Slovak National Report
to
International Union of Geodesy and Geophysics
1999 - 2002

23rd General Assembly of IUGG
Sapporo, JAPAN, June 30 -July 11, 2003

Slovak National Committee
for the International Union of Geodesy and Geophysics

2003

Contents

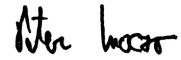
Foreword

The Slovak National Committee for IUGG is pleased to present the second Slovak National Report to IUGG which should provide a concise summary of the geophysical and geodaetic research, and results accomplished in the period of 1999 – 2002 in the Slovak Republic.

The Report consists of partial reports to five associations – IAG, IAGA, IAHS, IAMAS and IASPEI. The reports to associations were compiled by the national correspondents for the associations.

A positive feature of the geophysical and geodaetic research in the Slovak Republic during the reported period is a broader and more intensive international cooperation, mainly within international grant projects.

The Slovak National Committee believes that the presented National Report will be a useful reference for all who are interested in the geophysical and geodaetic research in the Slovak Republic.



Peter Moczo
President
Slovak National Committee
for IUGG

Report to IAG

Ladislav Brimich
IAG National Correspondent

POSITIONING

For the study of the Earth as a system it is necessary to build the space technology-based navigation, monitoring and alert intelligent systems on the territory of the Slovak Republic. The Global Navigation Satellite Systems (GNSS) are becoming more and more important. Every qualified use of the GNNS signals requires the building of the national infrastructure consisting of the GNNS reference stations, the data, processing and analysis centre, and communication infrastructure (communication channels). In the year 2002 there has been developed a project (*Klobušiak & Leitmannová,* 2002), in which the principles of establishing the national infrastructure, called SKPOS – Slovak Permanent Observation System – were specified. SKPOS is understood as part of the IGGOS (Integrated Global Geodetic Observation System), developed within the framework of IAG activities. Basic characteristics of SKPOS is the implementation of the Slovak Kinematic Terrestrial Reference Frame SKTRF 2001. By means of the SKTRF 2001 is defined the implementation of the International Terrestrial Reference Frame ITRF 2000 and the European Terrestrial Reference Frame, through which the European Terrestrial Reference System ETRS 89 on the territory of Slovakia is implemented. In (*Klobušiak et al.,* 2002) there is described Global positioning reference basis ETRS 89, its model realization process on the territory of Slovakia by means of the Slovak Terrestrial Reference Frame SKTRF 2001 and its official connection to the EUREF points class B. Description of SKTRF as a homomorphous model of a dynamic, stochastic, stage-by-stage built spatial geodetic network. Effective connection of stochastic, spatial and dynamic structures, with minimum loss of the information obtained by GPS measurement with emphasis on the estimate of parameters and their linear functional of the 1st and 2nd order of kinematics terrestrial reference frame. Official acceptance of 10 selected SGRN (Slovak Geodynamic Reference Network) points and their incorporation into the EUREF points group category B was realised at the EUREF Technical Working Group meeting in May 2003

(*Klobušiak et al.,* 2003). In all points there are determined, in addition to the positioning with boundary precision of several millimetres, also the point movement annual velocities related to the model velocity ITRF 2000. Therefore all SGRN points, that is not only those 10 selected ones, can be used for the study of global and local geodynamics. While the structure of observation plan is not adhered to and it is not possible to ensure the repeated position of the same antenna on the same geodynamic point from a long-term point of view, the positioning of a point with such high spatial resolution and the performance of repeated observation requires continuous development of the antenna phase centre positioning methods. In *Klobušiak et al.* (2001) there was proposed a project of observation on the temporary space base assuming movement of the antenna centre around the antenna reference point. Elaboration of measurements data by means of mathematical effective estimation model of parameters antenna centre. For the case of unsound knowledge of the antenna phase centre there was proposed a method of measuring at two positions of the antenna. Thus the elimination of the phase centre position uncertainty, that is the unbiased estimator of a control survey point, is ensured.

GENERAL THEORY AND METHODOLOGY

The Truncation Filtering Methodology (TFM)

TFM is a particular way of linear filtering the gravity data to facilitate gravity inversion or interpretation (*Vajda & Vaníček*, 1999a). With the use of integral transforms the gravity anomalies (gravity disturbances) are transformed into new quantities that allow interpretation with the help of pattern recognition. The integral transforms are in fact filters, and the regions of integration are caps with a variable radius, which can be systematically changed as a free parameter. Such filters may be understood as weighted spherical windows moving over the surface, on which the gravity data are defined, the kernel of the transform being the weight function. Instead of the original gravity data, the quantities resulting from the truncation filtering are interpreted or inverted. Subjective experience of the interpreter build on computer modelling and case studies makes the bridge between the observed dynamic patterns and the geology generating the gravity data. Depth estimates to some geologic elements result from interpreting the onsets of some patterns. The key feature of the truncation filtering methodology is data enhancement

and dynamic pattern recognition (*Vajda & Vaníček,* 1999b*; Vajda,* 2000a, 2000b).

When gravity data are given in an area referred to a plane or a reference sphere, the 3D truncation filtering is the tool used. If only profiles of gravity data (referred to a planar or spherical model) are available, the 2D truncation filtering is used as the aid in the gravimetric inversion or gravity data interpreting (*Vajda & Vaníček,* 2002).

The methodology is still under development, particularly in terms of establishing the knowledge of the dynamic patterns generated by certain simplified geological sets. So far only the dimple pattern is well known, which is produced by a point source of mass. This knowledge may be at the moment applied for instance to interpreting simple compact bodies that generate in the gravity data signal similar to that of a point mass source. In such case the interpreted point mass approximates the centre of mass of the body. This concept was illustrated on a synthetic case of a simplified sedimentary basin (in 2D) with a buried heavier body, the depth of which was recovered using the TFM, and on real data of the Kolárovo gravity high (in 3D) in the Danube Basin, Slovakia (*Vajda,* 2001; *Vajda et al.,* 2002a, 2002b, 2002c).

The ultimate goal is to develop the TFM into a tool in applied (exploration) geophysics for interpreting/inverting real gravity data in terms of realistic geological features. Computer simulations will be used to study patterns of more realistic geologic mass distributions to develop the pattern recognition skills and to establish relations between onsets of patterns and depth estimates of the individual geological elements. Attention will be also paid to the choice of kernels of truncation filters.

Geoid

The UNB approach for precise geoid determination based on the Stokes – Helmert method was presented (*Tenzer et al.,* 2003). This research aims at computation of regional terrestrial geoid with an accuracy of 1 cm.

GEODYNAMICS

Interpreting temporal changes of gravity

There are dynamic processes in earth's interior that generate deformations of the earth surface and changes of gravity. These are caused by a combination of heat sources, pressure sources, and redistribution of masses. Since the truncation filter is a linear integral transform, the temporal changes of gravity may be interpreted using the TFM in the same fashion as the gravity data themselves, resulting in interpreted sources of density changes, or heat or pressure sources (*Brimich,* 2000; *Brimich et al.,* 2001, 2002; *Charco et al.,* 2002 *Vajda et al.,* 2000; *Vajda & Brimich,* 2001, 2002a, 2002b).

Computer simulations for a point source of heat in an elastic halfspace, for a point source of pressure (force) in an elastic halfspace, and for point source of mass change have revealed, that all these three kinds of point sources produce dimple patterns (of slightly different shapes) in the respective truncation sequences. By analytical derivations the relationships between the dimple onsets and the depths of the individual sources were established. This work has alredy been published for 2D cases. This concept was tested on a real 3D case, interpreting the gravity changes observed at the Mayon volcano, Philippines (*Vajda et al*., 2003).

Slovak geodynamic reference network

In *Priam et al.* (2001) is Slovak geodynamic reference network described how base for building of the National spatial network for creation of the all geo-data spatial infrastructure and for geodynamic determination of Slovakia by means of repeated GPS measurements. Network consists of 45 passive geodetic points monumented mostly into rocks or by bars beaten into ground and 3 active permanent stations. Results of GPS repeated measurements are elaborated by Bernese GPS and WIGS software. On the ground of repeated measurements are global and local velocities of the network points estimated in period from 1993 to 2000. Preliminary results show that the Eurasian tectonic plate velocity model NNR-NOVEL 1A doesn’t represent effective movement of Central Europe.

The work on the SGRN points is included in the cooperation in the cross-border project “Tatry without borders” which is carried out together with Polish experts. Within SGRN there are repeatedly measured and interpreted

also the points of the local geodynamic network LGS-Tatry. In *Leitmannová et al.,* (2001) there have been realised description and application of LGS Tatry, interpretation of the preliminary results of repeated GPS and levelling measurements. Comparison of the geodynamic point SKPL and setting annual velocities determined by two independent technologies (GPS and levelling). Temporary graphic interpretation of the LGS Tatry velocity field is showed there.

Earth tides research

The Earth´s tides research was aimed at the study of the extensometric measurements at the tidal station of the Geophysical Institute of the Slovak Academy of Sciences in Vyhne (*Bednárik et al.,* 2001; *Dudášová*, 1999). The tidal measurements are affected by local effects. The problem of these effects can be solved by various methods. Estimationof this effects using the boundary integral method was presented in *Brimich* (2000). The finite element approximation is given in (*Kohút & Kostecký*, 2001; *Kostecký & Kohút,* 1999).

The study of the tilt of the building using the tiltmeters technic is presented in (*Brimich & Dudášová*, 2000, 2001).

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Report to IAGA

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Geomagnetism and aeronomy have the longest tradition in geophysical research in Slovakia, e.g. Geomagnetic Observatory Hurbanovo of Slovak Academy of Sciences celebrated centennial in year 2000. Most Slovak Specialists in geomagnetism work in Geophysical Institute of Slovak Academy of Sciences (founded in 1953) and in Department of Geophysics in the Faculty of Mathematics and Physics of the Comenius University at Bratislava. This Department begun geomagnetic measurements in 1993 in frame of very young Astronomical and Geophysical Observatory in Modra-Piesok (founded in 1992). From the beginning of 2003 its new name is Department of Physics of the Earth and Planets. Further, see also Section Solar terrestrial studies with information on other institutions making geomagnetic and aeronomic research in Slovakia.

This Report contents five independent Sections (in brackets are [corresponding subeditors]):

(1) Theories of geomagnetic field generation [J. Brestenský, S. Ševčík],

(2) Ground - based geomagnetic observations [M. Hvoždara, M. Váczyová],

(3) Magnetotelluric and magnetovariational studies and theoretical EM and DC modelling [M. Hvoždara, J. Vozár],

(4) Paleomagnetism and magnetism of rocks of Western Carpathians [O. Orlický, I. Túnyi] and

(5) Solar terrestrial studies [A. Prigancová, J. Sýkora].

THEORIES OF GEOMAGNETIC FIELD GENERATION

Explanation and understanding of magnetic field generation in the Earth's liquid core are inherent ingredients of the theoretical investigations in geomagnetism. Important condition for cosmic magnetic field maintainance is the convective motion of highly electrically conducting fluid in magnetic field. The interaction of velocity and magnetic field at electromagnetic induction processes maintains the magnetic fields. The whole process of magnetic field regeneration is studied by Dynamo Theory. In recent years due to

computational simulations the full dynamo theory strongly progressed and yields broad scale of results corresponding to real cosmic magnetic fields, and in particular to geomagnetic field. Those results, however, often miss the deeper understanding of their physical background. Therefore, the simplifying approaches continue to be important, e.g. by classical splitting of full dynamo theory into problems of kinematic dynamos and problems of magnetoconvection with obvious possibility to linearize equations and in any cases the weakly non-linear analysis does follow. Further, the choice of simple (e.g. planar) geometry is usually significant simplification. From the other side it allows to focus attention on more realistic ranges of determining parameters, on the nature of chosen physical processes and to study the role of various boundary conditions.

In the period 1999-2002 we continued to study some problems of magnetoconvection which are necessary part of the broader dynamo theory. Many recent models of rotating magnetoconvection (henceforth denoted RMC), which run in the regions where planetary dynamos do operate, reflect the main features of geometry and physical properties of real objects. However, many parameters are so far determined not sufficiently exact, and therefore there is necessity to study the magnetoconvection regimes in the broad ranges of parameters.

The unifying feature of almost all our models is the simplified geometry, usually planar fluid layer (instead spherical one), in which multidiffusional convection arises. It is known, the competing diffusional processes can dramatically change the basic balance of forces by the fact that individual diffusional processes reduce corresponding forces. Thus, in sensitive dependence on parameters of systems various modes of convection are generated which in non-diffusional approximation would not exist. The attention was focused on the study of oscillatory instabilities. Only those ones are excited in the horizontal layer with basic azimuthal magnetic field linearly growing with the distance from the axis of rotation. The studied oscillatory instabilities are MHD waves which in real conditions of the Earth's liquid outer core produce the regenerating mechanism of the magnetic field and simultaneously reflect themselves like secular variations of the geomagnetic field registered by observatory measurements and in particular be the methods of paleomagnetism.

On the basis of recent ideas (resulting from the kinematic dynamos studies) in the Earth's liquid core more generating mechanisms may operate. The most important are the ω and α-effects. The 1st one maintains the azimuthal part of magnetic field by the diffnd o6artanihte.2nthe ,nce from

turbulent flows or wave motion generates the poloidal magnetic field from the azimuthal (toroidal) one. The poloidal contrary to toroidal field is the magnetic field measured on the Earth's surface. The wave processes related to oscillatory convection studied in our RMC models can lead meanwhile to the α-effect generating process.

Rotating magnetoconvection (*Brestenský et al.,* 2001a*; Ševčík et al.,* 2000*; Revallo & Ševčovič,* 2002*; Brestenský & Ševčík,* 2000*; Šimkanin et al.,* 2001*; Brestenský et al.,* 2001b*; Tagare et al.,* 2001a; *Brestenský et al.,* 2001c*; Tagare et al.*, 2001bc)

In the broader range of ratios of different diffusive processes we continued in the study of cases when thermal diffusion is comparable or greater than magnetic one, thus for Roberts numbers $q = \kappa/\eta \geq O(1)$. The periods of arising instabilities are comparable with geomagnetic secular variations periods only in this investigated range of values of $q \geq O(1)$. Thus, our results indicate the dominancy of turbulent transport processes, i.e. turbulent diffusivities must be considered instead of molecular ones. We investigated arising instabilities of MAC waves kind in the dependence on basic parameters of the model, magnetic field, angular velocity of rotation as well as on viscosity for various cases of the Earth's core stratification (uniform or non-uniform) and for various mechanical and electromagnetic boundary conditions. It was shown that the particular viscosity causes arising of great amount of competitive modes interchanging the preference in the dependence on basic parameters of system. Furthermore, our previous result, that the electromotive force is much more complex than is supposed at many kinematic dynamos, was also confirmed for the instabilities of the MAC waves kind.

