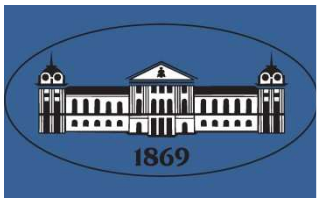

BULGARIAN ACADEMY OF SCIENCES

BULGARIAN NATIONAL COMMITTEE OF GEODESY AND GEOPHYSICS

NATIONAL REPORT

ON GEODETICAL AND GEOPHYSICAL ACTIVITIES IN BULGARIA

2007 – 2011

Prepared for the XXVth IUGG General Assembly
Melbourne – Australia
28 June – 7 July 2011

Sofia
June, 2011

FOREWORD

The IUGG National Committee of Geodesy and Geophysics is a purely scientific organization established to promote and co-ordinate studies of physical, chemical and mathematical properties of the Earth and its environment in space. These studies include the shape of the Earth; the nature of its gravitational and magnetic fields; the dynamics of the Earth as a whole and of its component parts; the Earth's internal structure, composition and tectonics; the hydrological cycle, including snow and ice; the physics and chemistry of the oceans; the atmosphere, ionosphere, magnetosphere and couplings between them as well as the solar-terrestrial relationships. The Bulgarian National Committee of Geodesy and Geophysics supports activities and studies of the Earth and its environment by ground-based and remote sensing measurements.

The main body of this report is organized into chapters representing the domain of each of the Associations of the IUGG where Bulgaria takes part. Each chapter discusses the obtained for the last four years (2007-2011) scientific results, outlines social benefits and important directions for interdisciplinary studies, and clarifies the participations in national and international projects mainly related to the EU FP7, NATO and COST activities.

This report comprises the materials prepared by the National Correspondents to the IUGG Associations. It would not have been possible without the assistance of numerous colleagues who gave generously of their time and insights.

Prof. DSc. Dora Pancheva

President of the IUGG National Committee of Geodesy and Geophysics

BULGARIAN ACADEMY OF SCIENCES

BULGARIAN NATIONAL COMMITTEE OF GEODESY AND GEOPHYSICS

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- Institute for Space and Solar-Terrestrial Research
- Institute for Oceanology "Prof. Fridtjof Nansen"

- **Bulgarian Antarctic Institute**

- Sofia University "St. Kliment Ohridski"
- South-West University "Neofit Rilski" - Blagoevgrad

GLACIOLOGY

Bulgarian Periglacial Programme

A programme for research and monitoring of sediment transfer processes in the periglacial zone of Bulgaria, *Bulgarian Periglacial Programme*, has been organized by the former Institute of Geography, which is now a part of the National Institute for Geophysics, Geodesy and Geography of the Bulgarian Academy of Sciences. The programme aims to investigate and observe contemporary geomorphic processes that occur in the Bulgarian periglacial zone located in the alpine and subalpine parts of the Rila and Pirin Mountains at altitudes of 2200-2925 m. The research is used to create a set of landscape models, which to be used for evaluation of the environmental reactions to global change and for environmental hazards risk assessment.

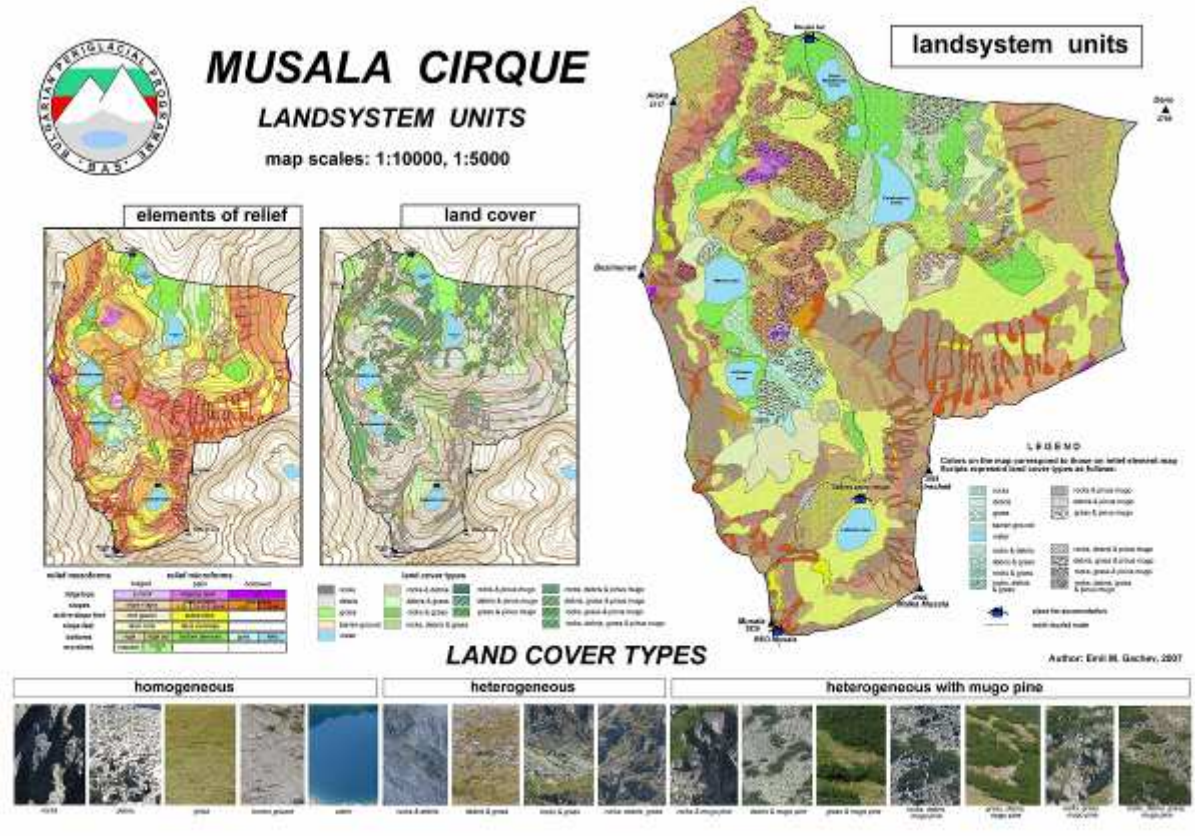

Fig. 1. Map of Musala cirque landsystem units (after Gachev, 2007).

Realization of the programme is of considerable importance for the Institute and for Bulgarian science as a whole and this type of research is currently lacking in the Bulgarian periglacial environment. The programme is performed in close collaboration with European and global scientific community, with application of up-to-date standardized methods which to allow comparison with results from studies conducted elsewhere in the world. In essence, the Bulgarian Periglacial Programme is not a project - it is much more a strategic line, which should generate series of project proposals that will ensure the fulfillment of all the tasks

planned. Hence, the main goal of the programme is to ensure an international partnership on wide basis.

As a result of the international contacts realized, the area of Musala - the highest peak at the Balkan Peninsula, has been included as a target location in the world network for research of the geomorphologic processes in cold environments to the Working Group on Sediment Budgets in Cold Environments (SEDIBUD) of the International Association of Geomorphologists. The primary aim of SEDIBUD is to provide an integrated quantitative analysis of sediment transfers, nutrient fluxes and sediment budgets across a range of key cold environments. The major focus is on the impact on sediment transfer processes in response to a variety of climate change scenarios at a scale, which incorporates sediment flux processes from source to sink.

Present State of Bulgarian Glacierets

It has been made a revision of the recent studies related to the Bulgarian glacierets, all located in the northern part of the Pirin Mountains. The studies carried out so far in the Pirin Mountains prove the persistence of two glacierets in the marble part of the massif – Snezhnika and Banski suhodol, and their relative stability (a small decrease) since the Little Ice Age.

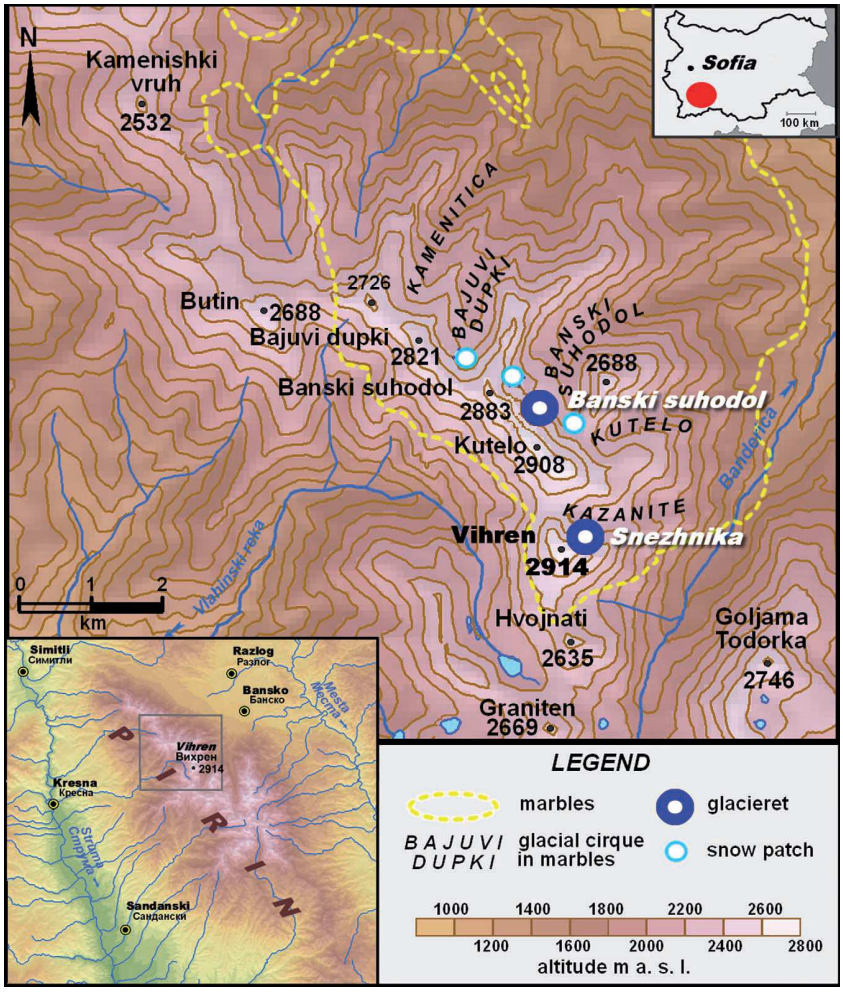

Fig. 2. Glacierets and snow patches in the Vihren area, Northern Pirin, Bulgaria (after Gachev et al., 2009).

The 16-year continuous observations of Snezhnika glacieret show that contrary to the similar features in the High Tatras, inter-annual size and mass fluctuations of Bulgarian glacierets are mainly related to variations in the temperature, in particular in the summer period (from May to October), while precipitation plays a secondary role. The newest size measurements carried out at the beginning of October 2009 show a good condition of the glacierets in the Pirin Mountains and size above the average for the last 2 decades. Comparisons with other parts of Southeastern Europe show that glacierets in the eastern part of the Balkan Peninsula, in the High Tatras and in the Adriatic area have at least three specific modes of development, determined by the differences in regional climate in terms of inter-annual fluctuations and long-term change. Each mode has its own scenario for future development, and trends in the different regions may be even controversial. In a long-term sense Bulgarian glacierets are expected to keep relative stability of size and mass with a slow trend towards decrease, related to the rise of air temperature.

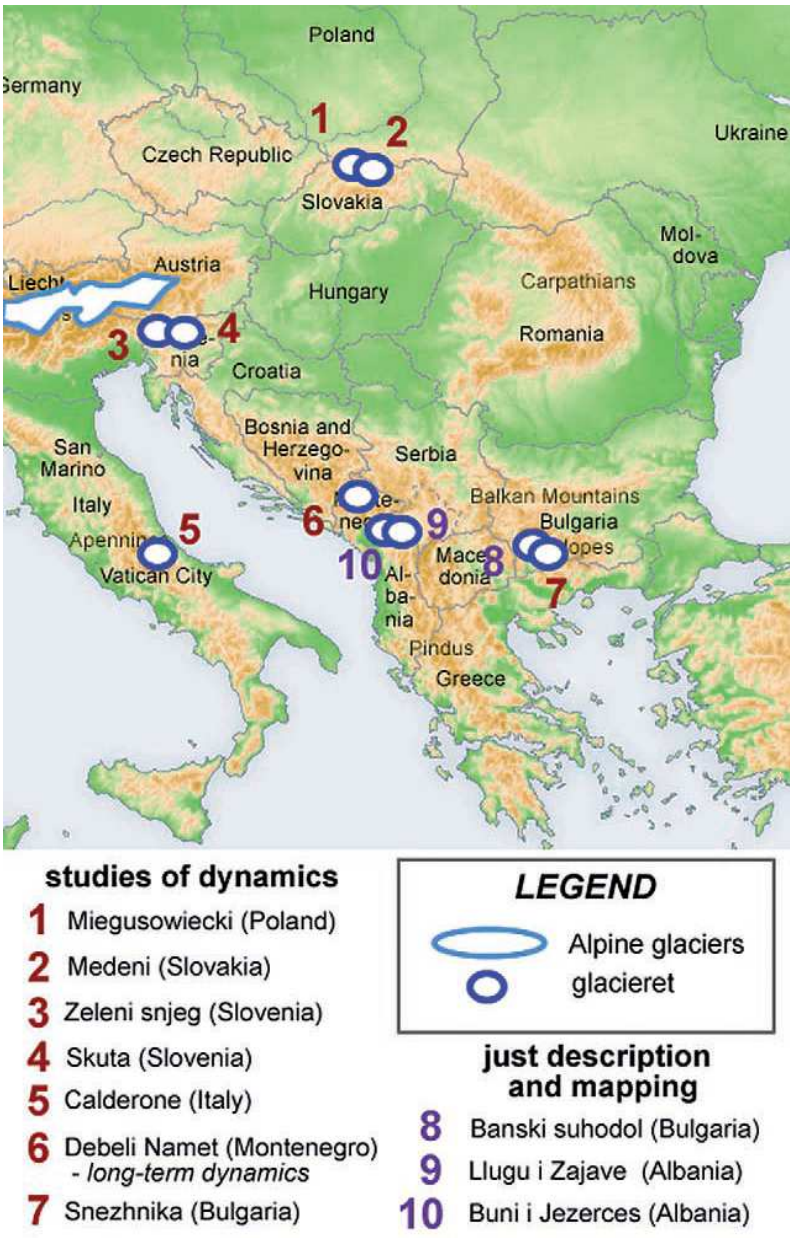

Fig. 3. Glacierets in the mountains of Southeastern Europe (after Gachev et al., 2009).

Late Quaternary Glaciation in Rila Mts., Bulgaria

According to the position and dating of terminal moraines in Rila Mountains, the Late Pleistocene glaciers had their largest extent during the LGM (Last Glacial Maximum) stage (23–19 ka BP). The last cold stage was the Little Ice Age (15th – 19th c. AD), when probably the last glacier (or microglacier) still existed in the uppermost part of Musala cirque. This glacial advance occurred synchronously in the mountains of Central and Eastern Europe. According to climate reconstructions, despite the overall cooling relations between average temperatures (and probably precipitation) during the LGM in Rila, Southern Carpathians and the High Tatras were quite much like at present, at least concerning northern slopes. This allows for analogies to be used for revealing the time of glacial retreat stages these three mountains. Traces for at least five such stages are found in the valley of Musalenska Bistrica, but the exact dating of some of them is still quite uncertain. For revealing the post-glacial evolution of the valley in more details a further research is needed. It should be focused on absolute dating of moraine deposits, sampling of lake sediments and correlations with other mountain areas.

Application of Remote Sensing to Monitoring Water Resources

The remote sensing techniques and equipment have a great potential to monitor water resources for the purposes of hydrology as a whole. The most suitable spectral ranges for solving various hydrologic problems are study of snow and ice covers, water basins and rivers, shallow waters and shelf, the volume and quality of water in artificial water catchments, and other examples, which are used to create models of water catchment surface change providing to calculate and monitor throughout the years the amount and quality of water contained therein.

Applicability of Remote Sensing in Hydrology and Glaciology. Major sources supplying water catchments are: (1) rain and snow precipitation, and (2) snow and ice-melted water. An important snow-cover parameter is its water equivalent. Knowing it is very important in forecasting the water amount that would be obtained during ice melting. It is already well known that a clearly expressed relationship is available between water equivalent and the emission capacity of snow cover in the microwave region.

The typical properties of snow and ice and their high contrast provide for their effective study by remote sensing methods and techniques. The extensive introduction of such methods and techniques provided for the emergency of a new section of glaciology – s*pace glaciology*. Ice and snow characteristics are studied in the visible, infrared, and microwave range of the electromagnetic spectrum. There are methods using space photos to calculate the melted-snow stock in river valleys based on the change in relative snow coverage of river basins and the configuration of seasonal snow boundaries. An important factor in snow-melting dynamics is air temperature above it and wind velocity. Operative information thereof is also obtained by Remote Sensing.

TABLE 1. Spectral ranges for remote sensing of water surfaces

Hydrological study	Wavelength (μm)
Snow cover in the plains	0.50–0.80
Snow cover in the mountains	0.80–1.30
Ice cover of rivers or lakes	0.44–0.52
	0.50–0.55
	0.79–0.84
	0.70–1.30
	8–14
River basins	0.68–0.76
	0.79–1.10
River floods	0.70–0.80
	0.80–1.30
Water surface	0.80–1.10
Water-flooded territories	0.70–0.80
	0.80–1.10
Coastline change	0.68–0.76
	0.78–1.30
Water layer of depth < 5 m	0.70–0.80
Water layer of depth < 15 m	0.60–0.70
Water layer of depth > 15 m	0.50–0.60
Shallow-water and shelf relief	0.52–0.55

Table 1 shows the most suitable spectral ranges for remote sensing of water surfaces for the purposes of hydrology (Mardirossian, 2007).

Subjects of studies have been some dams and rivers of great importance to Bulgarian economy, such as the Studen Kladenets Dam, the Pchelina Dam, the Mesta River, and the Strouma River. However, water, in all of its forms, causes as well great ecological catastrophes – floods, tsunami, and avalanches. This calls to study these extreme situations in all their aspects – forecasting, monitoring their development, evaluation of caused damages, etc. The potentials and prospects of remote sensing are an effective and operative means to combat water-caused catastrophes. Attention is paid as well to ground-based (contact) information, required *a priori* in complex experiments for remote sensing of water catchments, without which the effective interpretation of remotely sensed data would be impossible. During the last dozen of years researches in this field and their application in the studies of the geosphere – lithosphere, hydrosphere, and atmosphere, have been conducted by the Department of Remote Sensing of the Earth at the Institute for Space and Solar-Terrestrial Research of the Bulgarian Academy of Sciences.

CRYOSPHERE AND CLIMATE

Measuring and Forecasting Atmospheric Icing on Structures (COST 727 Action Project)

Bulgarian team in COST 727 Action from the National Institute of Meteorology and Hydrology: Dr. E. Moraliiski (model verification and investigation of the icing process in the mountain regions of Bulgaria), Dr. D. Nikolov (model verification, testing of forecasting schemes and mapping of icing events) and Dr. C. Dimitrov (data collecting).

Short Summary. Icing of technical constructions is a phenomenon observed every year in Bulgaria. The geographical location of the country with respect to the ways of the Mediterranean cyclones is exceptionally favourable for intensive icing process leading frequently to heavy accidents of various technical constructions (power electric lines, antennae, mast, etc.). The heaviest icing conditions are in the mountain regions and in Northeast Bulgaria. The icing investigations in Bulgaria began in 1949 of the mountain meteorological station Cherni vrach (2286 m). Later a special ice measurement device was mounted and some field investigations in the region of this peak were carried out. The greatest rime-ice load ever measured in Bulgaria was registered here - 55 kg/m. Systematic observations of the icing process and the ice depositions have been launched in some meteorological stations later in the years. These investigations were directed to the physical describing of the icing process and estimation of the meteorological conditions in cases of icing.

Modeling of the process. A physical-statistical model for assessment of the radius and the mass of the ice depositions on the basis of the available weather information has been developed. The model uses also three experimental found correlations between the weather data and some required input data, which are not routinely measured.

Icing conditions in Bulgaria. Data from 6 mountain weather stations and about 30 meteorological stations in the low parts of the country have been used for investigation of the meteorological conditions in cases of icing. Information for damages on the power distribution lines has been added also.

Objectives

- investigation and verification of icing models
- measurements of the parameters of ice depositions
- mapping of icing events and testing of some forecasting schemes
- prediction of ice loads and extreme icing events
- investigation of the rime icing in mountain regions and freezing rains in the low part of the country

Fig. 4. Botev Peak station – a test site for the COST 727 Action project.

Contributions to COST 727 Action

- development of suitable methods for operational implementation
- investigation and verification of various methods and models for icing on different technical constructions
- study of the extreme icing events
- investigation of the rime icing in mountain regions
- development of icing climatologies and occurrence thresholds for validation purposes and icing forecast
- estimation of potential icing conditions under a changing climate

Indicators for Modern and Recent Climate Change in the Highest Mountain Areas of Bulgaria

The highest Bulgarian mountains Rila (2,925 m a.s.l.) and Pirin (2,914 m a.s.l.) provide virgin mountain landscapes, intensive natural processes and a sharp sensitivity on natural and human impacts. There exist natural indicators for changes in climate during the last few centuries in the areas around the highest peaks Musala (the Rila Mountains) and Vihren (the Pirin Mountains), and the accent is put on the past and present existence of embryonic glacier forms. Dynamics of perennial ice bodies in the Pirin and the newly found fresh moraine ridge on the bottom of the Ledeno ezero Lake (the highest lake in the Rila Mts.) as well as the data from instrumental and historical records suggest a general trend of warming since the first two decades of the 20th century, especially expressed in the last 30 years. Inter-annual size variations of perennial ice bodies are found to be closely related to fluctuations of air temperature. Regional comparative studies show that perennial ice bodies in Bulgarian mountains are less sensitive to slight climate fluctuations than some other similar features in the Carpatho-Balkan area.

ANTARCTIC RESEARCH

Bulgarian Antarctic Institute

The Bulgarian Antarctic Institute (BAI) is noncommercial corporation society, registered in 1993, with 42 members and 4 collective members - The Ministry of Foreign Affairs, The Sofia University "St. Kliment Ohridski", The Academy of Medicine and The Atlantic Club of Bulgaria. The Chairman of the Executive Council of BAI is Prof. Christo Pimpirev. BAI works under the aegis of the President of Republic of Bulgaria and it is the National Operator of the National Antarctic Program.

BAI organizes annual Antarctic campaigns and operates the Bulgarian Antarctic base "St. Kliment Ohridski", Livingston Island, South Shetland Islands. In the expeditions have specialists of different areas: geology, geochemistry, geophysics, meteorology, glaciology, biology, medicine and etc. These investigations are published in many scientific editions and books.

BAI is in contact with the Antarctic Programs of Spain, Great Britain, Russia, Germany, Argentina, Brazil, Chile, South Korea, etc. It is a member of COMHAP (Council of Managers of National Antarctic Programs), SCALOP (Standing Committee on Antarctic Logistics and Operations), EPB (European Polar Board) and SCAR (Scientific Committee on Antarctic Research).

The main trends of the glaciological and meteorological studies are to design drills and equipment used in vertical and horizontal drillings, to investigate the microclimate phenomena related to complex geography, glaciers and proximately of the ocean and to automate the meteorological monitoring in order to collect data, necessary for the glaciological and biological observations. Dating the ice layers of the Hurd peninsula glaciers and analysis of the elements and isotopes of ice samples are among the expected results.

Fig. 5. Bulgarian expedition in front of the Bulgarian Antarctic Base "St. Kliment Ohridski", Livingston Island (BAI photo).

During the reporting period 2008-2011, BAI organized and conducted 4 annual expeditions, respectively from XVIth to XIXth one, fulfilling the following current projects:

(1) Complex geological, geochemical and ecological investigations in the region of the Bulgarian Antarctic Base "St. Kliment Ohridski", Livingston Island – a 5-year contract with the Ministry of Environment and Water of Bulgaria.

(2) Permafrost and Climate Change in the Maritime Antarctic (PERMANTAR - 1 and 2) – a project including organizations from Portugal, Spain, Argentina, Brazil, USA and BAI. PERMANTAR contributes to the global scientific effort to bridge the gap in the knowledge of Antarctic permafrost characteristics, sensitivity and implications for climate change. It is major contribution to the International Polar Year (IPY) core projects "TSP - Thermal State of Permafrost: an International Network of Permafrost Observatories" (IPA) and "ANTPAS - Antarctic and sub-Antarctic Permafrost, Soils and Periglacial Environments". Antarctic logistics are provided by the Spanish Antarctic Program and by the Bulgarian Antarctic Institute which have three research stations in the study area.

Permafrost is central to the carbon cycle and to the climate system, especially due to CH_4 and CO_2 release following thaw of organic-rich sediments. Compared with the Arctic, very little is known about the distribution, thickness, and properties of permafrost in the Antarctic. The main reason for this is the scarce network of permafrost temperature monitoring boreholes, as well as the short number of active layer monitoring sites. There is also a general lack of section exposures and a need for observation by drilling. The main objectives of the project (March 2007 - February 2009) are:

- installing boreholes (deep 6 to 25 m) for permafrost temperature monitoring (GTN-P) and sites for active layer monitoring (CALM-S);
- installing long-term sites for monitoring the present-day geomorphodynamics in order to evaluate the effects of climate change on landscape dynamics;
- identifying permafrost characteristics and spatial distribution;
- identifying the climate controls on permafrost temperatures and its sensitivity to climate change;
- studying volcano-permafrost interactions;
- modeling the climate variability of the Antarctic Peninsula region;
- evaluating the possibilities for downscaling of mesoscale atmospheric models in order to estimate ground temperatures in the South Shetlands;
- modeling permafrost distribution and temperature in space and time in order to assess the potential effects of climate change.

Fig. 6. Map of Livingston Island and Greenwich Island, 1:120 000 (BAI).

The study area is the South Shetlands, one of the Earth's regions where warming has been more significant in the last 50 years. Field activities focus in two islands with similar climate, but contrasting geological and geomorphologic settings: Livingston Island and Deception

Island. The expected scientific results of the project focus on the influence of climate change on permafrost temperature regimes, modeling the climate variability of the Antarctic Peninsula region using mesoscale climate models (ERA-40) and spatial and temporal modeling of permafrost distribution and characteristics. A significant contribution will be the evaluation of the possibilities for using the modeling approaches to other areas of the Antarctic Peninsula where permafrost hasn't been studied in detail. Another important contribution is the implementation of an open-access database on physical properties of the bedrock and deposits of both study areas, a service that may be at a later stage extended to other regions of the Antarctic. These types of data archive provide invaluable ground truth for the modeling community.

CRYOSPHERE AND BIOSPHERE

Postglacial Vegetation History of the Rila Mts., Bulgaria

Pollen analysis of sediments from the glacial Lake Trilistnika (2216 m) in the Northwestern Rila Mountains (Bulgaria), supplemented by 13 radiocarbon dates, allowed the reconstruction of the palaeoenvironment and vegetation history in postglacial time. The exact time of the cirque glacier retreat is still under discussion but the lake was free of ice before 15,000 cal. BP, when sedimentation of gray silt began. The lateglacial vegetation, composed of *Artemisia*, Chenopodiaceae and Poaceae, with isolated stands of *Pinus* and *Juniperus–Ephedra* shrubland, dominated during the stadials and partly retreated during the Bolling/Allerod interstadial complex. The afforestation in the early Holocene (11,500–7800 cal. BP) started with the distribution of pioneer *Betula* forests with groups of *Pinus* (*P. mugo, P. sylvestris and P. peuce*) at mid-high altitudes, and *Quercus* forests with *Tilia*, *Ulmus*, *Fraxinus*, *Corylus* below the birch zone. The change to more humid and cooler climate ca. 7800–7500 cal. BP favored the vertical migration of *Abies*, *P. sylvestris* and *P. peuce*. The establishment of *Fagus sylvatica* took place after 5200 cal. BP, when pure or mixed beech communities were formed. The last tree which invaded the coniferous belt between 4300 and 3400 cal. BP was *Picea abies*. The first expansion maximum of spruce was recorded after ca. 2700 cal. BP. The vegetation development in historical times was also influenced by human interference, indicated by the continuous presence of pollen anthropogenic indicators such as *Triticum, Secale, Hordeum, Plantago lanceolata, Rumex, Scleranthus, Juniperus*.

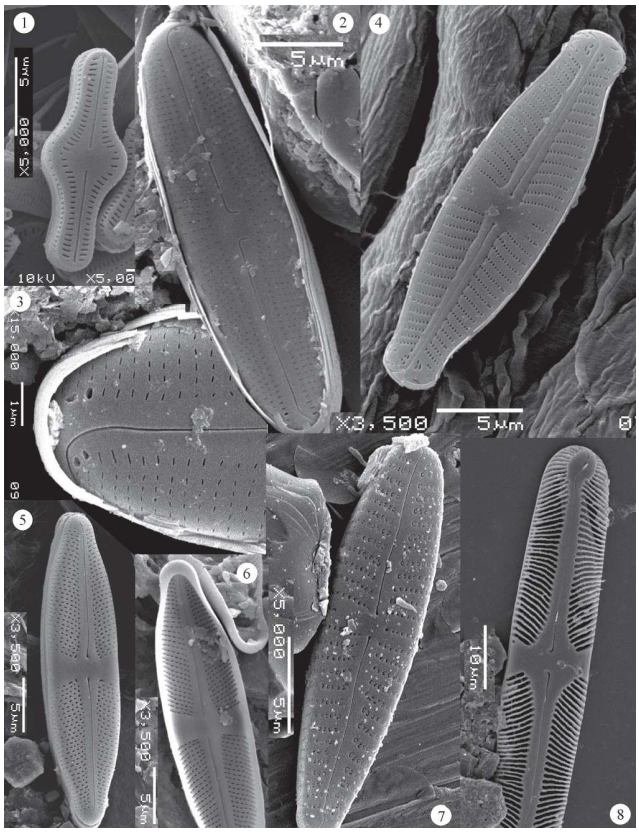

Fig. 7. SEM micrographs of algae from Livingston Island, Antarctica (after Zidarova, 2008)

Algae from Livingston Island, Antarctica

An investigation of the algal flora of Livingston Island was carried out during four consecutive Antarctic summer seasons (2003–2006). Direct microscopic analysis and culture studies revealed a diverse and rich algal flora of 302 taxa (286 species, 15 varieties and one form) from four divisions: *Cyanoprokaryota*, *Bacillariophyta*, *Ochrophyta*, and *Chlorophyta*. *Bacillariophyta* and *Cyanoprokaryota* dominate in terms of species diversity. One hundred and four species, 13 varieties and one form are reported for the first time for Livingston Island. Twenty-eight species are new records for the South Shetland Islands and 13 species are new records for Maritime Antarctica. Eighteen species and six varieties are new reports for Antarctica. A full list of algae found on Livingston Islands with their Antarctic and Sub-Antarctic distribution is available. LM and SEM micrographs of some of the taxa and short descriptions of the new records for Antarctica are provided.

First Record of Cryoseston in the Vitosha Mts., Bulgaria

Cryoseston is defined as the community of organisms living in snow. It is an attractive phenomenon of high mountains and polar regions. One of its most striking components is algae, which cause red, green or orange colouration of snow. The snow ecosystem is considered to be one of the most extreme environments on Earth, and snow algae have

developed numerous adaptations to life in conditions of low temperature combined with episodic freezing and high irradiance. Species composition of cryoseston was studied in the Vitosha Mountains, Bulgaria. The snow algal community was dominated by zygospores of various species. In addition to algae, it was also identified two fungal species. Five taxa are newly recorded for Bulgaria. Cryoseston was also found and described for the Stara Planina (Balkan) Mountains, Bulgaria.

List of Selected Publications:

Gachev, E. 2008. Starting a programme for research and monitoring of sediment transfer processes in the periglacial zone of Bulgaria (Bulgarian Periglacial Programme), *Norwegian Journal of Geography*, Vol. 62 (2), 132–134.

Gachev, E. 2009. Indicators for modern and recent climate change in the highest mountain areas of Bulgaria, *Landform Analysis*, Vol. 10, 33–38.

Gachev, E. 2009. Late Quaternary glaciation in the valley of Musalenska Bistrica (Rila mountains, Bulgaria). – In: Mathematics and Natural Science, Proc. Third Int. Sci. Conf., South-West University "Neofit Rilski" – Blagoevgrad, Vol. 1, 226-232.

Gachev, E., A. Gikov, C. Zlatinova, B. Blagoev. 2009. Present state of Bulgarian glacierets, *Landform Analysis*, Vol. 11, 16–24.

Lukavsky, J., S. Furnadzhieva, L. Nedbalova. 2009. First record of cryoseston in the Vitosha Mountains (Bulgaria)., *Nova Hedwigia*, 88 (1-2), 97-109.

Mardirossian, G. 2007. Application of Remote Sensing (Optical and SAR) to Monitoring Water Resources. - In: Water Supply in Emergency Situations, Y. Sharan, A. Tal and H. Coccossis (Eds.), Springer, 115-123.

Tonkov, S., E. Bozilova, G. Possnert, A. Velcev. 2008. A contribution to the postglacial vegetation history of the Rila Mountains, Bulgaria: The pollen record of Lake Trilistnika, *Quaternary International*, 190, 58–70.

Velikov, V., M. Stoyanova. 2007. Landscapes and Climate of Bulgaria. – In: Biogeography and Ecology of Bulgaria, V. Fet and A. Popov (Eds.), Springer, 589-605.

Zidarova, R. 2008. Algae from Livingston Island (S Shetland Islands): a checklist, *Phytologia Balcanica*, 14 (1), 19-35.

International Association of Geodesy (IAG)

IAG Activities in Bulgaria
2007 – 2011

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Geodetic organizations, institutions and universities in Bulgaria

Professional organizations:

Assembly of Geodetic Engineers http://www.kig-bg.org
Association of the Geodetic Companies
Union of the Geodesists and Land Surveyors http://geodesy-fnts-bg.org
Assembly of the Engineers of Investment Design http://www.kiip.bg

Institutions:

Geodesy, Cartography and Cadastre Agency, Ministry of Regional Development and Public Works http://www.cadastre.bg/
Military Geographic Service at Bulgarian Army
Department of Geodesy, National Institute of Geophysics, Geodesy and Geography at Bulgarian Academy of Sciences, http://www.niggg.bas.bg; http://clg.cc.bas.bg

Universities:

University of Architecture, Civil Engineering and Geodesy, Geodetic Faculty, Sofia http://www.uacg.bg
University of Mining and Geology, Geological Faculty, Sofia http://www.mgu.bg
Shumen University, Faculty of Technical Sciences, Shumen http://shu-bg.net

The government documents and laws for regulation of the geodetic and cartographic works in Bulgaria are:

Decree of the Council of Ministers No 1 from January 18, 2005 about "Distribution of the geodetic and cartographic tasks of national importance", State Gazette No 6, 18. 01. 2005

Law for Geodesy and Cartography, State Gazette No 29, 07. 04. 2006

Decree of the Council of Ministers No 153 from July 29, 2010 about "Decree for establishment of the Bulgarian Geodetic System 2005", State Gazette N 60, 06. 08. 2010

Instruction No 2 from July 30, 2010 about "Defining realization and maintenance of the Bulgarian Geodetic System 2005", State Gazette N61, 10. 08. 2010

Instruction for transformation of the existing geodetic and cartographic materials into the Bulgarian Geodetic System 2005 (prepared and ready for acceptance)

Instruction for determination of geodetic points with GNSS (prepared and ready for acceptance)

Bulgaria is a member of the EuroGeographics and successfully participate in a number of projects – EuroBoundaryMap, EuroGlobalMap, EuroRegionalMap and EuroDEM. Bulgaria participates in the activities and projects of the IAG sub-commission EUREF.

