30 – June 2, 2006, Pension Velké Dářko, Czech Republic

Organizer: Geophysical Institute, Academy of Sciences of the Czech Republic, Prague
Faculty of Mathematics and Physics, Charles University, Prague
Geophysical Institute, Slovak Academy of Sciences
Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava
http://rebel.ig.cas.cz/activities/CSSD2006.php

NMESD 2007
Workshop on Numerical Modeling of Earthquake Source Dynamics
September 2- 6, 2003, Smolenice Castle, Slovak Republic
Organizer: Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava
Geophysical Institute, Slovak Academy of Sciences
http://www.nuquake.eu/NMESD2007/

Bioclimatology and Water in the Land
Strečno, Slovakia, Sept. 2006, 117 participants from 9 countries
Organizer: Faculty of Mathematics, Physics and Informatics
Geophysical Institute, Slovak Academy of Sciences
Slovak Hydrometeorological Institute
Contact address: lapin@fmph.uniba.sk

ISCS 2003 Symposium Solar Variability as an Input to the Earth's Environment
23-28 June, 2003, Tatranská Lomnica, Slovakia
Organizer: Astronomical Institute of Slovak Academy of Sciences,
Geophysical Institute of Slovak Academy of Sciences
http://www.astro.sk

Solar Flares and Initialization of CMEs Workshop
13.–15. 9. 2006, Tatranská Lomnica, Slovakia
Organizer: Astronomical Institute of Slovak Academy of Sciences
http://www.astro.sk/~choc/open/06_wrkshp/06_wrkshp.html