The MC modes were revealed for the stronger magnetic fields. The eastward ones are possible only at finitely electrically conducting boundaries. The westward MC modes do exist only at sufficiently high viscosity. All MC modes can trigger the geomagnetic field inversions because they live due to the energy from the basic magnetic field.

The great amount of westward MC modes with various frequencies and wave lengths indicates that the inversions can be stimulated by various reasons.

Weakly non-linear analysis (*Revallo & Ševčovič,* 2001, 2002*; Tagare et al.,* 2001a)

The problem of RMC was not solved only in the planar layer but also in bounded geometry and even was advanced into the weakly non-linear analysis. First in weakly bounded cylinder (with radius $\rightarrow \infty$) the geostrophic flow due

to the interaction of the linear instabilities was the source of non-linearities. In the geometry of Busse annulus, the elegant approximation of spherical shell geometry, the non-linear Rossby waves modified thermally as well as magnetically were studied.

The compositional convection and simultaneously thermal convection, i.e. the thermosolutal convection in the presence of uniform horizontal magnetic field was studied (*Tagare et al*., 2001a) in the simplest possible geometry. In planar layer, Cartesian coordinate system was used. In linear analysis the conditions for the existence of codimension two and Takens-Bogdanov bifurcation points were analyzed. The range of parameters, for which the orientation of convecting steady rolls perpendicular to the magnetic field gives the preference in comparison with rolls parallel to the magnetic field, was investigated. Weakly nonlinear analysis led to the Ginzburg-Landau equation derivation.

Mushy layer at the outer/inner core interface (*Guba,* 2001)

The weakly non-linear analysis was applied also on the models related to mushy layer in the lowermost sublayer in the outer core at outer/inner core interface, where in the process of solidification the heavier fraction goes into the inner core while the lighter one causes important buoyant force leading to the compositional convection. It is estimated that outer core convection is on 75 % driven compositionally and on 25 % thermally.

Linear analysis of compositional convection in binary mushy layer at outer/inner core interface revealed inhibiting role of rotation on arising convection. This inhibition is due to effects in mushy layer developing in almost eutectic stay of system. However, at too intensive rotation the decreasing concentration wind causes destabilization, i.e. convection for smaller Rayleigh numbers. Non-linear aspects of compositional convection were investigated for steady convection in the forms of 2D inclined rolls and 3D cells with hexagonal symmetry. The corresponding bifurcation diagrams were studied.

GROUND - BASED GEOMAGNETIC OBSERVATIONS

Geomagnetic observations representative for the Slovak Republic territory are performed on a continuous regime at the Hurbanovo geomagnetic observatory (φ=47.87°, λ=18.18°, Φ=46.89°, Λ=101.12°). This observatory is the branch of the Geophysical Institute of the Slovak Academy of Science. Main equipment of the observatory includes the digital variometer station TPM

made in Poland (1996) and magnetoregistration device DI-fluxgate Magson gained on the co-operation bases with Geo Forshung Zentrum Potsdam and VW Stiftung. For absolute geomagnetic measurements there are used mainly: DI-fluxgate magnetometer, proton magnetometer ELSEC, QD declinometer. The magnetovariational data in one minute step are supplied by the internet to the INTERMAGNET centre. The hourly mean data of X, Y, Z components are nowadays published in the CD-ROM prepared according to INTERMAGNET rules (*Váczyová,* 2000a-b, 2002a-b).

The 100-year anniversary of the observatory was celebrated in 2000 (*Prigancová et al.,* 2000). On this occassion the IXth IAGA WORKSHOP ON GEOMAGNETIC OBSERVATORY INSTRUMENTS, DATA ACQUISITION AND PROCESSING was held at Hurbanovo on June 12-18, 2000. More than 100 participants from all over the world paid their attention to issues of the instrument calibration by means of comparison measurements and to practical problems of the geomagnetic field (GMF) monitoring. The invited talks and contributions presented within the scientific program were published *Prigancová & Vörös* (2001). The further progress in the observatory activities is 1min and 1sec measurements of the GMF components on a regular basis (INTERMAGNET program), which are at disposal for the world-wide community. The information on K-indices and special phenomena is also supplied to WDC and selected geomagnetic observatories.

The members of the Hurbanovo Observatory staff regularly perform field absolute geomagnetic measurements at secular points network and also on the selected Slovak airports. They also participate in magnetotelluric and magnetovariational field measurements.

The preparatory activities to make live geomagnetic measurements in the AGO Modra continue. More information about AGO observatory are in the section on Schumann resonances measurements.

MAGNETOTELLURIC AND MAGNETOVARIATIONAL STUDIES AND THEORETICAL EM AND DC MODELLING

There was performed interpretation of magnetotelluric (MT) measurements in the region of Herľany-Ďurkov geothermal reservoir (eastern Slovakia). These results confirmed existence of low resistive layer in the depths 2000-3000 m, which coresponds to hot and mineralized water (*Vozár et al.,* 2003). The short period MT measurements were also performed on 17 points in the Tríbeč Mts. The interpretation resulted in better knowledge of the geological structure this massiff, e.g. determination of extension high resistive granite

units (*Vozár et al.,* 2003). There was also participation in international CEMES project (Central Europe Magneto-Electric Study) coordinated by the Institute of Geophysics Polish Academy of Sciences. The preliminary geoelectrical model of the Pannonian basin is presented in paper *Hvoždara & Vozár* (2002). By means of scalar boundary integral equations there was calculated DC geoelectric field due to point electrode for 2-D body nearby a vertical contact (*Hvoždara & Vozár,* 2003). On the basis of electromagnetic theory there was derived model for space-temporal distribution of geomagnetic disturbances due to a solar eclipse and this was applied to the solar eclipse on August 11, 1999 (*Hvoždara & Prigancová,* 2002).

PALEOMAGNETISM AND MAGNETISM OF ROCKS OF WESTERN CARPATHIANS

The rocks samples of Paleogene and Neogene age from central part of Western Carpathians were studied and their interpretetion was used for assesment of paleorotations of various blocks in this mountain belt (*Túnyi & Köhler,* 2000; *Aubrecht & Túnyi,* 2001*; Túnyi & Márton,* 2002). The anisotropy of magnetic susceptibility of rocks was studied from various aspects - magnetic memory, induced magnetic anisotropy, determination of paleointensity, effect of mechanical stress (V*etchfinski, Túnyi*, *Vajda*, 2000).

Various types of Fe-Ti oxides (from quasi homogeneous titanomagnetite, pure magnetite to ilmenohematite) were carefully studied on large collections of volcanic rocks from central Slovakia and Japan (Haruna and Usu volcanos). Main purpose was determination of stability their thermoremanent magnetization. A study of the Haruna dacite (cca 600 years old) and ash from the 1999 Pinatubo eruption (Philipines) has proved the reproducible reversed thermoremanent magnetization (TRM). The carriers of the reversed TRM are the ilmenite-hematite (Ilm-Hem) solid solutions of thecomposition $Ilm_{45}Hem_{55}$ - to $Ilm_{53}Hem_{47}$. Results are presented in a series of papers (*Orlický, Funaki & Pagáč,* 2000; *Orlický & Funaki,* 2000a; *Orlický & Funaki,* 2000b*; Orlický & Funaki,* 2002).

The study of large collections of the Neogene volcanics from central and eastern Slovakia volcanic fields has proved the reproducible reversed partial thermoremanent magnetization (PTRM). The reversed PTRM of the andesites is due to self reversal mechanism in the ilmenite-hematites of the composition $Ilm_{15}Hem_{85}$ - to $Ilm_{25}Hem_{75}$. Magnetites (cubic phase), quasi homogeneous titanomagnetites (cubic phase), pure hematites (rhombohedral phase) are carriers of normal RM. The Ilm-Hem solid solution of the above defined

compozitions are the carriers of the self reversed TRM or PTRM (*Orlický,* 2002, 2002a-d, 2003).

SOLAR TERRESTRIAL STUDIES

The main Slovak scientific institutions engaged in Solar Terrestrial Studies are within the frame of the Slovak Academy of Sciences (SAS):

Astronomical Institute of SAS (AISAS) Tatranská Lomnica
Institute of Experimental Physics of SAS (IEPSAS) Košice
Geophysical Institute of SAS (GPISAS) Bratislava,

as well as the institutions within the frame of the Comenius University (CU):

Department of Physics of the Earth and Planets of CU (DPEPCU)
Department of Nuclear Physics of CU (DNPCU) Bratislava
Astronomical Institute CU (AICU) Bratislava

The STP activities are considered in terms od space experiments, ground-based observations and of main results in investigation in the field of solar physics, cosmic rays, X-ray activity, near-Earth palsma and response of the magnetosphere-ionosphere system.

Space experiments

Slovakia traditionally participates on joint space experiments within the frame of international spacecraft programs.

In spite of extremely limited financial possibilities the space experiments within the frame of INTERBALL-1 (finished on October 2000), INTERBALL-2 (finished on January 1999) and MIR (finished on 2001) missions were realized. IEPSAS participated in these projects with a number of instruments.

On February 20-28, 1999 the first Slovak astronaut Ivan Bella worked at the space station MIR during the Russian-French-Slovak mission. It was the first Slovak space mission named STEFANIK MISSION in honour of the outstanding Slovak astronomer, politician and French general Milan Rastislav Štefánik (1880-1919). Among the scientific experiments of the mission, the dosimetry experiment for monitoring of radiation situation in the near-Earth space prepared by IEPSAS (SK-1 project) was realized. Scientific tasks of the SK-1 project were measurements of CR LET-spectra of charged particles in the

variable conditions in space, the study of fragmentation parameter nuclei CR in shielding material, the study of charge states and of energy spectra of low energy CR nuclei (E<100 MeV, Z>2), being mainly responsible for radiation damage of biological objects and electronic elements and components.

IEPSAS took part in the development of particle devices for the CORONAS-F satellite (launched on July 31, 2001).

The experiments (SPRUT and SCORPION) for monitoring the corpuscular radiation on the ISS are prepared by IEPSAS with co-operation with the Moscow State University.

IEPSAS participates in two new international projects: (a) for ROSETTA – the technical documentation and realisation of the flight as well as the spare model of ESS Processor for the data connection between Lander and Orbiter, and (b) for Double Star – the design of Neutral Atom Imager in the collaboration with Chinese Academy of Sciences, STIL Maynooth, Ireland and IRF Kiruna, Sweden.

Ground-based observations

AISAS is responsible for the ground-based observations of the Sun. The Skalnate Pleso Solar Observatory, Lomnický Štít coronal station and Stará Lesná Observatory are in run (see for details *Slovak National Report to IUGG,* 1995-1998). The observational data are circulated on a regular basis. At the AISAS the coronal index (CI) time series up to the year 2002 was calculated and is available at the WDC Boulder Web site till 1998.

Some observations of the Sun are realized at the Slovak Central Observatory – Solar Section, Hurbanovo.

At the Astronomical and Geophysical Observatory of CU in Modra-Piesok located about 45 km from Bratislava, the refractor with diameter 200 mm and focal length 3050 mm is used for observation of the solar flares in H_α. The broad H_α filter (0.15nm) enables to observe the emission from rapidly moving plasma with large Doppler shift, solar chromosphere in larger range of heights and to resolve the smaller sunspots. This is important for comparison with observations in the white light and with solar magnetograms (AICU).

Neutron monitor (NM Lomnický štít) measurements with the resolution 1min, 5 min and 1 hour are realized by IEPSAS. The plots jointly with those of Yakutsk neutron monitor can be found at http://teor.ysn.ru/rswi/18nm64-yakutsk-lomnitsky.html. The data are used for computations of CR scintillation index applied for the experimental runs of the forecasts of space weather events. From October 2000 the testing of the real-time access to 1min data of

NM Lomnický štít is in operation for purposes of checking the fast increases of energetic particle fluxes and onsets of ground level events (GLE).

The new registration electronic unit unifying the records of different types of measurements at NM Lomnický štít designed and constructed by the IEFSAS technical group is now in the testing phase. Along with the recording of CR (each tube separately), pressure, temperature and other data defining the conditions of measurements, the device NEUMON allows to use the mode of the remote measurements as well.

GPISAS supplies observations of the Earth's magnetic field at the Hurbanovo Geomagnetic Observatory, as was noted above.

The Earth's magnetic field is continually recorded in the geophysical part of the Astronomical and Geophysical Observatory (AGO) of the Faculty of Mathematics, Physics and Informatics, Comenius University (DPEPCU, AICU) in Modra - Piesok. The conception of geomagnetic measurements is determined in such a way that it may be possible to measure and identify the whole spectrum of the Earth's magnetic variations including the magnetic SchR components - the most rapid variations in the Earth's magnetic field with frequencies from 0.01 to 40.0 Hz (see below).

Solar Physics

The physics of the Sun and solar variability is studied within the national projects and international programs. The both space observations (YOHKOH, HST, TRACE, SOHO, GOES) and ground-based measurements are used widely.

A new approach to the solar corona magnetic field diagnostics was proposed using the revealed functional relation between the degree of polarization and brightness, those being measured in the coronal Fe XIV 530.3 nm emission line *(Badalyan et al.,* 1999; *Sýkora et al.,* 1999*)*. The coronal holes recorded in the coronal green line from 1943 were analysed *(Sýkora et al*., 2000a*)*. On the basis of the coronal green line brightness distribution analysis it has been revealed that coronal activity within the middle latitude zones of both the solar hemispheres reflects different features of the 11-year solar activity cycles *(Sýkora et al.,* 2000b*)*.