Content

Foreword

The present report is composed by Assoc. Prof. D.Sc. Ivan Georgiev, IAG National Correspondent, on the basis of information and in close cooperation with the Geodesy, Cartography and Cadastre Agency, the Military Geographic Service and the Department of Geodesy of the National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences. Contributions are also made by the Geodetic Faculty of the University of Architecture, Civil Engineering and Geodesy and private companies.
The list of contributors is given in the appendix.
Since this is the first report for a number of years on the work in the field of geodesy in Bulgaria, the aspiration has been to cover the more important trends and activities and for this reason processes that have begun before the reported period, yielding results in the recent years, are also considered and discussed in this review!

Brief description of the main geodetic institutions in Bulgaria and their basic priorities and responsibilities:

Geodesy, Cartography and Cadastre Agency, Ministry of Regional Development and Public Works
The activities in the field of geodesy, cartography and cadastre in the Republic of Bulgaria have a more than 100-year history.
The beginning of topographic cartography in Bulgaria dates back to the end of the XIXth century. The systematic measurements on the creation of the state triangulation and leveling systems were started in the 20-ies of the XXth century and the first cadastral plans of the settlements were launched by the Cadastre Law in 1908.
The development of the activities in the field of geodesy, cartography and cadastre in Bulgaria is related with the enforcement of the Law for Geodesy and Cartography (2006) and the Law for Cadastre and Real Estate Registry (LCRER) (2001).
The Geodesy, Cartography and Cadastre Agency (Directorate of Geodesy and Cartography and Directorate of Cadastral and Specialized Maps), the national geodetic institutions – the Military Geographic Service of the Bulgarian Army, the Department of Geodesy of the National Institute of Geophysics, Geodesy and Geography of the Bulgarian Academy of Sciences and the private geodetic companies are the main institutions that are basically related to the geodetic activities in Bulgaria.
The Geodesy, Cartography and Cadastre Agency is an administrative body to the Minister of Regional Development and Public Works for realizing the cadastral activities in accordance with the Law for Cadastre and Estate Registry and the activities in the field of geodesy and cartography in accordance with the Law for Geodesy and Cartography (LGC).
The Directorate of Geodesy and Cartography organizes the performance of the basic geodetic and cartographic activities related with:

- the geodetic networks of local importance;
- the state leveling and mareographic networks;
- the large scale topographic map;
- the transcription and spelling of geographic denominations;
- the maintenance of the state geodetic, cartographic and cadastral fund (Geocartfund).

The Directorate of Cadastral and Specialized Maps organizes the activities on the systematic producing of cadastral maps and cadastral registries of territories with intensive turnover of real estates or high investment interest.

Military Geographic Service of the Bulgarian Army

The Military Geographic Service (MGS) is a specialized organ of the Ministry of Defense (MoD) for the formation of policies and carrying out all necessary activities for the development of geoinformation products (maps, schemes, terrain analyses, digital data for the localities and other geographic information) and ensuring the armed forces and state organs and structures with these products as well as rendering specialized technical assistance.

The main priorities of MGS are:

- meeting the obligations of the Republic of Bulgaria on the geographic support of the collective security system, including of the armed forces (AF) of the Republic of Bulgaria;
- meeting the obligations of the Ministry of Defense ensuing from the Law for Geodesy and Cartography – participation in the realization and maintenance of the unified geodetic data base of the Republic of Bulgaria by building and development of the state geodetic network, state gravimetric network and magnetic station network; establishment and maintenance of state topographic maps and orthophoto plans and topographic databases, including for ensuring the defense and security of the state, as well as for the purposes of navigation, aviation and shipping;
- organizing of cooperated production and exchange of geographic materials with the other geographic services of the other NATO countries;
- ensuring geoinformation materials and data to civil administrations and organizations in the Republic of Bulgaria;
- management of the activities on standardization and attainment of technical, technological and operative compatibility in the area of geographic provision.

Department of Geodesy, National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences

The Department of Geodesy (former Central Laboratory of Geodesy - CLG) is a department of the National Institute of Geophysics, Geodesy and Geography (NIGGG) of the Bulgarian Academy of Sciences. The Department of Geodesy has more than 60-year history and its main priorities are:

- participation in the international scientific integration for studying the shape and dimensions of the Earth as a planet, its orientation in space and its external gravitation field;
- carrying out fundamental and applied scientific research on introducing, updating and using the national reference and coordinate systems as part of the European and global ones with the view of the economic and social needs of the country;
- integration of the results from geodetic research and the results from other Earth sciences for the study of local, regional and global deformation processes and especially processes related to hazardous geodynamic phenomena (earthquakes, landslides, etc.);
- development of the geodetic aspects of the systems for monitoring and control of the natural and technogenic risks and protection of the environment;
- development of a concept for a national geodetic information database and elaboration of methods for its maintenance, renewal and integration with other national and international geoinformation systems;
- establishment of technologies, consulting and expert activities for supporting the competitive and sustainable development of society;
- training of specialists on General, Theoretical and Applied Geodesy.

According to the newly accepted Law for Geodesy and Cartography (2006), the responsibilities for the geodetic activities in the Republic of Bulgaria are distributed as follows: the Military Geographic Service (MGS) of the Bulgarian Army is responsible for maintenance of the National GPS Network and maintenance of the main gravimetric and magnetic networks. The Geodesy, Cartography and Cadastre Agency is responsible for the maintenance of the local geodetic networks, the National Vertical Network and the the Tide Gauge Network and for the geodetic and cartographic data base. All these activities are performed in close cooperation and active participation of the Department of Geodesy of NIGGG and the Geodetic Faculty of the University of Architecture, Civil Engineering and Geodesy.

1. Reference frames and networks

1.1 National GPS Network. Realization of the European Terrestrial Reference Frame ETRS89 in Bulgaria

In the last several years the geodetic systems and networks in Bulgaria have been radically updated. This activity was launched by the design, construction, processing and analysis of the measurements of the new National GPS Network. The approval of the official documents for introducing the new geodetic network was completed in 2010.

The project of the (new) National GPS Network and the program for its measurement were developed in the Military Geographic Service of the Bulgarian Army. The National GPS Network was realized in performance of the Act of the Council of Ministers 140/04.06.2001, which defined the Bulgarian Geodetic System and served for the radical updating of the (old) National Geodetic Network of Republic of Bulgaria. The National GPS Network consists of two orders of points unified in Main and Secondary orders.

The Main order of the network is created to realize, distribute and maintain the European terrestrial reference system ETRS89 on the territory of the country with an accuracy of 5-10 mm in position and 10-15 mm in height using the GPS technology. The full realization of the Main and Secondary orders will provide the possibility of using their points as reference for the establishment of local geodetic networks for the needs of the practical applications and actually, for all geodetic applications.

The Main Order network

The Main order GPS network includes the following types of points: the EUREF points in Bulgaria officially accepted at the EUREF Symposium in Istanbul 1996, including the points of the European Unified Vertical Network (EUVN) – Burgas (BUTG) and Varna (VATG); points of the I, II, III and IV orders of the existing (old) National Geodetic Network (NGN); newly built points during the period 2002 – 2003 especially for the National GPS Network (Table 1).

The requirements towards the GPS points are given in the “National GPS Network – Project of the network and program for measurement”, Ministry of Defense, Military Geographic Service, Sofia, May 2004. All points of the Main GPS Network are identified by number and name. All EUREF and NGN points have unique numbers. The names of the EUREF points, including of EUVN, are four-character abbreviations. The Main order points of the National GPS Network are shown in Fig. 1.

Reconnaissance of the points of the National GPS Network was performed in 2002 – 2003, as well as repair of existing and construction of new points - 219 existing points were repaired and 123 new points were built. The achieved coincidence between the points of the National GPS Network and the existing NGN points is about 70%. A final project and an observation

program for the National GPS Network were developed and approved by a commission appointed by order of the Minister of Regional Development and Public Works.

T a b l e 1. *Points from the Main GPS network*

№	Type of the points	Number	Note
1	EUREF pointsnetwork	15	1 NGN II order points
2	Points from EUVN	2	
3	Points from NGN I and II order	25	
4	Points from NGN III and IV order	46	
5	New points	22	
6	Points with special statute	2	
	Total	112	

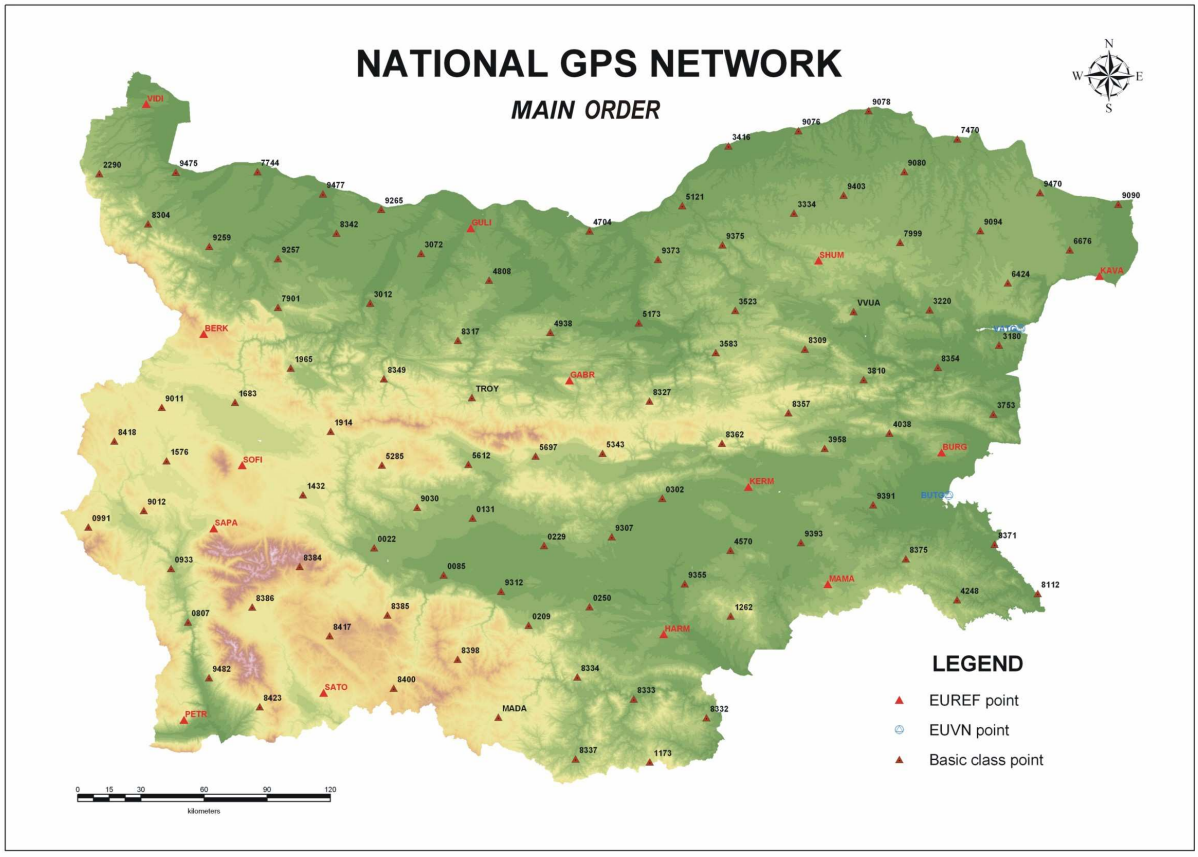

Fig.1. National GPS Network of Bulgaria – Main order. With red triangles the EUREF points and the two EUVN points – BUTG and VATG.

The measurements of the Main order of the National GPS network were performed in July – October 2004, GPS campaign BG 2004, by teams of the Military Geographic Service using geodetic receivers of the Trimble Company. The measurements of all Main order points were performed in sessions with duration of two days, from 0 h UTC, and additional two sessions with duration from 5 to 8 hours – before and after the two main sessions. All measurements were made with 15 seconds sampling rate and 10 degrees elevation mask. The measurements started July and ended September 2004.

The processing and analysis of the network were carried out in 2005 in the Department of Geodesy (Georgiev et al., 2006). The processing was done in the International Terrestrial Reference Frame 2000 (ITRF2000) realization of the International Terrestrial Reference Ssytem (ITRS), available at that time, by the Bernese 5.0 scientific research software - state-of-art software for GPS processing. The software has been created as a "tool for the highest accuracy in GPS processing in various applications". Details of the processing can be found also in Georgiev et al., (2010).
An example of the root mean square (rms) values in the position – north, east, up of the Helmert's transformations between ITRF2000 and some of the daily solutions are shown in Fig. 2 for the GPS week 1285.

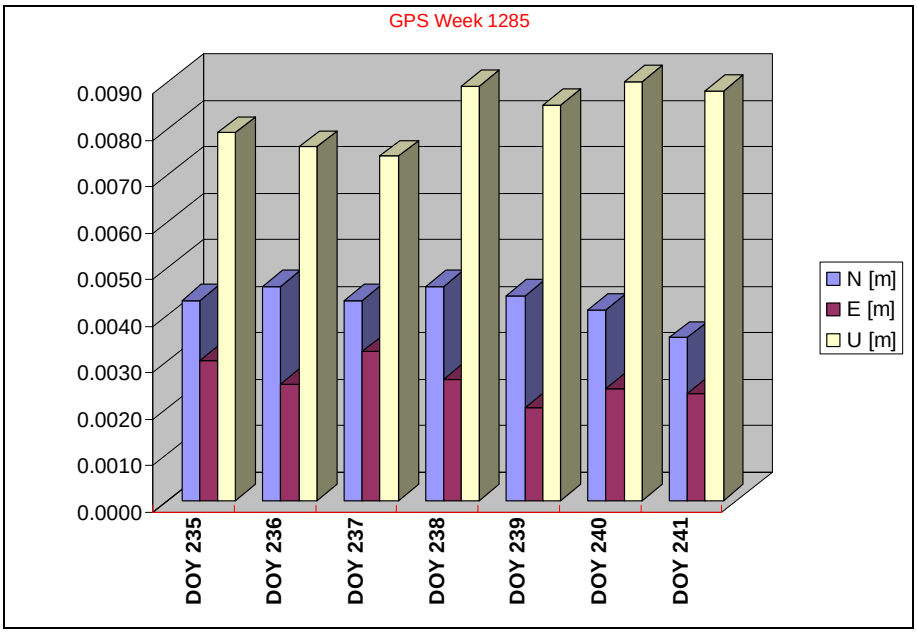

Fig. 2. Rms in north, east, up from the Helmert transformation between ITRF2000 and daily solutions for the GPS week 1285.

New solution for the EUREF BG 1993 GPS campaign

According to the agreement between Bundesamtes fuer Kartographie und Geodesie (BKG, former IfAG) and the Military Geographic Service the GPS EUREF BG 93 campaign was performed in the period 12.10. – 16.10.1993. The 15 points were measured in four sessions with duration of 24 h with Trimble 4000SSE receivers. The campaign was performed with the purpose to determine 15 points on Bulgarian territory in the ETRS89.
The reprocessing of the measurements from the EUREF BG 93 GPS campaign was necessary mainly because of two reasons: for control, comparison and analysis of the new solution and for obtaining the velocities of the EUREF points. The processing and analysis of the observations from the EUREF BG 93 campaign were performed according to the same strategy as the BG 2004 GPS campaign.

New realization of ETRS89 on the territory of Bulgaria

The results from the processing and analysis of the measurements of the Main order GPS network are accepted by an Expert Commission appointed by an order of the Minister of Defense of the Republic of Bulgaria RB-N-P-13/06.01.2006. The main conclusion drawn by the commission is: ***"The performed work and the obtained results in the development and***

processing of the Main order of the National GPS network are of fundamental importance for the state, comparable to that of the created in the 30-ies of the 20th century National Geodetic Network and correspond in their volume and accuracy to the regulating documents and to the advanced scientific achievements in this field".

The results are reported to the EUREF Technical Working Group at the annual international EUREF symposium in Riga, Latvia, 14-17 June, 2006. The results were accepted by the TWG in Resolution No 1 of the Symposium.

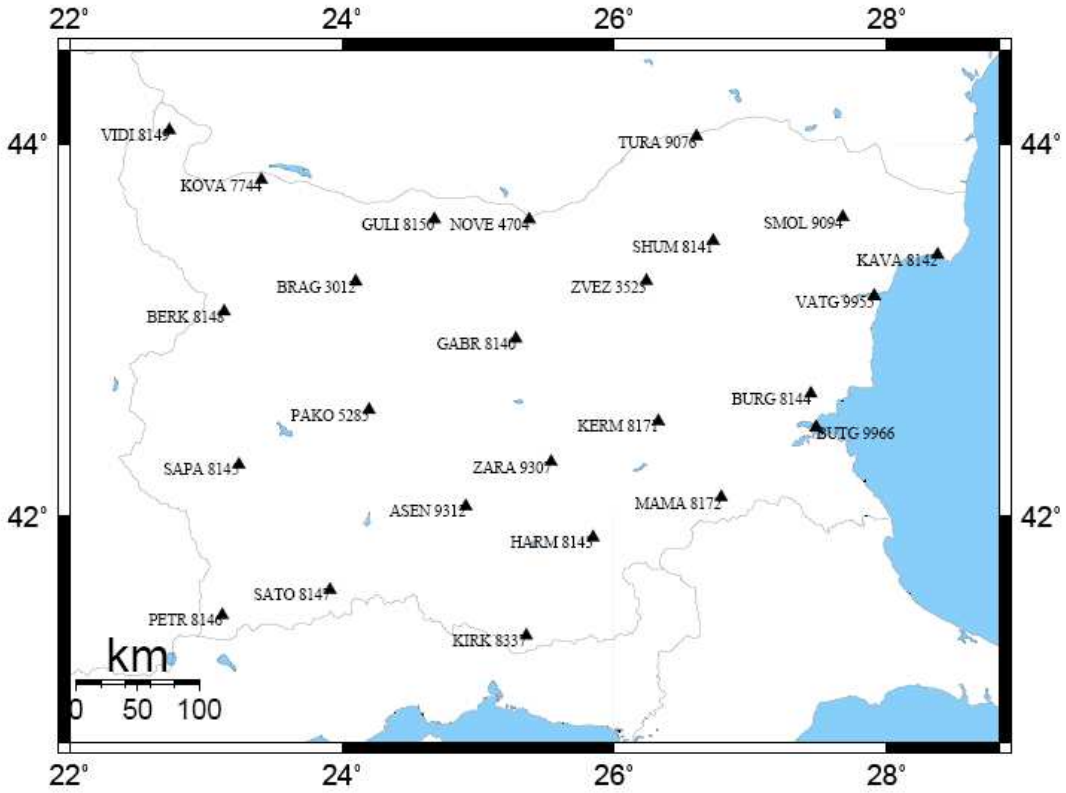

Fig. 3. New realization of the ETRS89 on the territory of Bulgaria (25 points) accepted by the EUREF TWG in Riga, 2006

Due to the good quality of the obtained results new official realization of the ETRS89 on the territory of Bulgaria, consisting of 25 points (Fig. 3) and replacing the previous 15 from 1996, was also accepted at the meeting of the Technical Working Group.

The processing and analysis of the Main order of the National GPS network and the obtained precise coordinates made it possible for Bulgaria to have, at the moment of its accession to the European Union, a modern geodetic network, tied to the European Reference System and meeting the requirements of the advanced achievements in the field of GPS technology. The analysis of the results shows that the accuracy of the obtained coordinates is 5-10 mm in position and 10-15 mm in height. The network is very important for updating the national geodetic networks in the country. In fact, the points of the Main order of the National network represent a densification of EUREF on the territory of the country.

The velocities of the points from the new realization of the ETRS89 obtained from EUREF BG 93 and BG 2004 GPS campaigns are shown in Fig. 4.

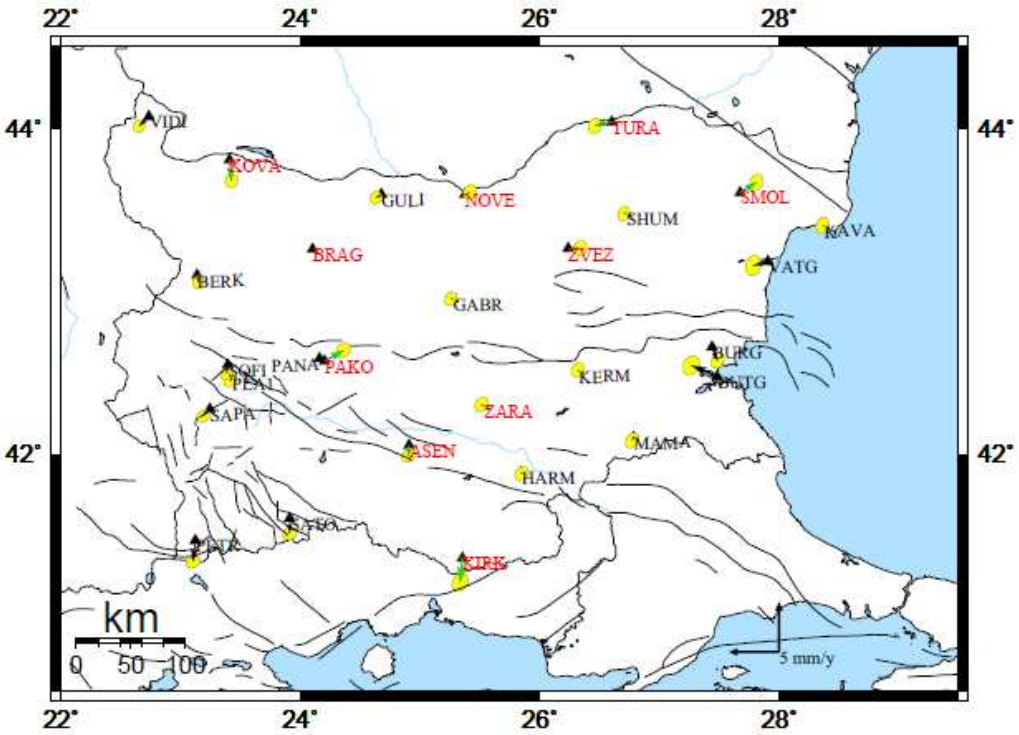

Fig. 4. Velocities of the points of the new ETRS89 realization on the territory of Bulgaria. The velocities of the new points are shown in green and their names are given in red

Secondary Order GPS network

The Secondary order GPS network was developed with the objective of densification of the Main order to an average distance between the points of 10 – 15 km. The wholesome realization of the Main and Secondary order networks will lead to a density allowing the use of their points as reference for all practical applications in Bulgaria. All the requirements towards the Main order GPS network are applied to in the process of design and selection of points for the Secondary order GPS network.

The points of the Secondary order GPS network are shown in Fig. 5. The total number of the points of the Main and Secondary order is 457. The Secondary order network includes the following types of points (Table 2):

The measurements of the Secondary order network were realized in two GPS campaigns – in October 2004 and in July-October 2005, by teams of the Military Geographic Service with geodetic receivers of the Trimble Company in sessions with duration of 8 hours. The sessions were measured with meeting the following requirements: minimum three points of the Main GPS network participate in each session; each session was connected with the adjacent (neighboring) with minimum three additional common points. All measurements were carried out with sampling rate 15 seconds and elevation mask 10 degrees.

The processing and analysis of the network were realized in the Department of Geodesy (Georgiev et al., 2007).

Table 2. *Points of the Second order GPS network*

GPS points of the Second class network					Total
NGN I and II order	NGN III and IV order	Local networks	Gravimetric points	Newly built points	
25	226	3	1	89	
					345

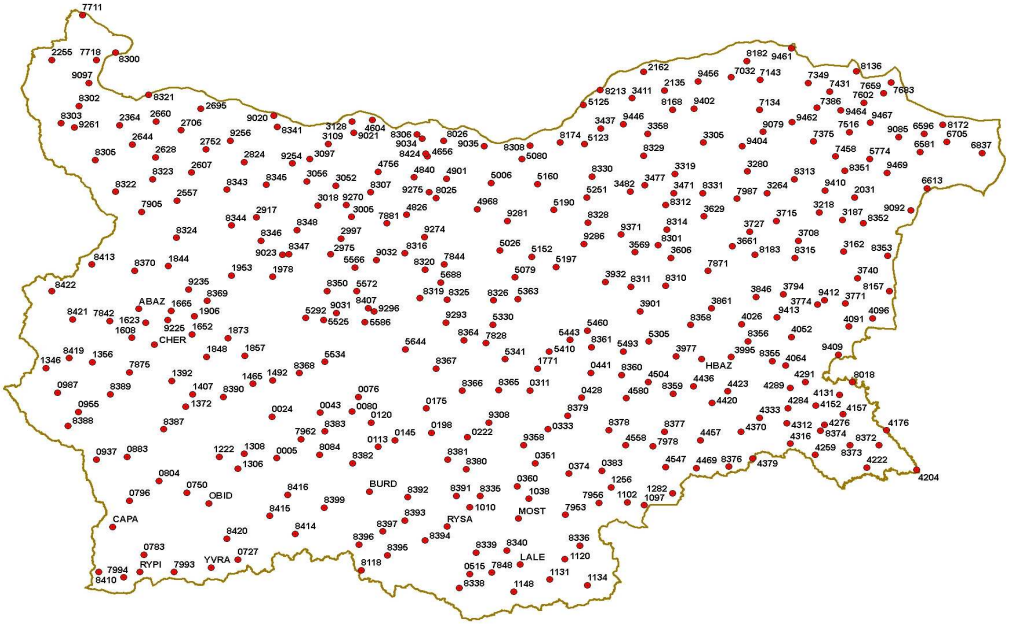

Fig. 5. National GPS network – Secondary order

The processing was performed by the Bernese 5.0 scientific software. The Main order points were used as referenced. Their coordinates obtained in the ITRS (ITRF2000) were extrapolated for the epoch of observation using the velocities: for the EUREF points – those obtained from the observations and for the rest of the points – those calculated according to the Eurasian rotation pole.

The two GPS campaigns from 2004/2005 were divided in daily (8-hour) sessions. Daily solutions were calculated for each session which (normal solutions) were then combined to obtain solutions for the campaigns. Each one of the GPS campaigns was processed individually and then the coordinates of all points were transformed to epoch 2005.0, the epoch of the coordinates of the Main order points.

The analysis of the Secondary order network solution show that the accuracy of the obtained coordinates is 10-15 mm in position and 15-20 mm in height. The results of the processing were reported at the annual EUREF symposium in London, 2007.

1.2 Permanent GNSS networks

Permanent network of the Department of Geodesy. Establishment of a national wide Permanent GNSS network

The first permanent GPS station in Bulgaria was installed in 1997 by the German Federal Service of Cartography and Geodesy in the observatory of the Military Geographic Service in the vicinity of Sofia (SOFI). The station is part of the EPN/IGS networks.

The Department of Geodesy initiated the establishment of a national wide Permanent GNSS Network. The basic requirements that are strictly followed in the network establishment are:

-stabilization of the points in a manner providing the possibility to avoid errors from centering. Usually these are reinforced concrete pillars with centering devices;

-free access to the data (30 second files), coordinates and velocities of the stations for all users;

-permanent processing of the GPS measurements, generation of time series of the coordinates and control on the stability of the points;

-using the results for the maintenance of the National GPS network and for all geodetic applications;

-using the results for various scientific applications – geodynamics, seismic hazard, GPS meteorology, etc.

The first permanent GNSS stations of the network were installed in May 2007 in Southwest Bulgaria within the framework of a project supported by the Science for Peace NATO program. At present the Department of Geodesy operates 16 permanent tracking GNSS sites.

Private Permanent GNSS networks in Bulgaria

At present 3 private companies operate commercial GNSS permanent networks in the country – NAVITEQ network (http://naviteq.net), GEONET network (http://www.geonet.bg) and BULiPOS SMARTNET network (http://www.bulipos.eu).

The Department of Geodesy has good cooperation with the private companies and supports their work with precise positioning, long term monitoring and time series analysis.

For example, the NAVITEQ in fact established the first commercial reference GPS network in Bulgaria. The first stations of the network were installed in the end of 2005 and today the company operates a network of 24 active stations (6 common with Department of Geodesy). According to the contract between the Department of Geodesy and NAVITEQ, the company submits the 30-second GPS data from all of its stations to the Department for processing and analysis and for various scientific applications. The Department of Geodesy realizes also the monitoring of the long-term stability of the NAVITEQ stations.

GNSS Analysis Center at the Department of Geodesy. Processing and analysis of the observation data from the permanent stations

A **Center for Analysis of GNSS Measurements** was established in the Department of Geodesy in connection with the obligations for the processing and analysis of the new State GPS Network and its long-term maintenance and the processing and analysis of the data from the permanent GNSS stations.

The Center for analysis has on its disposal modern software for processing and analysis of GPS/GNSS (and generally of satellite observations) – the Bernese scientific-research programs, GAMIT/GLOBK, QOCA, FONDA. The programs are based on the recent achievements in the GPS/GNSS technologies and satellite geodesy as a whole. As of the present moment data from the 28 permanent stations in Bulgaria, as well as from the regional permanent GPS stations in Romania, Turkey, Greece and Macedonia (about 70 in total), are received, archived, processed and analyzed in the Center for analysis – Fig. 6.

The Department of Geodesy uses the GAMIT/GLOBK scientific research software for processing and analysis of the GPS measurements from permanent sites.

GAMIT/GLOBK is a scientific research software reflecting the state-of-art in satellite geodesy and GNSS technology in particular, developed in the Massachusetts Institute of Technology, the Harvard-Smithsonian center on Astrophysics and the Scripps Institute of Oceanography. The software is intended mainly for obtaining estimates of coordinates and velocities of stations, stochastic and functional representation of post-seismic deformations, models of the atmosphere, satellite orbits and Earth orientation parameters.

Time series with the coordinates of the stations, as well as their horizontal velocities are obtained on a regular basis. Fig. 7 shows raw time series of one of the permanent stations.

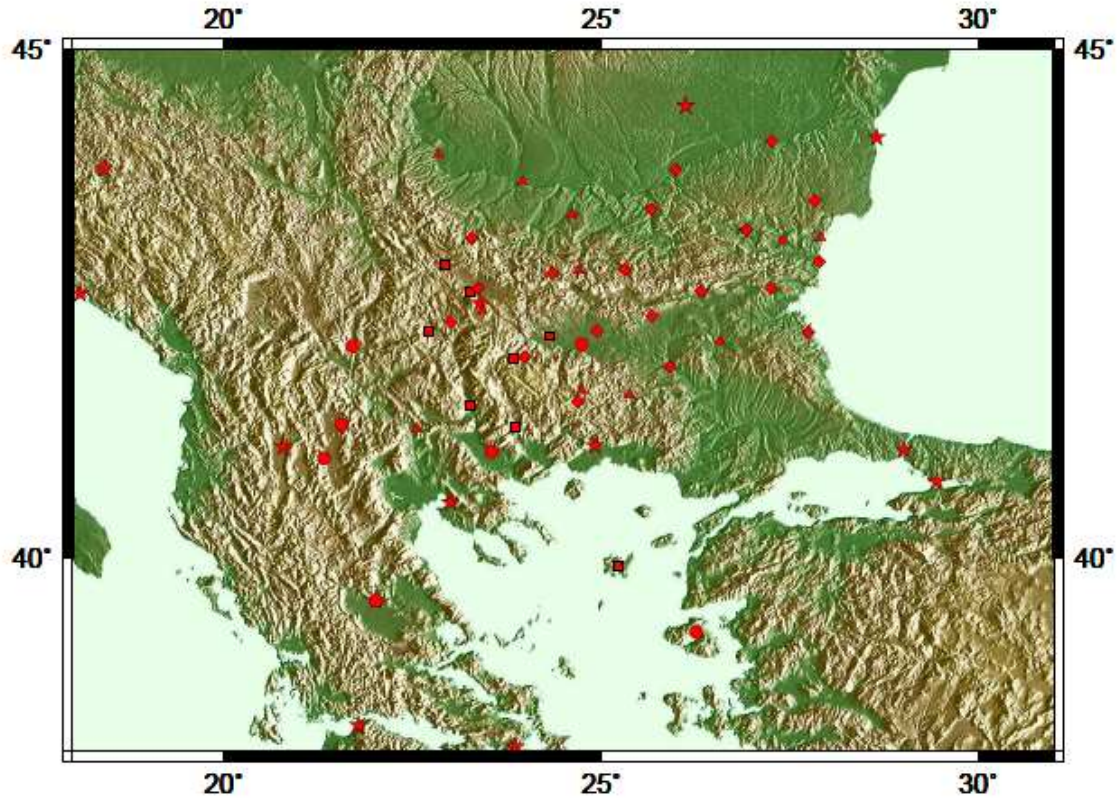

Fig. 6. Permanent GNSS sites which data are processed and analyzed in the Analysis Center in the Department of Geodesy. With squares and triangles are shown the Department of Geodesy sites, rhombs show NAVITEQ sites. With stars are marked EPN sites in the Balkans included in the processing.

The maintenance and extension of the GNSS network, the processing and analysis of the measurements and the free access to them are important for the scientific investigations and geodetic practice in the country. The permanent GNSS stations may be used for both the maintenance of the new National GPS network in Bulgaria and with the appropriate legal regulations – of all geodetic GNSS applications. The analysis of the measurements will be used successfully for long-term monitoring of the recent crustal movements and for the seismic hazard assessment.

Local Geodetic networks

The local geodetic networks are created for densification of the National geodetic network in connection with the large scale mapping of the territory, the cadastre of settlements and other tasks.

About 35 000 local geodetic points established by classical technology are preserved on the territory of the country. The present period of the development of local networks is related with the finalization of the National GPS network adjustment. In the recent years, since the mass introduction of the GPS technology in the geodetic practice, the established local geodetic networks possess already more than 3400 points.