It has been found that generally relevant correlation between solar corona activity and CR intensity does unexpectedly disappear during the maxima of the solar cycles, which is explained by the almost regular pronounced decrease of solar activity at the solar activity maximum of each cycle (known as the so-called Gnevyshev's gap of solar activity). The mutual relation between

evolution of both the corona shape and magnetic field topology has been revealed, which allows a new understanding of the corona flattening as a function of the solar cycle phase *(Sýkora et al.,* 2002*)*. The course of the coronal green line brightness during the last five 11-year solar cycles was used to predict parameters of cycles 23 and 24; there are indications for an exceptionally low cycle 24 *(Badalyan et al.,* 2001*)*. Significant correlation between solar magnetic field (MF) value (regardless of its polarity) and coronal green line intensity has been revealed (data from 1976–2000), which makes it possible to extrapolate the MF back to 1939 (time of starting of coronal green line observations); within the 1939–2000 period the MF increased at solar cycle maxima, except the current cycle 23, when both parameters studied are approximately half value, if compared with those of cycle 22 *(Badalyan et al.,* 2001*)*.

Using the revealed relationship between CI and total solar irradiance (TSI) for the 1978–1998 period, the TSI profile was extrapolated back to 1943; the TSI increase is evident from 1943 to 1999 showing that the TSI changes are associated with local magnetic fields, to which the increased coronal green line intensity is also due *(Sýkora et al.,* 2002*)*.

The observations and analysis of the green corona dynamics are continued *(Rybanský et al.,* 2001*)*. On the basis of the solar corona brightness data (for more than give solar cycles) a number of regularities in the cyclic and evolutionary processes on the Sun were revealed (*Sýkora et al.,* 2000a,b*; Sýkora & Badalyan,* 2000*)*. A clear anti-correlation between polarization and intensity of the solar coronal green line was reported *(Badalyan & Sýkora,* 2001*)*. A number of important aspect of the coronal green line intensity and coronal index were studied (*Minarovjech et al.,* 2000; *Rušin et al.,* 2000; *Rybanský et al.,* 2001; *Rušin & Rybanský,* 2002*)*.

Using the SOHO and TRACE data, the solar transtition region structures and dynamical processes associated were analyzed *(Rybák et al.,* 2001*)*.

Comparing the SOHO/EIT 195 Å and Hα images (Hvar and Modra-Piesok observatories) with the magnetic field extrapolations of MDI/SOHO magnetograms the loop structures of the July 19, 1999 flare were analysed. A new combined extrapolation technique, which includes localized electric currents, was used to model the current-carrying flux rope; the extended helical structure was found and the pitch angle of the helical thread was determined (*Kulinová & Karlický,* 2002).

The analysis of the expanding flare loops of C8.5/1F April 2, 2001 flare in EUV and H-alpha has showed that besides magnetic processes (reconection with $\beta << 1$) also the other processes with $\beta \sim 1$ can be of use in the flare

evolution. A possible role of the "ballooning" instability, destabilizing the loops, is discussed (*Kulinová et al.,* 2002).

A method to predict solar activity for an 11-year solar cycle ahead was proposed *(Badalyan et al.,* 2001*)*. The presence of the solar de Vries cycle (~205 years) during the last ice age was reported using data on cosmogenic nuclides studied in DNPCU *(Wagner et al.,* 2000*)*.

The observations of solar eclipse events are used to study a number of issues of solar physics *(Balalyan et al.,* 2002*)*.

On the basis of recurrence quantifications, wavelet and fractal analysis it was found, that the dynamical characteristics of solar convective zone turbulence change in concert with solar cyclical activity (*Pastorek & Vörös,* 2002*)*.

It was shown that the presence of an electron non-Maxwellian distributions (power and κ- distribution) in the solar corona influences the electron excitation rate (EER). The deviations in EER are sufficient to affect intensities of spectral lines; the simple diagnostics of the power distribution from three Fe lines was presented (*Dzifčáková,* 2000). The excitation equilibrium of the Fe XXV for the electron power distribution was determined. The diagnostics of the shape of the distribution function from intensities of Fe XXV lines was suggested. The results can be used especially in diagnostics of the impulsive phase of solar flares, where the deviations from the Maxwellian distribution can be large (*Dzifčáková & Kulinová,* 2001). The ionization equilibrium of Fe for the electron κ-distribution and new atomic data was determined. The diagnostics of the electron κ-distribution from ionic stage of Fe was proposed. It can be used preferable in the analysis of the ion composition of the solar wind (*Dzifčáková,* 2002a). The excitation equilibrium of Fe IX – Fe XV for the electron κ-distribution was analysed. The synthetic spectrum of Fe for the different distribution shape was computed and the possibilities of determination of the electron distribution were discussed (*Dzifčáková,* 2002b).

Cosmic rays and X-ray activity

Some aspects of measurements of solar and cosmic rays at Lomnický štít are reported (*Kudela et al*., 1999b,d, 2000c). Time evolution of low-frequency periodicities in cosmic ray intensity (*Kudela et al*. 2002b) and other features of the CR variability was studied (*Antalová et al.,* 1999a,b). The wavelet analysis of solar cosmic ray and cosmic ray data was carried out (*Rybák et al.,* 2001). The solar and cosmic ray synodic periodicity for period 19969-1998 was reported (*Antalová et al*., 2001b).

The low rigidity cosmic rays were analysed (*Antalová et al*., 2001a). Further clarification of the short-term relation of the low-rigidity CR to the large scale solar magnetic field distribution (*Jakimiec et al.,* 1999, 2000).

The kinetic approach to an anisotropic GLE , using non-diffudive particle pulse transport were examined (*Fedorov et al.,* 2002*; Stehlik et al.,* 2001).

Some direct and indirect relations of cosmic rays to space weather were discussed. (*Kudela et al.,* 2002a,g*; Minarovjech et al*., 2002).

The correlation dimension of underground muon time series was estimated with removing the background noise by means of wavelet expansion. A periodicity of 2.53 hours in time series of muon records was described over two solar cycles (*Yasue et al.,* 1999).

The daily soft X-ray indices for years 1985 and 1986 were determined (*Antalová,* 2001).

The dual peaks separated with the Gnevyshev gap coincide with magnetic reversal of the Sun. The study of the distribution of the green corona line intensity and the soft X-ray solar activity parameters, confirmed the double-peaked character of the last three solar cycles. The similar structure was found in the heliomagnetic field (*Storini et al*., 1999a,b) .

The detailed computations of CR trajectories in the geomagnetic field were done. The model includes both the internal and external sources of the field. The software for numerical integration of the equation of particle motion has been developed (*Bobik et al*., 1999).

The computation of asymptotic direction for charged particle access to the neutron monitors were made (*Storini et al.,* 2001a,b). The quasi-bienal modulation of galactic cosmis rays were studied (*Storini et al*., 2001c).

The variation of the heliospheric modulation strength during the neutron monitor era were descibed (*Usoskin et al.,* 2001a) and sensitivity of a neutron monitor to Galactic CR was considered (*Usoskin et al.,* 2001b).

The impact of selected parameters of cosmic ray trajectory computations in the model geomagnetic field, namely the length of elementary step, total number of steps and the approach to the shape of the Earth's body is examined (*Kaššovicová & Kudela*, 2001).

The computations of trajectories revealed the value of the effects of local time, geomagnetic activity level, the epoch and obliquely incident particles. First results indicating the influence of residual atmosphere, especially at high latitudes, were obtained (*Usoskin et al*., 1999).

The cosmogenic nuclides production in the Earth's atmosphere was analyzed *(Masarik & Beer*, 1999*)*. The possible link between cosmic rays and the Earth's climate was reported *(Wagner et al*., 2001*)*.

Near-Earth plasma

The plasma measurements of ions and electrons in the energy range 20 – 600 keV within the satellite Interball-1 (August 1995 – October 2000) and 2 (August 1996 – January 1999) (DOK2 instruments) and on subsatellites Magion 4 and 5 (DOKS instruments) experiment were processed. The review files with the detailed energy spectra on daily basis and the temporal profiles at selected energies have been prepared for both statistical and comparative studies (DOK2). Similar works are in progress for DOKS measurements (*Slivka & Kudela,* 2002a,b). The dependence of the 2-min average fluxes of ions on the geometry to bow shock becomes less pronounced with the increase of energy. While at the 20-30 keV energy, there is a clear difference in the distribution of fluxes for quasiparallel and quasiperpendicular model shocks (with the higher flux for the first cases which is consistent with the acceleration at the bow shock), this type of difference is generally negligible for energies above 200 keV. On the other hand, especially within the magnetosheath, the fluxes are generally higher at higher level of geomagnetic activity measured by Kp index, which is consistent with the expectations of magnetospheric ions being the source population (*Kudela et al.,* 1999a,b; 2000a,b; *Kudela, 2002c,d; Anagnosto-poulos et al.,* 2002).

The Interball-1 data on magnetic field and energetic particles measurements were used to identify plasma regimes (*Verkhoglyadova et al.,* 1999a,b; 2000) and particle fluxes were considered (*Kudela et al.*, 2000a,b). The comparative studies using also data from DOK2 on Interball-1 and 2 along with magnetic field on the same satellites, plasma distribution function on satellite Geotail and ground - based observations indicated the place where that time dispersed ion structures are formed (*Sergeev et al.,* 2000). The simultaneous study of a radar measurement with the plasma and flux of precipitating energetic particles measured by SPE1 device on Active satellite passing the region above the radar site was used to deduce fine structures of electron density and temperature (*Chen et al.,* 1999; *Foerster et al*., 1999).

Comparison with the POLAR data provided a possibility to study a unique case of ion acceleration at the bow shock to unusual high energies during a space weather event on May 4, 1998, when magnetosphere was strongly compressed. It was suggested that ions are accelerated at the quasi-parallel bow shock to energies as high as 1 MeV and subsequently transported into the magnetosheath during that event (*Chang et al*., 2001). In *Sibeck et al.,* (2000a,b) the magnetopause motion driven by interplanetary magnetic field variation was discussed using energetic particle data. Almost monoenergetic

fluxes of ions both in the magnetoaheath and in the region upstream from the bow shock were analysed (*Lutsenko & Kudela,* 1999) and energetic ion and electron spectra in the auroral region was considered (*Lutsenko et al*., 2002a,b). The energetic ions and dispersive events were studied (*Kudela et al.,* 2002d,e,f).

Plasma flow variation analysis and connection between a level of ion flux fluctuations and proton fluxes and their relation to the IMF orientation , according to the Interball-1 data, are presented (*Prech et al.,* 2002).

The energetic particles accelerated in the magnetotail have extensive influence on processes in the inner magnetosphere (*Sarafopoulos et al*., 2001).

The progress of travelling shocks between the Sun and the Earth using particle and plasma signatures recorded aboard SOHO, ACE, WIND and Interball was analysed (*McKenna-Lawlor et al.,* 2002a,b).

The relative importance of solar wind ions and particles leaking from magnetosphere was estimated up to 300 keV (*McKenna-Lawlor et al.,* 2002c). The low-energy (< 1MeV) proton observations at low orbit satellites near geomagnetic equator (L<1.15) on different altitudes were analyzed using data from Active satellite (1989-1991, altitude 500-2500 km, inclination ~82^{o}, energy 50 - 500 keV) and from the MIR station (year 1999, E=0.1 – 10 MeV, almost circular orbit, inclination 51.1^{o}, altitude ~400 km) (*Grachev et al.,* 2002).

It was shown that the high energy protons observed by SONG instrument can be used in the Forbush effect studies using the advantage of single detector scanning the variability of primary CR flux at various latitudes during one orbit. The comparison with ground - based neutron monitor data was done for two cases. The latitudinal anisotropy was deduced from these comparisons (*Bučík et al.,* 1999a,b, 2000, 2001, 2002; *Myagkova et al*., 1999; *Kuznetsov et al.,* 2002c).

The study of the effects related to the transfer of energy in the solar atmosphere, and in particular of acceleration of solar particles was carried out (*Kuznetsov et al.,* 2002a,b). Substorm investigations, using the data from orbital station MIR, were performed in (*Klimov et al*., 2002).

Response of the magnetosphere-ionosphere system

The dynamics of the near-Earth space was analysed with respect to its drivers on the Sun and in the interplanetary medium. The various aspects of magnetospheric physics were studied (GPISAS).

The analysis of the magnetic storm development is 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 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 Dst variation (*Feldstein et al.,* 2002).

To study geomagnetic fluctuations the nonlinear methods were exploited using the high resolution satellite and ground-based data. The application of the multifractal analysis for geomagnetic data revealed methodologically new approaches to study the time-frequency structure of the geomagnetic field disturbances. It was shown that the degree of intermitency of geomagnetic fluctuations in the auroral region decreases for higher frequencies and greater amplitudes (*Vörös,* 1999, 2000).

Using large deviation statistical concepts related to multifractal distributions it was demonstrated that geomagnetic fluctuations can be described by multiplicative models at the time scales of storms and substorms (*Vörös,* 2000). It was shown, that multi-scale processes play an important role in solar wind – magnetosphere interaction processes. As shown, global singularity spectra estimations of the single observatory measure (e.g. geomagnetic H component) and multi observatory measure (e.g. AE index) data sets on different scales allows to separate fluctuations of the solar wind and magnetospheric origin (*Vörös & Kovács*, 2001). Using wavelet and structure function analysis it was found that higher-order statistical properties of geomagnetic fluctuations agree well with the predictions of the shell-models of turbulence (*Kovács et al.,* 2001). On the basis of the analysis of nonlinear characteristics of the magnetic field it was found, that interplanetary disturbances having significant components of intermittent fluctuations are more geoeffective (*Vörös et al.,* 2002).

A neural network model for Dst index prediction was constructed with an optimized input parameter field of principal components (*Jankovičová et al.,* 2002). Exploiting artificial neural networks (ANN), a method for geomagnetic storm prediction was proposed, in which the information on occurrence of singular and intermittent fluctuations led to considerable improvement of one-step forecasts. The prediction technique which uses the extra information on local scaling exponents improves the performance of a layered ANN with feedback (*Vörös & Jankovičová,* 2002).

The possible links between variability of space weather and long-term modulation features in climate evolution were studied. On the basis data from a number of meteorological stations the analysis of the anomaly field for temperature and total precipitation was carried out. The oscillatory character in dynamics of main meteorological parameters has been reported, which seems to be related to solar forcing (*Prigancová & Petropoulos*, 2000; *Prigancová & Bieleková*, 2001).