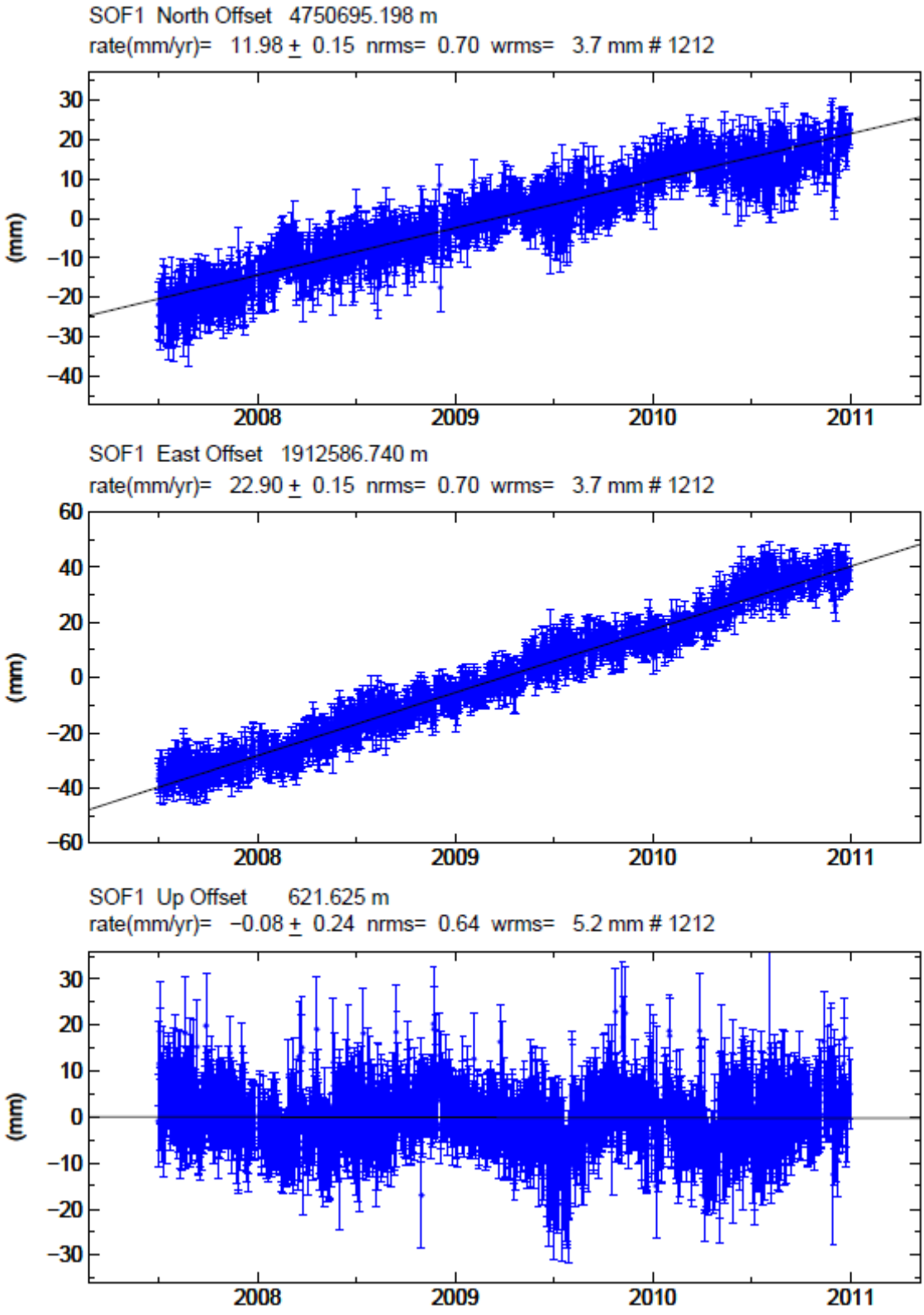

Fig. 7. Row time series of the SOF1 permanent site in Sofia.

1.3 Leveling networks. Realization of the European Vertical Reference System EVRS in Bulgaria

Unified European leveling network UELN

The UELN Unified European leveling network, including the leveling networks of the states in West Europe, was established in 1973 (UELN73), the initial point of the height system being the tide gauge in Amsterdam. A decision was made at the EUREF symposium in Warsaw in 1994 for adhering of the leveling networks of the countries in East Europe to UELN by launching the UELN95/98 project. Bulgaria joined this project in 2003 and was the 26th European country that joined UELN.

European unified vertical network EUVN

In 1995 the EUREF Commission made the decision to launch a European project for establishing a European Unified Vertical Network (EUVN). The principal objective of EUVN is to develop a homogeneous and unified height network and system in continental Europe. The purpose of the network is also to ensure a reference system for kinematic investigations of the vertical movements.

The EUVN network consists of: permanent EPN stations; GPS stations, situated in the proximity of the tide gauge stations; GPS points, coinciding with the nodal benchmarks of the national leveling networks. The first GPS campaign was realized within the frame of the EUVN project in May 1997 and comprised 196 stations in 32 countries. All these points received three dimensional coordinates in ETRS89. The average accuracy of the determined heights in EUVN is about 0.5 cm. The further efforts of the GPS-based EUVN are aimed at its combination with the classical leveling and gravimetric data for the development of the unified EVRS European vertical reference system.

European vertical reference system EVRS

EVRS is a ***kinematic*** vertical reference system, its last realization EVRF2007 is based on the combination of three main elements: ***network (EUVN), vertical coordinate system (vertical datum) and its changes with time***.

The EVRF2000 realization. Including the Bulgarian First order National Leveling Network (NLN) to the European network

Bulgaria joined the UELN95/98 project in 2003 with its First order NLN, III cycle measurement in the period 1974-1984. The network measurement was realized at two stages. Five polygons, comprising the territory of the whole country, were measured in the period 1974-1980, which were made denser with new lines in 1981-1984. The base of this network is represented by the 300 fundamental underground (secular) I and II order benchmarks, built in the period 1962-1963, their number reaching now 330 (together with these constructed after this period), Fig. 8. The total length of the leveling lines is 5 630 km and the number of nodal benchmarks is 33.

The activities on the project were financially supported by EuroGeographics and were carried out in the German Federal Service on Cartography and Geodesy in Leipzig. The inclusion of the First order NLN in UELN was realized via the leveling network of Romania. The trans-border leveling connections, established between the two countries in 1974-1977 at Vidin-Kalafat, Nikopol-Turnu Magurele, Ruse-Gyurgevo, Silistra-Kalarash and Kardam-NegruVoda, were used for this purpose.

The performed adjustment of UELN95/98 to obtain EVRF2000, with the First order NLN of Bulgaria, has the following parameters: number of unknown values (benchmark heights) – 3653, number of observations (height differences between benchmarks) – 5131, initial benchmark of the network – No 000A2530/13600 (the Netherlands) with geopotential benchmark 0,70259 kgal.m, normal height 0,71599 m, g = 9,81277935 m/s^2. The adjustment of UELN95/98 for the territory of Bulgaria includes 36 unknowns (the heights of nodal benchmarks, including these in the connections) and 63 height differences. The mean square error for the Bulgarian Leveling Network after the adjustment of the whole network is 1,18 mm/km, which a very good parameter when compared to other networks. The total mean error of UELN is 1,28 mm/km.

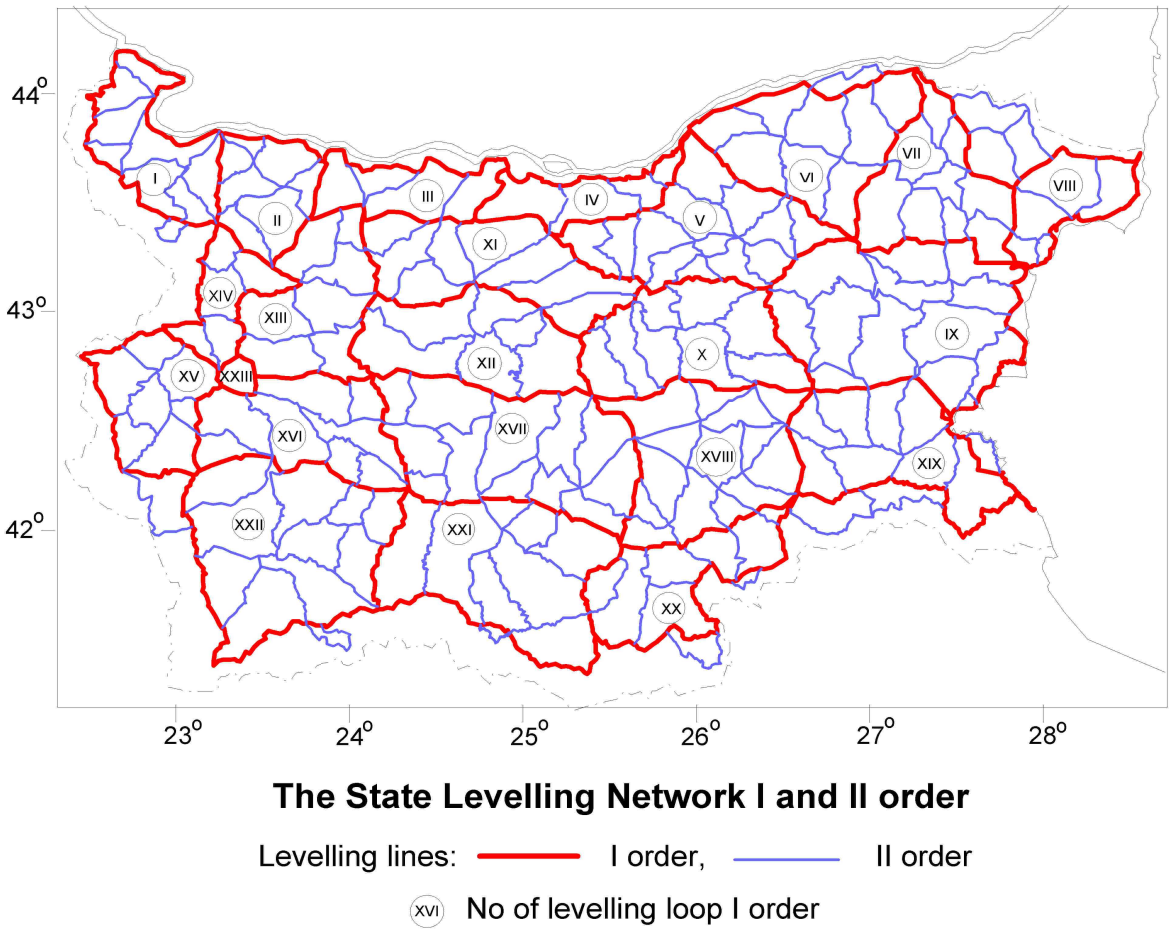

Fig.8. First and Second order leveling networks

The differences between the adjusted heights and the old Baltic height system are in average 18 cm.

Realization EVRF2007

A new adjustment of UELN was made in 2008 using as initial ones 13 benchmarks in Austria, Belgium, Denmark, Italy, the Netherlands, Hungary, Poland and Slovakia, situated in the

stable part of the Eurasian plate. This is the actual realization of EVRS - EVRF2007 on the territory of Bulgaria. Except for the nodal benchmarks, participating in the EVRF2000, it includes additional densification points on the territory of the country, determined in the frames of the EUREF project EUVN-DA (European Unified Vertical Network Densification Action) – their number being 22 and the initial benchmarks for their determination – totally 44 (see below). The mean square error of the adjustment of UELN (EVRF20007) for the Bulgarian leveling network is 1,14 mm/km.

The transformation parameters between EVRS and the (old) National (Baltic) system are: EVRF2000 – - for the system of geopotential heights: UELN - BG = +179 kgal.mm and for the system of normal heights: UELN - BG = +182 mm. The difference between the Baltic height system and EVRF2007 is +228 mm for the normal height system. The difference of 46 mm between the two realizations from 2000 and 2007 is due to the inclusion of new benchmarks as initial ones, as well as due to the effect of tidal deformations in the solid Earth's crust. During the adjustment in 2008 the geopotential differences were established for Earth potential, corresponding to the zero-tide system, while for EVRF2000 they were calculated for average-tide values.

The EUVN-DA project

In 2003 the Technical Working Group of EUREF launched the EUVN-DA project with the main objective – ***establishment of continental and homogeneous GPS/leveling network and databases compatible with ETRS89 and EVRS***.

The national (geodetic/cartographic) agencies of the European countries render broad support to the project, ensuring existing and/or new data. Till 2009 25 European countries participate in the project and the database contains more than 1400 GPS/leveling points. The EUVN-DA project was finalized in the end of 2009 but it is planned to continue and broaden the maintenance of the database within the frame of EVRS. The improvements will be published, when new data become available.

Bulgaria joined the EUVN-DA project with the points of the new realization of ETRS89 on its territory. The points meet the requirements of the above mentioned criteria and they have coordinates and velocities in the European Terrestrial Reference System. To meet all requirements of EUVN_DA, the points are affiliated to the I order State Leveling Network, i.e. to UELN, by precise leveling. Gravimetric measurements have been also realized for determining the gravity force values.

Leveling measurements for determining the heights of the EUVN_DA points

All heights of the 26 EUREF points, the new realization of the ETRS89 in Bulgaria, and height of the permanent station SOFI are also obtained by precise leveling. Precise leveling is performed between 23 of them and leveling nodal benchmarks from the National Leveling Network. As nodals are used: 13 points from the First order network, included to EULN in 2003; 8 points from Second order network, tied to EULN in 2007; 1 point from the Third order network; 1 point from the geodynamic network.

The heights of these benchmarks are determined at the last leveling of the National Networks: First order during 1974-1984 and Second order during 1987-1992 (one point is from the previous epoch 1947). The Third order point was determined in 1960. The rest three points – SOFI, VATG and BUTG, are determined within the frame of the EUVN project in 1997.

The heights of 19 EUREF points are measured from one nodal point, and those of four others – from two points. The measurements were completed in 2006 by the MGS, for 4 points

measurements from 1996-1997 were used. The mean distance from the nodal points to the EUREF points is 5.3 km; the mean error for 1 km leveling distance is ± 0.46 mm/km$^{1/2}$.

Gravimetric measurements for determining the gravity force values of the EUVN_DA points

Gravimetric measurements were carried out in 2007 at the points and the initial leveling benchmarks for the calculation of the geopotential benchmarks and normal heights of the EUVN-DA points. Points of the Reference Gravimetric Network of Bulgaria are used as initial gravimetric points. The measurements were made by teams of CLG BAS and the MGS of BA using GAK-7T No 524 and GR/K2 No 1319 gravimeters. The average value of closure of the gravimetric polygons from the measured gravity force differences is 0,09 mGal.

The leveling data, the geopotential differences and normal heights are controlled and evaluated in the EUVN/UELN Center in Leipzig, Germany. The EUVN-DA points, affiliated to the UELN benchmarks, represent a part of the UELN network and are included in its adjustment.

Precise leveling of the National GPS Network Main order points

In 2006 the MGS started precise leveling of the points from the Main order of the National GPS Network in order to obtain their normal heights. The measurements were performed with two Topcon DL-101C digital levels and invar rods. A total of 483 km precise leveling was performed and normal heights of 58 Main order and 61 Secondary order poins were obtained (Fig.9). In order to check the initial benchmarks, from which the point heights are determined, additional 411 km leveling was performed.

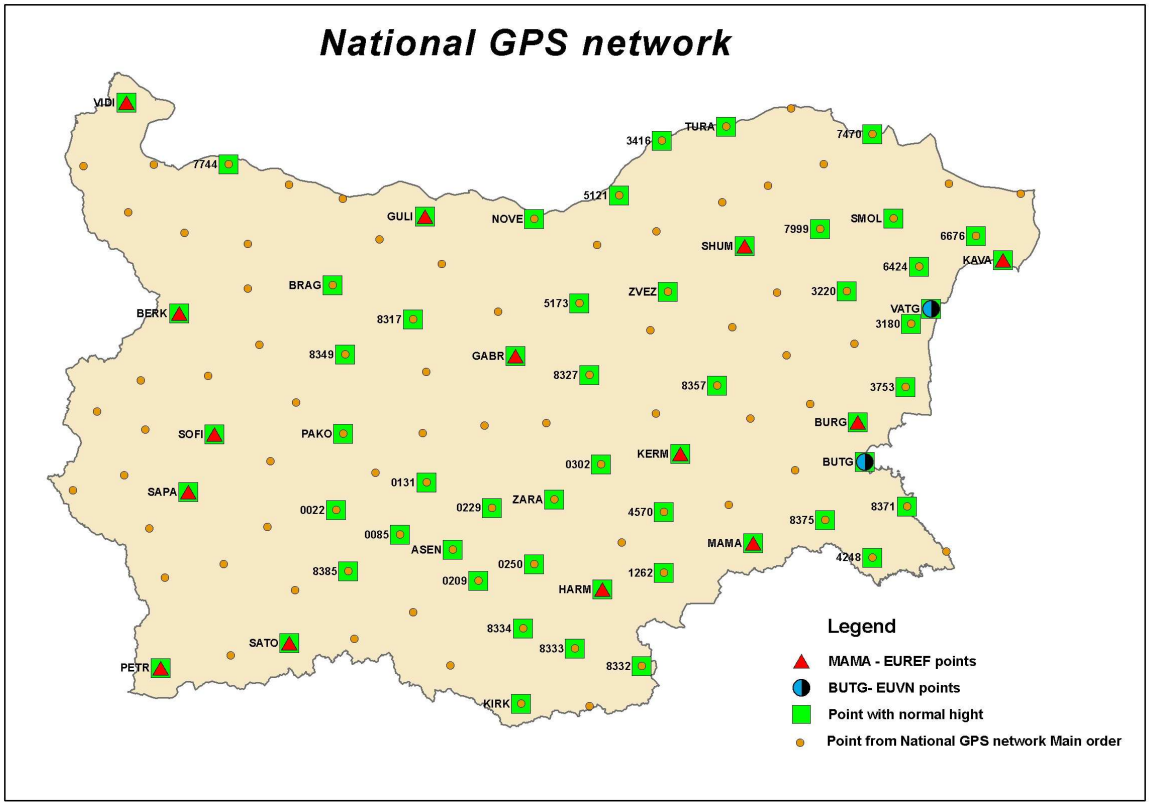

Fig. 9. Points from GPS network Main order with précis leveling.

New measurements of the First order leveling network

In 2008 a new cycle of measurements of the First order National Leveling Network was started.
Ten leveling lines of the I order leveling network, being in the process of re-measurement, were determined in 2008-2009. These lines are from polygons VI, VII, VIII, IX, XV and XIX. The total length of the measured lines is 1405 km, which represents 25% of the whole network.
The measurement was made with Leica DNA 03 and NA 3003, Topcon DL-101C, Zeiss DiNi 10 and Trimble DiNi 03 digital levels. Gravimetric measurements were performed at the leveling benchmarks to determine the corrections for non-parallel level-surfaces. The average value of the mean error per 1 km is ± 0,38 mm/km$^{1/2}$.

Gravimetric networks

The activities carried out with respect to the gravimetric networks are: the performed relative gravimetric measurements of points from the National GPS network, ETRS89 realization on the territory of the country (see above) and the reanalysis of the gravimetric data from the Bulgarian Main (Etalon) gravimetric network (Fig. 10) and the Zero, First and Second order gravimetric networks – Fig. 11. The data are submitted and included into the newly developed European geoid model EGG08 (see below).

Fig. 10. Bulgarian Main (Etalon) gravimetric network

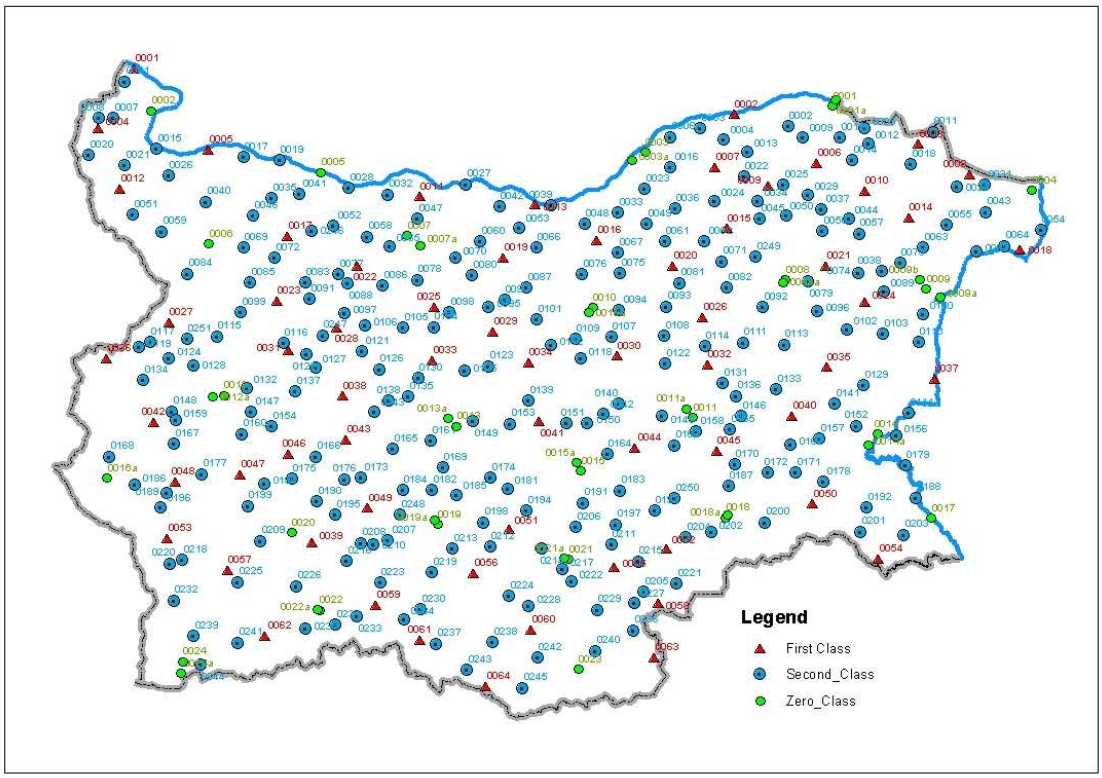

Fig. 11. Zero, First and Second order gravimetric networks

1. 5 Bulgarian Geodetic System 2005 (BGS2005)

The affiliation of the geodetic and leveling network of Bulgaria to ETRS89 and EVRS provided the possibility of introducing the (new) Bulgarian Geodetic System 2005 based on the Decree of the Council of Ministers No 153 from 29.07.2010 and Act No 2 from 30.07.2010 for the definition, realization and maintenance of the Bulgarian Geodetic System 2005 (BGS 2005), in pursuance of Article 12, paragraph 2 of the Law for Geodesy and Cartography.

By definition BGS2005 includes:

- fundamental geodetic parameters according to the Geodetic Reference System 1980 (GRS80);
- the geodetic reference system ETRS89;
- the height system, realized by the leveling benchmarks of the State Leveling Network, included in the Unified European Leveling Network (UELN), and determined in the European Vertical Reference System (EVRS) by means of gravity force data in the unified gravimetric system (IGSN 1971);
- the geodetic projection – Universal transversal cylindrical projection of Mercator (Universal Transverse Mercator – UTM), and the orthogonal plane coordinate system introduced by means of it;

The introduced BGS 2005 provides the possibility of implementing the GNSS technology and realizing a unified geodetic base, which ensures standardized and compatible geospatial materials and data. The transformation of the materials and data when introducing the new geodetic system represents a basic problem, since five coordinate systems exist in the country till the present moment – from 1930, 1942, 1942/83, 1950 and 1970.

1.6 Tide Gauge Network

Historically, the State leveling is related with four mareographic stations, situated along the Black Sea coast, the result of their activity being the records of the Black Sea level and its fluctuations in the course of more than 70 years. The Geodesy, Cartography and Cadastre Agency, together with the Department of Geodesy, operates four tide gauge stations: two in the towns of Burgas and Varna – functioning since 1928 and situated in the immediate proximity of the UELN points and two – in the town of Ahtopol and the Irakli locality (between the village of Obzor and the Emine cape) – in operational since 1971.

2. Determination of the Gravity Field

2.1 Contribution to the EGG08 development

Gravimetric data for Bulgaria in EGG08

The gravimetric data included in the territory of the country are from the State gravimetric networks of the Zero, First and Second order, from the Reference gravimetric measurements and from the last gravimetric measurements within the EUVN-DA project. All data are digitalized, analyzed and verified in cooperation with the computing center on the European Gravity and Geoid Project (EGGP) of IAG in Hanover. About 10 % of all gravimetric data are evaluated and excluded as low-quality. All other points are submitted and included in the EGG08 development.

An estimation of the model accuracy for the territory of Bulgaria is made by its comparison with GPS/leveling data – about 350 regularly distributed points. The comparison proves that the differences do not exceed 10 cm for the greater part of the country. The zones, where higher differences are observed, are situated in the Southwest and Central part of Bulgaria (the mountainous regions) – of the order of 20-30 cm.

3. Geodynamic applications

3.1 Position of Bulgaria in the regional geodynamic settings

One of the important application of the Main order of the National GPS network, underlain during its design, is the possibility to use the results for solving scientific and applied tasks – geokinematics and geodynamics, assessment of the recent geodynamic processes and seismic hazards. This is of special significance due to the fact that on the territory of Bulgaria the residual velocities, i.e. the velocities with respect to the stable part of the Eurasian plate are different from zero.

The area of the East Mediterranean is complicated tectonically and seismotectonically active region with significant, reaching up to 35 mm/y, horizontal movements (Fig. 12). The region of South Bulgaria, and especially Southwest Bulgaria and the Rhodopes, is the most active tectonic and seismotectonic area of the country with proved recent active tectonic structures and crustal movements. The strongest earthquake, with magnitude 7.8, in continental Europe in the last two centuries is occurred here, in the Krupnik-Kresna region;

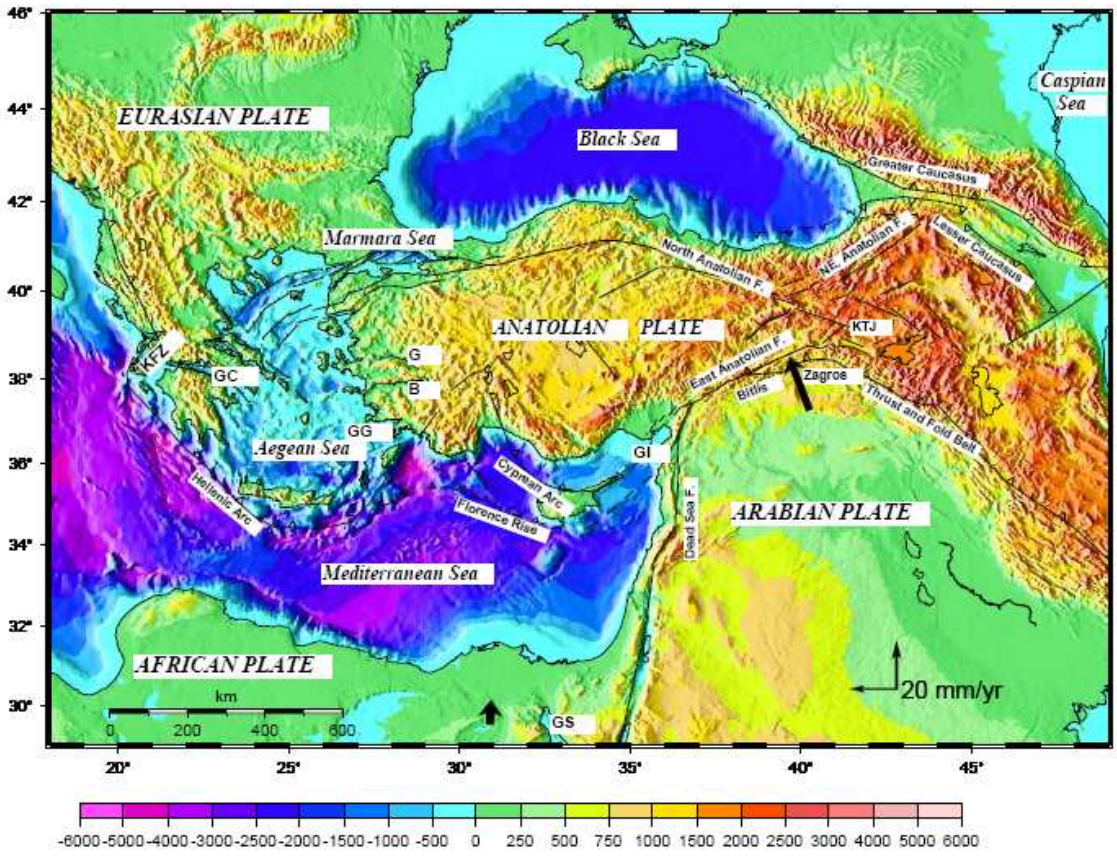

Fig. 12. Simplified tectonic map of the region of the East Mediterranean with displayed continental and micro-plates and main faults

Tectonic settings in the East Mediterranean The tectonic settings in the East Mediterranean are dominated by the collision of the Arabian and African plate with Eurasia. The models of plate movements show that the Arabian plate moves in north-northwest direction with respect to Eurasia with a velocity of about 18–25 mm/y. These models also show that the African plate moves in north direction with respect to Eurasia with a velocity of about 10 mm/y. The leading edge of the African plate is subducted along the Hellenic Arc under the Eurasian plate with higher rate than the relative movement in north direction of the African plate itself due to the slight effect of plate rotation. The known data support the regional extension with dominating north-south direction and all authors agree about the extensional regime in the north-northwest from the North Anatolian Fault (NAF).

Southwest Bulgaria – the most active tectonic and seismotectonic region in the country

The tectonic processes in South Bulgaria during the Neogene and the Quaternary are result from the destruction of the Late Alpine orogen, the extensional regime in the west and north parts of the Hellenic Arc and the complex interaction of the intensive vertical and horizontal movements in the region.

Southwest Bulgaria is the most active tectonic area of the country characterized also by high seismicity. The territory belongs to the southern part of the Central-Balkan neotectonic region – a zone with recent extension of the crust and with complex interaction between the horizontal and vertical movements of the tectonic structures. The geological and geophysical data confirm the recent activity of the fault structures formed during the Late Neogene and the Quaternary. The area is located in the northern part of the North Aegean region and is strongly affected by its tectonics and high seismicity (Fig. 13).

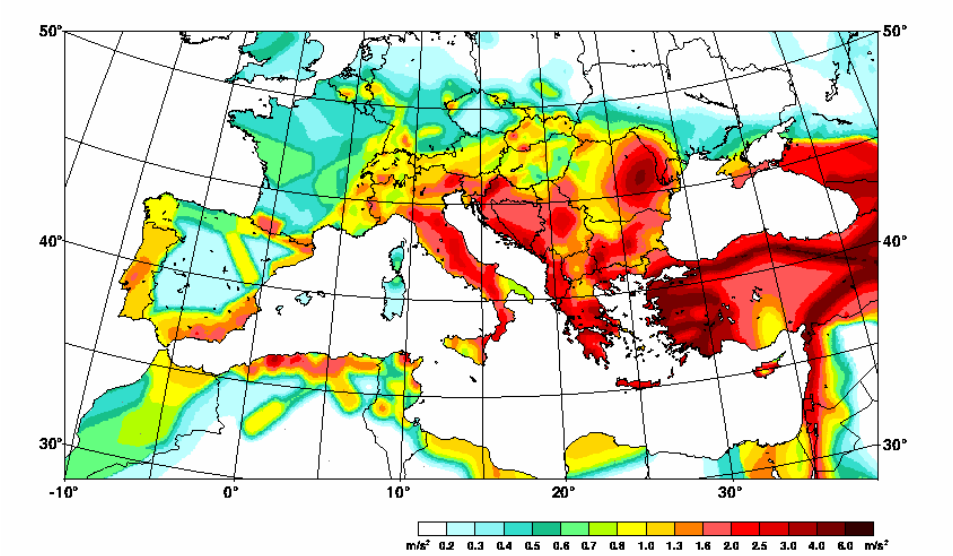

Fig. 13. Map of the seismic hazard according to the Global Seismic Hazard Assessment Program, a part of the International Lithosphere Program. The seismic hazard is expressed as peak ground acceleration with a 10% probability for expected event within 50 years

The recent seismicity recorded by the National Operation Telemetric System for Seismic Information (NOTSSI) of the NIGGG at BAS shows concentration of the events in the Krupnik-Kresna area and the Mesta River valley.

The recent crustal movements in SW Bulgaria are result from the continuous extensional movement in the internal part of the Aegean region. The complex effect of the southwestern movements of the Anatolian and North-Aegean plate along the North-Anatolian fault zone (NAFZ), in the Aegean Sea provoke the formation of the extensional zone to the north of the North-Aegean Trough (NAT). The region of SW Bulgaria is of key importance for the regional neotectonics and recent tectonics because it is located in the intersection points between several fault lineaments of high significance: the Struma (Kraishtide) lineament with NNW-SSE direction, the Maritsa lineament with WSW-E direction, and the northern-most fault branches of the North Anatolian fault zone NAFZ.

Geodynamic networks in Bulgaria

Scientific research GPS network in Southwest Bulgaria and the Rhodopes

A detailed geodetic study of the recent geodynamic processes in the region of Southwest Bulgaria and the Rhodopes has been initiated by Department of Geodesy and Geodetic Faculty of UACEG in the early 2000. Geodynamic GPS network in Southwest Bulgaria and the Rhodopes for long-term monitoring of recent crustal movements has been established. The network consists of 52 points, selected to cover the main tectonic structures (see Fig. 13 below). The choice of each point was made after geological and terrain investigation. The first GPS campaign for observing the geodynamic network was realized in 2001 – SWB 2001. Except this national scale geodynamic network another two local geidynamic networks are regularly measured – both in the regions of the strong earthquakes in 1904 in Krupnik and in 1928 in Chirpan-Plovdiv

A considerable number of GPS campaigns in the period 1993-2009 have been either performed by or submitted to Department of Geodesy. These are ***all the measurements*** of points from the Main and Secondary orders of the National GPS network, measurements of the geodynamic network in SW Bulgaria and the Rhodopes, the local geodynamic networks in

the regions of Sofia, Krupnik-Kresna and Chirpan-Plovdiv: totally 33 GPS campaigns are processed and analyzed.

On the basis of the processing and analysis of 33 GPS campaigns during the period 1993 – 2007 the horizontal velocities of 89 GPS points have been obtained. They represent the velocity field in the country at the moment.

The recently active faults and fault structures are localized by the analysis of the horizontal velocities in the region of SW Bulgaria and the Rhodopes, vertical crustal movements, geological, tectonic and seismic data. The territory of SW Bulgaria is divided in five blocks with homogeneous recent movements and average velocity in south-southwest direction of 1.3 ± 0.3 mm/y with respect to stable Eurasia. This movement is in good agreement with the regional kinematics in the East Mediterranean.

The horizontal velocities of totally 89 points on the territory of Bulgaria are estimated. The velocities of the points in SW Bulgaria show movement in southern direction with respect to stable Eurasia. This movement is in good agreement with the right strike-slip movement along the western parts of the North Anatolian fault and the North Aegean extensional province. Having in mind that the movement of the Aegean plate is times more than the recent movements in Southwest Bulgaria it is obvious that the counter-clockwise rotation of the Anatolian plate and the movement of the Aegean plate to the south are accompanied by its detachment from stable Eurasia. The increasing horizontal movements from north to south explain also the north-south extensional regime in the North Aegean area (see below Fig. 15).

The established GPS geodynamic network in the region of Southwest Bulgaria and the Rhodopes for monitoring the recent crustal movements is important for the assessment of the recent geodynamic processes in this most active tectonic and seismotectonic region in Bulgaria, for assessment of the seismic hazard and for the seismic zoning.

Velocity field in Bulgaria and the Balkan Peninsula

A comprehensive GPS study of recent tectonics of Bulgaria, Albania and Northern Greece has been done in cooperation with French, Albanian, Macedonian and Greek colleagues in the frame of joint Bulgarian-French project.

A huge amount of GPS data collected between 1996 and 2009 is used. Except data from Bulgaria (National GPS Network and geodynamic networks) GPS data from Albania, Macedonia and Northern Greece are included – about 100 points.

The reoccupation networks included data from GPS campaigns on the territory of Albania, Northern Greece and Macedonia are:

Albania: dense GPS network has been installed to better localize areas undergoing current deformation. Benchmarks allow direct centering of antennas to avoid centerings errors and bad determinations of antenna heights. Measurements of 34 GPS stations were analyzed in 4 campaigns in 2003, 2006, 2008, and 2009. The observation sessions are between 36 and 72 hours. The sampling rate of the observation is 30 s, with an elevation cut-off angle of 10 degrees.

Northern Greece: GPS data from 21 points are used to determine crustal displacements collected in 1999, 2000 and 2008. In 1999 and 2000 only short sessions (3-10 hours) were performed whereas in 2008, points measurements were between 48 and 72 hours.

Macedonia: measurements of 5 points are analyzed from three campaigns in 1996, 2000 and 2008. The data for 1996 are courtesy given by the Macedonian Agency of Cadastre. For that campaign measurement sessions for each GPS station were 72 hours. In the 2000 campaign

the observation sessions were 24 hours. The observation session for each GPS station was 24 hours. The 2008 campaign was made in collaboration with Department of Geodesy, BAS and Faculty of Civil Engineering, Chair for Geodesy, University "St. St. Cyril and Methodius", Skopje, Macedonia, with observation session duration of 8 hours.

The velocity field in Bulgaria, Northern Greece and Albania is presented in Fig. 14. The figure shows also results of other author for the rest of the region.

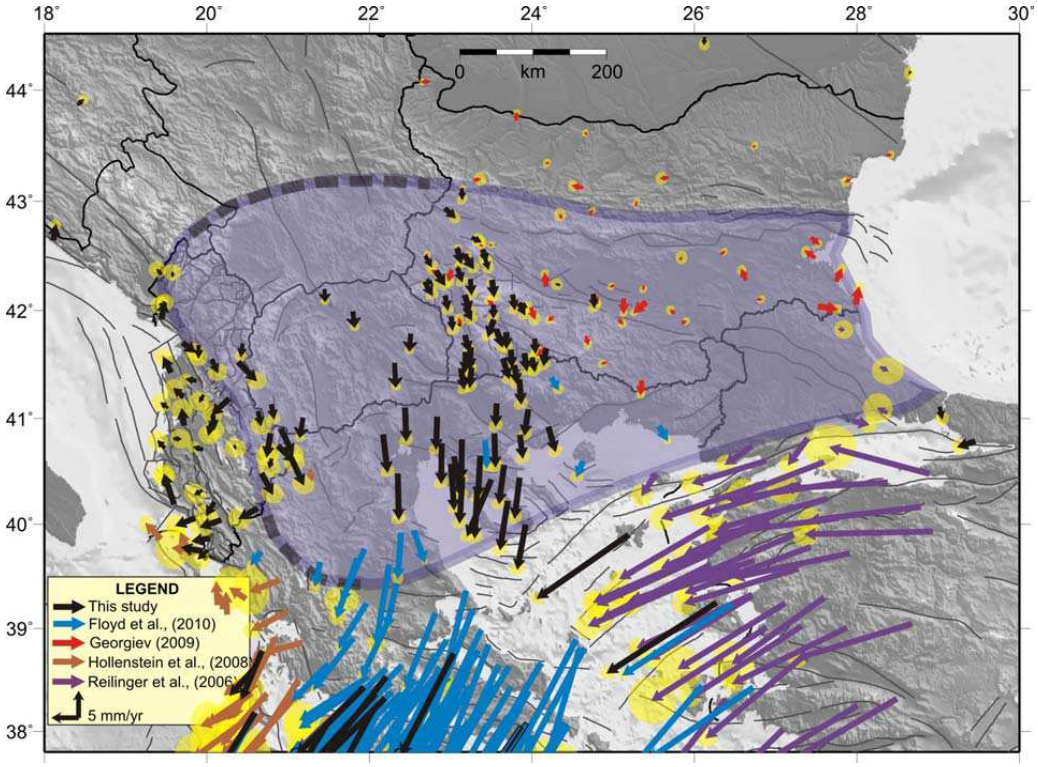

Fig. 14. Velocities in Bulgaria, Northern Greece and Albania obtained in the Department of Geodesy and other authors along with modified west boundary of South Balkan extension region. Velocities are expressed in Eurasia fixed reference frame.

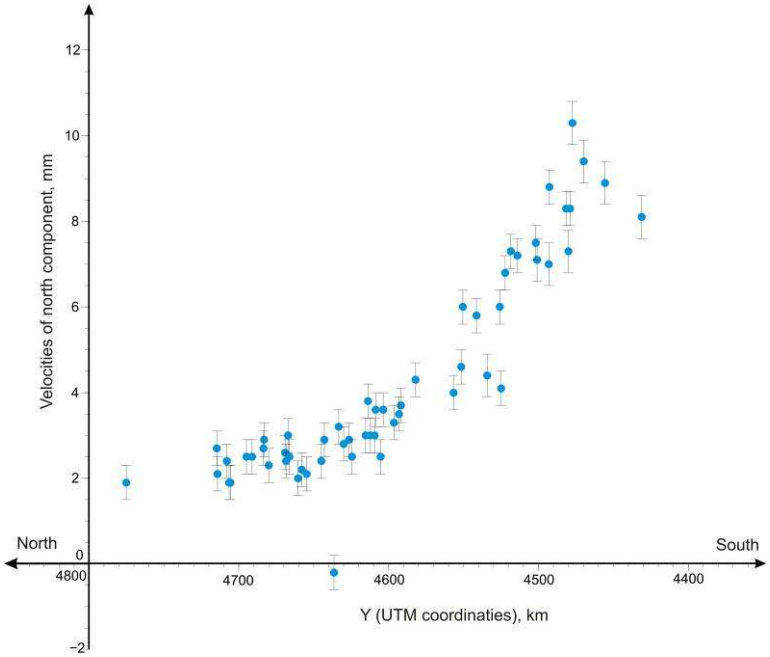

Fig. 15. Velocity gradient from central Bulgaria (Balkan Mountain) to Northern Greece (Halkidiki)

Crustal deformation in the East Mediterranean by InSAR

Along with the University Pierre and Marie Curie – Paris VI, France, a comprehensive study on the crustal deformation in East Mediterranean was done using InSAR technology and seismotectonic data.

The principal objectives are to determine by radar interferometry the fields of deformations of the Earth's crust caused by several specific shallow seismic events which occurred in the East Mediterranean, to suggest dislocation models using the Okada formalism and to delineate some tectonic structures in the investigated region. Where additional data like GPS or others are available, comparisons and complex analyses are introduced.

Two of the studied events, namely the Konitsa sequence of shocks from July-August 1996 and Valandovo earthquake from May 2009 have small magnitudes between 5.0 and 5.3 and their detection by InSAR is a serious challenge. In the case of the Konitsa earthquake (in the border area between Greece and Albania) the crustal deformations are very clear on the processed interferogram and are revealed as two fringes, corresponding to at least 5.6 cm displacement (Fig. 16). In comparison, the Valandovo event (northward of the Dojran Lake) has similar magnitude and parameters to the previous one, but could not be detected by radar interferometry mainly because of the deeper location of the fault and probably due to the different geological structure of the area. No earthquake signal can be found also in the time series of the Valandovo permanent GNSS site.

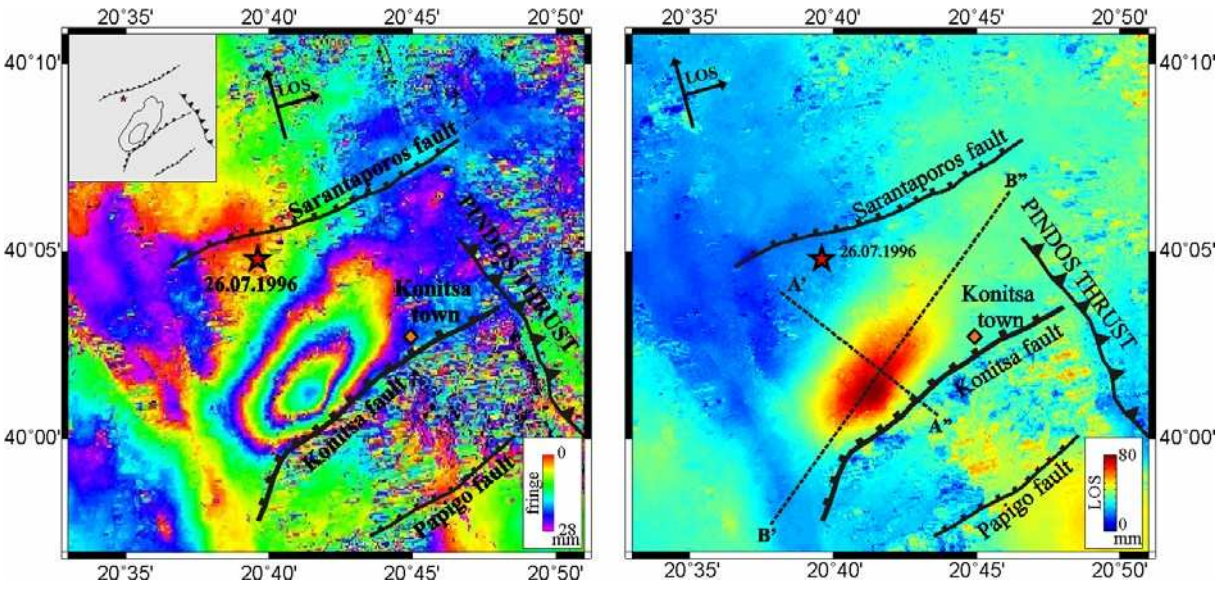

Fig. 16. Left: Ascending differential co-seismic interferogram – *ifg*8 (Bp 95m). The star shows the main shock from 26.07.1996; orange diamond – Town of Konitsa; the arrows – direction of ascending flight and side of looking of the satellite. Inset: the observed fringes used for the inverse modelling. Right: The same interferogram but unwrapped.

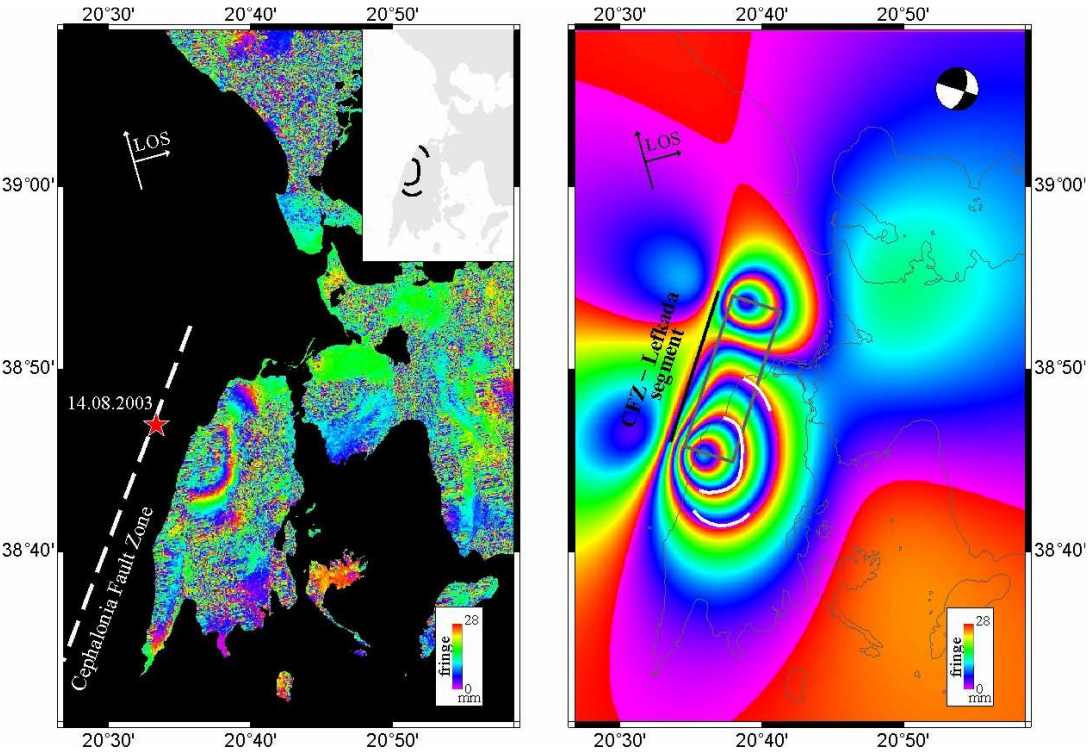

Fig. 17. SAR interferometry results for the Lefkada earthquake. (Left) Differential ascending interferogram – *ifg*5 (BL 88m). The star shows the main shock according to NOA; the arrows – direction of ascending flight and side of looking of the satellite. Inset: The observed fringes. (Right) Synthetic ascending interferogram obtained from inversion of the received observed fringes (left). The rectangle represents the approximate model of the fault segment.

On the other hand, the other examined shock, the Lefkada Island earthquake from 2003 occurred with bigger magnitude of 6.3. Regardless of the bigger size of this event, it has other specificities for which it rouse interest. The particular situation related with the Lefkada event is that the shock stroked in the sea, near the coast of the island, and the difficulty is to produce and interpret an interferogram for a small island surrounded by big areas with very low backscatter capabilities. The interferograms obtained are influenced by the specific conditions and contain vast decorrelated areas. Nevertheless, a surface deformation of about 5.6 cm has been detected (Fig. 17).

The new knowledge obtained for the fault structures in the region of Lefkada confirms the hypothesis for the existence of a separated tectonic structure – the Central Ionian Islands block, comprising the Northwest Peloponnesus, the area of Akarnania on the mainland part of Greece and the Central Ionian Islands.

4. Position and applications

Recently introduced instructions

Important instructions have recently been adopted for datum transformations and GNSS positioning for survey purposes. These documents are addressed at providing local survey and mapping works with standardized procedures for a smooth transition to the new BGS2005 datum introduced last year, for both existing and newly collected data and products.

The first document, Instructions for transformation of existing survey and mapping data into BGS2005, deals with the basic definitions related to BGS2005 and the legacy datum widely used through the years which still provide geodetic reference of most digital and paper

products. Emphasized are the transformation procedures which are presented in details, down to simple computation steps, in the numerous appendices to the specification. Parts of them are published for the first time.

Since BGC2005 is an ITRS based reference system, important part of the Instructions are the IERS and EUREF adopted procedures providing the models and digital data necessary for transformations between the specific frames and observation epochs. For the sake of completeness, various numerical procedures relevant to datum transformations and conversions are also given.

The second document, Instructions for GNSS positioning, treats a wide range of practical surveying and mapping problems where GPS, GLONASS and other future systems are implemented. Being the second Instructions of similar type, after the original one published in 1995, it is focused on the most actual aspects relevant to positioning of control points, detailed surveys and staking-out using the existing GNSS infrastructure, and referenced to the BGS2005 datum. Covered are first of all the precise relative carrier phase positioning technologies, both static and kinematic, post-processed and in real time. Regulations on simplified decimeter accuracy applications and differential sub-meter methods are also included.

For the first time, requirements for GNSS infrastructure operators are also articulated, along with certification rules aimed at their public identification and recognition. This is an initial attempt to establish control over the service quality available to users and the responsibilities of the service providers.

The public demand on both documents was realized long time ago, but they could emerge only after BGS2005, which provides the necessary technological and legal background, has been introduced.

Another instructions deal with "Ordinance for the planning, implementation, monitoring and acceptance of aerial imaging and the results of remote sensing methods for scanning and interpretation the earth surface" is also prepared. The Instructions specifies the planning, implementation, control and approving aerial imaging for civilian purposes and results of various remote sensing methods for scanning and interpreting surface.

5. International cooperation

In the recent years fruitful cooperation between geodetic institutions in Bulgaria and European and worldwide geodetic community is going on – EuroGeographics, IAG EUREF sub-commission, Royal Observatory of Belgium; Ecole Normale Superieure and CNRS, France, Astronomical Institute of the Czech Academy of Sciences; Center for Space Research of the Polish Academy of Sciences; Massachusetts Institute of Technology, USA.

Below are listed some of the international projects of the Department of Geodesy along with finance institutions:

Central European Geodynamic Project (CERGOP2), European commission, Directorate I “Protection of the ecosystem – protection of the environment”;

Balkan Geodetic observing system (BALGEOS), Austrian Federal Ministry of Science and Investigations (BMWF), represented by the Center for social Innovations, Vienna, Austria;

Research on the seismotectonic manifestations of the earthquakes on 14 and 18 April 1928 in South Bulgaria, Royal Observatory of Belgium;

Investigation of the mechanisms of the Earth's crust deformations, Ministry of education and science, France;

Monitoring of the Earth's crust deformations in West Central Bulgaria and North Greece by means of the Global Positioning system GPS – HemusNET, NATO, Science for Peace program;

Investigation of the surface deformation mechanisms of the lithosphere, Bulgarian Science Foundation at the Ministry of education, youth and science and the Ministry of education and science, France;

An international school and work meeting for the state-of-art GNSS software GAMIT/GLOBK, developed in the Massachusetts Institute of Technology, was organized by the Department of Geodesy between November 30 and December 02 2007 in Sofia.

6. Contributors of the Report

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7. Selected publications

A few journals are related to geodesy and geodetic practice in Bulgaria: "Geodesy", the Department of Geodesy issue (in English); "Geodesy, Cartography and Land Surveying", issue of the Union of the Geodesists and Land Surveyors and "Geomedia", the Geomedia Ltd. issue.

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International Association of Geomagnetism and Aeronomy (IAGA)

IAGA Activities in Bulgaria
2007 - 2011

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Institutions

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- **Institute for Space and Solar-Terrestrial Research**
- **Sofia University "St. Klimenth Ohridski"**
- **University of Mining and Geology "St. Ivan Rilski"**

Foreword

The International Association of Geomagnetism and Aeronomy (IAGA) is focused on understanding the near Earth space environment. This ranges from studying the dynamics of the core magnetic field of the Earth, to the chemistry, dynamics and electrodynamics of the thermosphere and ionosphere, to the interaction between the Earth's magnetic field with the Sun's atmosphere and magnetic field, and finally to the Solar dynamics which ultimately drive most of the science in the near-Earth space environment.

Participation of the Bulgarian scientists has been focused on research from **Division I** - WG 1, 3; **Division II** – WG C, D; **Division IV** and **Division V**. The report is arranged in the following way: (i) it starts with the IAGA activities accomplished by the scientists from the National Institute of Geophysics, Geodesy and Geography; (ii) then the activities from the Institute for Space and Solar-Terrestrial Research follow, but they are divided into two parts according to the activities in the formers Institute for Solar-Terrestrial Influences and Institute for Space Research.

Division I – WG1

Generation of Earth's magnetic field and interpretation of potential fields

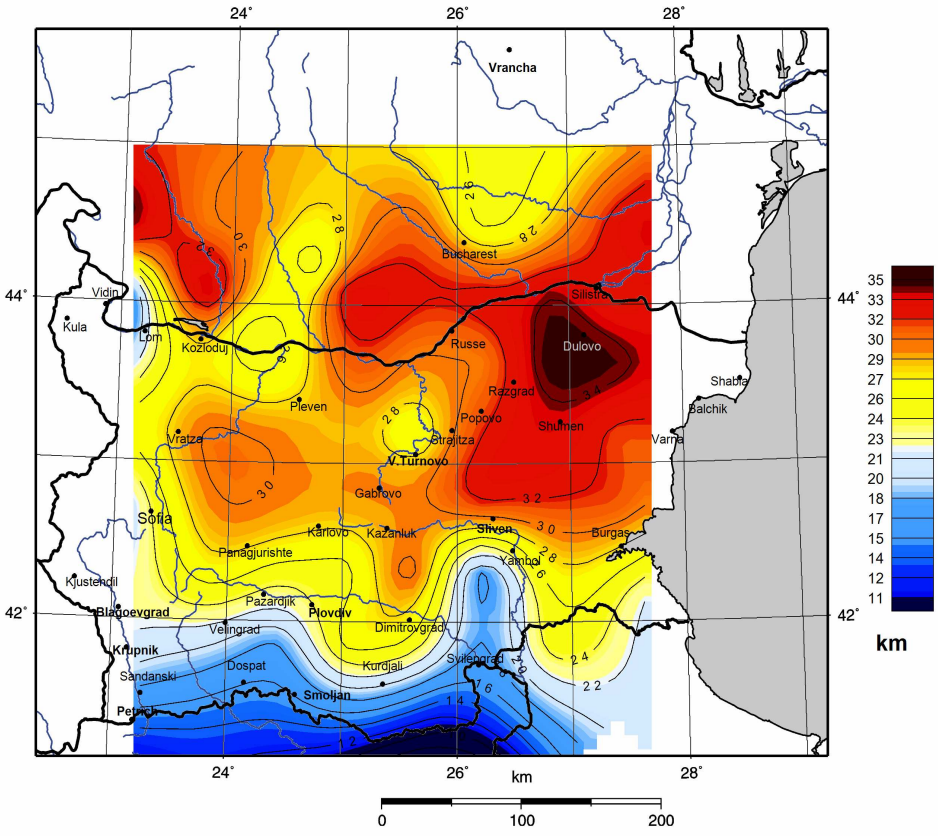
National Institute of Geophysics, Geodesy and Geography - Dr. Alexander Anufriev, Dr. Totka Petrova, Dr. Zheljo Zhelev, Dr. Bozidar Srebrov, Dr. Petya Trifonova

***Main results*:**

1. The problem of applying the Boussinesq approximation to the convection in the Earth's core is discussed. It is shown that the Boussinesq approximation neglects the essential part of the heat transport in the core, the adiabatic heat flux, which does not vanish in the incompressible limit. It also neglects the cooling due to the work of the Archimedean force. As a result, the law of energy conservation reduces to the heat conservation only. Thus, the Boussinesq approximation is inadequate for describing of the Earth core convection. Therefore we propose here a new, Incompressible approach, which takes all these effects into account. In the frame of this new approach we estimate the "natural" units for the Earth's core convection. On this base we redefine the value of the Rayleigh number which is widely discussed in literature.
2. Complex 3D geophysical model of hydrothermal field Poljanovo-Ajtos has been realized applying hydrogeologic, geothermal and hydrochemical investigations and after electro-sounding and magnetotelluric profiling. This is the only one hydrothermal object in Bulgaria investigated with such techniques.
3. New map of the anomalous gravity field for the Black sea aquatorry has been created, based on sea measurements. New map of the normal and anomalous geomagnetic field in the Black sea aquatorry has been created, based on sea measurements.
4. Analysis of the spectral structure of anomalous geomagnetic field on the territory of Bulgaria. Long-wave components of the field were separated and interpreted,

representing large sources in the upper lithosphere. Study of the possible presence of residual anomalies, caused by non-exactnesses in the description of the model for the main magnetic field.

5. Interpretation of geomagnetic anomalies (forward and inverse modeling, spectral methods). Curie point depths of Bulgarian territory were calculated using geomagnetic anomaly data and map of the Curie isotherm was drawn for the first time.



Research projects:

Curie Point Depth of Bulgarian Territory and its Correlation with Regional Thermal Structure and Seismicity NATO SECURITY THROUGH SCIENCE PROGRAMME, REINTEGRATION GRANT CBP.RIG.982373 2006-2009. Project Leader: Dr. Petya Trifonova.

Analysis of Geophysical Time Series and Geophysical Field Data (mainly Gravity and Geomagnetic) Oriented towards Monitoring and Investigation of the Inner Structure of the Upper Part of the Earth and Dangerous Natural Events (Volcanoes, Earthquakes, etc.). Project Leader: Dr. Zheljo Zhelev

Selected Publications:

Anufriev A. Approximation of incompressible fluid to the geodynamo convection. *Bulg. Geophys. J.*, v.33, 20-34, 2007.

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Conference contribution:

Trifonova P., Zh. Zhelev, T. Petrova (2007) Locations of Curie point depths and Moho of the Bulgarian territory, EGU General Assembly 2007, Vienna, Austria.

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Trifonova, P., Z. Zhelev, T.Petrova, N. Petkov (2009) Correlation of Curie point depths, heat flow data and geothermal modeling for Bulgarian territory, Proceedings of the 5th Congress of Balkan Geophysical Society, Belgrade, Ref.# 6291

Division I – WG3

Environmental magnetism and palaeomagnetism

National Institute of Geophysics, Geodesy and Geography - Dr. Diana Jordanova, Dr. Neli Jordanova

Main results:

1. Study of magnetic properties of outdoor and indoor dust, collected monthly from 6 towns in Bulgaria (Sofia, Bourgas, Russe, Pleven, Plovdiv, St.Zagora) has been performed for testing the applicability of magnetic methods for evaluation of the degree of pollution in urban areas. Dust material collected contains coarse and fine grained inorganic particles, organic particles and pollens. SEM observations on mineral grains and pollens show the presence of abundant iron-containing spherules. Pollen grains are usually characterized by stacked on their surface mineral particles, some of them also highly magnetic. Using statistical data for year 2009, provided by the National Center for Health Information for the corresponding towns, it has been shown that the ratio of magnetic susceptibility of indoor dust (Xindoor) to magnetic susceptibility of outdoor dust (Xoutdoor), is proportional to mortality due to respiratory deceases. This finding confirms once again that respiratory deceases are linked to the air quality. The results obtained suggest that magnetic methods can be successfully applied for evaluation of environmental quality and its effect on human health.

2. Magnetic study of the degree of erosion of agricultural land in the area of Trustenik (Russe region) has been carried out to evaluate the effect of the natural factors and tilling. The area studied is characterized by significant slope (up to 7^{o}) and comprises about 4.5 ha, which is used as corn field. Soil type is typical Chernozem. Results from carried out field measurements and laboratory investigations allows evaluation of the degree of soil re-distribution as a result of water- and wind erosion, caused by tilling. The obtained 3D-maps of the field magnetic susceptibility and map, constructed on the base of samples gathered, reflect the influence of the heavy agricultural machines which cause significant compaction of the soil.

3. Relations between the emplacement and fabric-forming conditions of the Kapitan-Dimitrievo pluton and the Maritsa shear zone (Central Bulgaria): magnetic and visible fabrics analysis. The Kapitan-Dimitrievo pluton was emplaced within the very wide Maritsa shear zone during the Upper Cretaceous. Though difficult outcrop conditions, samples have been collected in 23 sites spread in the entire massif. Rockmagnetism studies points the presence of pure magnetite in large grains. Petrographical observations show that magnetite occurs in two mineral generations (Kamenov et al., 2003). The first one is early crystallized in the magma chamber (depth between 8 and 12 km), before pluton emplacement at a depth around 4 to 8 km. The second one is later crystallized after the main rock-forming minerals. It is quite better present in quantity and with larger size than the first generation. On a map, the magnetic foliation shows coherent evolution in the main pluton, plunging NW for the western sites, N to NNW for the northern sites and mostly NE for the northeastern border. The foliation plunge is steep in the northwestern part of the massif and moderate in the other sites. The magnetic lineation presents also a remarkable evolution, turning regularly on the massif

border from N-plunging to the west to SE-plunging in the northeast. Only some eastern sites have less coherent magnetic fabric. Syn-magmatic (visible magmatic fabric due to magma flow) and late-magmatic (magnetic fabric connected with regional stresses) structures are different, but both mainly related to the shearing conditions in this shear zone.

Projects:

SCOPES Project IB7320-110723 "Environmental Applications of Soil Magnetism for Sustainable Land Use"; 2005 – 2008. Partners: Institute of Geophysics, ETH-Hönggerberg, Dr. Ann Hirt; Institute for Terrestrial Ecology, Soil Chemistry, ETH-Schlieren, Prof. Dr. Ruben Kretzschmar; Geophysical Institute, BAS, Dr. Diana Jordanova; Faculty of Geology and Geography, Sofia Univ. "St. Kl. Ohridski", Assoc. Prof. Dr. Dimo Dimov

NATO Linkage Grant "Integrated environmental screening by bioindicators and magnetic proxies" 2006-2008, scientist in charge for the Bulgarian team: D. Jordanova; coordinator: Doc. V. Hoffmann (Germany)

Bulgarian Ministry of Science and Education "Magnetic properties of soils as a reflection of their ecological status", Grant NZ1510, 2006 – 2008

FP7, Collaborative project (small or medium – scale) iSOIL: "Interactions between soil related sciences – Linking geophysics, soil science and digital soil mapping" 2008-2011.

Bulgarian-French PHC Rila program "La collision Europe-Dinarides: Le cisaillement alpin majeur de la Maritsa en Bulgarie centrale" 2009 – 2010, scientists in charge: Assoc. Prof. D. Dimov (Sofia Univ.), Dr. B. Henry.

Bilateral cooperation project "Magnetic fabric of Strandja and Central Srednogorie plutons (Bulgaria) and structural implications", 2006-2007, between BAS (Geophys. Inst.) and IPGP (Paris, France)

Bulgarian National Science Fund: "Geophysical investigations of the environmental pollution level and its effect on human health in urban areas", Proj. No DO 02-193/2008, 2008-2012

Bulgarian National Science Fund, National contribution to the FP7th project iSOIL "Interactions between soil related sciences – Linking geophysics, soil science and digital soil mapping", Proj. No Do02-147/2009

Publications:

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2010. Conference Proceedings, vol.1, 783 – 790, 2010, ISBN-10: 954-91818-1-2; ISBN-13: 978-954-91818-14

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Henry, B., Jordanova, D., Jordanova, N. Derder, M., Bayou, B., Amenna, M., Dimov, D. Composite magnetic fabric deciphered using heating treatment. *Stud. Geophys. Geod.* 51, 293-314, 2007.

Jordanova, N., Jordanova, D., Tsacheva, Ts. Application of magnetometry for delineation of anthropogenic pollution in areas covered by various soil types. *Geoderma*, 144 (3-4), 557-571, 2008.

Jordanova, D., Hus, J., Geeraerts, R. Palaeoclimatic implications of the magnetic record from loess/palaeosol sequence Viatovo (NE Bulgaria). *Geophysical Journal International*, 171, 1036-1047, 2007, doi: 10.1111/j.1365-246X.2007.03576.x

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Archaeomagnetism

National Institute of Geophysics, Geodesy and Geography - Prof. Mary Kovacheva, Dr. Maria Kostadinova-Avramova

Main results:

1. Archaeological burnt clay is a basis for reconstruction of geomagnetic field variations during past epochs. Important results for newly discovered magnetic phase, identified in such materials gathered allover Europe have been obtained. These results change our understanding about magnetic identification of high-coercivity minerals with low unblocking temperatures. Exclusive thermal stability of this new phase makes it

suitable as a carrier of magnetic information about the palaeodirection and palaeointensity of the geomagnetic field. On the other hand, frequently observed anomalous directions of the thermoremanent magnetization vector in the low-temperature interval requires careful selection of the temperature interval for palaeodirection and palaeointensity estimation. This achievement improves the application of archaeomagnetic dating of newly excavated archaeological sites on the territory of Bulgaria.

2. Revised and completed with new data archaeomagnetic set of determinations in Sofia Palaeomagnetic Laboratory is compared with calculated geomagnetic elements variations for our geographic coordinates, applying the global model of Korte and Constable (2005). The results show that the model CALKS7K.2 leads to strongly smoothed variations because it is based on irregular and inhomogeneous distribution of archaeomagnetic data over the Earth. Comparison of our dataset with an alternative modeling method SCHA.DIF.3K (local spherical analysis), including only archaeomagnetic data from Central Europe (Pavon-Carrasco et al., 2009) shows much better fit, especially in the intervals with extreme values.

Project:

National Archaeological Institute with Museum, Contract No 803: "Archaeomagnetic investigation of burnt clay remains from Early Bronze site near Dragantzi village, Trakia highway, object No 36 and archaeomagnetic synchronization with different levels of Early Bronze site near Djadovo village", 2010-2011.

Publications:

McIntosh, G., Kovacheva, M., Catanzariti, G., Donadini, F., Osete, M.L. High coercivity remanence in baked clay material used in archaeomagnetism. *Geochemistry Geophysics Geosystems (G3).*

Donadini, F., Kovacheva, M., Kostadinova-Avramova, M. Archaeomagnetic Study of Roman Lime Kilns (1 c. AD) and One Pottery Kiln (1st c. BC – 1st c. AD) at Krivina, Bulgaria, as a Contribution to Archaeomagnetic Dating. *Archaeologia Bulgarica,* XIV, 2 (2010), 23-38. ISSN 1310-9537.

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Kovacheva, M., Chauvin, A., Jordanova, N., Lanos, P., Karloukovski, V.. Remanence anisotropy effect on the palaeointensity results obtained from various archaeological materials, excluding pottery. *Earth, Planets and Space*, 61, 6, 711-732, 2009.

Herries, A.I.R., Kovacheva, M., Kostadinova, M. and Shaw, J. Archaeo-directional and -intensity data from burnt structures at the Thracian site of Halka Bunar (Bulgaria): the

effect of magnetic mineralogy, temperature and atmosphere of heating in antiquity. *Phys. Earth Planet. Inter*., 162, 3-4, 199-216, (2007), doi: 10.1016/j.pepi.2007.04.006

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McIntosh, G., Kovacheva, M., Catanzariti, G., Osete, M.L. and Casas, L. Widespread occurrence of a novel high coercivity, thermally stable, low unblocking temperature magnetic phase in heated archeological material. *Geophys. Res. Lett., 34*, (2007), L21302, doi:10.1029/2007GL031168.

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Herries, A.I.R., Kovacheva, M., Kostadinova, M. Mineral magnetic analysis and archaeomagnetic dating of an oven at the Mediaeval site of Zlatna Livada, Bulgaria. AARCH Special Issue of *Physics and Chemistry of the Earth*, 33, 496-510, 2008, doi: 10.1016/j.pce.2008.02.021, ISSN 1474-7065.

Donadini, F., Kovacheva, M., Kostadinova, M., Hedley, I.G. and Pesonen, L.J. Palaeointensity Determination on an Early Medieval Kiln from Switzerland and the Effect of Cooling Rate. AARCH Special Issue of *Physics and Chemistry of the Earth*, 33, 449-457, 2008, doi: 10.1016/j.pce.2008.02.019, ISSN 1474-7065.

Education

University of Mining and Geology “St. Ivan Rilski”, Department of Applied Geophysics

Fields of activity:

The Department of Geophysical Methods of Prospecting at the Faculty of Geology was created in 1953. In 1983 the department was included in the new nomenclature under the name Applied Geophysics.

After its establishment the department was consecutively headed by: Prof. Grozdan Nikolaev (1953-1956), Prof. Lyuben Dimitrov (1957-1968), Prof. Toma Dobrev (1969-1988), Prof. Vera Ivanova (1989-1993), Assoc. Prof. Ivo Lozenski (1994), Prof. Vera Ivanova (1995-1998), Prof. PhD Radi Radichev (1999-2007), Assoc.Prof. PhD Stefan Dimovski (since 2008).