The influence of the Sun on the near-Earth environment was manifested in terms of an eclipse-induced effects in the ionosphere and magnetosphere. Using the data on the GMF measuremnts during the total solar eclipse on 11 August 1999, it has been analytically shown that the pronounced signatures of these effects can be followed mainly in the Y component of the geomagnetic field (*Hvoždara & Prigancová,* 2002).

The features of the ionized ionosphere were studied (DPEPCU). Effects of solar proton events in ionosphere have also been studied using an 1-D photochemical model of neutral atmosphere and an 1-D model of lower ionosphere. The models are reasonable up to 80 km. Above 80 km the response is lower because high-energy particles of lower energies were not included into calculations. Below 80 km the electron densities are substantially larger than those of the empirical model for riometric absorption of 2.5 dB. This reflects the fact that the studied Oct 1989 SPE was extremely strong (*Krivolutsky et al*., 2000). Immediately after the onset of SPE, electron densities increase by 2-3 orders of magnitude (*Krivolutsky et al.,* 2001a,b). Below 80 km, shortly after the onset of SPE the daytime electron densities are by 200% higher than those at night. The composition parameter f^+ significantly decreases during the Oct 89 SPE but not as much as during the Nov 69 SPE. The midday values of f^+ are lower than the night values, and this is true also for the most disturbed days (*Ondrášková et al.,* 2002a,b).

Schumann resonances observations

The Schumann resonances (SchR) are electromagnetic oscillations mostly produced by lightning activity in the cavity resonator between the electrically conductive Earth's surface and the lower ionosphere. The SchR parameters and dynamics depend on the conditions in the resonator, respond to the changes of its conditions and motions of the ionosphere. They are also affected by other processes which follow from interaction between solar activity and upper atmosphere of the Earth.

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Report to IAHS

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HYDROLOGICAL PROCESSES AND MATHEMATICAL MODELLING

The need to develop an increased understanding of hydrological processes was stressed in the international scientific community in recent years. Areas such as the study of hydrological processes on different temporal and spatial scales, land atmosphere interactions, understanding the impact of climate change on the hydrological cycle and water resources, etc., were increasingly tackled in international science. International and interdisciplinary co-operation was seen as one of the prerequisites for development. This report reviews the response of hydrologic research in Slovakia to these tendencies. Results of the main research programs in hydrology from 1999 to 2002 are reviewed and references given.

Soil-water-plant-atmosphere interactions

Research on water, ion and energy transport in the soil-water-plant-atmosphere system have been partly focused on quantification of water balance components in the unsaturated zone of agricultural soils (*Štekauerová & Šútor*, 2001), agricultural ecosystems (*Šútor, Štekauerová & Majerčák*, 2002a) and lowland forest ecosystems (*Šútor, Štekauerová & Majerčák*, 2002b). The hydraulic conductivity of the topsoil was measured with a suction and a double-ring infiltrometer, and the bypassing ratio (i.e., the ratio of the rate of macropore flow and the rate of total flow in soil) was estimated (*Lichner & Houšková*, 2001). It was found that the spatial and temporal variability of the soil's hydraulic conductivity decreases with an increase in the percentage of effective pores (i.e., pores through which water and solute are transported). The bypassing ratio was found to be high during the whole growing season; therefore, transport of agrochemicals or pollutants in surface-vented macropores can be expected in the course or after a heavy rainstorm.

Experimental laboratory and field research on shrinking and swelling processes in heavy soils was conducted on the East Slovak Lowland (*Šútor, Gomboš & Ivančo,* 2001ab). Relationships between the volume changes in these soils and the soil water content, fractions with various soil particle sizes, and density were derived (*Šútor & Gomboš*, 2001, *Gomboš & Šútor,* 2002). These can be used to estimate crack porosity, net formation of crack's, subsidence of the soil's surface, and the potential for linear extensibility (*Gomboš, Šútor & Tall,* 2002).

Evapotranspiration from agricultural canopies and its distribution over the territory of Slovakia was analysed and modelled in *Novák* (2001). The relationship between transpiration and nutrient uptake dynamics in plant canopies, which is applicable to the modelling of the soil's chemical balance, was derived (*Novák & Vidovič*, 2002).

The amount of cadmium adsorbed by soil particles smaller than 10^{-5} m was measured by means of a new radioactive tracer technique within the framework of the joint Czech and Slovak Project No. 185/099 (*Lichner & Čipáková*, 2002). Cadmium adsorbed by those soil particles can be transported to deeper soil horizons via soil macropores (particle-facilitated transport) in the course or after a heavy rainstorm. From the Cd concentration versus the depth distributions measured in situ, it was concluded that not only the water-soluble fractions of cadmium, but also the fraction adsorbed by soil particles smaller than 10^{-5} m, should be taken into account in the simulation of the transport of cadmium in a macropore domain.

From the results of the radioactive tracer technique, the distribution coefficients K_{dm} and K_{df} were calculated for the soil matrix and macropore domains, respectively (*Čipáková et al.*, 2002). These were used in simulations of the cadmium transport using a two-domain model. It was found that the share of cadmium adsorbed by the soil particles smaller than 10^{-5} m decreased with the cadmium's residence time in the soil due to the flocculation of clays and the ion exchange (residence time/aging effect).

Cadmium distribution in soils was also studied using the Tessier sequential extraction method (*Čipáková*, 2002b). In *Babejová et al.* (2001) and *Čipáková* (2002a) it was concluded that the mobility of cadmium in soils could be affected by the content of the soil's organic matter and the application of zeolite. *Babejová* (2001) and *Lichner et al.* (2002) studied the effect of changes in the content of humid acids and kaolinite and of the drying temperature on soil's water repellence.

Runoff generation processes and tracer methods

For the direct measurement of transpiration through a stem (sap flow), the heat balance method was used. Continuous observation through the vegetation season permitted an analysis of the diurnal and seasonal courses of transpiration in the Danube floodplain forest. Based on this analysis a selection of the most relevant parameters affecting the transpiration was performed. Relationships, which allowed for the estimation of the transpiration rates indirectly from the meteorological measurements, were found (*Mészároš*, 2000b).

The SOLEI-32 model for an estimation of the energy income and evapotranspiration was further developed and applied to determinate the areal variation in the energy income and evapotranspiration in mountainous basins of the West Tatra Mountains (*Mészároš,* 2000a), (*Mészároš & Miklánek,* 2000), (*Mészároš et al.*, 2002). A new method for estimating cloudiness index (*Kostka,* 2000) was included in the model.

Research in snow hydrology has a long tradition in Slovakia (*Holko et al.*, 2001). Re-evaluation of the large database of historical field measurements from 1960 to 1993 in the Low Tatra Mountains resulted in a determination of overall the trends in the spatial and temporal distributions of snow density, height and water equivalent in several mountainous catchments (*Holko et al.*, 1999; *Pecušová & Holko,* 2002; *Pecušová et al.*, 2002). The estimation of snow redistribution by wind was also outlined (*Kostka,* 2001).

The modelling of snow accumulation and melt was practically oriented recently; the modification and application of the degree-day based Snowmelt Runoff Model SRM (*Parajka,* 2001b) and the development of the distributed version of the Utah Energy Balance Snow Accumulation and Melt Model UEB was at the centre of interest (*Parajka et al.*, 2001).

Tracer techniques were used to study the movement of soil water, the separation of runoff components and the mean transit times in catchments (*Holko,* 1999, 2002; *Lichner,* 2001; *Lichner & Holko,* 2001). A runoff separation method based on the relationship between stream discharge and the groundwater table was successfully verified in several small experimental catchments in Europe (*Holko et al.*, 2001, 2002). The impact of land use on the hydrological regime was evaluated using a new, original two-step method for the separation of the three-components of the hydrograph based on the use of one tracer (*Pekárová, Miklánek, Koníček & Pekár,* 1999).

The areal extent of the contributing areas in the Jalovecký potok mountainous catchment was modelled by TOPMODEL (*Kostka & Holko,*

2001). Analysis of the rainfall-runoff events in the same catchment indicated

A cheap and generally accessible system for the monitoring and early warning of water pollution was proposed within the framework of the EC's 5th Framework Program Project "System for European Water Monitoring" SEWING (http://www.sewing.mixdes.org). It is based on new types of ISFET (Ion Selective Field-Effect Transistors) and is 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 will make the sensors suitable for various types of waters and waste waters, especially in high-risk industrial regions, giving the possibility of monitoring, early warning and finding sources of pollution (*Lichner et al.,* 2002).

River morphology and sediment transoprt

The granulometry of river sediments of an alpine-type river in the West Tatra Mountains was assessed and studied in *Kostka & Nagy* (2001).

Qualitative and quantitative investigations of the effect of river morphology on ichthyological fauna in both natural and regulated segments of selected rivers were conducted. Fish species composition, species diversity, the abundance and biomass of particular species, the mean individual weight and the ichthyomass were monitored during the spring and autumn seasons. Factors affecting fish population density were specified *(Macura, Kohnová & Ivančo,* 1999). It was observed that in a natural stream segment, the number of species, the diversity of species and equitability indices were higher than in regulated ones (*Macura, Ivančo & Kohnová*, 2000; *Macura & Kohnová*, 2000).

Several projects were focused at the study of river and floodplain processes (flow regime, development of river channel and floodplains, sediment transport) of the lower Morava River by means of numerical and physical models in order to analyse the negative impacts of river regulation and other human interventions at the environmental quality of the river and of the adjacent protected landscape area (*Holubová & Lisický,* 2001; *Holubová,* 2002).

The study of meander hydrodynamics and sediment transport regime on the Morava River was aimed at evaluating the efficiency of recently implemented river restoration measures. Morphologically stable and environmentally sensitive river training measures were proposed with the aim to support the creation of natural range of instream and bankside habitats for fisheries, flora and fauna, and to protect the wetland ecosystem of the lower Morava river against successive degradation (*Holubová,* 1999, 2001; *Holubová & Lukáč,* 2000).

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 hydropower schemes Freudenau and Gabčíkovo. The impact of river training, dredging and other human interventions at the riverbed of the Danube were also analysed with regard to the possible morphological development of the riverbed in the future (*Holubová & Szolgay*, 1999; *Holubová*, 2000ab).

Groundwater

Quantitative aspects of groundwater formation and regime were studied in several regions. Several studies were concerned with the interrelationship between surface waters and groundwater under withdrawal (*Fendeková & Némethy*, 2001*; Némethy & Vlčková-Michalíková*, 2000*; Fendeková*, 1999a; *Fendeková & Fendek*, 2002b).

Research of the influence of human activities on the recharge of groundwater amounts under different hydrologic conditions was conducted using both stochastic and physically based numerical models. Numerical modelling of the transboundary aquifer of the Zohor-Marchegg depression across the Slovak–Austrian border was used in estimating the withdrawable amounts of water in excess of the existing exploitation of the groundwater resources (*Fendek & Fendeková*, 2002), (*Fendek et al.*, 2002). Stochastic modelling was used for the estimation of the relationship between surface waters and groundwater in the weathered zone of granitic rocks in High Tatra Mountains, where very quick runoff and an immediate reaction of groundwater on external inputs were observed (*Fendeková & Fendek*, 2002a*)*.

Several numerical groundwater models based on finite elements and boundary elements were used for the analysis, prediction and control of groundwater levels on several water structures in Slovakia (*Šoltész*, 2001; *Šoltész*, 2002; *Šoltész & Baroková*, 2002; *Balážová et al.*, 2002). It was concluded, that technical measures could be used to improve the groundwater regime even in extreme hydrologic conditions.

Regionalization and mapping

The generation of an extensive database of physiographic characteristics of small basins of Slovakia (*Solín et al.*, 2000) was used in the process of a new and comprehensive hydrogeographical regional typification of Slovakia. Six

regional types of minimum and mean annual runoff regimes were identified using the mean annual precipitation and mean altitude of the basins as differentiating factors (*Solín & Grešková*, 2000*; Solín & Cebecauer*, 2001).

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 regional frequency analysis of floods and extreme rainfall and in the estimation of their respective design values for engineering purposes.

In several studies different regional approaches based on the Hosking and Wallis methodology were applied to annual and seasonal maximum flood data from more than 260 basins in Slovakia (*Kohnová & Pochybová*, 2001*; Kohnová & Szolgay*, 1999, 2001, 2002*; Solín*, 2002). Other studies dealt with regional frequency analysis of one to five days' maximum annual and seasonal precipitation *(Jurčová, Kohnová & Szolgay*, 2002*; Stehlová, Kohnová & Szolgay*, 2002*).*

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 regional frequency analysis of floods and extreme rainfall under the rather heterogeneous runoff generating conditions in Slovakia were studied and discussed (*Kohnová, Schneider & Szolgay*, 2000*; Kohnová & Solín*, 2002).

Hydrological maps often represent the cartographic output of hydrological research. Selected principles of hydrological mapping for the visualisation of the spatial and regional variability of hydrological characteristics were explained in *Solín* (2001).

Estimation of the spatial patterns of precipitation is particularly difficult in mountain regions, where data are sparse and the spatial variability of the governing processes and of properties of the hydrological environment is high. Several studies were aimed at the development of methodologies for the spatial interpolation of precipitation data for hydrological mapping and rainfall runoff modelling. The applicability and effectiveness of using GIS-based methods and grid representation of precipitation data for the computation of areal averages of precipitation, precipitation maps of average and extreme precipitation and daily rainfall fields as input for rainfall runoff modelling were tested. The predictive accuracy of the different interpolation methods using "jack-knife" and split sample techniques, as well as using GIS map algebra operations, was evaluated (*Parajka*, 1999, 2000ab, 2001a; *Hofierka et al.*, 2002*; Parajka*,

Kohnová & Szolgay, 2002; *Kohnová, White & Szolgay*, 2000; *Kohnová & Parajka*, 2002).

Extreme events

A number of very high 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 (*Majerčáková & Škoda*, 1998; *Šťastný & Majerčáková*, 2003). An assessment of the historical floods in the rivers of the Bodrog River Basin in East Slovakia was preformed in *Halmová* (2001). An analysis of this dataset indicated an increased extremeness of the flood regime on the Uh River, which is the Bodrog`s tributary (*Pekárová & Miklánek, 2001*).