Scientists:

Currently, the department consists of 1 professor, 4 associate professors and 2 assistant professors:
Prof. PhD. Radi Radichev; Assoc. Prof. PhD Lyuben Gugov, Assoc. Prof. PhD Chavdar Gyurov, Assoc. Prof. PhD Stefan Dimovski, Assoc. Prof. PhD Alexander Tsvetkov, Ass. Prof. Hristian Tsankov, Ass. Prof. Miglena Yankova
The academic and research work at the department is supported by Eng. Nikolai Kirilov and Eng. M.Sc.Svetla Dimitrova.
The academic staff of the department has published more than 1000 scientific papers, 7 monographs, 13 textbooks and 5 manuals for practice seminars. The department has several laboratories – Physical Properties of the Rocks, Gravimetric and Magnetic Methods in Geophysics, Electrical Prospecting and Drilling Geophysics, Radiometry and Nuclear Geophysics.
The department trains students in the degree course Applied Geophysics as well as other Bachelor and Master Degree courses at the Faculty of Geology. Five Master Degree courses exist – Applied Geophysics, Prospecting Geophysics, Petroleum Geophysics, Natural Risks, Geophysical Study of the Earth and Planets. If necessary, training can be provided in other up-to-date fields of applied geophysics – e.g. Engineering Geophysics, Mining Geophysics, etc.
The personnel development in the department is traditionally targeted in two main directions: (i) attracting of young specialists to become members of the academic staff, and (ii) scientific development of the academic staff – preparation of PhD theses for the assistant professors, preparation for habilitation as associate professor and professor.
An important element for the development of the educational content is the systematic updating of the logical interrelations between the different disciplines in the educational curriculum. This is also the main prerequisite for the purposeful updating of the educational programs for the specific disciplines.
The Applied Geophysics Department has always had international cooperation within direct contracts with geophysical faculties and scientific units at the Moscow Institute of Geology Prospecting, Moscow Institute of Oil and Gas, the International Scientific Research Institute on Management Issues, Moscow, the Section on Mining Geophysics at the Mining Institute of the Russian Academy of Sciences, the Freiberg Mining Academy (Germany), the Department of Geophysics at the Polytechnic University, Mishkoltz, Hungary, etc.
The priority areas of research in the department are mainly targeted at:
Improvement of the educational process – educational programmes and curriculum, practical training, forms of examination, etc.
Analysis and interpretation of the data for the study of the in-depth structure of the Earth and study of separate territories and regions in relation to the search and exploration of minerals and solving of different tasks in relation to the geological profile.

Research in the field of engineering geology, mining, construction, ecology and all aspects related to forecasting of natural and technogenic risk situations.

Applying geomagnetic methods for searching and investigating of natural resources, geomagnetic and geological mapping, archeological surveys, and ecological purposes.

Main results:

1. Training students in the degree course Applied Geophysics which includes the following courses:

(i) For the Bachelor degree - Magnetic Methods in Geophysics; Course Project in Magnetic Methods in Geophysics;summer practice in Magnetic Methods in Geophysics;

(ii) For the Master degree - Theoretical basics of the electromagnetic fields, radiowave methods and appliances in geophysics; Earth's magnetism and geoelectrical fields

2. *Establishing of a Complex scientific-educational center for geology and geophysics at the University of Mining and Geology "St. Ivan Rislki" (incl. geomagnetic appliances: magnetometers GSM-19, GSM-19T and two kappaemters KT-10)

*In development

Research projects:

Tsvetkov, A., L. Gugov, L. Ch. Tzankov. Developing of a map of magmatic bodies in Eastern Srednogorie including quantitative valuation of their physical and geometrical properties. 2009

Radichev, R., Tzankov, Ch., Kirilov, N. Determination the thickness of the sediments and the depth to the underlying bedrock field in perspective area "Rakitna". 2008/09

Publications:

Tzankov, Ch., R. Radichev. 2010. Interpretation of the anomalous magnetic field in perspective area "Rakitna" for determination the thickness of the sediments and the depth to the underlying bedrock. International scientific session at the University of Mining and Geology, Sofia, 2010

Krastev, N., P. Stavrev, R. Radichev, V. Stanchev, G. Schwamborn. 2009. Integrated geophysical investigations in the area of Bulgarian Antarctic Base at the Livingston Island. 5th Congress of Balkan Geophysical Society, Belgrade, 2009.

Radichev, R. Str. Strashimirov, St. Pristavova, St. Dimovski, N. Tzankova. 2009. A complex scientific-educational center for geology and geophysics at the University of Mining and Geology "St. Ivan Rislki". Advances in Bulgarian Science, 3/2009.

Tsvetkov, A., Ch. Tzankov. 2009. Schematic map of volcanic centres and intrusive bodies in Eastern Srednogorie and Eastern Rhodopes. 5th Congress of Balkan Geophysical Society, Belgrade, 2009

D. Gerovska, M. J. Arauzo-Bravo, K. Whaler, P. Stavrev, and A. Reid, Three-dimensional interpretation of magnetic and gravity anomalies using the finite-difference similarity transform, *Geophysics*, 75(4): L79 - L90, 2010.

D. Gerovska, M. J. Arauzo-Bravo, P. Stavrev, and K. Whaler MaGSoundDST -- 3D automatic inversion of magnetic and gravity data based on the differential similarity transform, *Geophysics*, 75(1): L25 - L38, 2010.

Stavrev P. and Reid A. Degrees of homogeneity of potential fields and structural indices of Euler deconvolution, *Geophysics*, 72, p. L1-L12, 2007.

Stavrev P. Inversion of elongated magnetic anomalies using magnitude transforms, *Geophysical Prospecting***,** 54, p. 153-156, 2006.

Conference contributions:

International scientific session at the University of Mining and Geology, Sofia, 2010.

5th Conference and Exhibition of Balkan Geophysical Society, Belgrade, 2009.

Division II – WG-C; WG-D

Coupling of the atmosphere-ionosphere system defined by ground-based measurements and assimilated atmospheric fields (UKMO and NCEP data)

National Institute of Geophysics, Geodesy and Geography – Prof. Dora Pancheva, Plamen Mukhtarov and Dr. Borislav Andonov

Main results:

1. Vertical coupling of the atmosphere-ionosphere system by planetary waves (PWs) defined by the radar measurements, assimilated atmospheric fields as UKMO (UK Met Office) and NCEP (National Centre for Environmental Prediction) data and ground-based ionosonde measurements (*foF2*) and magnetometer measurements which determine the current systems in the dynamo-region. By using a new, advanced method for analysis of 2D (time-longitude) time series the following results are obtained: (i) PWs are generated in the lower thermosphere by thermal and orographic non-homogeneities and propagate vertically upward where their amplitudes increase with increasing the altitudes; (ii) in the mesosphere, where both PWs and atmospheric tides have large amplitudes, they nonlinearly interact between each other; this coupling process leads to a modulation of the atmospheric tides with

periods of the PWs; (iii) the PW amplitudes sharply decrease near altitudes of 90-95 km, while the modulated atmospheric tides propagate up to the dynamo region (110-120 km) where through the electrodynamics the electric currents are modulated with the periods of PWs; and (iv) the modulated electric fields through vertical plasma drifts transfer the effects f the PWs to the levels of the ionospheric F-region.

2. Vertical coupling of the stratosphere-mesosphere-lower thermosphere system (20-120 km) during periods of sudden stratospheric warmings (SSWs) determined by the radar measurements and assimilated fields (UKMO and NCEP) – it is obtained that the stratosphere and mesosphere are strongly connected by directly propagated PWs which are significantly amplified during the periods of SSWs, while in the lower thermosphere the PWs are *in-situ* generated through the dissipation of the filtered gravity waves by the changed background zonally mean zonal flow in the stratosphere during the SSWs.

3. Latitudinal coupling of the stratosphere-mesosphere during the period of SSWs – by analysis of UKMO assimilated fields and radar measurements it is found an opposite response of the zonally mean flows at high and low latitudes; this is due to a significant amplification of the zonally symmetric waves which are generated by nonlinear interaction between the zonally propagating and stationary PWs.

4. PW variability of the ionosphere forced by solar and geomagnetic activity – it is found that the solar and geomagnetic activity with periods which belong to the PWs (2-30 days) generate zonally symmetric (with zonal wavenumber s=0) waves in the ionosphere.

Selected Publications:

Pancheva, D., W. Singer and P. Mukhtarov, Regional response of the mesosphere-lower thermosphere dynamics over Scandinavia to solar proton events and geomagnetic storms in late October 2003, *J. Atmos. Sol.-Terr. Phys.*, v. 69, 1075-1094, 2007.

Pancheva, D.V., P.J. Mukhtarov and B.A. Andonov, Zonally symmetric oscillations in the Northern hemisphere stratosphere during the winter of 2003/2004, *Geophys. Res. Lett.*, v.34, L04807, doi:10.1029/2006GL028666, 2007.

Smith, A.K., D.V. Pancheva, N.J. Mitchell, D.R. Marsh, J.M. Russell and M.G. Mlynczak, A link between variability of the semidiurnal tide and planetary waves in the opposite hemisphere, *Geophys. Res. Lett.*, v.34, L07809, doi:10.1029/2006GL028929, 2007.

Merzlyakov, E. and D. Pancheva: The 1.5-5-day eastward waves in the upper stratosphere-mesosphere as observed by the Esrange meteor radar and the SABER instrument, *J. Atmos. Sol-Terr. Phys.*, v.69, pp. 2101-2117, 2007.

Mukhtarov, P., D. Pancheva, B. Andonov, N.J. Mitchell, W. Singer, W. Hocking, A. Manson, C. Meek, Y. Murayama and E. Merzlyakov, Large-scale thermodynamics of the stratosphere and mesosphere during the major stratospheric warming in 2003/2004, *J. Atmos. Sol-Terr. Phys.*, v.69, pp. 2338-2354, 2007.

Takahashi, H., C. M. Wrasse, D. Gobbi, D. Pancheva, M. A. Abdu, I. S. Batista, L. M. Lima, P. P. Batista, B. R. Clemesha, N. Schuch, K. Shiokawa, J. Fechine, M. G. Mlynczak, J. M. Russell, Signatures of Ultra Fast Kelvin wave in the equatorial middle atmosphere

and ionosphere, *Geophys. Res. Lett.*, v.34, L11108, doi:10.1029/2007GL029612, 2007.

Haldoupis, C., D. Pancheva, W. Singer, C. Meek and J. MacDougall, An explanation of the seasonal dependence of midlatitude sporadic E layers, *J. Geophys. Res.*, v. 112, A06315, doi:10.1029/2007JA012322, 2007.

Pancheva, D., P. Mukhtarov, N. Mitchell, D. Fritts, D. Riggin, H. Takahashi, P. Batista, B. Clemesha, S. Gurubaran and G. Ramkumar, Planetary wave coupling (5-6-day waves) in the low latitude atmosphere-ionosphere system, *J. Atmos. Sol-Terr. Phys.*, v.70, pp. 101-122, 2008.

Pancheva, D., P. Mukhtarov, N.J. Mitchell, E. Merzlyakov, A.K. Smith, B. Andonov, W. Singer, W. Hocking, C. Meek, A. Manson and Y. Murayama, Planetary Wave Coupling of the Stratosphere and Mesosphere during the Major Stratospheric Warming in 2003/2004, *J. Geophys. Res. – Atmospheres*, v. 113, D12105, doi:10.1029/2007JD009011, 2008.

Pancheva, D., P. Mukhtarov, N.J. Mitchell, B. Andonov, E. Merzlyakov, W. Singer, Y. Murayama, S. Kawamura, J. Xiong, W. Wan, W. Hocking, D. Fritts, D. Riggin, C. Meek and A. Manson, Latitudinal Wave Coupling of the Stratosphere and Mesosphere during the Major Stratospheric Warming in 2003/2004, *Ann. Geophys.*, v. 26, pp. 467-483, 2008.

Takahashi, H., M.A. Abdu, C.M. Wrasse, J. Fechine, I.S. Batista, D. Pancheva, L.M. Lima, P.P. Batista, B.R. Clemesha, K. Shiokawa, D. Gobbi, M.G. Mlynczak, and J.M. Russell, Possible influence of ultra-fast Kelvin wave on the equatorial ionosphere evening uplifting, *Earth Planet Space.*, v. 61, v. 61, pp. 455-462, 2009.

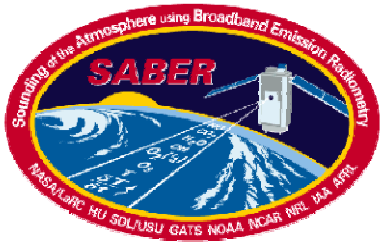
Rao, R.K., S. Gurubaran, S.S. Kumar, S. Sridharan, T. Nakamura, T. Tsuda, H. Takahashi, P.P. Batista, B.R. Clemesha, R.A. Buriti, D.V. Pancheva, and N.J. Mitchell, Longitudinal variability of intraseasonal oscillation (ISO) in the tropical mesosphere and lower thermosphere, *J. Geophys. Res. – Atmospheres*, v. 114, D19110, doi:10.1029/2009JD011811, 2009.

Mukhtarov, P., B. Andonov, C. Borries, D. Pancheva, and N. Jakowski, Forcing of the ionosphere from above and below during the Arctic winter of 2005/2006, *J. Atmos. Sol.-Terr. Phys.*, v. 72, pp. 193-205, 2010.

Recent progress in the stratosphere-mesosphere-lower thermosphere coupling based on the SABER/TIMED satellite measurements

National Institute of Geophysics, Geodesy and Geography – Prof. Dora Pancheva, Plamen Mukhtarov and Dr. Borislav Andonov

The **SABER** instrument on board of the **TIMED** satellite



SABER:
Sounding of the Atmosphere Using Broadband
Emission Radiometry

TIMED:
Thermosphere Ionosphere Mesosphere
Energetics & Dynamics

Main Results:

The global spatial (altitude and latitude) structure, seasonal and interannual variability of the atmospheric tides (migrating and nonmigrating) and planetary waves (stationary and zonally traveling) derived from the SABER/TIMED temperature measurements are found for full 6 years (January 2002-December 2007). The mean wave amplitudes and phases are presented for the latitude range 50^{o}N-50^{o}S and from the lower stratosphere to the lower thermosphere (20-120 km). The main advantage of the these recent results is that the migrating and nonmigrating tides as well as all significant planetary waves found in the SABER/TIMED temperatures are ***extracted simultaneously*** from the raw data (downloaded from the SABER web site temperatures: http://saber.gats-inc.com). Therefore, using the same analysis techniques and the same data set makes it possible to get a ***consistent picture*** of the wave activity in the stratosphere-mesosphere-lower thermosphere system. Concerning the atmospheric tides, in addition to the migrating diurnal and semidiurnal tides the following nonmigrating tides also received significant attention: diurnal eastward propagating with zonal wavenumbers 2 and 3 and westward propagating with zonal wavenumber 2 and semidiurnal westward propagating with zonal wavenumber 3 and eastward propagating with zonal wavenumbers 2 and 3. A special attention is paid to the climatology and interannual variability of the temperature SPW1 and its origin in the lower thermosphere, as well as for following zonally propagating planetary waves: the ~5-day *Rossby* wave; ~6-day *Kelvin* wave, the ~10-day *W1* wave and ~16-day *W1* wave. The presented detailed picture of the spatial (altitude, latitude) structure and temporal variability of the considered atmospheric tides and planetary waves can serve as a benchmark and guide for future numerical modeling studies aimed at better understanding the stratosphere-mesosphere-lower thermosphere coupling by tidal and planetary wave patterns. Most of the above results are obtained for the

first time and are mainly due to using an advanced data analysis method. Because of the originality and importance of these new results they are included as an ***overview paper in the recent IAGA Division II Monograph published by Springer***.

Project:

CAWSES-II "Climate and Weather of the Sun-Earth System - II", worldwide project of SCOSTEP (2009-2013) – TG4, Project 3: *How do the different types of waves interact as they propagate through the stratosphere to the ionosphere? – project leader: Dora Pancheva*

Selected Publications:

Pancheva D., P. Mukhtarov, B. Andonov, N.J. Mitchell, and J. Forbes, Planetary waves observed by TIMED/SABER in coupling the stratosphere-mesosphere-lower thermosphere during the winter of 2003/2004: Part 1, Comparison with the planetary waves observed in the UKMO temperature data, *J. Atmos. Sol.-Terr. Phys.*, v. 71, No 1, pp. 61-74, 2009.

Pancheva D., P. Mukhtarov, B. Andonov, N.J. Mitchell, and J. Forbes, Planetary waves observed by TIMED/SABER in coupling the stratosphere-mesosphere-lower thermosphere during the winter of 2003/2004: Part 2, Altitude and latitude planetary wave structures, *J. Atmos. Sol.-Terr. Phys.*, v. 71, No 1, pp. 75-87, 2009.

Mukhtarov, P., D. Pancheva and B. Andonov, Global structure, seasonal and interannual variability of the migrating diurnal tide seen in the SABER/TIMED temperatures between 20 and 120 km, *J. Geophys. Res. – Space Physics*, v. 114, A02309, doi:10.1029/2008JA013759, 2009.

Mukhtarov, P., D. Pancheva and B. Andonov, Method for assessing the amplitude modulation of stationary planetary waves, *Ann. Geophys.*, v. 27, No 2, pp. 617-622, 2009.

Pancheva, D., P. Mukhtarov, and B. Andonov, Global structure, seasonal and interannual variability of the migrating semidiurnal tide seen in the SABER/TIMED temperatures (2002-2007), *Ann. Geophys.*, v. 27, No 2, pp. 687-703, 2009.

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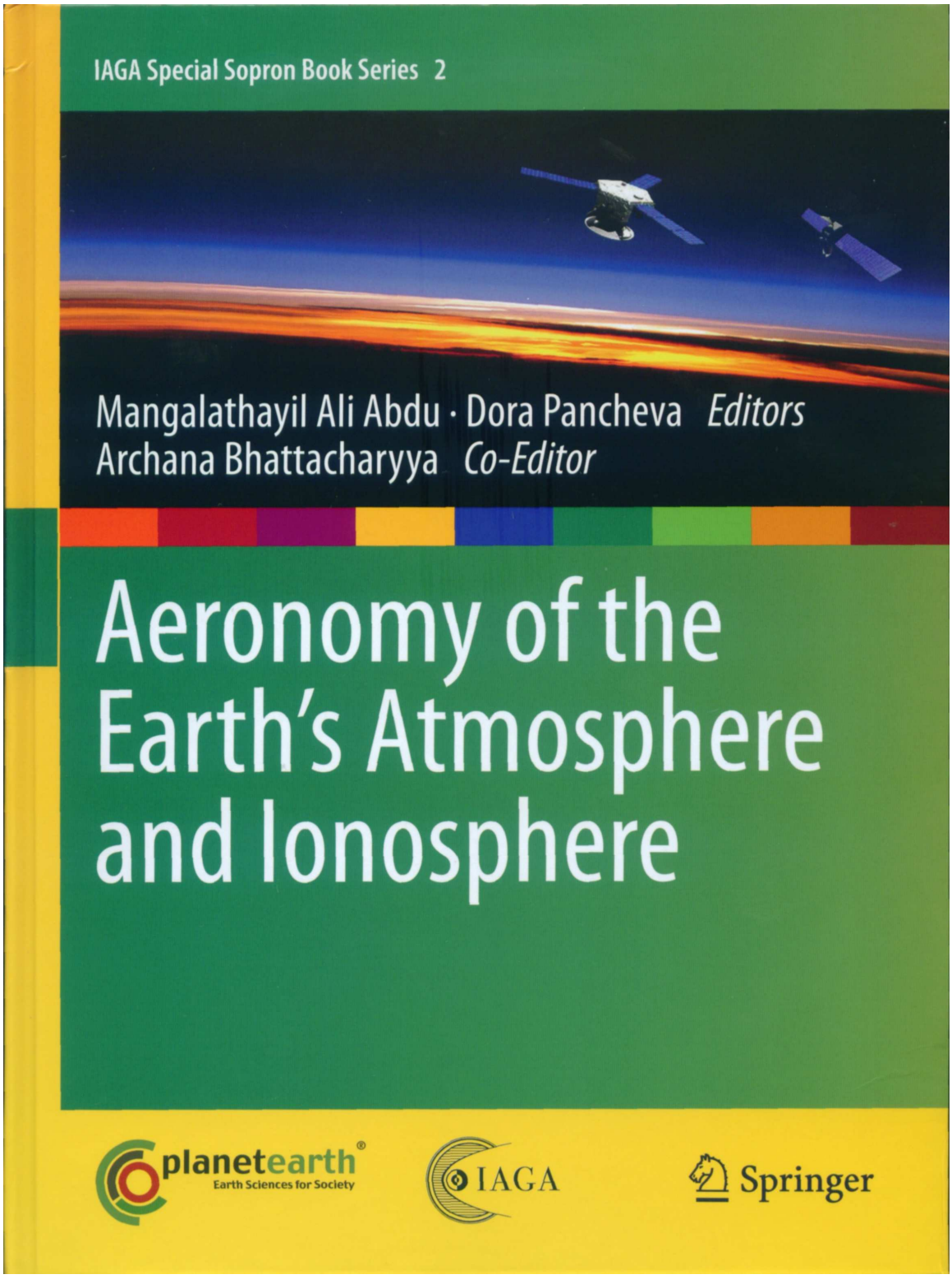
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Mukhtarov, P., D. Pancheva, and B. Andonov, Climatology of the stationary planetary waves seen in the SABER/TIMED temperatures (2002-2007), *J. Geophys. Res. – Space Physics*, v. 115, A06315, doi:10.1029/2009JA015156, 2010.

Pancheva, D., P. Mukhtarov, and B. Andonov, Climatology of the eastward propagating tides seen in the SABER/TIMED temperatures (2002-2007), *Adv. Space Res.*, v. 46, pp. 257-274, doi:10.1016/j.asr.2010.03.026, 2010.

Portnyagin, Yu. I., E.G. Merzlyakov, T.V. Soloveva, A.I. Pogoreltsev, E.V. Suvorova, P. Muktarov, and D. Pancheva, Height-latitude structure of the vertical component of the migrating semidiurnal tide in the upper mesosphere and lower thermosphere region (80-100 km), *IAN-Fiz. Atmos. Okeana,* v. 47, N 1, pp. 118-129, 2011.

Pancheva, D. and P. Mukhtarov: Atmospheric tides and planetary waves: Recent progress based on SABER/TIMED temperature measurements (2002-2007), in *Aeronomy of the Earth's Atmosphere and Ionosphere*, eds. M. Abdu and D. Pancheva, doi:10.1007/978-94-007-0326-1_2, Springer, 2011.

Climate sensitivity to solar activity variation

National Institute of Geophysics, Geodesy and Geography – Dr. Natalia Kilifarska

Main Results:

It is found a 22 year periodicity in upper stratospheric total ozone, which is related to the corresponding variability of galactic cosmic rays (GCR).

Non-linear statistical analyses of total ozone (from Arosa station) revealed that centennial cycle of the GCR variability is a driving factor for corresponding total ozone variations.

A new mechanism for the GCR influence on climate variability is found out, which is capable of resolving the discrepancies between: (i) the amplitudes of total solar irradiance variations and climate response, and (ii) the absence of correlation between the GRC and aerosols' concentration, clouds properties, etc. reported in the recent investigations.

Projects:

COST ES1005 "Towards a more complete assessment of the impact of solar variability on the Earth's climate" (2011-2014)

BlackSeaHazNet - Complex Research of Earthquake's Prediction Possibilities, Seismicity and Climate Change Correlations, FP7-PEOPLE-2009, project No. 246874 (2011-2013)

Factors Determining the Climate Sensitivity to Solar Activity Variations, funded by National Science Fund of Bulgaria (2005-2009)

Investigation of Solar diameter, Shape and Irradiance, funded by International Space Science Institute (ISSI), Bern, Switzerland (2006-2008)

Selected Publications:

Kilifarska N.A., Y.K. Tassev, Cosmic Ray Showers and their relation to the Stratospheric Sudden Warmings, *Sun and Geosphere*, v. 3, No.1, 10-17, 2008, ISSN: 1819-0839.

Kilifarska N.A. Mechanism of Solar influence on the winter time Polar Atmosphere, *Sun and Geosphere*, v.4, No.1, 79—84, 2009, ISSN: 1819-0839.

Werner R., Stebel K., Hansen H.G., Hoppe U.-P., Gausa M., Kivi R., von der Gathen P., Orsolini Y., Kilifarska N., Study of the seasonal ozone variations at European high latitudes, *Adv. Space Res.*, 2010 (in press).

Kilifarska N.A. Mechanisms and Modelling of a 22 Year Cycle in the Stratospheric Winter Time Ozone Variability, *Compt.Rend.de l'Acad. Bulgar. des Sci.*, 64, 2011.

Kilifarska N.A. Long –term variations in the Stratospheric Winter Time Ozone Variability – 22 year cycle, *Compt.Rend.de l'Acad. Bulgar. des Sci.*, 64, 2011.

Space weather studies and empirical modeling of the ionosphere

National Institute of Geophysics, Geodesy and Geography –Prof. Ivan Kutiev.

Main Results:

1. In the framework of GALOCAD project, an advanced model of the total electron content (TEC) has been developed. The empirical model, named LLT (Latitude, Longitude, Time) model, approximates GPS-derived TEC data obtained by the Belgian Dense Network receivers by analytical functions of latitude, longitude, and time over the area [-1°, 11°]E and [46°, 52°]N. Estimated model error is less than 3 TEC units (TECU). A special technique was developed to localize TEC disturbances. The latter structures were identified as the residuals obtained by the subtraction of two model runs with different degree of approximation. This technique allows following disturbed structures across the working area and determining the speed and direction of their propagation.

2. Within the same GALOCAD project, a hybrid model of a new K_D index (proxy of the geomagnetic Kp index) was developed. The new model obtained first K_D by using on-line solar wind data from ACE satellite and then corrected the model quantity with the K index, issued on-line by Dourbes (Belgium) magnetic station. The applied correction reduced the model error to 0.33 K units, almost twice less compared with the error based on solar wind data solely. The new geomagnetic index is issued on-line at http://gpsweather.meteo.be/geomagnetism

3. A new model of the electron density (Ne) in topside ionosphere and plasmasphere, named TaD, was developed in the frame of AOARD project. TaD (TSM-assisted Digisonde) reconstruction model improve the accuracy of the topside ionosphere and plasmasphere electron density (Ne) profiles produced by Digisonde software as a complement to the measured bottomside profile. TaD uses the topside scale height (H_T), transition height (h_T), and their ratio (R_T) provided by TSM (Topside Sounder Model) and calculates Ne profile up to GPS orbit heights. Recently, the accuracy of TaD model was significantly improved by adjusting the model profiles with the TEC measured by co-located GPS receivers. TaD is widely validated using measured topside electron density profiles from ISIS-1 satellte, those from Malvern Incoherent Scatter Radar, and TEC derived from ground-based and satellite-based GNSS receivers. A demonstrator of the optimized TaD performance with real-time autoscaled data from Athens Digisonde is given at http://www.iono.noa.gr/ElectronDensity/EDProfile.php.

Projects:

COST Action ES0803 "Developing space weather products and services in Europe" (2008-2012).

Project **GALOCAD** "Development of a Galileo Local Component for the nowcasting and forecasting of atmospheric disturbances affecting the integrity of high precision Galileo applications", GJU/06/2423/CTR/GALOCAD (2008).

Project "An improved model for operational specification of the electron density structure up to geosynchronous heights, **AOARD** Contract No FA5209-09-P-0253 (2009).

Selected Publications:

Kutiev I., P. Marinov, A. Belehaki, B. Reinisch, N. Jakowski, Reconstruction Of Topside Density Profile By Using The Topside Sounder Model Profiler And Digisonde Data, *Adv. Space Res*., 43, 1683-1687, 2009, doi 10.1016/j.ast.2008.08.017.

Kutiev I., P.Marinov, S. Fidanova, R. Warnant, Modeling medium-scale TEC structures, observed by Belgian GPS receivers network, *Adv. Space Res*., 43, 1732-1739, 2009, doi 10.1016/ j.ast.2008.07.021.

Kutiev, I., P. Muhtarov, B. Andonov, R. Warnant, Hybrid model for nowcasting and forecasting the K index, *J. Atm. Solar-Terr. Phys.*, 71, 589–596, 2009, doi:10.1016/j.jastp.2009.01.005.

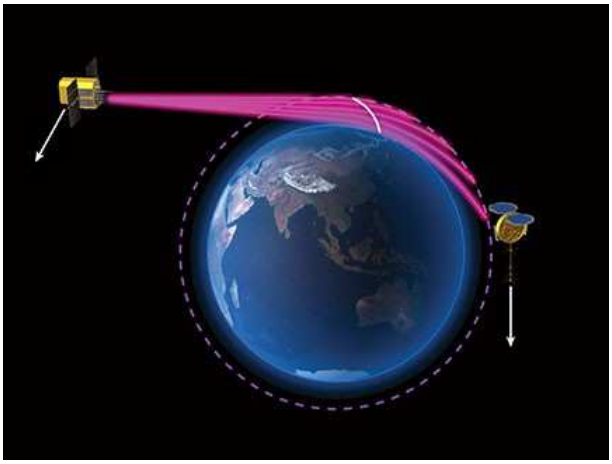
Kutiev, I., P. Marinov, A. Belehaki, N. Jakowski, B. Reinisch, C. Mayer, and I. Tsagouri, Plasmaspheric electron density reconstruction based on the Topside Sounder Model Profiler, *Acta Geophysica*, 58, 2009, doi: 10.2478/s11600-009-0051-4

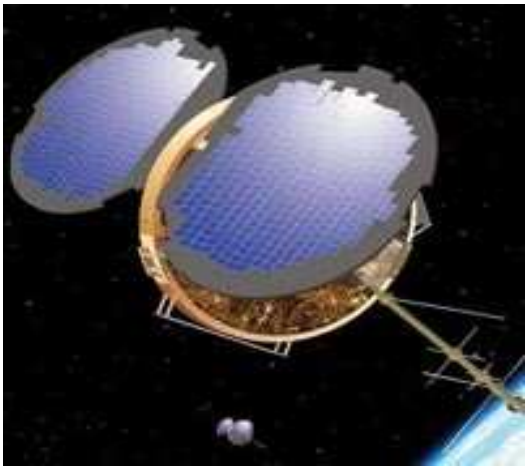
Belehaki, A., Kutiev, I., B. Reinisch, N. Jakowski, P. Marinov, I. Galkin, C. Mayer, I. Tsagouri, and T. Herekakis, Verification of the TSMP-Assisted Digisonde Topside Profiling Technique, *Acta Geophysica*, 58, 2009, doi: 10.2478/s11600-010-0052-3

Warnant, R., J. Spits, H.J. Strangeways, G. Wautelet, N. Zernov, N. Jakowski, U. Foelsche, M. Aquino, B. Bidaine, V. Gherm, M.M. Hoque, I. Kutiev, S. Lejeune, J.-P. Luntama, Mitigation of ionospheric effects on GNSS, *Annals of Geophysics*, 52, 3-4, 2009.

Recent progress in the atmosphere-ionosphere coupling based by the ionospheric COSMIC satellite measurements

National Institute of Geophysics, Geodesy and Geography –Prof. Dora Pancheva and Plamen Mukhtarov.

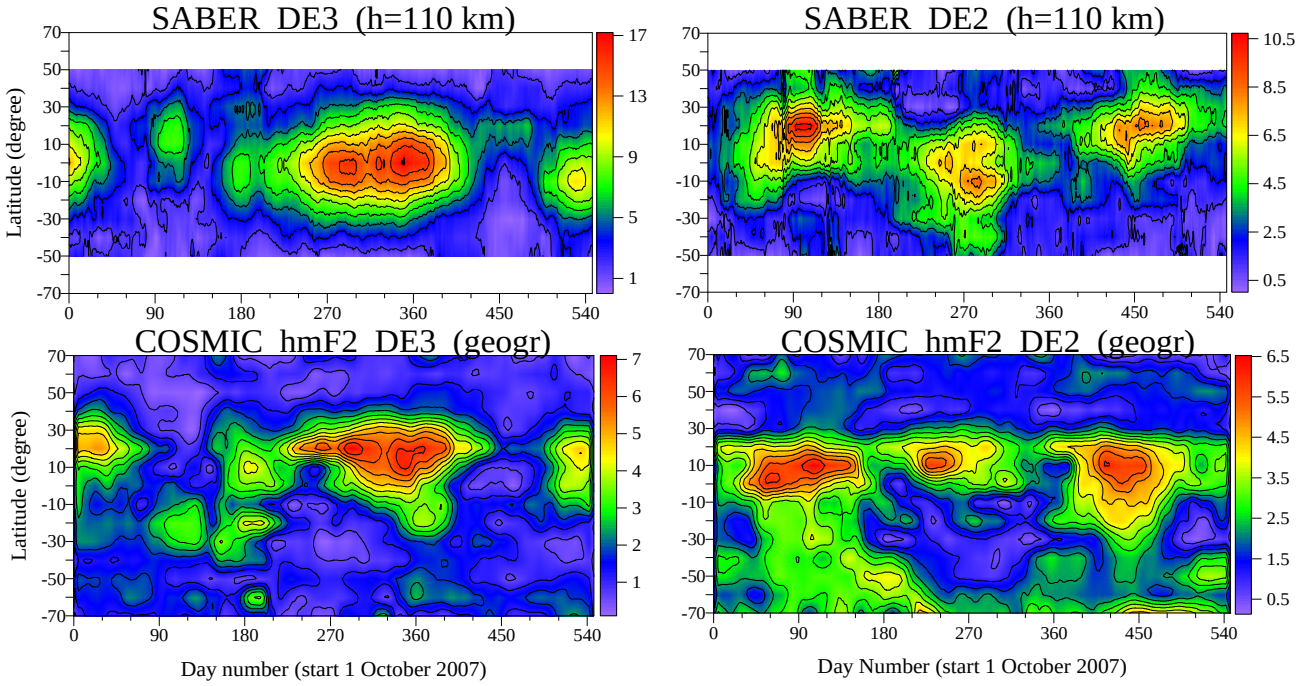




Main Results:

1. An overview on the recent progress in studying the ionospheric response to atmospheric tides forced from below is done. The global spatial structure and temporal variability of the atmospheric temperature tides and their ionospheric responses are considered on the basis of modern satellite-board data (COSMIC and SABER/TIMED). The tidal waves from the two data sets have been extracted by the same data analysis method. The similarity between the lower thermospheric temperature tides and their ionospheric responses provide ***evidence for confirming the new paradigm of atmosphere-ionosphere coupling.*** This study provides also new experimental results which give an explanation why the WN4 and partly WN3 longitude structures are so prominent pattern in the ionosphere. These results present evidence indicating that the WN4 (WN3) structure is not generated only by the DE3 (DE2) tide as it has been often assumed. The DE3 (DE2) tide remains the leading contributor, but the SPW4 and SE2 (SPW3, DW4 and SE1) waves have their effects as well in a way that the ionospheric response becomes almost double (1.5 time stronger). The study presents also the global distribution and temporal variability of the sun-synchronous 24-h (DW1), 12- (SW2) and 8-h (TW3) electron density oscillations. It has been shown that while the latitude and altitude structure of the ionospheric SW2 response is predominantly shaped by the migrating SW2 tide forced from below the DW1 response is mainly due to daily variability of the photo-

ionization. The presented for the first time peculiar vertical structure of the ionospheric TW3 response, indicating downward/upward phase progression, put a question for the physical processes shaping this ionospheric response.



The above result presents the first observational evidence for confirming the new paradigm of atmosphere-ionosphere coupling by nonmigrating tides forced from below.

2. For the first time the global spatial (latitude and altitude) structure of the mean ionospheric response to Sudden Stratospheric Warming (SSW) events in winters of 2007/2008 and 2008/2009 is investigated by using the COSMIC satellite data. To elucidate the effect of the SSWs on the ionosphere the COSMIC foF2, hmF2 and electron density data at fixed altitudes are analyzed. Both the mean f_oF2 and h_mF2 parameters and the mean electron density at fixed heights indicate regular negative responses to the SSW temperature pulses at high latitudes. Similar response is found for the diurnal variability of the COSMIC electron density. The response is confined mainly to low and middle latitudes. A possible mechanism causing the observed negative ionospheric response is suggested. The main advantages of the obtained results are: (i) this is the first study to present experimental evidence of changes in the mean electron density and in the diurnal component as an ionospheric response to sudden stratospheric warmings (SSW), (ii) the study demonstrates repeatability of these changes in several different SSW events, which is another important step; and (iii) the idea that the equatorial plasma drifts are related to the lower thermospheric temperature increase at high-latitude during the SSW events is a new interpretation which presents the result in the context of "disturbed dynamo".

Selected Publications:

Pancheva, D. and P. Mukhtarov, Strong evidence for the tidal control on the longitudinal structure of the ionospheric F-region, *Geophys. Res. Lett.*, v. 37, L14105, doi:10.1029/2010GL044039, 2010

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Division IV

Physical model of 6-cell field-aligned current (FAC) structures - relationship between FAC and solar wind parameters

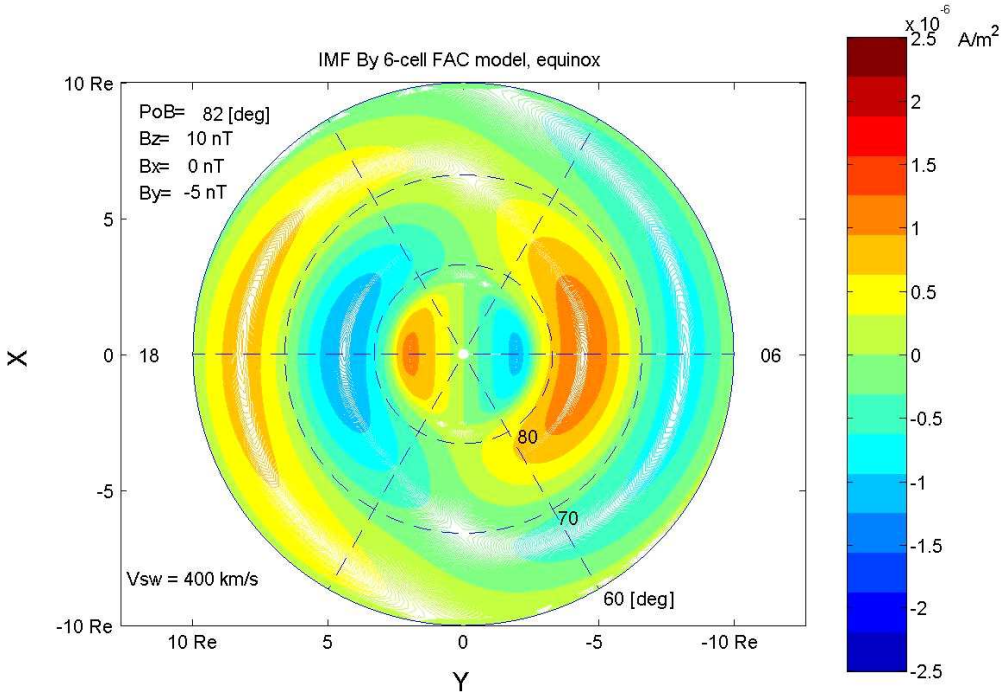
National Institute of Geophysics, Geodesy and Geography –Prof. Petko Nenovski

Main Results:

A physical model of large-scale field-aligned current (FAC) that consists of 6-cell structures has been proposed (Nenovski, 2008). It is grounded on a non-linear interaction of the solar wind with the Earth's magnetosphere. FAC structure solutions are subsequently derived from a non-linear (NL) dispersion relation that connects the FAC polarity and intensity distribution with the solar wind and the interplanetary magnetic field parameters. The strong effect of the IMF B_y component on the FAC structure and distribution is quantitatively revealed (Nenovski, 2008).

The FAC polarity and intensity distribution has been quantified (parameterized) as a function of the solar wind velocity and density and the interplanetary magnetic field (IMF) components that enter as input parameters. Besides, input parameters intrinsic to the Earth's magnetosphere as the size of the polar cap and the boundary regions and their plasma density ratio are involved. Depending on the IMF B_y magnitude the predicted six-cell FAC structure falls to evolve in spiral-like one (see Figure). This large scale FAC pattern model has been compared with experimental data (EISCAT, Tromso, 30 June-02 July, 2008, TNA program) for both polar cap FAC and Region 1 and Region 2 FAC systems.

The Figure below illustrates how negative/positive IMF B_y component influences on the SW mode large-scale FAC structure. Both polar (as seen above the ionosphere) and Decartes (in the distant high-latitude Earth's magnetosphere) coordinates are given. When the IMF B_y module well exceeds 2 nT, the six-cell large-scale FAC structure evolves into two FAC 'spirals' of inverse polarity. During positive IMF B_y the Region 1 system from the dawn sector is extended across the noon sector; the Region 1 system from the dusk sector (of inverse polarity) continues into the Region 2 system from the dawn sector. In the midnight sector the dawn (dusk) Region 1 structure goes continuously to dusk (dawn) Region 2 cell. If IMF B_y component reverses its sign the sense of the FAC 'spirals' also reverses. The IMF B_z and B_z components are set to 0 and 10 nT, respectively. Polar cap boundary (PoB) is placed at 82 degrees.



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Division V

Geomagnetic Observatory "Panagyurishte"

National Institute of Geophysics, Geodesy and Geography - Dr. Ivan Butchvarov, Dr. Petya Trifonova

Geomagnetic observatory Panagjurishte (managed by the *National Institute of Geophysics, Geodesy and Geography–BAS)*

IAGA Code PAG

Name Panagjurishte

Opened 1937-01-01

Latitude 47.485°N

Longitude 24.177°E

Altitude 556.0m

Country Bulgaria

INTERMAGNET Member 2007 - present

http://www.geophys.bas.bg/panag/index_en.html

INSTRUMENTS:

In 2005, with the support from Prof. M. Mandea, head of Section 2.3 Earth's Magnetic Field of the GeoForschungsZentrum (GFZ), Potsdam, a cooperation agreement was signed between GFZ, Germany and the Geophysical Institute – BAS, Bulgaria. According to that agreement, the following equipment was provided gratuitously to Geomagnetic Observatory Panagyurishte:

- DI-flux theodolite Zeiss THEO 020B, Bartington Magnetometer MAG 01H;

- 3-component flux-gate magnetometer MAGSON;

- Overhauser proton magnetometer GSM-90;

- Data logger MAGDALOG;

The apparatuses were installed, put into operation and tuned by Dr. Linthe, deputy head of the "Adolf-Schmidt" Observatory, Niemegk and Mr. Yurgen Haseloff. During the next year, the same team installed the newly purchased by NIGGG **three-component fluxgate magnetometer (FGE)-hanging version**, produced by the Danish Meteorological Institute, and the data logger MAGDALOG and the GPS system were gifted to GFZ.

After installment of the two digital recording systems, PAG Observatory fulfilled the INTERMAGNET condition and was joined to the largest world network of observatories that send to world centers minute values of the GMF components in real time.

A new **DI-system for absolute measurements on the basis of a non-magnetic theodolite Zeiss 015B** and a **Bartington magnetometer MAG 01H** was purchased in the beginning of 2007. In that way PAG Observatory met the enhanced requirements for higher precision and performance for collecting and using geomagnetic data (Jankovski & Sucksdorff, 1996).

ACTIVITIES:

Natinal Institute of Geophysics, Geodesy and Geography, through PAG Observatory, maintains the geomagnetic standard and is the only one centre of geomagnetic measurements on the territory of Bulgaria. This is legally stipulated in the Law on Geodesy and Cartography, issued in 2006, which provides that GPhI and the Military Geographic Service with the Ministry of Defense are jointly responsible for drawing up maps of the magnetic declination for the needs of the army and navigation. PAG Observatory provides current information on the geomagnetic field conditions to medical centers, to the media and other institutions and firms, as well as on the Internet site of NIGGG. The Observatory is a centre where students from the Sofia University “St. Kl. Ohridski” and from the Mining and Geological University “St. Ivan Rilski” become practically acquainted with the equipment and methods of measurement of the geomagnetic field.

Scientific results Obtained in Space and Solar-Terrestrial Research Institute at the BAS concerning IAGA

2007-2011

Space and Solar-Terrestrial Research Institute at BAS (SSTRI-BAS) is a new establishment created on 1st of July 2010, that is why many of the facts mentioned in the report below was achieved by the former **Solar-Terrestrial Influences Institute (STIL-BAS)** http://www.stil.bas.bg/ and Space Research Institute (SRI-BAS) http://www.space.bas.bg/.

1. Section Solar-Terrestrial Physics at SSTRI-BAS (Thematic)

1.1. Scientific instruments

The thematic group includes 11 persons from STIL-BAS staff. The team has 22 years' experience in satellite and aircraft experiments aimed at investigation of space radiation risk, both in device development, performing in-situ experiments, data processing and interpretation. LIULIN spectrometer-dosimeter flow successfully at Mir space station in 1989-1994 time interval (Dachev et al. 1989). A new generation of compact and intelligent battery operated systems of cosmic radiation detectors have been developed in STIL-BAS after 1994.

Fig. 1. Liulin-E094 system.

Liulin-4 type was developed calibrated and tested in cooperation with scientists from Germany, Russia, Belgium and Japan (Dachev et al. 2002). First use of Liulin-4 type instrument was in the Mobile Radiation Exposure Control System - Liulin-E094 (Fig. 1.). It contains 4 active individual dosimeters and worked successfully between May and August 2001 on the board of US Laboratory module of the International Space Station (ISS). The system was a part of the ESA "Dosimetric Mapping" experiment, which was placed in the US Laboratory Module in the composition of the Human Research Facility (HRF). Very similar system named Liulin-MKS (Fig. 2.) were successfully launched in September 2005 toward the Russian segment and will be used as part of the Russian radiation monitoring system in next 15 years.

Fig. 2.The 4 active Liulin-MKS dosimeters at Russian Segment of ISS. Picture was taken on 3rd of March 2011 by Russian Astronaut Kondratiev.

thirt

The section is involved in several ESA projects for space radiation risk assessment. We are co-investigators of the space spectrometer R3DR (Fig. 3.) of the EXPOSE-R experiment part of ESA ELIPS Programme "Spores in artificial meteorites". The instrument measured successfully the radiation environment on Russian segment of ISS in the period

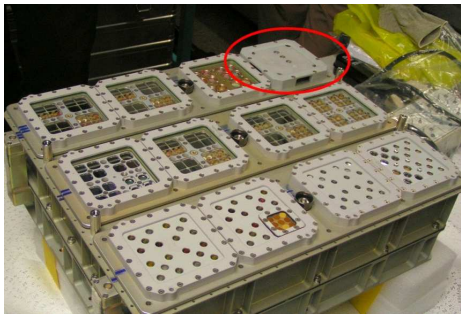

Fig. 3. R3DR view as mounted inside of EXPOSE-R facility.

March 2009-January 2011.

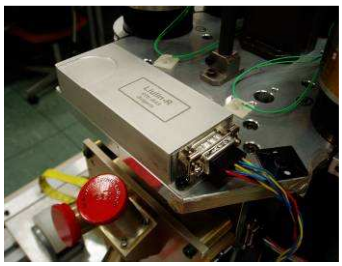

Fig. 4. Liulin-R in HotPay2 rocket.

Very similar instrument named R3DE was used March 2008-September 2009 at European Columbus module of the ESA EXPOSE-E facilities (Dachev, 2009). Both experiments are headed by Dr. G. Horneck, DLR Institute of Aerospace Medicine, Köln, Germany (Horneck et al., 1989). STIL-BAS was co-investigators on them together with University of Erlangen, Germany, where the team, where the team was leaded by Prof. Dr. D.-P. Häder. (Häder and Dachev, 2003)

On 31 January 2008 was successfully launched from Andoya, Norway, the HotPay2 rocket up to 377 km altitude with Liulin-R (Fig. 4.) instrument on board. HotPay2 is financed through the sixth framework programme of the European Union and includes scientific instruments from six European countries and a guest instrument from USA. Project Manager is K. Hauglund (Tomov et al 2008).

Fig. 5. External view of the dosimetric telescope Liulin-5.

RADOM instrument worked on Indian Chandrayaan-1 satellite on the way to the Moon in the Earth magnetosphere and at 100/200 km Moon orbit between October 2008 and August 2009. RADOM instrument is very similar to the Liulin-R instrument shown on Fig. 4. (Dachev et al., 2009).

DrSc Jordanka Semkova is principle investigator of Liulin-5 (Fig. 5.) dosimetric experiment in the human phantom in the Matroshka - R international project (launched 2004) on ISS, which includes the ESA – facility MATROSHKA, lead by Dr. G. Reitz from DLR, Germany, and the Russian spherical tissue–equivalent phantom, lead by Dr. V. Petrov from IMBP-RAS Russia. In May 2007 the Liulin-5 instrument (Semkova et al., 2010) was delivered to ISS and in June 2007 it has been mounted to the phantom. Since then the experiment Liulin-5 runs continuously aboard ISS.

Mobile Dosimetry Unit MDU-6 (Fig. 6.) was used between 2008 and 2011 on Czech Airlines (CSA) aircraft at different routes as comparison measurement with aircraft crew individual dosimetry. The experiments and data analysis were managed by Prof. F. Spurny (Spurny and Dachev, 2009).

Fig. 6. External view of MDU-6.

Very similar instruments to the Mobile Dosimetry Units MDU-6 are used by scientific groups in Spain (Sáez Vergara and Román, 2009) and Germany (Wissmann et al., 2010) for radiation measurements at aircrafts.

Fig. 7. External view of Internet based Liulin-6MB.

Liulin-6S, Lilun-M, Liulin-6MB (Fig. 7.) and Liulin-6R are internet based instruments. They use internet module to generate web page. The obtained deposited energy spectra data are transmitted via LAN interface by HTTP and FTP protocols. They worked for different periods since 2005 at Jungfrau (Switzerland) 3453 meters Above Mean Sea Level (AMSL) http://130.92.231.184/), Moussala (Bulgaria) 2925 meters AMSL http://beo-db.inrne.bas.bg/moussala/ and Lomnicky Stit (Slovakia) 2633 meters AMSL http://147.213.218.13/ peaks and at ALOMAR

observatory in Norway (http://128.39.135.6/). The three peak instruments are working well till now (May 2011) and their data can be obtained online on the mentioned above addresses;

A new instrument Liulin-Phobos (Dachev et al., 2009a) for radiation research are ready to be flown till end of 2011 in Phobos-Soil sample return mission to the satellite of Mars – Phobos. Phobos-Soil sample return mission is an international project, leaded by Russian Space Agency and Russian Academy of Sciences. The main goal of Liulin-Phobos experiment (Fig. 8.) is investigation of the radiation conditions and radiation doses in the heliosphere at distances of 1 to 1.5 AU from the Sun and in near-Mars space. Radiation measurements are envisaged during the cruise phase, on Mars's orbit and on the surface of PhobosThree other instruments are under development to be used on BION-M1, Progress and Luna-Glob satellites till 2013.

Fig. 8. External view of Liulin-F.

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3. *Space Geophysics and Space Weather Prediction Center*

Main Results:

1. The effects of galactic and solar cosmic rays (CR) in the middle atmosphere and ionosphere are investigated and modeled with respect to the CR modulation by solar wind and the anomalous CR component. A new analytical model for CR ionization by protons and nuclei with charge Z in the lower ionosphere and the middle atmosphere is developed by the use of special approximation of the ionization losses for the energetic charged particles by the Bohr-Bethe-Bloch formula. More accurate expressions for CR energy decrease and electron production rate profiles are derived with account to the geomagnetic cut-off rigidity. The full CR composition is taken into account. The computations are made for different geomagnetic cut-off rigidities *R* in the altitude interval 35-120 km.

2. An improved CR interaction model is developed. The interval ionization rate estimation includes the electron production rate of the charge decrease interval and of both intermediate intervals which couple the main three energy intervals of the ionization losses function. For the altitude above 50 km an analytical thin target model is created. In the altitude range from 30 to 50 km, an intermediate target model needs to be used, that accounts also for the particle's deceleration due to ionization losses. The analytical and numerical full target model includes an analytical approximation of the direct ionization by CR primaries as well as CORSIKA/FLUKA program system Monte-Carlo simulations with account of hadron interactions. Our improved ionization rate model is important for investigation of the different space weather effects. The cosmic rays and XUV radiations determine to a great extent the chemistry and electrical parameters in the middle and upper atmosphere, where are situated strato-mesosphere and thermosphere. They create ozonosphere and influence actively the stratosphere ozone O_3 processes. But the ozonosphere controls the meteorological solar constant and the thermal regime and dynamics of the lower atmosphere, i.e. the weather and climate processes. CR influence dominates during the night and sunrise-sunset periods. Also, CR flux is modulated by solar activity. These relations show a way to a non-contradictory solution of the key problems of the solar-terrestrial physics.

3. Studies are carried out related to the outstanding 20th January 2005 solar event which was accompanied by strong gamma-ray emission and by an unusually hard-spectrum solar energetic particle flux near the Earth. We study by simulation the nuclear-electromagnetic-lepton cascade produced by the primary cosmic ray particles in the Earth atmosphere which release energy via nuclear interaction and ionization losses. A common tool for atmospheric cascade investigation is Monte Carlo simulation of the cascade process. We apply CORSIKA 6.52 code with corresponding hadronic interaction models FLUKA 2006 and QGSJET II for cascade simulations in the atmosphere. The spectrum is studied in two parts: at 08:00 UT a high energy part with slope of 2.32 and at 23:00 UT low energy part with slope of 3.43, with corresponding intensities. The ionization rate is estimated for 40º N, 60º N and 80º N at Greenwich meridian taking into account the corresponding rigidity cut-off. We simulate 50 000 events (primary proton nuclei) per energy spectrum and assuming US Standard Atmosphere model, which is divided per 10 g/cm^2. This permits a detailed description of ionization profiles. The contribution of the different cascade components is

explicitly taken into account, namely the electromagnetic, muon and hadron component. The ionization rate is obtained according Oulu model and following Sofia algorithm. The detailed description of obtained ionization rate profiles is shown for various geomagnetic cut-offs. Generally, the ionization rates quickly become smaller with decreasing geomagnetic latitude.

4. An analytical model which generalizes the differential galactic cosmic ray spectrum in the heliosphere is proposed. The model parameterizes the spectrum at different physical conditions, including the most important effects controlling the cosmic ray intensity like diffusion – convection and energy losses. By a suitable choice of parameters the proposed model uses two approximations: one close to "force - field" model (describing the energy losses of cosmic ray in the inner heliosphere) and "convection - diffusion" equation (giving the reduction of cosmic ray intensity in the outer heliosphere).
   The modulated galactic cosmic ray differential spectra are compared with force-field approximation to the one-dimensional transport equation and with solutions of two-dimensional cosmic ray transport equation. Fitted parameters from the model equations are related to three 11-year solar cycles: 20, 22 and 23 through IMAX92, CAPRICE94, AMS98 and BESS experimental spectra for protons and alpha particles. The proposed analytical model gives practical possibility for investigation of experimental data from measurements of galactic cosmic rays and their anomalous component.

5. Processes in the global atmospheric electrical circuit (GAEC) and its characteristics on regional scale related to a thunderstorm (TS) are investigated by modeling under varying factors and different solar activity. This investigation is related to the conception that GAEC can play a role of an important link between Sun and the weather and climate. We study the quasi-electrostatic fields (QESFs) and currents generated in the region between TS with lightning discharges and the ionosphere. The effects of these fields in the mesosphere and lower ionosphere such as electron heating and changes in chemical balance are also a subject of study. One goal is to determine the conditions of generation of red sprites in the mesosphere and lower ionosphere. An analytical model based on Maxwell's equations under conditions of curl-free electric fields is developed. The QESFs and the profile of temporal peak are studied as function of the lightning discharges parameters and of atmospheric conductivity. Conditions are determined by which the QESF can cause a breakdown, and remains large enough in space and time for formation of nets of streamers in the mesosphere. The conduction and Maxwell currents generated over TS, and forming the GAEC’s link between the TSs and the ionosphere, are also studied, as well as their sensitivity to factors which vary with the solar activity, and also to those which are independent. A simulation model is established of the influence of the solar wind and interplanetary magnetic field on GAEC realized by the non-uniformity of the ionospheric potential distribution in the polar caps due to ionospheric convection. We show that the formation of large-scale trans-polar (dawn-dusk) potential difference of 30-140 kV, which is controlled by space weather parameters, significantly modifies the electric currents and fields in GAEC at polar and high latitudes down to the surface.

6. The galactic cosmic rays (GCR) create ionization in the terrestrial atmosphere, particularly in the stratosphere and the troposphere. They present a basic ionization source under the altitude 35 km towards the sea level. The solar CR are generated in

their great part by solar proton events. The coronal mass ejections (CME) also generate energetic particles. Usually the solar cosmic rays have energy of a few hundreds MeV, rarely - a little above several GeV. The primary cosmic ray particles create Bremsstrahlung in the terrestrial atmosphere from nuclear cascade processes in it. The high energy primary particles penetrate in the terrestrial atmosphere, collide with the atmospheric nuclei and create new energetic particles. The secondary particles give up their energy in the terrestrial atmosphere. As a result from it the atmosphere is ionized. The corpuscular-electromagnetic cascades in the atmosphere play important role in the physics and the chemistry of the ion balance there. It is well known, that the low energy particles intensity is greater than that of the high energy particles. Therefore the ionization appreciation for different events will be very interesting, because the ion balance in the atmosphere will be also different. On that basis the influences and changes concerning the minor constituents' density, as the ozone density, will be determined. The following cosmic ray events are investigated: Solar Proton Event on 20 January 2005 (GLE 69) according international CR event classification. For this purpose the energy spectra of particles in two different moments for every proton event are calculated. After that the ionization rate in the middle atmosphere is evaluated in these moments. The ozone production rate in the atmosphere is determined on the basis of this ionization rate for these different moments.

Research projects:

Project **EU COST ESO803**: Development of products and services for space weather in Europe.
Theme: Interaction of the cosmic rays and solar energetic particles with the system magnetosphere-ionosphere-atmosphere. International collaboration of EU. The participants in the project work in collaboration with scientists from Switzerland, Finland, Israel, Russia, etc. Theoretical and operational models for space weather and climate are developed. Project leader: Prof. P. Velinov

Project **"Rays"** – Cosmic rays as a factor of the space weather and their influence on the electrical statue of the ionosphere and atmosphere. International project of the program for academic interchange between SSTRI-BAS and IZMIRAN at Russian academy of sciences – (2011-2015). Project leader: Prof. P. Velinov

Project "**Connections-Rays"** – Connection of the cosmic rays with the ionization and conduction currents in the atmosphere based on continuous terrestrial measurements and model computations. International project of the program for academic between SSTRI-BAS and IZMIRAN at Russian academy of sciences – (2011-2015). Project leader: Prof. P. Velinov

Modeling of the induced ionization by cosmic rays in the ionospheres and atmospheres of the Earth and planets. International project between SSTRI-BAS and the Geophysical observatory Sodankila, University of Oulu, Finland. The participants in the project work in collaboration with scientists from Finland and Russia on development of theoretical models. Project leader: Prof. P. Velinov

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Report of the former Space Research Institute (SRI-BAS) http://www.space.bas.bg/.

Main scientific activities (based on their 40-year experience in the field of near-Earth space exploration):

1. Plasma turbulence and energy transfer across transition regions in the Earth magnetosphere (POLAR, CLUSTER, INTERBALL, EISCAT, CHAMP).

2. Troposphere-lower atmosphere-ionosphere interaction processes in the context of global climate understanding (DMSP, DEMETER, future EOARD project).

3. Natural hazard's effects on the Earth's ionosphere, electromagnetic emissions and ionospheric perturbations associated with anthropogenic activity (DEMETER, DMSP).

4. Further development of new algorithms and information technologies of data processing, data transfer and storage and data interpretation.

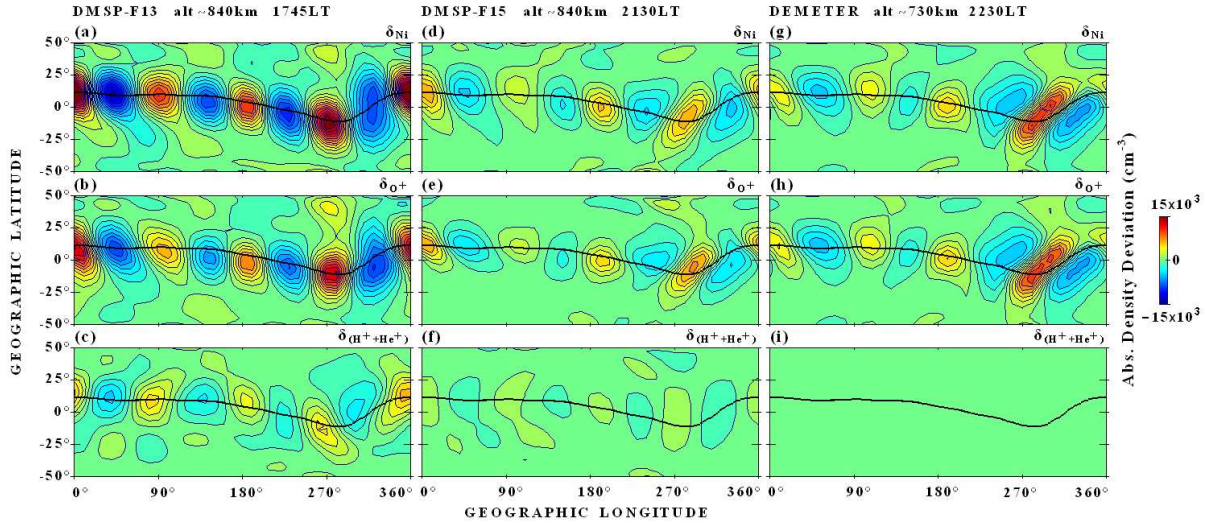
5. Plasma and wave environment of large body in space by *in situ* diagnostics (International Space Station - Russian segment).

6. Spin-off technologies and sensors developed in the Space Physics Dept. (vitreous carbon electric field sensors, materials and samples).

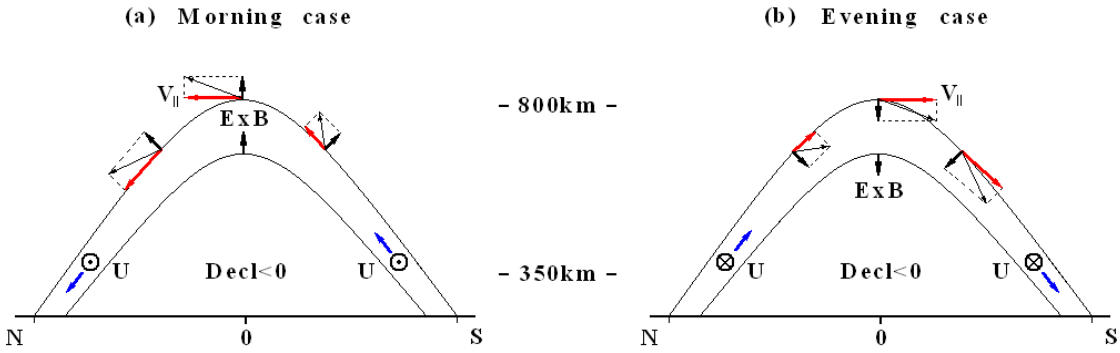
Main Results:

1. WN4 effect on longitudinal distribution of different ion species in the topside ionosphere at low latitudes by means of DEMETER, DMSP-F13 and DMSP-F15 data

It was shown that global scale variations in the topside plasma density have significant latitude and longitude structuring produced by a WN4 variation in the E×B drift and due to large-scale F-region zonal winds. We suggested that the E×B driver for the WN4 variations was most active in the daytime and may be absent during nighttime. However, the WN4 variations in ion density and composition once produced, are retained during the night while they decay. Longitude variations driven by F-region winds were present at all local times in the topside ionosphere and modulate the magnitude and location of the peak WN4 variations during the daytime and the nighttime. The role of the large-scale uniform neutral wind has been exposed, but the role of wind fields with longitude variations themselves required further investigation. Further study of intra-annual climatology of WN4 density and drift variations in the topside ionosphere is required to reveal both zonal and meridional wind influences on density distributions that display WN4 variations.



Evening WN4 density deviation maps from DMSP-F13, DMSP-F15 and DEMETER (left to the right) within ±50º geographic latitude vs. 0º÷360º geographic longitude, are shown. From top to the bottom of each column, δNi, δO^+ and $\delta(H^{++}He^+)$ variations are given. Thin black contours of 25 deviation levels correspond to the linear color bar given at the right side, within the range -15.10^3 cm^{-3} to 15.10^3 cm^{-3}.



Topside F-region plasma dynamics induced by E×B difts and neutral winds. Field-aligned motions (red arrows) are produced by the combined effects of E×B drifts (thick black arrows) and neutral winds in the meridian (blue arrows). Combined with field-aligned diffusion, the net plasma flow (thin black arrows) produces asymmetries in the ion density.

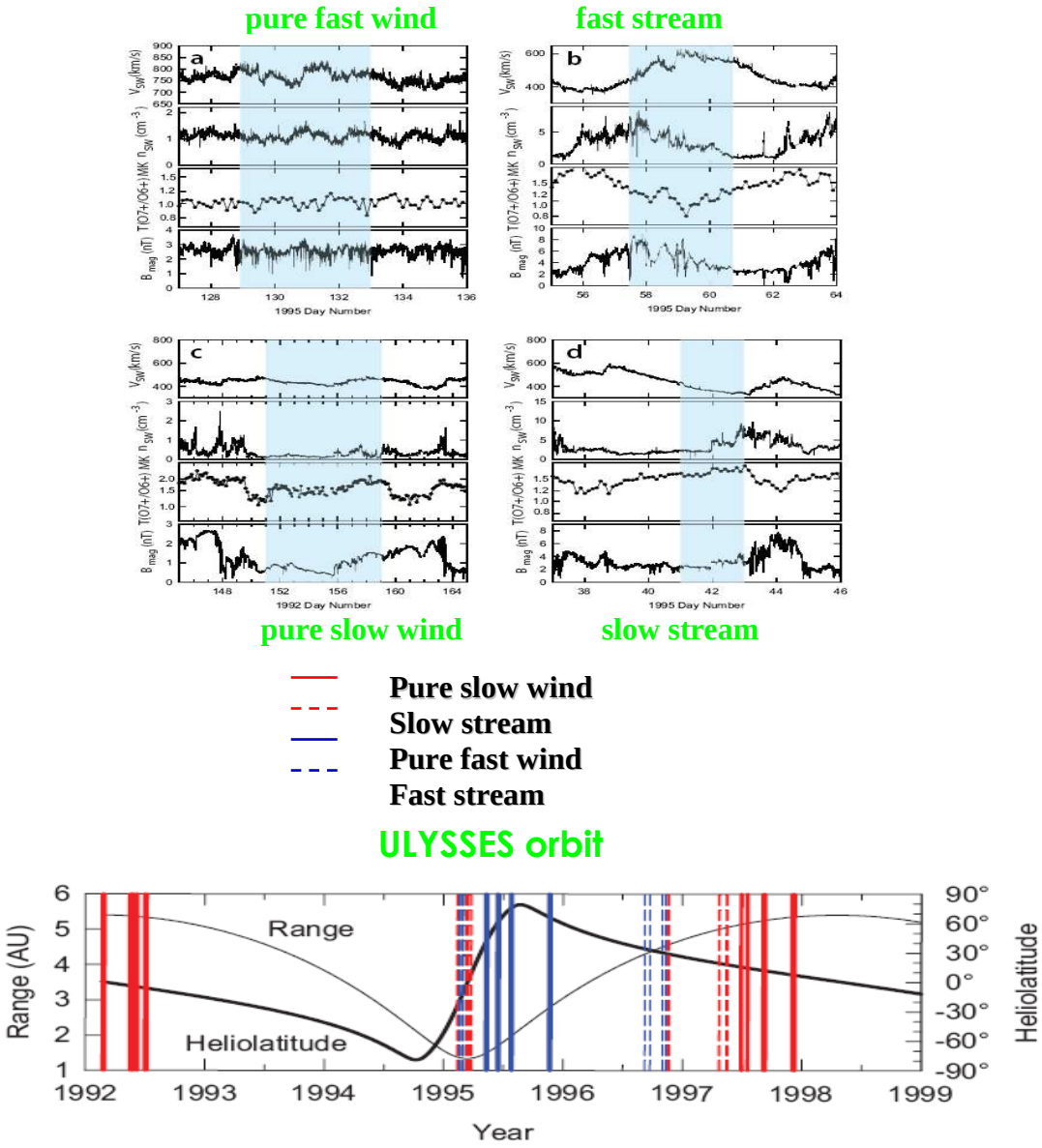
2. DEMETER and DMSP satellite observations of the disturbed H^+/O^+ ratio caused by Earth's seismic activity in the Sumatra area during Dec. 2004

Plasma probe data taken from DEMETER and DMSP-F15 satellites were used to study the ion density and temperature disturbances in the morning topside ionosphere, caused by seismic activity at low latitudes. French DEMETER (Detection of Electro-Magnetic Emissions Transmitted from Earthquake Regions) micro-satellite mission had been especially

designed to provide global scale observations in the topside ionosphere over seismically active regions. Onboard the DEMETER satellite, the thermal plasma instrument called "Instrument Analyser de Plasma" (IAP) provides ion mass and densities, ion temperature, three component ion drift and ion density irregularities measurements. As a part of "Defense Meteorological Satellite Program", DMSP-F15 satellite is on orbit operation since 1999. It provides ionospheric plasma diagnostics by means of the "Special Sensor-Ion, Electron and Scintillations" (SSIES-2) instrument. We examined few examples of possible seismic effects in the equatorial ionosphere, probably associated with seismic activity during December month in the area of Sumatra Island, including main shock of giant Sumatra event. It was found that the localized topside ionospheric disturbances appear close to the epicenters of certain earthquakes in the Sumatra region. In two cases, ion H^+/O^+ ratio rised more than one hour before the main shock, due to the O^+ density decrease at the winter side of the geomagnetic equator, with longitudinally closest location to the epicenter of the earthquakes. These anomalous depletions in O^+ density do exist in all cases of SSIES-2 data. Particularly for Sumatra main event, more than one hour after the main shock, large-scale depletion in O^+ density northward of the geomagnetic equator at winter side hemisphere was observed. Associated with O^+ depletion, ion temperature latitudinal profile around the geomagnetic equator showed enhanced asymmetry with minimum at the summer side and maximum in positive Ti deviation from mean value at the winter side. This disturbance lasted for more than three hours, later in time observed at the same place by IAP/DEMETER.