Annual and seasonal maximum one to five day precipitation depths in 19 raingauges in the Upper Hron River basin in Slovakia were studied in *Stehlová, Kohnová & Szolgay* (2001); *Parajka, Kohnová & Szolgay* (2002) and *Jurčová, Kohnová & Szolgay* (2002). N-year values of the maximum precipitation depths were estimated at-site by using several distribution functions and at site and regional parameter estimation methods. Although the number of statistically acceptable distribution functions was found to be rather high in the region, the comparison of the resulting design precipitation values estimated from these distribution functions showed that these did not exhibit significant differences.

The results of the Danube flood research were summarized in a monograph by *Svoboda et al.* (2000). It includes a re-evaluation of the probabilities of flood occurrences on the Danube in Slovakia, the development of a scenario for a catastrophic flood and the simulation of the movement of a catastrophic flood in the Slovak – Hungarian reach of the Danube by a hydrologic flood routing model.

The changes in flood travel times on the upper Danube between Germany and Hungary were studied in *Miklánek, et al.* (2002). Volumes of flood waves were statistically analysed separately for dry and wet periods in *Mitková et al.* (2002).

The various risks associated with flooding were characterised by simple relations based on informative numerical values deduced from the actual conditions of the Slovak Republic. Reduction of the flood risks achievable by

geotechnical measures covering stability increases in embankments, transport communications and buildings was suggested in *Hulla* (2002).

Climate change impact on hydrological processes and water resources management

The expected impact of climate change in general, vulnerability assessment and adaptation measures for Slovakia were summarised in the Third National Communication on Climate Change (2001); an overview of impacts on climate-related sectors is given in *Lapin et al*. (2002), and hydrological impacts were reviewed in *Majerčáková* (1999, 2000).

Time series of precipitation and runoff were analysed within the framework of the Slovak National Climate Change Program (SNCCP) in several studies in order to detect climate change signals in data series. The annual maximum daily precipitation totals were analysed at more than 600 climatological stations from 1950 to 2000 using statistical methods (*Cebulak et al.*, 2000; *Faško et al.*, 2000; *Gaál et al.*, 2002). *Demeterová* (2000), *Ľupták et al.* (2000), *Šipikalová* (2000), *Miklánek, et al.* (2002), *Koníček* (2000) and *Holko et al.* (2001) assessed trends in the runoff of measured and experimental basins.

Trends and expected changes in the groundwater regime were studied in *Fendeková* (1999, 2000) and *Fendeková & Némethy* (2001). An study of groundwater runoff changes in different geological conditions in the last four decades showed a decrease of groundwater runoff in most of the assessed catchments of Slovakia (*Fendeková*, 1999b). Study of spring yields in karstic areas of Slovakia showed very distinct decreasing trends almost in all evaluated cases (*Fendeková*, 2000).

Hrvoľ et al. (2001) presented model calculations of solar radiation balance and evapotranspiration for 32 Slovak localities from 1951 to 2000 including a complex statistical and trend analysis of monthly and seasonal data.

Pekárová et al. (2001a, 2001b) and *Pekárová & Pekár* (2000) analysed the long-term variability of runoff using mean annual runoff series of Slovak rivers as well as rivers in the temperate zone of the Northern Hemisphere and the sub tropic and equatorial zones. They estimated the main cycles of the series and detected a time shift in the occurrence of runoff extremes in the studied regions of the world.

Several analogous, incremental and GCM (General Circulation Model) based climate change scenarios were constructed for the 2010, 2030 and 2075 time frames within the framework of the Slovak National Climate Program. It was attempted to construct physically plausible scenarios of monthly and

annual time series for air temperature, precipitation and air humidity. The outputs of CCC M1, CCC M2 and GISS98 GCMs with coupled systems of atmospheric and ocean circulation were downscaled. Attempts to design scenarios of extreme monthly and daily precipitation totals for selected time frames (2010, 2030, 2075) started (*Lapin et al.*, 1999, 2000, 2001, 2002).

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 the majority of the territory of Slovakia.

For determining climate change impact on mean annual flows, the Turc model has been selected. 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 areal averages of expected changes of runoff for the climate change scenarios. Regions with different degrees of climate change hazard were defined (*Hlavčová et al.*, 1999; *Hlavčová et al.*, 2000; *Parajka et al.*, 2002a).

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 (*Szolgay et al.*, 2000; *Hlavčová et al.*, 1999; *Hlavčová et al.*, 2000; *Hlavčová et al.*, 2002; *Parajka et al.*, 2002b; *Petrovič*, 1998, 2000; *Majerčáková & Takáčová*, 2001; *Kostka & Holko*, 2000; *Halmová et al.*, 2002 and *Kostka & Holko*, 2002b. *Šútor, Štekauerová & Majerčák* (2002cd) studied the impact of climate change on the water regime of the soil aeration zone in the Slovak lowlands.

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 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.

The impact of a possible climate change upon the yields of the main water reservoirs in Slovakia was studied in *Halmová* (2000ab). It was concluded that the changed climate conditions could considerably affect withdrawals from the reservoirs. The maximum uniform withdrawal that could be supplied under different climate change scenarios ranges between 65 and 90 % of the respective recent values.

Basic strategies for the adaptation processes in water resources management in order to account for climate change impacts were suggested (*Hlavčová et al.*, 1999; *Hlavčová et al.*, 2000; *Szolgay et al.*, 2000; *Szolgay et al.*, 2002). These include a recommendation for transforming natural hydrologic resources into managed resources. Interannual and seasonal redistribution of water and 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. Revitalisation 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.

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The Slovak National Committee for IAHS

The Slovak Committee for Hydrology (SCH) has been established under the leadership of the late Dr. Ľudovít Molnár after the division of former Czechoslovakia in 1993. It has formed its own bodies, Statutes, Bye-laws and has been accredited at 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 activities of Slovak hydrologists in 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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INTERNATIONAL PROJECT ON CLIMATE CHANGES AND VARIABILITY IN THE WESTERN CARPATHIANS

In collaboration of climatologists from the Institute of Meteorology and Water Management from Cracow and the Slovak Hydrometeorological Institute several valuable papers have been presented in the conferences and several monographs have been published. In 1994 a new project titled "Climate Changes and Variability in the Western Carpathians" was established. Climatologists from the Polish Institute of Meteorology and Water Management (IMWM) branch in Cracow and the Slovak Hydrometeorological Institute (SHMI) in Bratislava took part in this project. The main

are situated in the Central Europe and they are lying parallel with latitude. Due to its orientation it is also a climatic boundary. The crestline of the main ridges is the frontier between Poland and Slovakia so that a full account of the mountain climate required the collaboration of climatologists from both countries. More detail can be found in the selected papers prepared by *Lapin et al.,* 1998, *Cebulak et al*., 1998 and 2000, *Falarz et al.,* 1998. In some other papers also wind, atmospheric circulation, air temperature and air humidity have been investigated.

UPPER ATMOSPHERE METEOROLOGY, OZONE, UV RADIATION AND AEROSOLS

The long-term temperature course at selected levels was compared with total ozone in *Chmelík* (2000). The negative total ozone trend significantly correlates with both positive temperature trend in the troposphere and negative temperature trend in the lower stratosphere. Since 1976 the cooling trend of annual temperature mean in the stratosphere caused particularly by stratospheric ozone loss has been -0.8 degrees per decade at 70 hPa standard

isobaric level. During last decade the considerable ozone destruction was recorded also in period April-August. Upper-wind in the layer 1-30 km over Slovakia was processed. Frequency of wind direction in eight main sectors and average wind speed were calculated. Vertical distribution of wind direction and wind speed and yearly course of wind direction were analysed. The data from the Poprad upper-air station for the period 1976-1995 was used. Presented characteristics represent wind conditions over Slovakia from the 3 km level. Below the 3 km level, the air flow is affected by both deformation effect of the High Tatras massif and local thermal circulation (*Chmelík*, 1998). Wind direction above Central Europe is influenced by the air pressure systems and the frontal zone position. Typical meteorological situations in Slovakia consist of 28 types (by catalogue). Wind speed and wind direction are significantly connected with the synoptic types occurrence especially in the period December – April (*Bochníček,* 2001). Measurements of broadband ultraviolet and total irradiances at Stará Lesná and Skalnaté Pleso were used to define attenuation by cloud cover. In annual mean sense, clouds reduce the ultraviolet radiation to levels from 58% at Skalnaté Pleso to 61% at Stará Lesná of the values that would exist if skies remained clear over measurement sites. Comparison of total irradiance with simultaneous broadband ultraviolet irradiance indicated that clouds provide less attenuation in ultraviolet range. The regression models were derived to estimate the attenuation of broadband ultraviolet and total radiation using fractional cloudiness values (*Ostrožlík & Závodská,* 1999). Relations between total column ozone and measured or numerically forecasted (model Aladin) meteorological parameters were discussed and the best-correlated parameters were chosen for the creation of statistical regression model. Regression coefficients were calculated from parameters measured at the Poprad-Gánovce in 1993-1998 period. The aim was to find the total column ozone forecast model acceptable as a part of the short-term biologically active UV-radiation forecast procedure (*Pribullová & Chmelík,* 2001). Prediction model, process of its preparation, results and evaluation of the first forecast period, as well as proposals for the next improvements of UV-index forecast in Slovakia were presented (*Pribullová,* 2001). Direct solar radiation measurements of the Poprad–Gánovce Brewer spectrophotometer were used for the spectral total optical depth and aerosol optical depth calculation. The 1993-2001 morning half days were selected for this purpose. The results were derived graphically and mathematically, subtracting the average Rayleigh, O_3 and SO_2 optical depth of the total optical depth obtained from Langley plots (*Pribullová,* 2002).

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 2001. 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 from Hurbanovo from 1871. Detailed studies on precipitation variability in Slovakia, including daily total extremes and seasonality changes, have been prepared mainly at the Slovak Hydrometeorological Institute (Faško, Šťastný, Vivoda) and at the Department of Meteorology and Climatology, Comenius University (Lapin, Melo, Damborská, Gaál, Pishvaei). Correlation among precipitation, air pressure and atmospheric circulation indices has been studied by Lapin, Pišútová and Faško by use of circulation indices prepared by *Niedzwiedz* (1992) in 1998. *Hrvoľ et al.,* (2001), investigated changes and variability of solar radiation and evapotranspiration at 32 stations in Slovakia. General conclusion from above mentioned studies indicate serious changes in precipitation variability by the end of the 20th century. In the same time significant increase in air temperature occurred, mainly from January to August 1988-2002. Increase in potential evapotranspiration decrease in precipitation totals caused dramatic decrease of evaporation, soil moisture and some hydrologic characteristics in the 1971-1993 period and only small increase in those elements up to present. Besides rise of air temperature the changes in atmospheric circulation over central Europe are considered as main reason. Research of climate variability concentrates mostly on air the temperature and precipitation series. Other climatic elements, including cloudiness and sunshine, are only rarely considered. On the other hand both these elements are important in the climatic conditions forming. The main aim of the study is the determination of influence of the Western Carpathians chain on the cloudiness and sunshine conditions. Homogenous data from both sides of the mountains was required to solve the problem (*Bochníček et al.,* 1998). Hourly global solar radiation sums at Skalnaté Pleso and Stará Lesná were evaluated to study the time and vertical variability of this element in the high-mountain conditions. Different altitudes as well as orographical conditions in the both localities are manifested in the different global solar radiation sums. Obtained results at Skalnaté Pleso represent the high-mountain conditions and the corresponding values at Stará Lesná may characterize the global solar radiation receipt for forest ecosystems in the Slovak territory (*Ostrožlík,* 2002).

RADIATIVE PROCESSES IN THE ATMOSPHERIC BOUNDARY LAYER

Measurements of the long-wave radiation flux density, air temperature, air humidity as well as clouds observation in two atmospheric were used to evaluate the radiative cooling or heating rates in the atmospheric layer between Stará Lesná and Skalnaté Pleso. It was shown that whereas the cloudiness in the investigated layer decreases the radiative cooling rate up to 43% in general, the vertical thermal gradient decrease evokes an increase of the radiative cooling rate. The highest values of the radiative cooling rate occurred by a strong inverse thermal stratification and a small water vapour content (*Smolen & Ostrožlík,* 1999). Based on the differences of the short-wave radiation balance in the observational sites (Skalnaté Pleso and Stará Lesná) the radiative flux divergence in the atmospheric boundary layer at the average cloud conditions, the clear sky, and the overcast sky was evaluated. An analytical relation was found to express a dependence between the radiative flux divergence and the reflecting power of the active surface. It was shown that this dependence can be expressed by polynomial of degree 3 (*Smolen & Ostrožlík,* 1999). On the basis of the vertical change of the balance of the short-wave radiative fluxes in the atmospheric boundary layer between Stará Lesná and Skalnaté Pleso the cause of sudden change of radiative temperature changes rate in the later afternoon hours was explained. The main reason of this change consists in a great horizon exceeding at Skalnaté Pleso observatory from the south-western to the northern side. An analytical relation was find for the expression of the dependence between radiative temperature changes rate and difference of surface albedo between levels Stará Lesná and Skalnaté Pleso (*Smolen & Ostrožlík,* 2000a). Simultaneous measurements of wind speed, precipitation, air temperature, and air humidity enabled to evaluate the quantitative influence of the selected meteorological factors on the biometeorological cooling intensity at Mlyňany. Coefficient of heat transfer between the receiving part of frigorimeter and the near surroundings was

spectrum range (*Smolen & Ostrožlík,* 2001). Short- and long-wave radiative fluxes in the high-mountain positions Skalnaté Pleso and Stará Lesná were used to study the influence of the atmospheric boundary layer on the radiative fields in the High Tatras. Beside the time and space variability of the radiative fluxes the attention to the emissivity, radiative cooling and heating in the investigated atmospheric layer as well as the influence of the low clouds on the long-wave radiation balance is paid (*Ostrožlík & Smolen,* 2001-2002).