3. Turbulence and intermittency in the heliospheric magnetic field in fast and slow solar wind

The nonuniform solar wind turbulence was studied by using high-resolution Ulysses magnetic field data measured at different solar activity level, heliospheric latitudes, and distance. We defined several types of solar wind dependent of the coronal region of origin and also of the dynamical behavior of the different streams, namely, "pure" fast wind, fast streams, "pure" slow wind, and slow streams. The turbulent properties of the solar wind types were investigated in terms of their scaling properties and spatial inhomogeneity. A clear trend in the power spectrum of the solar wind magnetic field magnitude is observed: the "pure" fast wind has a slope ~−1.33 ($1/f$-like), the fast streams ~−1.48 (Kraichnan-like), the "pure" slow wind ~−1.67 (Kolmogorov-like), and the slow streams ~−1.72. We found that the "pure" fast wind in the polar heliolatitudes was less intermittent than the other types: "pure" slow wind and both slow and fast streams, which is because of the absence of dynamical interactions between streams with different speeds. On the other hand, fast streams were more intermittent than the "pure" fast wind, and slow streams were less intermittent than the "pure" slow winds. A clear radial and latitudinal evolution of the intermittency was observed only for the "pure" fast wind, while in the equatorial plane, the fast streams, the "pure" slow wind, and the slow streams did not show evolution either in heliolatitude or in heliocentric distance.



4. Cosmic RAY Spectra Approximation Model for Protons and Alpha Particles in the Heliosphere

A new empirical model which generalizes the differential galactic cosmic ray (CR) spectrum in the heliosphere was proposed. The model is called Cosmic Ray Spectra Approximation (CRSA). This model parameterizes galactic CR spectrum at different physical conditions including the most important effects controlling the CR intensity like diffusion-convection and energy losses. For given values of model parameters it turns into the two well known analytical solutions “force-field” (describing the energy losses of CR in the inner heliosphere) and “convection-diffusion” (giving the reduction of CR intensity in the outer heliosphere) that makes CRSA model an omni-directional approach for calculation of the CR spectrum. A new mathematical relation between parameters in CRSA model and the modulation potential ø was found. The computed parameter values in CRSA model correspond to an exact determined value Ø in FF approximation. Changing one or two CRSA parameters, an amplitude and slope discrepancies between the two model solutions can be gained. For example, CRSA well fits BESS 2000 and BESS2002 experimental measurements while

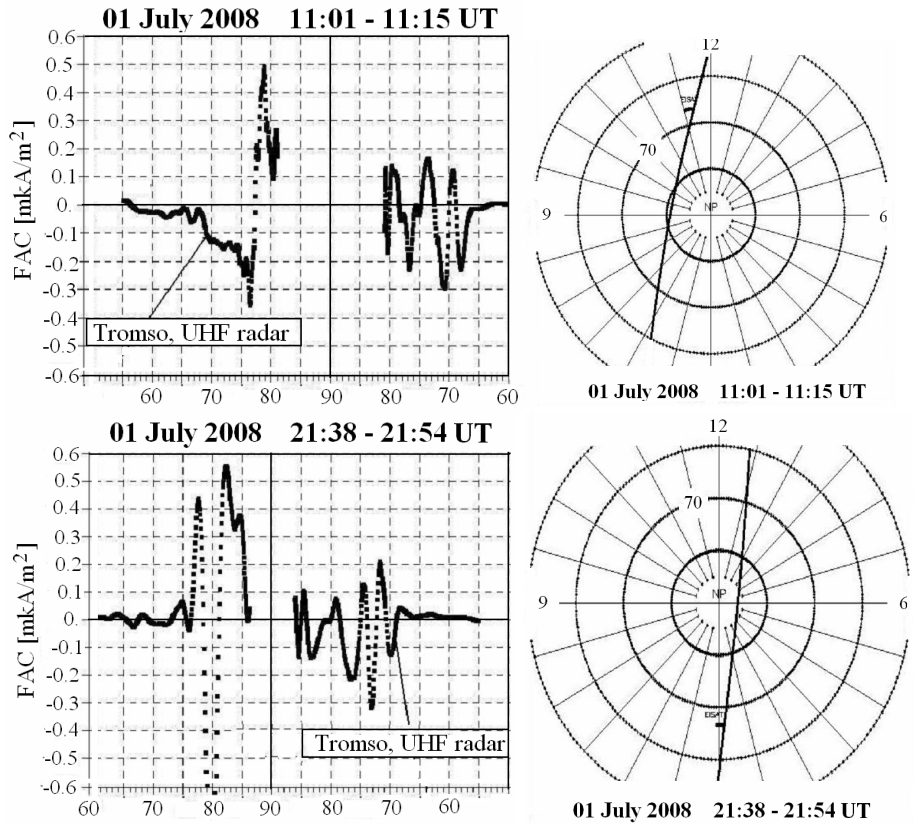
between these experimental data and the FF model small discrepancies can be seen. Therefore the proposed generalized model is more flexible to the data fitting than FF approximation. The next task to be studied is how the discrepancy between FF approximation and CRSA model is changed by varying one of the CRSA parameters. It is worth to notice that modulation potential φ (used from force-field approximation for CR spectra parameterization) is not advisable (from physical considerations) on short time scales and during periods of active Sun. The CRSA model does not have such a problem what make it more universal and applicable for different time scales and levels of solar activity.

5. Ionospheric quasi-static electric field anomalies during seismic activity in August–September 1981.

The study proposeed new results, analyses and information for the plate tectonic situation in the processing of INTERCOSMOS-BULGARIA-1300 satellite data about anomalies of the quasi-static electric field in the upper ionosphere over activated earthquake source regions at different latitudes. An earthquake catalogue is made on the basis of information from the United State Geological Survey (USGS) website. The disturbances in ionospheric quasi-static electric fields are recorded by IESP-1 instrument aboard the INTERCOSMOS-BULGARIA-1300 satellite and they are compared with significant seismic events from the period 14 August–20 September 1981 in magnetically very quiet, quiet and medium quiet days. The main tectonic characteristics of the seismically activated territories are also taken in account. The main goal of the above research work is to enlarge the research of possible connections between anomalous vertical electric field penetrations into the ionosphere and the earthquake manifestations, also to propose tectonic arguments for the observed phenomena. The studies are represented in four main blocks: (i) previous studies of similar problems, (ii) selection of satellite, seismic and plate tectonic data, (iii) data processing with new specialized software and observations of the quasi-static electric field and (iiii) summary, comparison of new with previous results in our studies and conclusion. We establish the high informativity of the vertical component *Ez* of the quasi-static electric field in the upper ionosphere according observations by INTERCOSMOS-BULGARIA-1300 that are placed above considerably activated earthquake sources. This component shows an increase of about 2–10 mV/m above sources, situated on mobile structures of the plates. The paper discusses the observed effects. It is represented also a statistical study of ionospheric effects 5–15 days before and 5–15 days after the earthquakes with magnitude M 4.8–7.9.

6. Magnetosphere/Ionosphere coupling: Large scale and small scale FAC structure interactions and energy transfer in the system http://www.eiscat.se/ TransNationalAccess

A study of high-latitude ionosphere response at Tromso (Norway) during quiet geomagnetic conditions (30 June–02 July 2008) was conducted. A comparison between *ground based (EISCAT) and satellite (CHAMP) observations* enabled us to delineate field-aligned current (FAC) contributions to observed ion temperature T_i distribution in height and its maximum at the F2 region. A brief summary of results is given below:



On the left, CHAMP data of the field-aligned currents (FACs) flowing in the Northern hemisphere are shown. On the right the CHAMP orbit crossing Tromso on 01.07. 2008 (evening session) is depicted.

In summary, our study based on EISCAT and CHAMP data demonstrates that large-scale FAC distribution and corresponding Joule heating do not quantitatively reconcile temperature increase ΔT which maximizes at height close to the maximum height, h′F2max, of the F2 region critical frequency, foF2 frequency. Joule heating analysis and its effects at the F2 heights conducted here however does not account for much more important components of Joule heating due to more intense (by orders) fluctuations of smaller spatial and temporal scales in the FAC, electric field or ion drifts.

Selected Publications:

Bankov, L.**,** Heelis, R., Parrot, M., Berthelier, J.-J., Marinov, P., and Vassileva, A. (2009) WN4 effect on longitudinal distribution of different ion species in the topside ionosphere at low latitudes by means of DEMETER, DMSP-F13 and DMSP-F15 data, *Ann. Geophys.*, 27, 2893-2902, 2009.

Perri, S., E. Yordanova, V. Carbone, P. Veltri, L. Sorriso-Valvo, R. Bruno, and M. André (2009), Magnetic turbulence in space plasmas: Scale-dependent effects of anisotropy, *J. Geophys. Res.*, 114 (A2), CiteID A02102, 2009.

Smirnova, N.F., Stanev G.D, Determimation of the Photoelectron Current Density Based on Comparison between IESP -2 and KM-7 Probe Measurements on the Interball -2

Satellite Potential Relative to Plasma. ISSN 0016-7932, *Geomag. Aeron.*, 49 (8), 1204-1207, 2009.

Yordanova, E., Balogh, A., Noullez, A., and Von Steiger, R., Turbulence and intermittency in the heliospheric magnetic field in fast and slow solar wind, *J. Geophys. Res.*, 114 A8), CiteID A08101,2009.

Buchvarova, M. Cosmic Ray Spectra Approximation Model For Protons and Alpha Particles in the Heliosphere, *Compt. Rend. Acad. Bulg. Sci.*, 62 (11), 2009, pp. 1439-1448.

Gousheva M., D. Danov, P. Hristov, and M. Matova. Ionospheric quasi-static electric field anomalies during seismic activity in August–September 1981, *Nat. Hazards Earth Syst. Sci*., 9, pp. **3–15,** 2009

Hristov P., P. Angelov, M. Gousheva. Models of Autonomous Control Systems Software. *Cybernetics and Information Technologies (CIT),* v. 9, No 1, 2009. pp. 55-63.

Bankov L.G., M. Parrot, R.A. Heelis, J.-J. Berthelier, P.G. Marinov and A.K. Vassileva. DEMETER and DMSP satellite observations of the disturbed H^+/O^+ ratio caused by Earth's seismic activity in the Sumatra area during December 2004, *Adv. Space Res.*, 46(4), 2010, pp. 419-430.

Carbone V., S. Perri, E. Yordanova, P. Veltri, R. Bruno, Y. Khotyaintsev, and M. Andre, Sign-singularity of the reduced magnetic helicity in the solar wind plasma. *PRL 104*, 181101, 2010; DOI: 10.1103/PhysRevLett.104.181101

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Sorriso-Valvo L., E. Yordanova and V. Carbone, On the scaling properties of anisotropy of interplanetary magnetic turbulent fluctuations, *EPL*, 90, 59001, 2010; DOI: 10.1209/0295-5075/90/59001

Buchvarova M. Primary Cosmic Ray Spectra in the Planetary Atmospheres in Extreme Phases of the Solar Cycle. Compt. Rend. Acad. Bulg. Sci, 63, 3, 2010, pp.419-426. *Compt. rend. Acad. bulg. Sci.*, 2010, 63, 5, 633-644.

Erokhin N., N. Zolnikova, L. Mikhailovskaya, R. Shkevov. Charged Particles Surfatron Acceleration by a Set of Electromagnetic Waves with Smooth Envelope in Space Plasmas. Fifth International Conference with International Participation SENS-2009, Sofia, Bulgaria, 2-4 November 2009. Proceedings SENS 2009, Space Research Institute-Bulgarian Academy of Sciences, Sofia, 2010, p.339-344.

Teodosiev D., E. Yordanova, P. Nenovski, T. Nikolova, D. Danov, G. Crowley, L. Baddeley, St. Buchert. Ion Temperature Distribution in the High-Latitude Region (EISCAT UHF Radar Observations) – What is the Field-Aligned Currents Influence? *Compt. rend. Acad. bulg. Sci.*, ISSN1310-1331, 2011 (in press).

Projects:

N	TITLE OF THE PROJECT	PRINCIPAL INVESTIGATOR	FUNDING
1	Experimental Study of the Ionospheric Effects over Seismically Active Regions by Means of Coordinated Ground Based, DEMETER and DMSP Satellite Data	Res. Fell. L. Bankov SRI-BAS	Joint Res. Project R N 661/18.05.2005
2	A Study of the Polar Cap Potential Distribution as a Result of Interplanetary Magnetic Field Fluctuations	Res. Fell. L. Bankov SRI-BAS	Budget of BAS
3	Turbulence and intermittency in the heliospheric magnetic field in fast and slow solar wind	Res. Fell. Dr. E. Yordanova SRI-BAS	Budget of BAS
4	Cosmic RAY Spectra Approximation Model for Protons and Alpha Particles in the Heliosphere	Sen.Res Dr.M. Bachvarova SRI-BAS	
5	Study of Anomalous Effects in the Ionosphere Registered on board of the *IC- Bulgaria-1300* Satellite over Seismically Active Regions	Res. Fell. M. Gousheva SRI-BAS	Budget of BAS
6	Magnetosphere/Ionosphere Coupling: Large Scale and Small Scale FAC Structure Interactions and Energy Transfer in the System	Sen. Res. Dr. D.Teodosiev SRI-BAS	TNA Program, EISCAT
7	Project *Charge-ISS*	Sen.Res Dr.G. Stanev, SRI-BAS	Budget of BAS
8	Specialized Electromagnetically Complexes for Investigation of Ion Spherical-Magnitospherical Plasma and Lit Spherical Phenomena	Sen. Res. Dr. B. Boychev SRI-BAS	Budget of BAS
9	Electromagnetic Monitoring of Areas with Intensified Seismic Activity.	Sen. Res. Dr. B. Boychev SRI-BAS	MoES
10	*Balkansat* - Development of Micro-Satellite Platform for Scientific Investigations	Prof. Dr. P. Getsov SRI-BAS	BAS-RAS/FSR SRI-RAS(2006-2010)
11	*Charge* - Investigation of Surface Processes of Space Crafts Polarization	Sen. Res. Dr. G. Stanev SRI-BAS	BAS-RAS/FSR SRI-RAS(2006-2010)
12	*Avrora-R* - Research of Dynamic Ionosphere Plasma and Auroral Phenomena in Different Heliogeophysical Conditions on Base of Experimental (Satellite) Data for Electrical Fields and Parameters of Ionosphere Plasma	Sen. Res. Dr. B. Boychev SRI-BAS	BAS-RAS/FSR IZMIRAN-RAS (2006-2010)
13	ULF/ELF/VLF Characteristics of Magnetospheric Structures Based on Satellite and Ground-Based Observations	Sen. Res. Dr. D.Teodosiev SRI-BAS	IAF-CzAS(2008-2010)
14	*Shuman* - Study of Satellite and Ground-Based ULF Electromagnetic Field Data for Diagnostic of Solar and Seismic Effects in the Near Earth Space	Sen. Res. Dr. D.Teodosiev SRI-BAS	BAS-RAS/FSR IZMIRAN-RAS (2008-2010)
15	A Study of ELF/ULF Waves and Field-Aligned Current Systems by Satellite and Ground Based	Prof. Dr. P. Getsov SRI-BAS	INT /BULGARIA

	Measurements		/B28/02 Bulgaria - India
16	Satellite Observations of The Atmospheric Gravitational Waves	Res. Fell. L. Bankov SRI-BAS	Joint Res. Project R N 665/01.12.2006
17	*Volna-R* - Research of Electromagnetic Waves in Resonance Processes of Energy Transfer in Ionosphere –Magnetosphere Plasma on Based Measurements from High Apogee Satellites.	Sen. Res. Dr. B. Boychev SRI-BAS	BAS-RAS/FSR SRI-RAS (2006-2010)
18	POPDAT "Problem-oriented Processing and Database Creation for Ionosphere Exploration"	Res. Fell. L. Bankov SRI-BAS	FP7 Collaborative project, Teme [SPA.2010.2.1-03], Grant agreement no: 263240

International Association of Hydrological Sciences (IAHS)

IAHS Activities in Bulgaria
2007 – 2011

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Report on Hydrological scientific activities in Bulgaria

Hydrological research studies are cared out in Bulgaria in several institutions, mostly in the Bulgarian Academy of Sciences, National Institute of Meteorology and Hydrology (www.meteo.bg, www.hydro.bg). Few aspects directed to hydraulics are covered in the University of Civil Engineering and Architecture, faculty of Hydrotechnic, as well as in Sofia University, faculty of Geography, mostly geographical aspects. Following the increasing demands in the industry and society the Bulgarian hydrologist are developing in the recent several years range of projects, studies and expertises in the field of:

- Hydrological modeling for the purposes of flood forecasting that includes special evaluation of flood frequencies, stochastic modeling of flood extreme values for different return periods, regionalization of different hydrological parameters related to floods.
- Hydrological modeling for the purposes of the reservoir inflow forecasting.
- Hydrological modeling for the purposes of the draws identification and forecasting that includes development of different indicators, soil moisture related studies, etc.
- Studies of hydrological balances for the purposes of the fresh water resources evaluation that includes spatial modeling of precipitation and actual evapotranspiration distribution, spatial distribution of the specific discharge and other GIS-base models.
- Studies of minimal and maximal flows duration at ungaged for the purposes of renewable energy production.
- Other studies asked by specific donors.

Some recent projects implemented by the NIMH researchers:

Bulgaria 2005	Project financed by the Ministry of Environment and Water: ”Operation system for water resources evaluation methodology for evaluation surface water resources, base statistics indexes, computer application for calculating annual resource characteristics”
Bulgaria 2006	Phare BG-TR JSPF BG 2003/005-632-02.01-02 ; Floods in the Maritza river basin: risk analysis and evaluation, mobilization of information sources for floods impact decrease”
European region	2005 to now, Partner in ongoing JRC project: “European Flood Alert System”, leading the Bulgarian group, Sub-contractor in its sub-projects: - European Flood GIS, NIMH is subcontractor to Atkins Ltd. - UK - European Terrestrial Network for River Discharge, NIMH is subcontractor to the Federal Institute of Hydrology – Germany
Bulgaria - Turkey	Capacity improvement for flood forecasting in the Bg-TR CBC region. EC Phare 2005/017-453.01.01 project. NIMH is beneficiary for the TA and Supply component and currently operate the Maritza Flood Forecasting system www.plovdiv.meteo.bg/maritsa_phare
Bulgaria - Turkey	Capacity Improvement For Flood Forecasting And Flood Control in The Tr-Bg Cbc Region, Phare CBC project EuropeAid/125003/D/SER/TR, NIMH is a consortium partner to the Danish Hydraulic Institute - Danmark

European region	Enviro Grids, EC FP7-2007-SPACE-1 project consortium member
European region	Services and Applications For Emergency Response, EC FP7-2007-SPACE-1 project consortium member.
Bulgaria – Germany - Austria	Partnership agreement concerning the Civil Protection project (DAMSAFE) (Grant Agreement No. 070401/2010/579114/sub/C4) “Improving flood prevention and flood hazard awareness through the development of a standardized approach for small dams risk assessment and management based on European best practices and shared experience
European region	“EUMETSAT Satellite Application Facility on Support to Operational Hydrology and Water Management (H-SAF)”- project funded by Eumetsat

International Association of Meteorology and Atmospheric Sciences (IAMAS)

IAMAS Activities in Bulgaria
2007 - 2011

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INSTITUTES:

NATIONAL INSTITUTE OF GEOPHYSICS GEODESY AND GEOGRAPHY
NATIONAL INSTITUTE OF METEOROLOGY AND HYDROLOGY

UNIVERSITIES:

SOFIA UNIVERSITY, DEPARTMET OF METEOROLOGY AND GEOPHYSICS

JOURNALS:

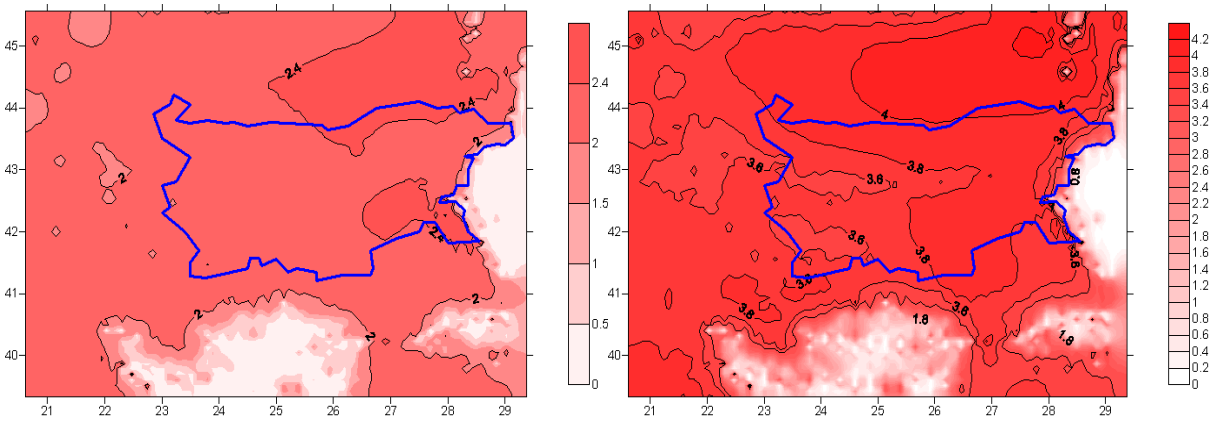
BULGARIAN GEOPHYSICAL JOURNAL
BULGARIAN JOURNAL OF METEOROLOGY AND HYDROLOGY

SOME ACHIEVEMENTS

CLIMATE CHANGE

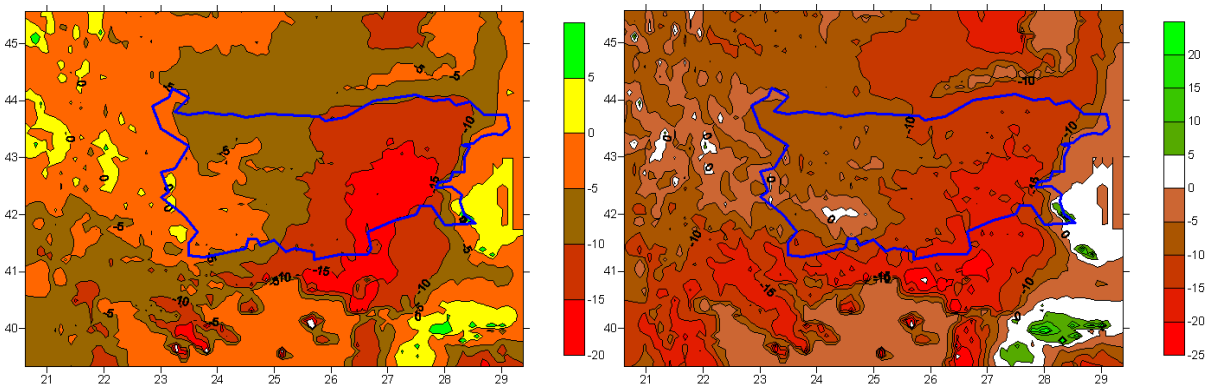
Most of the results are from the CECILIA FP6 programme (http://www.cecilia-eu.org/). The main objective of CECILIA is to deliver a climate change impacts and vulnerability assessment in targeted areas of Central and Eastern Europe. Emphasis is given to applications of regional climate modelling studies at a resolution of 10 km for local impact studies in key sectors of the region. The project contains studies of hydrology, water quality, and water management (focusing at medium-sized river catchments and the Black Sea coast), air quality issues in urban areas, agriculture (crop yield, pests and diseases, carbon cycle), and forestry (management, carbon cycle). For the Balkan Peninsula region the climate version of ALADIN model was implemented. The IPPC A1B scenario for 2021-2050 and 2071-2100 simulations was assumed. On the figures below the changes are compared with 1961-1990 period.

Temperature changes against 1961-1990 in ^{0}C
Annual mean



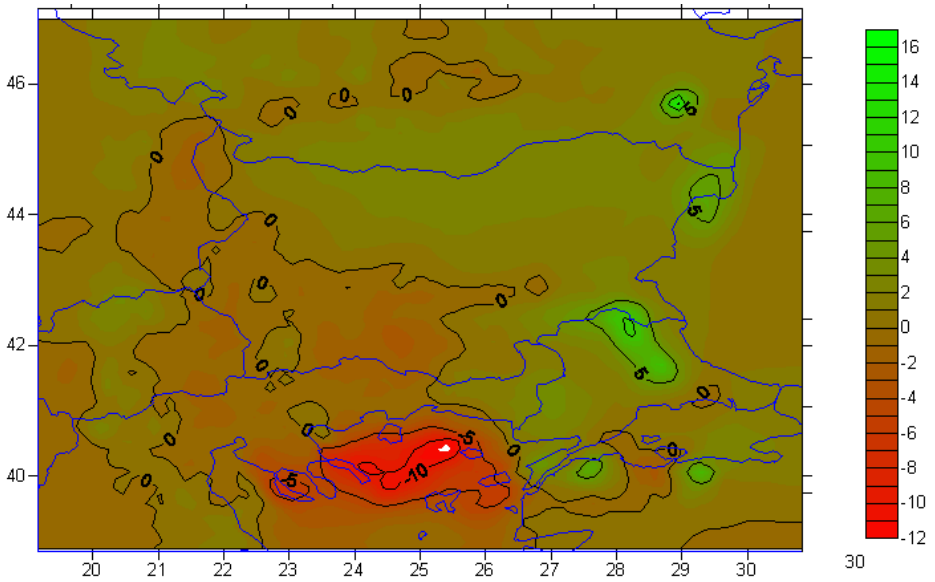
2021-2050 **2071-2100**

Precipitation changes against 1961-1990 in %
Annual mean



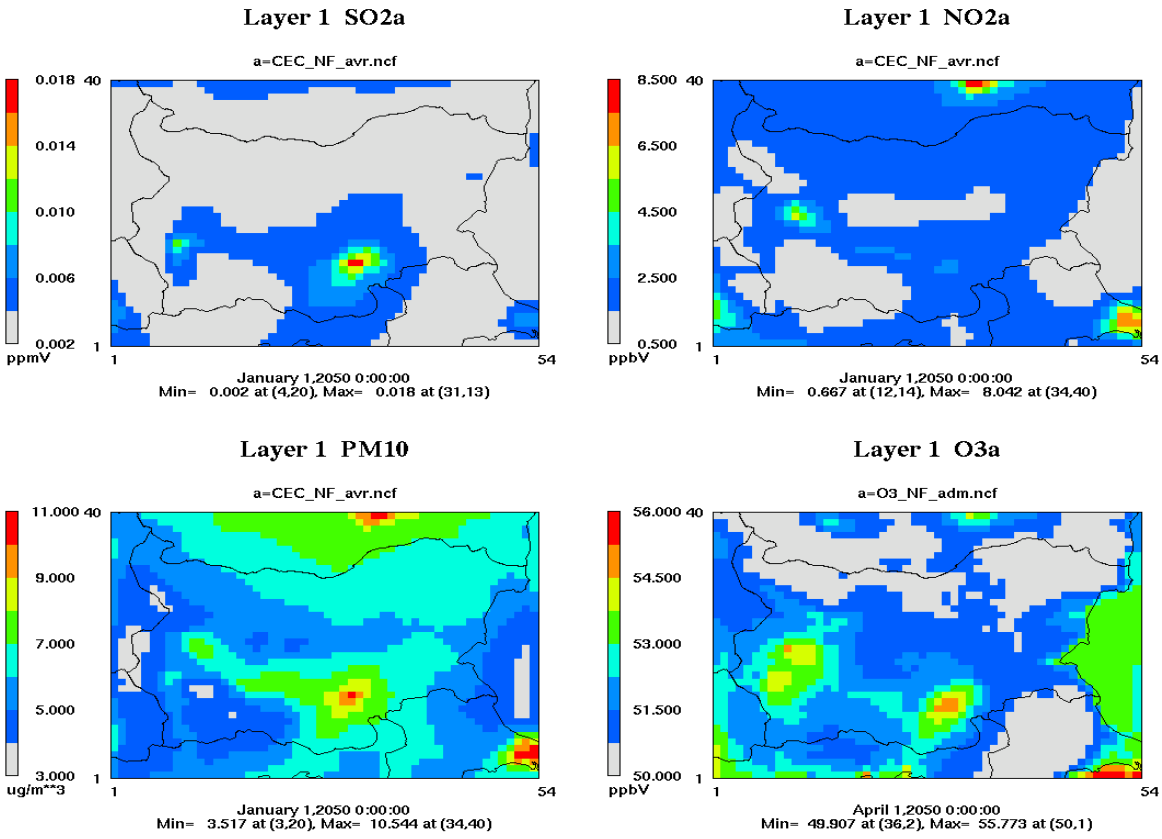
2021-2050 **2071-2100**

WIND POWER CHANGES IN % AT 30 m ABOVE THE SURFACE



2021-2050 against 1971-2000

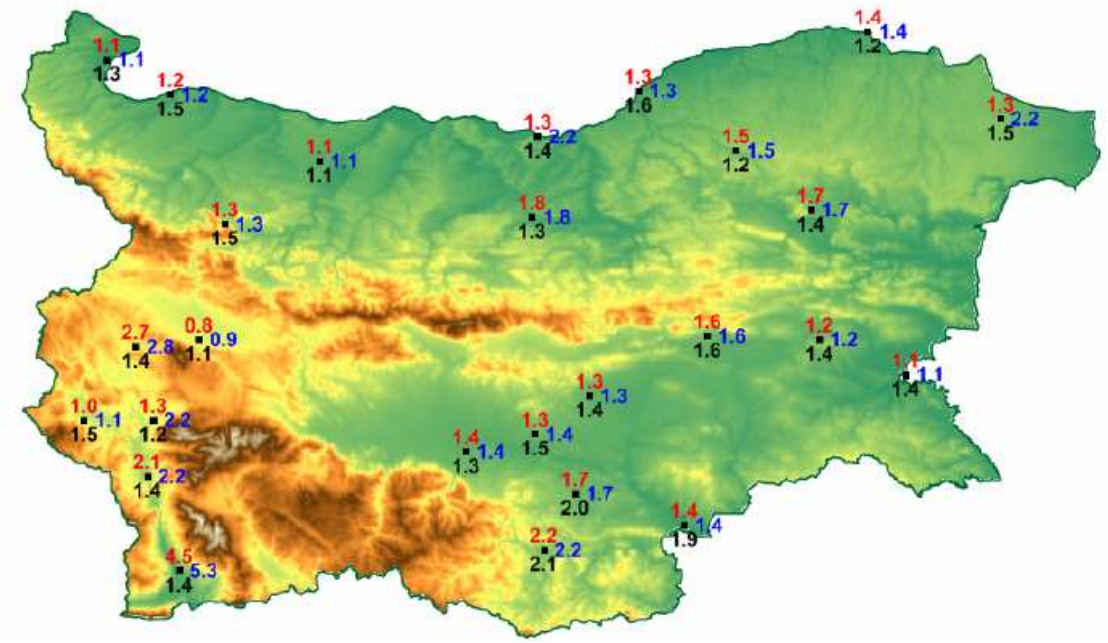
Air quality



10-year averaged fields of SO2 (up-left), NO2 (up-right), PM10 (down-left) and Ozone ADM (down-right), Near Future (2041-2050)

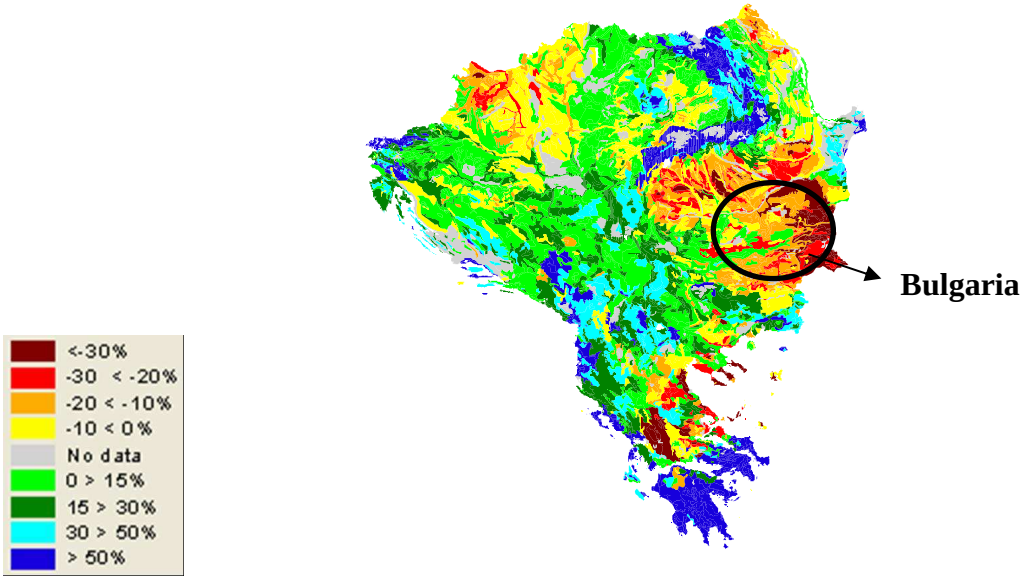
Health

Percentage of hot days (Tmax≥30 °C)
The hot days would increase up to 30% till the end of 21st century



1961-1990 (black), 2021-2050 (blue), 2071-2100 (red)

Agriculture



Expected changes in harvest yield of sunflower 2071-2100

NUMERICAL FORECASTS

The operational model for weather forecast used in NIMH is ALADIN The acronym ALADIN (**A**ire **L**imitée **A**daptation **D**ynamique développement **I**nter**N**ational) describes several facets of an international project (for limited area mesoscale modelling) involving as many as 160 persons from 16 National Meteorological Services. ALADIN was entirely built on the notion of compatibility with its "mother" system, IFS/ARPEGE. The latter, a joint development between the European Center for Medium-Range Weather Forecasts (ECMWF - IFS) and Météo-France (ARPEGE), was only meant to consider global Numerical Weather Prediction applications; hence the idea, for ALADIN, to complement the IFS/ARPEGE project with a limited area model (LAM) version, while keeping the differences between the two software as small as possible. The parameterization of the physical processes is very flexible and gives the opportunity to adapt the model to specific features of the area where the weather forecast is produced. That is possible by tuning of many parameters and logical switches in the code. For more details see http://www.cnrm.meteo.fr/aladin/

The ALADIN has become an operational model in Bulgaria since 15 of May 1999 with one run from 00 UTC. Since 15 of June 1999 the 48 hours forecast has been run twice a day using initial and boundary conditions from ARPEGE at 12 and 00 UTC.

Several applications are linked to the output of ALADIN: Marine forecasts for the wave height; Snow evolution and melting for hydrological models; Forecast for rapid temperature changes and averaged solar radiation for electricity companies etc.

The hardware platform is LINUX cluster, containing four nodes, each node has two processors Intel Glovertown E.5310 at clock rate 1.8 GHz, Quad core. Thus, we have eight kernels per node. Each node has 8 G bytes memory and 250 GB local disk storage.

There is additional server with four processors and 1.4 TB disk storage. It is hosting several servers running on it - DNS, DHCP, NFS, http (web), the software managing, the RAID controller. The front end machine is virtual one running on two processors of this server. It is hosting also the common file system visible and accessible for the front end machine and the nodes. For MPI exchange the nodes are connected via Infini Band switch, inside nodes shared memory is used, and 1GB switch for NFS. For MPI is used mvapich2-1.2-intel-x86_64 release of MPI2. Composers are Intel FORTRAN and C composerxe-2011.2.137, 64 bit release. The operating system is 64 bit LINUX 2.6.18-194.32.1.el5xen #1 SMP.