METEOROLOGY OF THE SURFACE LAYER OF THE ATMOSPHERE

Results of microclimatic profile measurements carried out above a maize strand were analysed 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 (*Matejka,* 1998). 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 vapour 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 stabilising effect on energy balance of forests and consequently on their microclimate (*Matejka et al.,* 1999). 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 analysed. The relationships between the evapotranspiration and surface resistances were quantified for the selected crops (*Hurtalová et al.,* 1999). Microclimatic effects of a young spruce forest were examined over one growing season. The comprehensive analysis of air temperature and humidity within the forest and above it showed that the daily maximum of air temperature occurred in the lowest part of the canopy near the soil surface. Consequently, the soil below the canopy was the dominant source of heat in this case. However, there were two sources of water vapour localised at the soil surface and in the upper part of the canopy where the most intensive transpiration is going on (*Matejka et al.,* 2000). With aim to identify the factors affecting the surface characteristics, the saturation deficit and surface temperature were determined from the vertical profiles of air temperature and water vapour pressure. It was found out that the relationship between surface

temperature and the saturation deficit at the surface can be considered as quite conservative, however only under the conditions of light or gentle wind and sufficient soil water content. Soil moisture changes and thermal properties in the topsoil layer affected by different crops were examined. It was shown that the spatial distribution of soil moisture was determined by a type and growth stage of vegetation, and meteorological conditions. The effect of plant cover on soil thermal properties observed on cultivated fields was manifested by the soil moisture changes, in turn affected by type and growth stage of plant canopies (*Usowicz et al.,* 2001). Daily courses of the actual transpiration of a spruce forest stand were determined using an experimentally verified mathematical model. The transpiration responded sensitively to the changes in the soil moisture and consequently the evapotranspiration and its components were strongly reduced by drying of the soil. The mean reduction of the actual transpiration in the analysed period of 30 days was 77 % from the drought-free transpiration. The evaporation from the soil was reduced even more (*Matejka et al.,* 2002).

Variations in the zero plane displacement, the dynamic roughness length, the drag coefficient, and in the aerodynamic resistance for maize canopy during one growing season were investigated. With this aim the vertical wind speed profiles measured in and above the maize canopy during the vegetation season were analysed. Throughout the season, the roughness length started at 0.04 m (monthly average in May) and increased to a maximum of 0.24 m (monthly average in August) for closed maize canopy surface (*Hurtalová et al.,* 2002a). Over flexible vegetation, during windy conditions, a coupling of the airflow and vegetation takes place. The builds up a waving form of the canopy surface in addition to producing streamlining and a fluttering phenomena. Consequently, it may be estimated that the aerodynamic properties vary with the wind speed. This is one of the most striking phenomena of airflow over vegetation. Therefore the vertical wind speed profile measurements in and above the young spruce forest stand measured during growing season of 1999 were analysed in order to investigated the aerodynamic properties of this vegetation (*Hurtalová et al.,* 2001). The comparison of some aerodynamic parameters estimates obtained from wind speed profile measurements and from sonic anemometers in and above a young spruce forest stand from July to October 2000 was presented. The friction velocity and the roughness length values from profile measurements are higher than their values from the sonic anemometer (*Hurtalová et al.,* 2002b). Air flow an air layer affected by vegetation cover is very strongly dependent on aerodynamic properties of its active surface. On the base of the vertical wind speed profiles analysis the

deformation of the air flow in such layer over a young spruce forest stand was investigated. The experimental site is represented by the monoculture of young Norway spruce stand with density of 2600 trees per ha on Fd plot as well as of 1880 trees per ha on Fs plot. The zero plane displacement d was 0.73 h for Fd plot with the mean stand height h = 8.86 m and d = 0.59 h for Fs plot with h = 8.07 m. The mean dynamic roughness length z_0 was found to be 0.61 m for Fd plot and z_0 = 0.70 m for Fs plot for growing season of 2001 (*Hurtalová et al.,* 2002c).

SNOW IN MOUNTAINOUS ENVIRONMENT

Requirement of regular snow temperature measurements was assigned for selected ski centers, hydrology resorts and avalanche precaution. Respect is focused on the analysis of measurement provided by automatic weather station during the existence of snow cover (December 1999 – April 2000) at the most exposed place of the Nízke Tatry mountain. Thermal (as well as mechanical) impacts effect snow cover in the process of metamorphosis and diagenesis, what is documented by thermal gradients (magnitude and direction). Finally the possible risk of the snow temperature measurement interpretation at the end of the winter season is included (*Bochníček,* 2002). Snow cover depth is regularly measured at the Slovak climatological/precipitation stations since 1921. Linear-quadratic model has been used for snow cover depth drop in the process of melting and its disappearance providing of no snowing, 14 variables (measured meteorological elements) came into the model. "Stepwise Regression" retained only those ones that improved the model. The result of the mentioned model was a prediction on 2, 3, 4, 5, and 6-day period in fiction of no new snow. The results were compared with measured drop of snow cover depth and individual values were compared and predicted with 95% confidence interval. This research consists of knowledge how the snow cover depth acts with respect to meteorological elements especially in the spring 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. The decrease in concentration of

nitrogen compounds in air and precipitation was not so apparent. 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. Only for ground level ozone, a complex non-linear relationships of concentration to the precursor emissions and multi-scale character of ozone formation process were confirmed (*Mitošinková et al.,* 2002). 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 model does not respond to the change of the mixing height. If the built-up area around the street is not continuous, the model respond to the change of the portion of area of no building-up only slightly (*Hesek,* 2000). A parking place and a collective garage are both included among the small sources of pollutants. A collective garage with the air-conditioning is really a small source. Pollutants are emitted over the roof into the free atmosphere with good dispersion conditions. The impact of such a pollutant source on the quality of the surface layer of the atmosphere is small. The parking place is a ground source of pollutants and its influence on the air pollution in the vicinity of a big parking place can be high. It is therefore important to determine the pollutant emission of the parking place. (*Hesek,* 2001). 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. Emission factors correspond roughly in a city to the mean speed of the vehicle 20 km h^{-1}, outside the city 60 km h^{-1}. The speed-dependent emission factors are introduced. On the basis of the empirical speed-dependent emission factors for *CO, NO_x VOC* and *TPM* found by the Corinair working group for each vehicle category, and on the basis of the vehicle fleet composition, the mean speed-dependent emission factors are calculated (*Hesek,* 2002).

METHODS OF PRECIPITATION MEASUREMENTS

Compatibility of precipitation measurements of various national gauges commonly used in the Northern Hemisphere countries has been evaluated,

WMO Solid Precipitation measurement Intercomparison Project. Slovakia participated in these WMO activities since 1980. Recent results of the Project were published in *Yang et al.* (2001) paper, including M. Lapin contribution concerning evaluation of precipitation measurements in Slovakia. Little difference (less than 5%) is found between national rainfall data, but a significant discrepancy (up to 110%) exists between national snowfall records. This difference is not constant and it varies with wind speed and temperature. Strong linear relations among daily national gauge measurements have been definedfor several national gauges commonly used in the Northern Hemisphere.

CLIMATIC ATLASSES AND MONOGRAPHS

After about 20 year gap the new Atlas of the Slovak Republic's Country was issued in 2002 (*Atlas krajiny...*). 37 completely new climatic maps, graphs and tables have been prepared by Slovak climatologists. The 1961-1990 period of observation was mostly used at elaboration. Compared to previous atlasses new approach was applied at climatic classification, drought and evaporation, dynamic climatology, wind and inversions, mugginess and fog elaboration. Continuation of the Slovak National Climate Program (NCP) monographs took place in 2000 and 2001. Some papers are descibed more in details within the chapter on Climate Change issues. Most of the NCP results have been used at the Third Slovak National Communication to Climate Change completing in 2001. According to new regional climate change scenarios (based on Canadian CCC M2 and US GISS 1998 model outputs) new impacts and adapting measures in hydrology, water managemment, agriculture, forestry, fores and field ecosystems have been prepared by many authors from about 20 institutions.

The contribution prepared by *Bochníček* (1998), suggests importance of maximum daily wind gust research at the selected stations in Slovakia. Wind gusts represent immediate speed which effect is harmful in many cases in the sense of their repeating in waves, and causing considerable material damages. Dynamic and climatological access has been used for explanation of wind gust distribution. Meteorological standartization of synoptical situations above Central Europe territory enabled to table wind gust occurrence for sufficient time period (1961 - 1997). The last step in the treatment of climate data sets at the Swiss Meteorological Institute (SMI) and the Slovak Hydrometeorological Institute (SHMI) is the homogenization of monthly climate data series realized at irregular intervals. For this purpose an application THOMAS (Tool for

Homogenization of Monthly Data Series) has been developed. The homogenization is operationally achieved thanks to a graphical user interface depending on the computer operational system with access to a library of mathematical functions. This package allows to perform every necessary steps in data series homogenizing, including basic graphical and statistical data analysis, selection and calculation of reference series, a variety of homogeneity tests and the adjustment of shift and trend inhomogeneities. Monthly and annual standard climate normals can be calculated from the homogenized data series (*Begert et al.,* 1998).

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 Department 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 (*Damborská et al.,* 2002; *Lapin et al.,* 1999, 2000, 2001, 2002; *Melo,* 2003). Designed scenarios for selected time frames (2010, 2030 and 2075) or in the format of monthly data time series (2001-2090) have been widely used at climate change impact assessment and at adaptive options design (*Hlavčová et al.,* 1999; *Petrovič,* 1998; *The Third National Communication,* 2001 and many others). Very serious impacts are expected in the water sector (water resources shortage, runoff decrease, flash floods increase, *Hlavčová et al.,* 1999, 2001*; Kostka et al.,* 2001; *Petrovič,* 1998), in forest ecosystems (*Minďáš et al.,* 2000) and in

agriculture (*Šiška et al.,* 2000; *Rehák et al.,* 2000*; Takáč et al.,* 2000). The first assessments of climate change impacts have been calculated for biodiversity (*Fedor et al.,* 2001; *Halgoš et al.,* 2001), health, transportation, tourism and recreation sectors (*Lapin,* 2001).

PHENOLOGY AND CLIMATE

The first objective of the study presented in *Braslavská* (2000) was to identify the tendencies or trends in the phenological event timing during the grapevine growing season (from April to September) at the locality Dolné Plachtince (Southern Slovakia, 228 m s.s.l., lat. 48°12´ and long. 19°18´) in the period 1971 – 2000. The second objective was to compare the phenological event timing with the air temperature and sunshine duration of the growing season. The shift from early summer phenological events to harvest to an earlier onset and quantity changes in the air temperature and sunshine duration were detectable in grapevine-growing seasons from 1971 to 2000. The paper presented by *Sparks & Braslavská* (2001) uses information on the arrival and departure dates of the swallow in the Slovak Republic for the 30 years 1961-1985 and 1996-2000. Records were taken at 19 localities throughout the Republic representing an altitude range from 105 m to 760 m. Monthly temperature data were constructed from six meteorological stations. With the use of regression techniques, trends towards later arrival, earlier departure and the effect of latitude, altitude and temperature are all apparent. Each degree of latitude delays arrival by 6,5 days and each 1000 m of altitude delays arrival by 11,1 days. Departure date is only significantly related to latitude with a coefficient suggesting 4,0 days earlier departure for each degree of latitude. The strongest relation between arrival date and monthly mean temperature existed for the month of April.

EDUCATION IN METEOROLOGY AND CLIMATOLOGY

Two new textbooks in Meteorology and Climatology have been issued at the Comenius University Press recently. The first one (*Tomlain & Damborská*, 1999) deals on the Physic of the Atmospheric Boundary Layer, including theory of the basic principles of the atmospheric dynamics, turbulence in the atmosphere, vertical regimen of meteorological elements, continuity equation, vorticity and energetic balance of the Earth's surface. The second one is devoted to the General and Regional Climatology (*Lapin & Tomlain*, 2001), the problem firstly published in Slovak language. In this textbook all important

problems of Climatology are included, i.e. the theory of Earth's climatic system, climate forming factors, data observations and scientific elaboration, climatography of selected elements, dynamic climatology, climatic classifications, climatic changes and variability, anthropogenic influence on climatic system, radiation and energetic balance of Earth's.

Acknowledgements: Report to IAMAS was prepared by the experts from 3 scientific institutions: Department of Meteorology and Climatology (established in 1946) at the Faculty of Mathematics, Physics and Informatics, Comenius University; Division of Physics of the Atmosphere at the Institute of Geophysics (established in 1954), Slovak Academy of Sciences; Slovak Hydrometeoro-logical Institute (firstly established in 1939, the existing institute was established in 1969), all in Bratislava. This report does not cover all Slovak activities in meteorology and the atmospheric sciences in 1998-2002, it can be considered as a selection preferred by the authors listed in references.

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Report to IASPEI

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NUMERICAL MODELING OF SEISMIC WAVE PROPAGATION AND EARTHQUAKE GROUND MOTION

Development of computational methods

Moczo, Kristek & Halada (2000) investigated stability and grid dispersion in the 3D 4th-order in space, 2nd-order in time, displacement-stress staggered-grid finite-difference scheme. They explicitly treated only displacement-stress scheme but results also apply to the velocity-stress and displacement-velocity-stress finite-difference schemes.

They derived independent stability conditions for the P and S waves by exact separation of equations for the two types of waves.

Having onsidered the P-wave stability condition as a joint stability condition, and the spatial sampling of the S wavelength at a given frequency as an argument in both dispersion relations, they consistently investigated the P- and S-wave grid dispersion.

Due to a larger wavelength of the P wave, propagation of the P wave is modeled by the FD scheme much better than that of the S wave. Compared to the P wave, there is relatively considerable grid-dispersion anisotropy of the S-wave phase and mainly group velocity. The phase velocity β^{grid} does not differ from the actual velocity β more than, approximately, 1% and 0.5% for the spatial sampling ratios $s = 1/5$ and $s = 1/6$, respectively. However, the group velocity β^{grid}_{group} can differ from β as much as 5% for the spatial sampling ratio $s = 1/5$ while it is 2.5% for $s = 1/6$. Therefore, sampling a minimum S wavelength by 6 grid spacings (instead of 5 that is prevailing practice) can be recommended in the earthquake ground motion simulations.

Grid dispersion is strongest for a wave propagating along a coordinate axis and weakest for a wave propagating along a body diagonal.

It follows from comparison of the grid dispersions in the 2nd-order and 4th-order FD schemes that the 4th-order scheme models wave propagation much better than the 2nd-order scheme. Moreover, the grid dispersion in the 2nd-order

scheme for the sampling ratios $s = 1/10$ and $s = 1/12$ is larger than the grid dispersion in the 4th-order scheme for $s = 1/5$ and $s = 1/6$, respectively.

Compared to the 4th-order 2D P-SV FD scheme, the grid dispersion in the 4th-order 3D FD scheme is considerably less sensitive to a value of the stability parameter p.

Moczo, Kristek & Bystrický (2000) similarly investigated the stability and grid dispersion dispersion in the 2D P-SV 4th-order in space, 2nd-order in time, displacement-stress staggered-grid finite-difference scheme. Although explicitly treated only scheme but The results apply to the displacement-stress, velocity-stress and displacement-velocity-stress finite-difference schemes.

Due to a larger wavelength of the P wave, propagation of the P wave is modeled by the FD scheme better than that of the S wave. Compared to the P wave, there is considerable grid-dispersion anisotropy of the S-wave phase and mainly group velocity. Grid dispersion is strongest for a wave propagating along a coordinate axis and weakest for a wave propagating in the direction of a plane diagonal.

The phase velocity β^{grid} does not differ from the actual velocity β more than, approximately, 0.9 % and 0.5 % for the spatial sampling ratios $s = 1/5$ and $s = 1/6$, respectively. However, the group velocity β_{group}^{grid} can differ from β as much as 5 % for the spatial sampling ratio $s = 1/5$ while it is 2.5 % for $s = 1/6$. Therefore, we recommend to sample a minimum S wavelength by 6 grid spacings (instead of 5 that is prevailing practice).

The 4th-order scheme models wave propagation much better than the 2nd-order scheme. Moreover, grid dispersion of the S wave in the 2nd-order scheme for the sampling ratios $s = 1/10$ and $s = 1/12$ is larger than grid dispersion in the 4th-order scheme for $s = 1/5$ and $s = 1/6$, respectively.

Kristek, Moczo & Archuleta (2002) investigated several techniques for simulating a planar free surface in the 3D 4th-order staggered-grid finite-difference schemes in order to find the most accurate and efficient one.

They numerically tested two formulations of *Levander's* (1988) stress-imaging technique - the H formulation with normal stress-tensor and horizontal displacement/particle velocity components located at the free surface, and the W formulation with shear stress-tensor and vertical displacement/particle velocity components located at the free surface. Numerical tests against the discrete-wavenumber method showed that both formulations require at least 10 grid spacings per minimum shear wavelength in order to achieve reasonable accuracy in modeling Rayleigh wave propagation in the range of the epicentral

distances up to $15 l^{S}_{dom}$ in a homogeneous halfspace.

Because spatial sampling $l_{\min} / h \ł\ 10$ obviously degrades efficiency of the 4th-order FD modeling to the 2nd-order level, they have developed two alternative techniques: (1) W-VRG: Combination of the W formulation of the stress imaging with Rodrigues' (1993) vertically refined grid near the free surface. (2a) H-AFDA: H formulation (normal stress-tensor and horizontal displacement/ particle velocity components at the free surface) with adjusted FD approximations to the *z*-derivatives at the grid points at and below the free surface (the technique uses no virtual values above the free surface and no stress imaging). (2b) W-AFDA: W formulation (shear stress-tensor and vertical displacement/ particle velocity components at the free surface) with adjusted FD approximations to the *z*-derivatives at the grid points at and below the free surface (the technique uses no virtual values above the free surface and no stress imaging).

Numerical tests of the developed techniques against the discrete-wavenumber method in the range of the epicentral distances up to $15 l^{S}_{dom}$ showed that for the spatial sampling $l_{\min} / h = 6$ they give results very close to those obtained by the discrete-wavenumber method. Because, however, W-VRG requires 3 times smaller time step (due to the vertically refined grid near the free surface), it was concluded that AFDA is the most accurate and efficient technique from the examined formulations in the homogeneous halfspace. While H-AFDA gives slightly better phases, W-AFDA gives better amplitudes. W-AFDA can be recommended for the earthquake ground motion modeling in surface sedimentary structures.

In practical calculations it is desirable to obtain values of the displacement/particle velocity components directly at the free surface. In the stress-imaging techniques it is possible to use averaging across the free surface in order to obtain the missing component(s) at the free surface, as suggested by Gottschämmer and Olsen (2001). In the AFDA technique it is possible to apply extrapolation formulas of different orders of accuracy. The 4th-order formula is necessary to obtain good accuracy.

Moczo, Kristek, Vavryčuk, Archuleta & Halada (2002) analyzed the problem of a heterogeneous formulation of the equation of motion and proposed a new 3D 4th-order staggered-grid finite-difference (FD) scheme for modeling seismic motion and seismic wave propagation.

They first considered a 1D problem for a welded planar interface of two halfspaces. Simple physical model of the contact of two media and mathematical considerations were shown to give an averaged medium

representing the contact of two media. An exact heterogeneous formulation of the equation of motion and Hooke's law was a basis for constructing the corresponding heterogeneous FD scheme.

In a much more complicated 3D problem they considered three cases: (1) a planar-interface contact of two isotropic media with the interface parallel to a coordinate plane in the Cartesian coordinate system, (2) a planar-interface contact with the interface in general position, and (3) a nonplanar-interface contact of two isotropic media. Five independent elastic coefficients are necessary to describe the averaged medium representing the planar-interface contact of two isotropic media because the averaged medium is transversally isotropic in the 1st case. In other words, Hooke's law for the averaged medium includes five independent elastic coefficients. In the 2nd case, 21 generally nonzero elastic coefficients are necessary to describe the averaged medium at a point of the interface, and, even more importantly, all strain-tensor components are necessary to calculate each stress-tensor component at a point of the interface. This means, that, in fact, the staggered spatial grid is not well applicable and the corresponding heterogeneous FD scheme would require tremendous computer memory. The same is true for the 3rd case assuming that a tangential planar interface is used at a point to approximate the nonplanar interface.

Therefore, *Moczo, Kristek, Vavryčuk, Archuleta & Halada* (2002) considered simplified boundary conditions at the contact for which the averaged medium can be described by only 2 elastic coefficients – as any of the two isotropic media in contact.

Based on the simplified approach they constructed the explicit heterogeneous 3D 4^{th}-order displacement-stress FD scheme on a staggered grid with the volume harmonic averaging of the shear modulus in grid positions of the stress-tensor components, volume harmonic averaging of the bulk modulus in grid positions of the normal stress-tensor components, and volume arithmetic averaging of density in grid positions of the displacement components.

The displacement-stress FD scheme can be easily modified into the velocity-stress or displacement-velocity-stress FD schemes.

The new scheme allows for an arbitrary position of the material discontinuity in the spatial grid. Numerical tests for 12 configurations in four types of models showed that the scheme is more accurate than the staggered-grid schemes used so far.

An important finding based on the numerical tests is that differences in thickness of a soft surface or interior layer smaller than one grid spacing can cause considerable changes in seismic motion. The results thus underline the

importance of having a finite-difference scheme with sufficient sensitivity to heterogeneity of the medium.

Moczo, Kristek & Gális (subm.) numerically tested accuracy of the AFDA technique (described above) in models with lateral material discontinuities reaching the free surface. For each of two physical models of soft valleys (one with a rectangular cross-section, the other with a parallelogram-shaped cross-section) embedded in the halfspace they considered four different positions of the valley in the staggered spatial grid. They compared the finite-difference (FD) synthetics with synthetics calculated by the standard finite-element (FE) method. The FE method was used because, unlike the FD method, it naturally and sufficiently accurately satisfies boundary conditions at the free surface and at internal material discontinuities. The comparison showed (1) very good accuracy of the AFDA technique in simulating the planar free surface, (2) very good sensitivity of the FD modeling to different positions of the same physical model in the spatial FD grid.

The implication of the investigation is that the AFDA technique can be used for simulating planar free surface in models with lateral material discontinuities which is the case of realistic models of surface sedimentary structures.

Kristek & Moczo (in press) addressed basic theoretical and algorithmic aspects of memory-efficient implementation of realistic attenuation in the staggered-grid finite-difference modeling of seismic wave propagation in media with material discontinuities. They considered the problem of accounting for a material discontinuity in heterogeneous FD schemes for perfectly elastic and viscoelastic media. They showed that the anelastic coefficients and elastic moduli of the averaged medium representing contact of two media can be determined from averaging applied to viscoelastic and elastic moduli, respectively.

In order to account properly for material discontinuities and, at the same time, be memory-efficient, they defined (1) the anelastic functions in a new way – as being independent of anelastic coefficients (that is, independent of material parameters) and (2) a new coarse spatial distribution of the anelastic functions. As a consequence, in the sum of the anelastic functions in Hooke's law we can, at a given grid position, account for anelastic functions at neighboring grid positions (and thus for other relaxation frequencies) by proper weighted averaging of the anelastic functions from neighboring grid positions without artificial additional averaging of the material parameters themselves.

If the anelastic functions are determined from volume harmonic averages of the viscoelastic moduli, a consistent extension of the new elastic FD scheme developed by *Moczo, Kristek, Vavryčuk, Archuleta & Halada* (2002) is

obtained.

Numerical tests against the discrete-wavenumber method demonstrate that the developed approach enables more accurate viscoelastic modeling than other approaches.

Kristek & Moczo (2002a) developed program package NOISE within the European Commission's 5th Framework Programme SESAME project. Program package NOISE, written in Fortran 95, is designed for random generation of seismic noise and numerical simulation of seismic noise propagation in 3D laterally heterogeneous viscoelastic media with planar free surface.

NOISE consists of two codes - RANSOURCE and FDSIM. RANSOURCE is designed for random space-time generation of point sources. A point source corresponds to an arbitrarily oriented single body force. The random generation is controlled by a minimum source-source distance, minimum and maximum source-receiver distances, minimum and maximum numbers of sources acting at the same time, ratio between the numbers of delta-like and pseudo-monochromatic signals, and maximum-amplitude distribution. RANSOURCE output files serve as input files for FDSIM. FDSIM is designed for numerical simulation of seismic motion in a heterogeneous viscoelastic half-space with a planar free surface. The code is based on the explicit heterogeneous 4th-order displacement-velocity-stress staggered-grid finite-difference (FD) scheme. A realistic attenuation is included based on rheology of the generalized Maxwell body, and new definitions of anelastic functions and their memory-efficient spatial distribution.

In the case of distant sources, the calculation can be performed in two steps. In the first step, the wavefield is generated in a large-scale structure and recorded on a boundary of a local heterogeneous surface structure. In the second step, the recorded motion serves as an input for the wavefield calculation in the local structure.

Program package NOISE is a suitable numerical tool to investigate seismic noise in canonical and realistic models. The program package enables to investigate effects of noise-generation parameters, velocity contrast, Poisson's ratio, sediment thickness, sediment/basement interface geometry and other factors on characteristics of seismic noise.

ANALYSIS OF SEISMIC HAZARD

Seismic activity on the territory of Slovak Republic is not very high but certainly is not negligible in terms of seismic hazard. Need of seismic hazard

analysis is underlined by the fact that nuclear power plants, large water structures and other important facilities are in operation.

The research in the seismic hazard was focused on the following topics: investigation of historical earthquakes, analysis of macroseismic data, investigation of regional attenuation, seismic hazard analysis for the territory of Slovakia and for the Bohunice nuclear power plant site.

ANALYSIS OF SEISMIC SIGNALS

The analysis of seismic signals is an important and irreplaceable tool for understanding and interpreting not only recorded earthquake ground motion but also numerically simulated seismic motion. As recently developed computational methods enable simulation of seismic motion in complex 3D models of surface geological structures, the signal analysis methods become more and more an inevitable part of the seismic motion modeling effort.

The research has been recently focused on development of more accurate methods for time-frequency analysis (TFA). The way in which the signal is mapped into the time-frequency plane significantly determines the amount of information that can be obtained. Hence, several methods of TFA, including traditional windowed Fourier transform, Wigner distribution, continuous and discrete wavelet transform, wavelet packets, windowed Fourier transform with the reassignment method, continuous wavelet transform with the reassignment, and the matching pursuit decomposition with the redundant Gabor dictionary, were implemented and compared. The properties of the above methods were compared for a set of simple canonical synthetic test signals and for a complicated nonstationary synthetic signal with a known time-frequency content. Though the Wigner distribution has many excellent properties, due to cross-terms it is not good for TFA of complicated multicomponent signals. The windowed Fourier transform is not suitable due to the fixed window width. Suitable methods are, e.g., the continuous wavelet transform and its combination with the reassignment. The reassignment method can improve localization properties and readability of the time-frequency representation. The wavelet transform and its combination with the reassignment method were used for comparison of synthetic seismograms computed by different approaches in numerical modeling (*Moczo, Kristek, Kristeková & Archuleta,* 2001). A very promising TFA method is the matching pursuit decomposition with the Gabor dictionary. The method has already found several applications in exploration seismology. *Kristeková* has developed an improvement of the

MONITORING OF EARTHQUAKES

National network of seismic stations

The Slovak National Network of Seismic Stations undergoes a substantial modernization. The Government of the Slovak Republic released SKK 14.25 million for the project *Modernization and Extension of the National Network of Seismic Stations*.

The main objectives of the three-year project (March 2001- February 2004) are to modernize four already existing seismic stations (ZST, MODS, SRO, and VYHS; improvement of the technical equipment) and to build up seven new seismic stations on the territory of Slovakia. Two new seismic stations will be built up close to seismic station SRO and Komárno focal region. The other new seismic stations will be Demänovská jaskyňa, Kečovo, Stebnícka Huta, Červenica and Kolonica. The modernized national network will cover the whole territory of the Slovak Republic. The network should allow to better define active seismic source zones in future, detect and localize earthquakes with epicenters on the Slovak territory and with possible macroseismic effects on the Slovak territory. The network should allow to carry out the 1st automatic localization of earthquakes within 30-60 minutes after their occurrence.

GEOPHYSICAL STUDY OF THE CONTINENTAL LITHOSPHERE

Integrated interpretation and modeling of geophysical fields

Various interpretations of seismic, magnetotelluric and geothermal data have resulted in distinctly different models of the structure and thickness of the lithosphere in the Western Carpathian-Pannonian Basin region. The model inconsistencies, which are at least partly due to the use of non-unique single-method data inversion, led *Zeyen & Bielik* (2000); *Zeyen, Dérerová & Bielik* (2002); *Bielik, Dérerová & Zeyen* (2002); *Dérerová, Zeyen, & Bielik* (2001a,b; 2002) to the application of integrated lithospheric multi-method modelling. This approach combines the interpretation of surface heat flow, gravity and topography (local isostasy) data in order to constrain the continental lithospheric thermal structure in the Western Carpathians and their adjacent tectonic units. The results indicate clear variations of the lithosphere thickness along the Western Carpathian orogen. The lithospheric thickness was found to be 90 to 120 km underneath the Bohemian Massif, 115-140 km beneath the Polish platform and 60 to 90 km beneath the Pannonian basin. A thick

lithosphere (up to 130-150 km) was indicated underneath the central and eastern parts of the Western Carpathians with a tendency of thickening eastwards. This structure was interpreted as a remnant of a subducted slab of the European plate. In contrast, no lithospheric root showed up in our models of the westernmost part of the Western Carpathians. The result proved the different geodynamic evolution of both parts of the Western Carpathians.

Bielik & Ádám (1999); *Bielik, Vozár, Šefara, Hók, Bezák, Tomek, Konečný, Šantavý, Szalaiová & Vozárová* (2000); *Bielik, Vozár, Šantavý & Šefara* (2001); *Bielik, Vozár, Šantavý, Šefara& Hók* (2001); *Bielik, Vozár & Šantavý* (2002); *Bielik & Pohánka* (2000); *Konečný, Huraiová & Bielik* (1999) and *Bielik* (1999a,b; 2000; 2002) undertook comprehensive study of the structure and dynamics of the lithosphere in the Western Carpathians. Based on multidisciplinary geophysical and geological interpretation it was found that the deep structure of the contact zone of the Bohemian Massif and the Western Carpathians was influenced mainly by transpressional deformations that run along sinistral deep-seated fault (Záhorie fault, Mur-Mürz-Leitha fault). The fault has flower structure and it is dominant seismic and seismologic feature of this contact zone. On the base of macroseismically observed earthquakes epicenter distributions it is the most notable and significant tectonic lineament in the Western Carpathians. The deep contact of both colliding plates is very steep, almost vertical. The most essential source of the Carpathian gravity minimum of the western segment of the Western Carpathians are light low-density Tertiary deposits of the Vienna basin with depth up to 6.5 km and the deposits of the outer Western Carpathian Flysch, that dip in the direction towards the Klippen Belt to depth up to 15-18 km. Also another deep structures have certain but lower influence on this gravity anomaly low. They are represented by the gravity effect of the upper crust of the Bohemian Massif and 2-3 km crust thickening. The structure and P-T-X-fO_2 conditions of the upper mantle were evidenced from lherzolitic xenoliths hosted by Plio-Pleistocene alkali basalts (southern Slovakia).

Rheology predictions

Large effort was devoted to determination of rheology predictions within the lithosphere beneath the Western Carpathians, the Bohemian Massif and the Pannonian Basin. The aim of this study was to mention the implications of rheology predictions for tectonic scenarios of these different units. *Lankreijer, Bielik, Cloetingh & Majcin* (1999); *Bielik, Lankrajer & Zoetemeijer* (2000a,b) and *Bielik & Lankreijer* (1999) concentrated their effort main on spatial

variations in recent lithospheric strength in the Western Carpathians and its vicinity. It was found that mentioned tectonic units, differing in thermo-tectonic age, lithologic stratification and crustal and lithospheric thicknesses, cause important variations in their rheology. The results clearly indicate a general decrease in strength from the oldest tectonic units (the Teisseyre-Tornquist zone, the Bohemian massif and European platform), across the Western Carpathians towards the youngest ones (the Pannonian basin).

The thickness of the upper crustal brittle zone in the Western Carpathians *(Lankreijer, Bielik, Cloetingh & Majcin,* 1999; *Bielik, Zeyen & Lankreijer*, 1999a,b; *Bielik, Bezák, Zeyen, Lankreijer & Šefara,* 2000), which varies from 0 to 15 km, is in a good accordance with the statement about the depth of earthquakes in this region. Practically all earthquakes originated at the maximum depth of 15 km (*Labák,* 1996; *Labák & Brouček,* 1996; *Schenk et al.,* 2000) and coincide with our predicted the upper crustal brittle zone.

Interpretation of gravity field

The use of gravimetry, as one of the geophysical methods for identification of brittle deformations – faults active during the neo-Alpine development of the Western Carpathians, confirmed its role in research of the orogene geodynamic evolution. The study performed by *Bielik, Lillie & Šefara* (1999) and *Bielik, Kováč, Kučera, Michalík, Šujan & Hók* (2002) in the western part of the Western Carpathians documents the fact, that the maps obtained by means of different effective gravimetric methods of transformations and visualization of gravity data can be well correlated with the age, and thus also with the depth of the faults. The results and interpretation indicate, that the map of residual anomalies displays mainly the deep faults of the initial rifting and of the synrift stage of the back-arc basin development and the map of the vertical gradient displays most of all the young shallow marginal faults and faults linked with the postrift thermal subsidence stage and tectonic inversion of the basin.

The structure and geodynamics of the crust in the central part of the Upper Egypt (24-28°N, 30-36°E) and El-Khatatba area in Egypt has been advantageously studied by means of interpretation and modeling of long-wavelength gravity and magnetic anomalies (*Radwan, Bielik, Mahmoud, Tealeb & Abde Alla Trakhan,* 2002; *Ahmed, Bohoty, Noshy, Hassan, Brimich & Bielik,* 1999).

Density modeling in local isostatic equilibrium and 2D interpretation of gravity field along the N-S directed transect TIBET that is identical with longitude 93°E have been done by *Bielik, Hsu, Fang, Zhifeng & Dérerová*

(2000). The general motivation for this research was to improve knowledge and understanding of the continental. The results indicate that the lithosphere structure beneath the Tibetan Plateau is characterized by significant crustal root with depths more than 70 km. Deeping of the Moho in the southern part of the Tibetan Plateau is very steep. Minimum depth of the Moho is 45 km underneath the Gashun Gobi region. It is interesting that the crustal root beneath the Tibetan Plateau is not accompanied by lithospheric thickening. In contrast to the Moho the lithosphere-asthenosphere boundary is almost horizontal. The lithosphere average thickness is 122 km underneath the Tibetan Plateau.

The Truncation Filtering Methodology (TFM) is a particular way of linear filtering the gravity data to facilitate gravity inversion or interpretation (*Vajda, Bielik & Pohánka* (2002); *Vajda, Bielik & Pohánka* (2002); *Vajda, Bielik & Pohánka* (2002). With the use of integral transforms the gravity anomalies are transformed into new quantities that allow interpretation with the help of pattern recognition. The integral transforms are in fact filters and may be understood as weighted spherical windows moving over the surface, on which the gravity data are defined, the kernel of the transform being the weight function. Instead of the original gravity data, the quantities resulting from the truncation filtering are interpreted or inverted. Subjective experience of the interpreter build on computer modelling and case studies makes the bridge between the observed dynamic patterns and the geology generating the gravity data. Depth estimates to some geologic elements result from interpreting the onsets of some patterns. The key feature of the truncation filtering methodology is data enhancement and dynamic (animated) pattern recognition.

Makarenko, Legostaeva, Bielik, Starostenko, Dérerová & Šefara (2002) demonstrated the results of the 3D forward gravitmetric problem. The method of 3D forward gravity modeling was applied in the Carpathian region. At the beginning the thickness-density models of the sediments in the outer Carpathians, the Pannonian Basin and Transylvanian Basin were determined. An exclusive approach to 3D gravity modeling developed by *Starostenko et al.,* (1997, 1998) has been used to calculation of gravity effects of sedimentary fillings. The gravity effects of these sedimentary fillings were used for calculation of the stripped gravity map in the whole Carpathian region.

Seismic activity and neotectonic character of the Western Carpathians

In most cases the seismic events are immediately related to movements along the fault surfaces. Therefore it is possible to correlate more or less

successfully earthquake hypocentres with the fault structures, which are from the genetic point of view of seismic events in an appropriate angular relationship with the principal stress axes. Based on the geological structure, tectonic deformation, localised earthquake epicentres and geophysical characteristics, *Kováč, Bielik, Hók, Kováč, Kronome, Labák, Moczo, Plašienka, Šefara & Šujan* (2002) and *Hók, Bielik, Kováč & Šujan* (2000a,b) tried to identify geological structures, which could generate seismic events.

Seismic refraction experiment CELEBRATION 2000

The CELEBRATION 2000 effort (*CELEBRATION 2000 Organizing Committee and CELEBRATION 2000 Experiment Team* 2001; *CELEBRATION Organising Commettee and Working Group* 2000; *CELEBRATION Working Group* 2002a; *CELEBRATION Working Group* 2002b; *CELEBRATION Working Group* 2002c; *CELEBRATION Working Group* 2002d; *CELEBRATION Working Group* 2002e and *CELEBRATION Working Group* 2002f) is to investigate the deep structure of Central Europe lithosphere. The experiments was integrated into the framework of the EUROPROBE Program – Trans European Suture Zone, EUROBRIDGE (East European Precambrian Craton) and PANCARDI (Pannonian basin, Carpathian Arc, Dinarides) projects. CELEBRATION 2000 targets many of the questions that remain about the geodynamics and structural relationship in the studied area. The primary scientific goals of CELEBRATION 2000 are:

- Investigate the deep structure of southwestern Baltica and its relationship to younger terranes
- Delineate the major terranes and crustal blocks in the TESZ region (e.g. Bohemian Massif, Upper Silesian Massif, and blocks exposed in the Holy Cross Mountains)
- Investigate the origin and the structural framework of the Pannonian basin and its subbasins
- Investigate the nature and extent of thrust faulting along the northern front of the Carpathian Mountains
- Investigate the relationships between the Bohemian Massif and Western Carpathians
- Construct the 3-D model of the lithospheric structure in the study area
- Evaluate and develop geodynamic models for the tectonic evolution of the region

The layout of the experiment was a network of interlocking profiles whose total length was about 9000 km. The station spacing along the profiles was 2.8

or 5.6 km, so that in addition to forming an array about 5400 km of profiles were obtained. Covering this network of profiles required three deployments over a period of 1 month (June 2000).

Realising that the lithospheric structure in the targeted area is very complex, the need for a 3-D approach was recognised early in our planning process. Recent advances in seismic instrumentation have made many more instruments available so that 3-D approach could be implemented. In fact by pooling European and US resources, more than 800 new matched seismic instruments that were jointly developed by the University of Texas at El Paso and Refraction Technology was available for this experiment. Other Canadian, European, and US instruments brought the total number of instruments deployed to 1230.

A large number of seismic sources were also required, and again the pooling of resources proved to be effective. Ultimately, scientific organisations in Poland, Hungary, the Czech Republic, the Slovak Republic and Austria funded 142 sources. An additional 5 shots were made in Russia, Belarus and Germany. These sources ranged in size from 15,000 to 90 kg with the average being ~ 500 kg. Since some of these sources were small we estimate that about 100,000 useable vertical component seismograms were obtained. In addition, about 15% of the stations were occupied by 3-component recorders and included two horizontal seismometers producing even more seismograms. International Consortium for CELEBRATION 2000 Experiment consisted of 28 institutions from 13 countries in Europe and North America. CELEBRATION Working Group consists of over 50 geophysicists.

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APPENDIX

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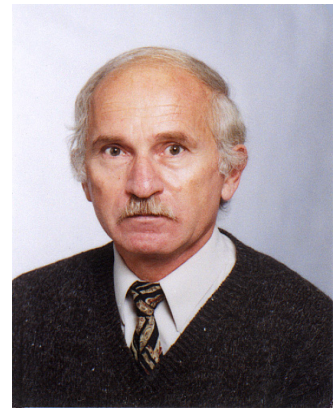

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Project coordinator: Sven Halldin, Deptartment.of Earth Sciences, Uppsala University, Sweden
Subproject No. 26 „Water regime of plant canopies and the structure of their energy balance“
June 1994 – December 2000
Subproject coordinator: František Matejka, Geophysical Institute, Slovak Academy of Sciences, Bratislava, Slovak Republic
Participating institutions from: Czech Republic, Denmark, Finland, Germany, Hungary, Netherlands, Norway, Slovak Republic, Sweden.

Bialteral German – Slovak project: Evaluation of Phenological Data for Climatological Purposes
Project coordinator: Olga Braslavská, Slovak Hydrometeorological Institute, Banská Bystrica, Ernst Dittmann, Deutsche Wetterdienst, Offenbach, Germany
July 2000 – December 2003

Participating institutions SHMI Bratislava, Slovakia, Deutsche Wetterdienst, Offenbach, Germany

Seismic experiment of European and North American institutions
CELEBRATION 2000
June 2000 – December 2003
National Coordinator: Jozef Vozár
Coordinator: Alexander Guterch
Participating Institutions from: USA, Canada, Poland, Slovak Republic, Hungary, Czech Republic, Denmark, Turkey, Finland, Germany, Austria, Russia, Belorussia

IGCP 430/UNESCO
Mantle Dynamic Implications for Thetyan natural Hazards mitigation
Januar 2000 – December 2005
National Coordinator: Miroslav Bielik
Coordinator: Martin Flower
Participating Institutions from: USA, Romania, Poland, China, Vietnam, Slovak Republic, Hungary, Turkey, Russia

INCO-COPERNICUS
Grant Project PL963311 (ISMOD)
Towards an integrated strong motion modelling: Comparison of source, path and site effects on the example of EUROSEISTEST data
1997-1999
Coordinator: Pierre-Yves Bard
National Coordinator: Peter Moczo
Participating Institutions from: Czech Republic, France, Greece, Slovak Republic

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1997-1999
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EC 5th Framework Program
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Coordinator: Pierre-Yves Bard
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Supervisor:	Dr. František Matejka, PhD., Geophysical Institute, Slovak Academy of Sciences, Bratislava, Slovak Republic
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Student: Peter Labák
Supervisor: Peter Moczo
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Student: Jozef Kristek
Supervisor: Peter Moczo
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Institution: FMFI, Comenius University, Bratislava, Slovak Republic
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