Model ALADIN is used for operational regional weather forecasting. It is spectral model developed by consortia of sixteen countries. Here we will give only the main characteristics of the model.

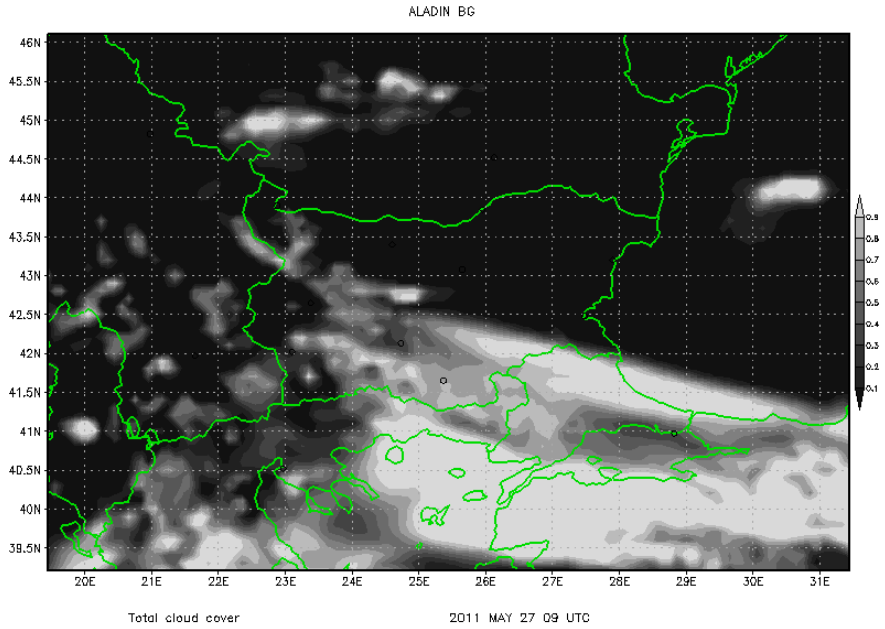
The operational application is using the code of Cycle 32t3 on domain of 144x108 points, using so called linear grid in spectral space with nine kilometers horizontal resolution and 60 levels on vertical and three hours coupling frequency. The vertical coordinate is hybrid, following the terrain. The advection scheme is semi-Lagrangian.
LBCs are provided by the global model ARPEGE of Meteo France.
We are producing two times daily 72 hours forecast with 06 and 18 UTC starting time.
Due to technological reasons we are produce so called shifted forecast, the initial conditions are the six hours forecast of the global model.

The creation of model of model output is with hourly frequency, post-processing for visualization purposes and some of the end users is off-line on regular lat-lon grid with resolution 0.1x0.1 degrees.

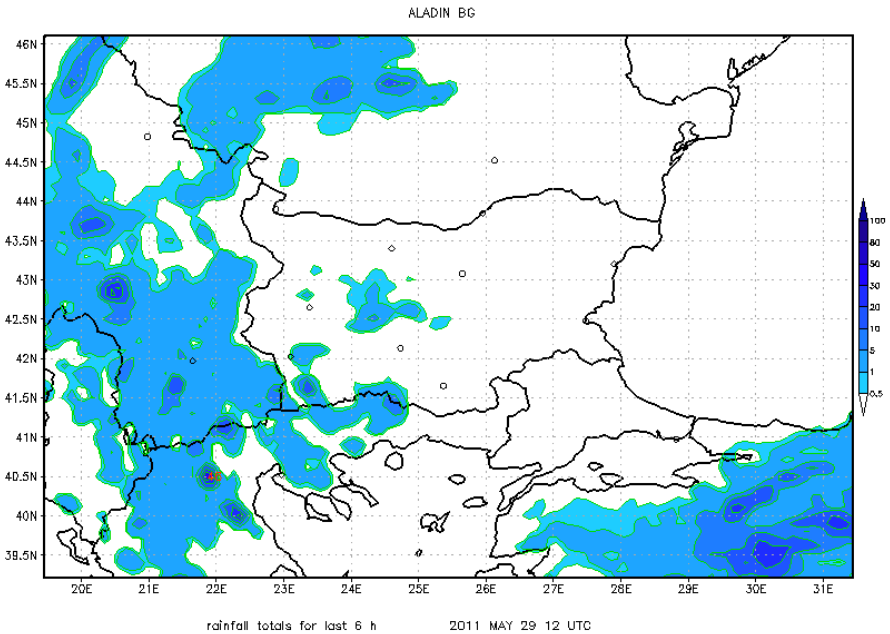
For the purposes of visualization GRADS is used.

Dedicated end-users are the wind wave model, forecasting the wind waves and swell for the Black sea region, the system for forecasting of the air quality in the region of Stara Zagora, GRIB coded messages are prepared for SYNERGIE, producing of the files for RODOS system and so on.

Here are some examples of the visualization of the operational forecast:



Total cloud cover

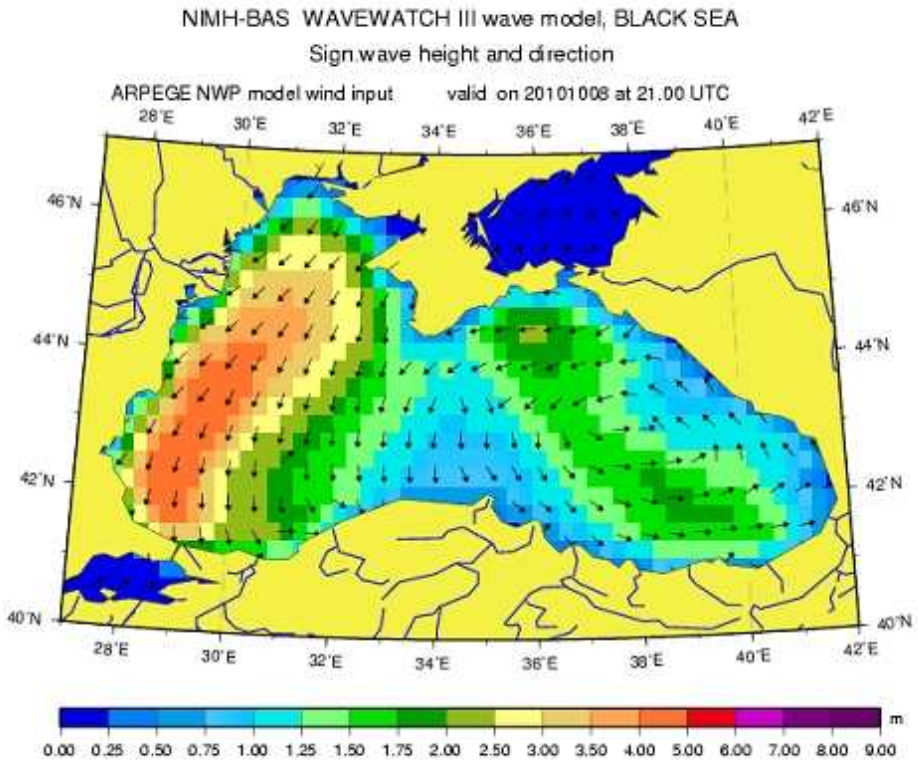


6 hour accumulated precipitation

Marine meteorology

Two models are used :

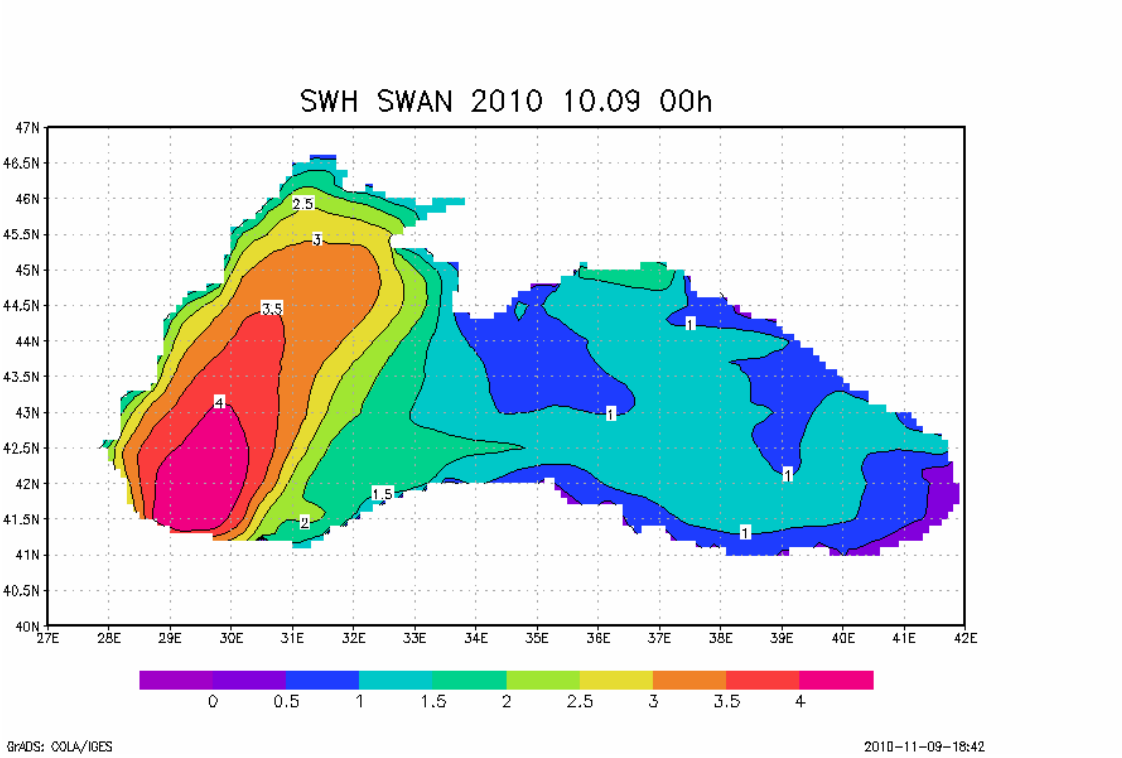
WAVEWATCH III™ (Tolman 1997, 1999a, 2009) is a third generation wave model developed at NOAA/NCEP in the spirit of the WAM model (WAMDIG 1988, Komen *et al*. 1994). It is a further development of the model WAVEWATCH, as developed at Delft University of Technology (Tolman 1989, 1991a) and WAVEWATCH II, developed at NASA, Goddard Space Flight Center (e.g., Tolman 1992). WAVEWATCH III™, however, differs from its predecessors in many important points such as the governing equations, the model structure, the numerical methods and the physical parameterizations.WAVEWATCH III™ solves the random phase spectral action density balance equation for wavenumber-direction spectra. The implicit assumption of this equation is that properties of medium (water depth and current) as well as the wave field itself vary on time and space scales that are much larger than the variation scales of a single wave. WAVEWATCH III is operational at NIMH-BAS with mesh size of 0.125 degree.
An example of WAVEWATCH output:



SWAN (Simulating Waves Near Shore) is a third-generation wave model that computes random, short-crested wind-generated waves in coastal regions and inland waters.
SWAN accounts for the following physics:

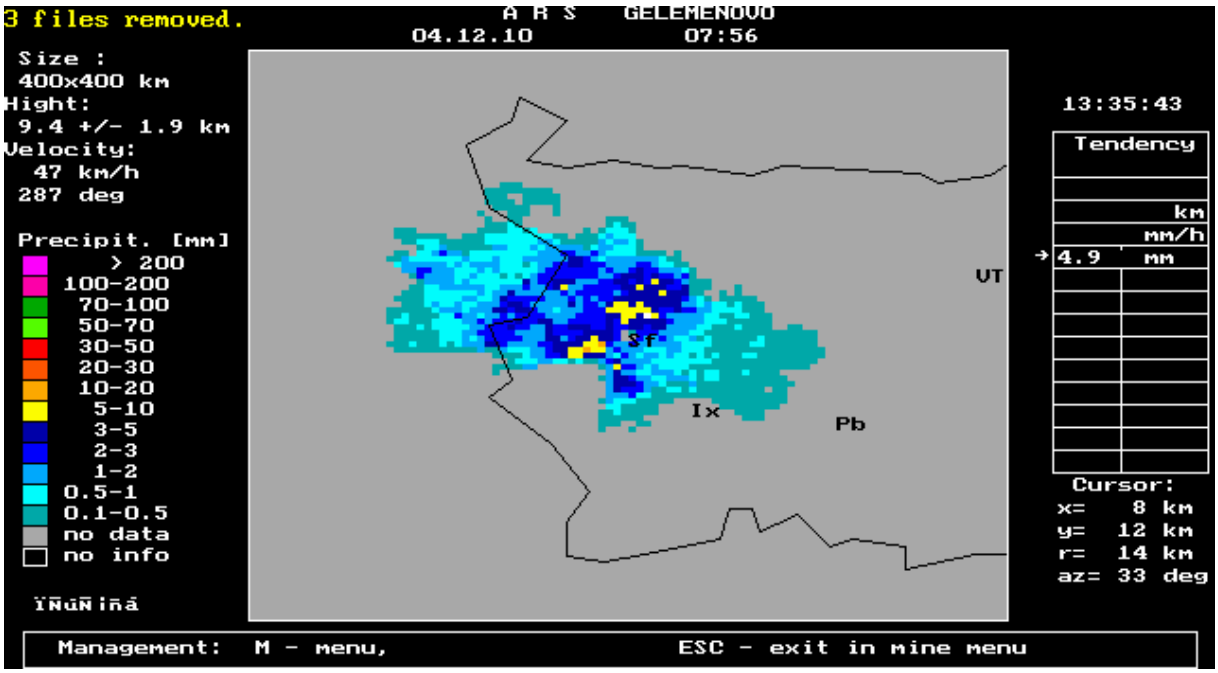
- Wave propagation in time and space, shoaling, refraction due to current and depth, frequency shifting due to currents and non-stationary depth.
- Wave generation by wind.
- Three- and four-wave interactions.
- Whitecapping, bottom friction and depth-induced breaking.
- Dissipation due to vegetation.
- Wave-induced set-up.
- Propagation from laboratory up to global scales.
- Transmission through and reflection (specular and diffuse) against obstacles.
- Diffraction.

SWAN Model is quasi-operational at NIMH-BAS- domain 1 (SWAN Black Sea) covers the entire Black Sea with a mesh size 2 minutes and domain2: SWAN Burgas Bay is nested within SWAN Black Sea- it's mesh size is 500 meters.

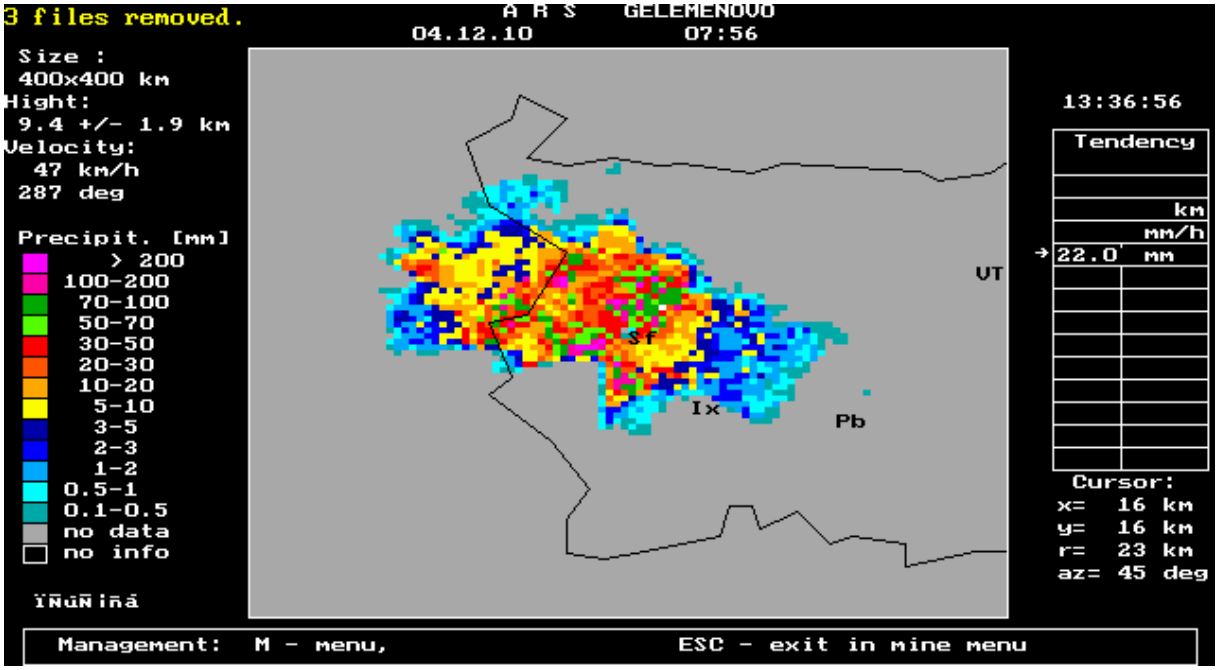


NOWCASTING

A new scheme for precipitation analysis using radar data combined with automatic raingages network. On rte figures below is presented an illustration of flood in Sofia on 04.12.2010.



Without raingages, the maximum of precipitation is 5-10 mm/h (yellow)



The same but with calibration, the maximum of precipitation is 70-100 mm/h (green)

OZONE MONITORING AND RESEARCH IN BULGARIA

Assoc.Prof. Dr. Staytcho Kolev

OBSERVATIONAL ACTIVITIES

One of the goal of the ozone research in Bulgaria is the systematic measurements, which provide the basis for understanding the ozone regime, its trends and validation the effects

Column measurements of ozone and other gases/variables relevant to ozone loss

In Bulgaria, the first total ozone measurements were initiated to the early 1960s, under the supervision of Prof. Dr. R. D. Bojkov. Germany carried them out using Dobson spectrophotometer # 64 provided for about 5 years. After a few years interruption Russian filter ozonometers started to be used in the Bulgarian National Institute of Meteorology and Hydrology. In 1998 with the financial support from WMO two Russians ozonometers M-124 were renovated and calibrated at the Main Geophysical Observatory – St. Petersburg. The measurements at only one station (NIMH-Sofia) could be maintained (but experiencing technical problems because of the device age). Unfortunately, in the recent years these devices demonstrated a lot of measurement errors, which led stopping further measurement with it.

Profile measurements of ozone and other gases/variables relevant to ozone loss

In the period 1983-1992, balloon ozone soundings were released once a week at the NIMH-Sofia. For that purpose were used ozonesondes OSE – manufactured in the former German Democratic Republic. The activities were interrupted largely due to financial difficulties resulting from transition to market economy. From May- 2001 a Vaisala DigiCORA III –a PC based radiosounding system for measuring pressure, temperature and humidity has replaced the Russian radiosounding system. The present financial status doesn't allow us to expand the measurements of the ozone vertical profiles with the above-mentioned Vaisala system, because of the expensive additional equipment (ozone sensors, special balloons, etc.).

SCIENTIFIC RESULTS

The data , used for the study the total column ozone over Sofia are derived by satellite and recently by "SCIAMACHY", which is an atmospheric sensor aboard the European satellite ENVISAT. The comparison between the monthly variations of the total column ozone over Sofia for 2006 and 2007 is presented at the next Fig.1.

A comparison for the monthly mean magnitudes over Sofia, Rome, Thessaloniki for 2006 (derived by SCIAMACHY/ENVISAT) are presented at the further Fig.2.

Fig.3 presents the comparison for the monthly mean magnitudes of the total ozone (Sciamachy) over Sofia, Rome, Thessaloniki and Turkey (Brewer) 2007. The author would like to acknowledge a favor to the colleagues from the Turkish Met Office for placing their Brewer data for 2007 at our disposal.

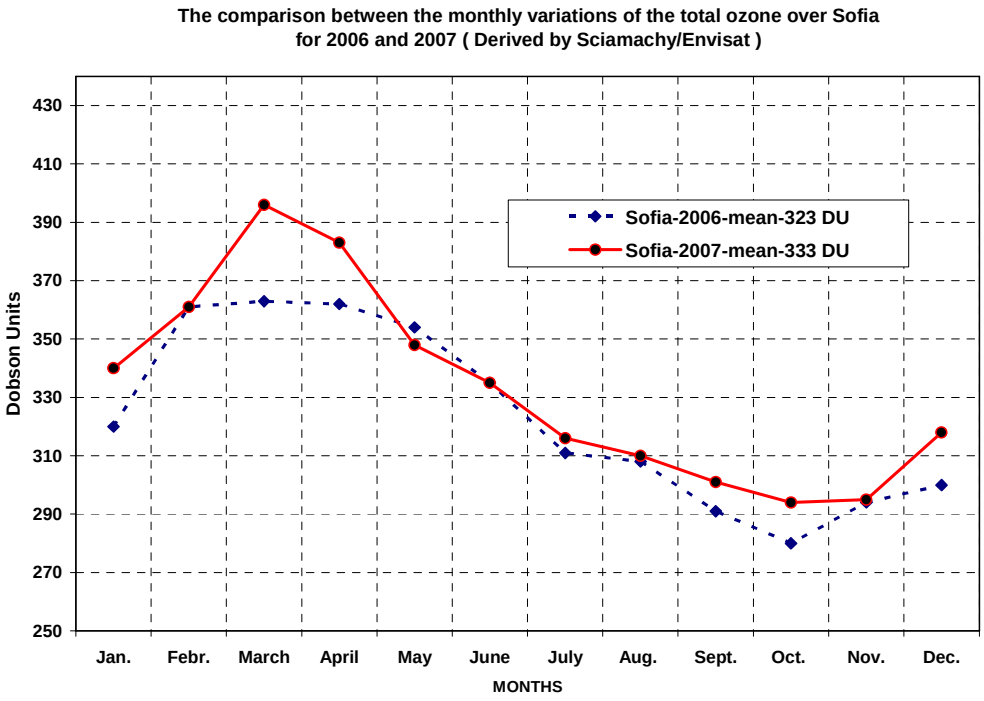


Fig.1

It is clear seen that during 2007, the mean value of the magnitudes of the total column ozone are increased.

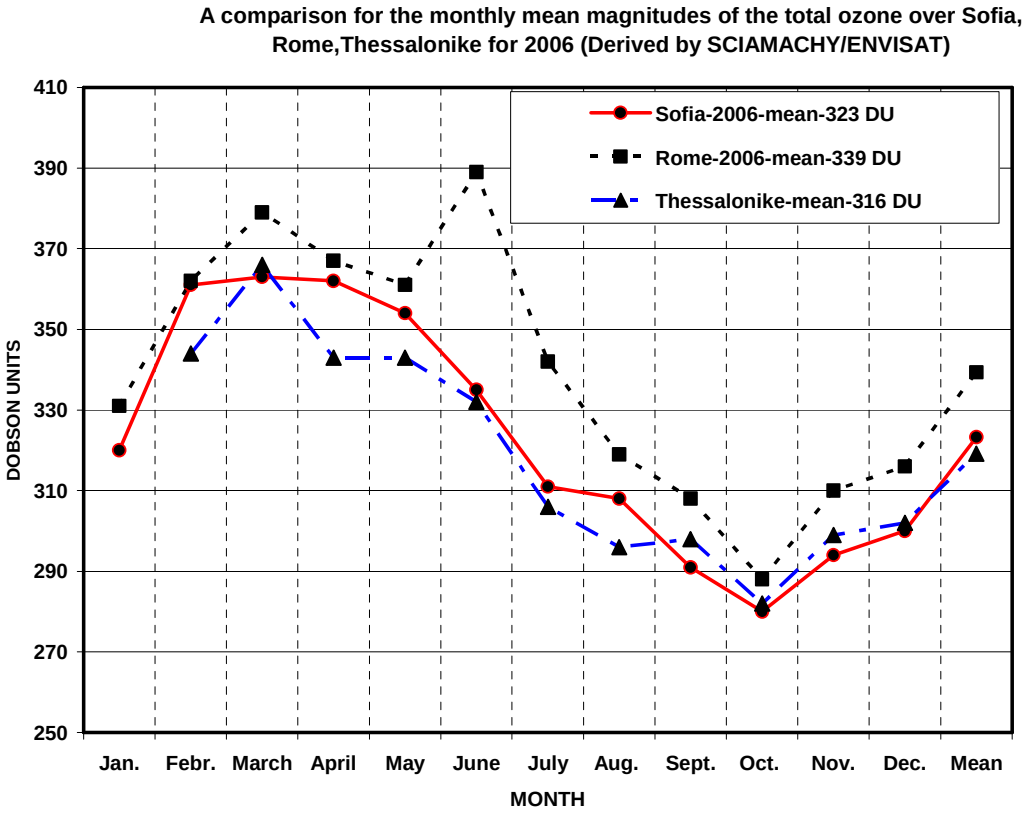


Fig.2

One can see that the annual run for Sofia is very similar to that of Thessaloniki.

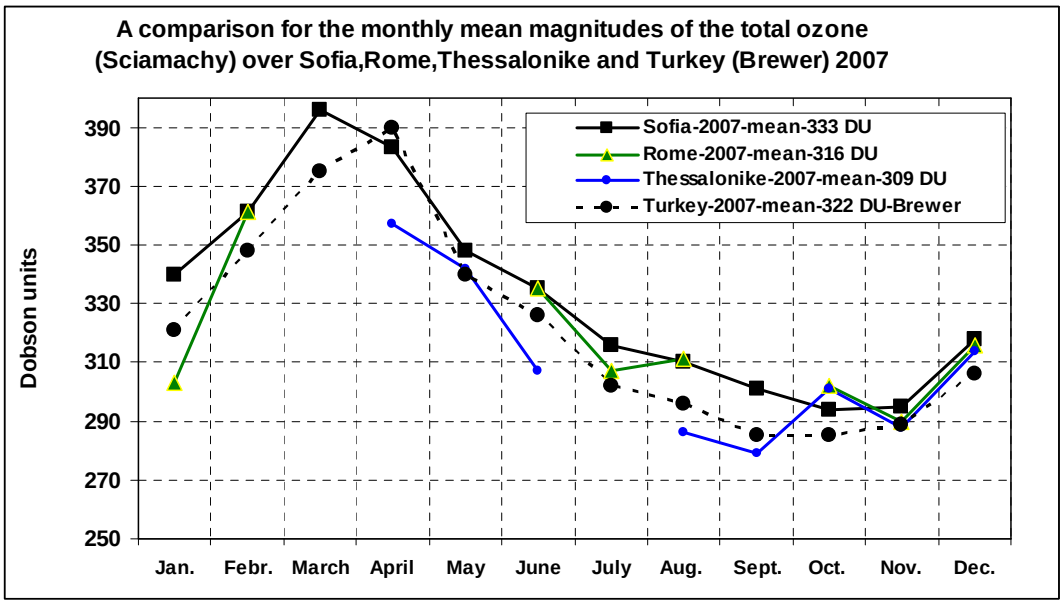


Fig.3

It is obvious that the annual run of the total column ozone magnitudes follows well their seasonal variations and latitude dependence.

Surface ozone

Another important topic is the surface ozone. Initial investigations of the surface ozone in Bulgaria began ten years ago. The following goals were pursued: to evaluate the surface ozone state in Sofia ; to ascertain the diurnal and seasonal ozone variations, ; to investigate ozone behaviour with respect to meteorological conditions.

Site description. The measurements were performed in Sofia, located in the western part of Bulgaria (42^o 49' N, 23^o 23' E, 530 m. a.s.l.). The observation site is about 7 km to southeast of Sofia center and possesses a ground cover of fairly well vegetation. At 100 m distance from the site the road of considerable car traffic runs. The ozone recorder was installed at height of about 10 m above the ground level.

Instrument. The ozone detector used in the investigations is chemiluminescent analyzer, model 3-02P1, OPTEC Inc. The measuring principle of the sensor is arisen in ozone presence chemiluminescence of an organic dye, adsorbed on the solid state composition. The ozone analyzer has the following characteristics: response time is no more than 1 s, the sensitivity is 2 μg/m3. Periodically, the analyzer was calibrated by using an external O3 generator.The measurements were performed mostly at the daylight hours and less regularly in twenty-four hour period. The analysis of the diurnal ozone variations is carried out by using the hourly values of the ozone concentrations determined as 15-min average.

Diurnal variations. The pattern of diurnal variations of the surface ozone concentrations is strongly influenced by meteorological conditions. The pronounced O3 maximum in the daytime, which is explained in terms of vertical mixing process and photochemical ozone production, occurred on clear windless afternoons.

The ozone data show a maximum in summer months , roughly three-four times higher that in winter months. During the fine windy weather the dilution of the atmospheric pollutants takes place. So the decreased ozone concentrations are detected and ozone level is approximately constant throughout the day. However, in the cases when vertical exchange is limited (autumn-winter period, nocturnal inversions) the wind enhances the vertical mixing

and increases the ozone content near the ground. The cloudiness strongly decreases the ozone concentrations near the ground but when it is foggy the ozone content is very low, often zero.

So, the ozone concentrations sensitively reflect meteorological conditions at which measurements are performed. It is very like that more realistic information about temporal and spatial ozone variations may be obtained if ozone data received at similar meteorological situations are analyzed. The surface ozone behavior clearly shows a seasonal variation with a summer maximum.

The variations are indicated by monthly mean, obtained by averaging clear and overcastted days mean concentrations. The minimal, 19-33 μg/m3 ozone concentrations were detected during winter period, the maximal, 50-90 μg/m3 ozone content near the ground was observed in summer months.

Only in windless days diurnal cycle of ozone concentrations displays pronounced maximum in the early afternoon (12:00-14:00 Local Time). The forcing of the wind with increased speed and the cloudiness decreases ozone pollution. Average summertime daylight means at site vary from 100 to 50 μg/m3, depending on meteorological circumstances.

The peak concentrations during photochemical episodes rarely exceeded 125 μg/m3 and are observed a several times during summer season.

It is considered that episodes with high surface ozone concentrations in southern Europe show local character and are associated with local primary pollutant emissions, but in western Europe summer smog is due to long-range transport of ozone and its precursors and so has transboundary character.

Summary :The experimental data from Sofia site and from other sites of Balkan peninsula (with the exception of Athens), for which information is available show that summer ozone concentrations (peak and average) have more lower values in comparison with those, measured in western and central Europe.

In general, the ozone pollution doesn't exceed the EU threshold values. The result is consistent with the model calculations, which show that in spite of the efficiency of the photochemical ozone production (the number O3 molecules per NOx molecule) is higher in southern Europe than in western Europe, the chemical ozone formation per unit area is more intensive in the western part of the Continent due to the high precursors concentrations.

PROJECTS AND COLLABORATION

National project, Peculiarities in the ozon variations and a study of the proceessess which determine them. Project № НЗ 1406, 2004-2007,funded by the Bulgarian Ministry of Education and Science.

NEEDS AND RECOMMENDATIONS

NIMH needs modern equipments for measuring total column ozone and the ozone profiles, UV solar radiation , NOx profiles.

SOFIA UNIVERSITY, DEPARTMENT OF METEOROLOGY AND GEOPHYSICS

At the Departmen of Meteorology and Geophysics, Faculty of Physics in Sofia University the students and the teachers, together with the colleagues from the National Institute of Meteorology and Hydrology and Geophysical Institute work in the fields of Dynamic Meteorology, Physics of Climate, Air polutions, Ozone, Clouds and Precipitation and Thunderstorm electrification .

CITY VERSUS MOUNTAIN TROPOSPHERIC OZONE:

The Sofia-Plana region in an air quality and ecological sustainability perspective.

Status of the Scientific Problems. We started measurements of non-urban O_3 in Bulgaria in 1994 (with the help of RMFRES, Ft. Collins, Colorado, USA) at the Ovnarsko mountain climatology site. This site (influenced by mountain-valley wind flow) is located within the Govedartsi Valley on the northwest slope of the Rila Mountains in southwest Bulgaria (Zeller et al. 1996, 1997; Donev et al. 1996, 1998, 1999). Measurements at a second mountain monitoring site, Rojen, were initiated in October 1998 in the Rhodopa Mountains in south central Bulgaria, on a gentle peak (1700 m above sea level) without 'local' wind flow characteristics. In June 1999 the monitoring equipment at the Ovnarsko site was moved to Ahtopol, a coastal site in southeast Bulgaria close to Turkey, so as to enable comparisons of Rojen O_3 behavior with a remote coastal site, influenced by land-sea wind flows.

The west-to-east transect of these three sites provides a first evaluation of rural-background O_3 in this southern Bulgaria region (Donev et al. 2002). All three sites are located far from densely populated and industrial areas. The analysis of O_3 at these three very different remote sites has demonstrated the impact of local geography and associated wind flows on concentrations. Compared to Rojen (the mountain top site), Ahtopol (the sea-coast site) has overall lower O_3 concentrations and Ovnarsko, the mountain-valley site, experiences higher hourly concentrations. Rojen appears to be the best site for estimating background O_3 concentration values for southern Bulgaria; these have been found to be 46 to 50 ppb (Donev et al. 2002). Later, we found good agreement in seasonal trends and background levels after comparing the time series from Rojen and Ahtopol with the Greek station Livadi. A representative average background ground-near ozone level for the south Bulgaria and north Greece regions is estimated at approximately 48 ppb (Donev 2006). Especially remarkable are data for the short-term (5 days) AOT40 values (for definitions see e.g. WHO 2005) for all maximum-concentration periods over the years 1994 to 1999 in Ovnarsko. Also, during the period from 1999 to 2001 measurements in Rojen and Ahtopol revealed situations with ozone concentrations that were 8 times above the critical level for causing visible injury to field-grown plants. Even more remarkable, even alarming, are the results from the calculations of the ozone stomatal flux F_{st} (based on the model developed in UNECE, 2003, Mapping Manual Revision). The results show that cumulated stomatal ozone fluxes substantially exceed (by a factor of 4 to 8) the critical level over the entire growing season (Donev 2006). Additional results and conclusions from these measurements are in the process of publishing.

The project is organized as a number of interacting work packages:

Instrumental monitoring of ozone concentrations and meteorological parameters:

- Assessment of the AOT40 index
- Modeling the stomatal flux of ozone
- Phytodetection of the ozone presence at phytotoxic levels using bioindicator plants
- Applying statistical analyses of time series of the meteorology parameters and ozone concentrations.
- Monitoring of the height of the atmospheric boundary layer (ABL), spectral irradiance, and aerosols
- Estimations (preliminary) of the energy resources of the solar radiation and the wind regime

Measurements of the above type were started by our team in 2006 at a site in the Central Park of Sofia, and in 2007 at a site in Plana (Central Laboratory of Geodesy). The city site is in the northeastern part of the Central Park of Sofia, the largest forested area inside Sofia. The site is located as far as possible away from buildings. The mountain site is situated in the central part of Plana Mountains. The site is approximately 25 km south of the Sofia site and is relatively far from any industrial activities that generate transport of pollutants coming from the east, south and west. Note that the experimental station "Plana" is prepared for involvement in the World network for long-term scientific ecological research – regional net Europe (ILTER-LTER-Europe).

SOME PUBLICATIONS

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International Association for the Physical Sciences of the Ocean (IAPSO)

IAPSO Activities in Bulgaria
2007 - 2011

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- **Institute for Space and Solar-Terrestrial Research**

International Activities:

ASCABOS - Communications, data and information exchange are the key elements of the operational ocean monitoring and forecasting networks, defined in the Global Ocean Observing System (GOOS). Development of observing and closely related operational forecasting system in the Black Sea region requires the exchange of significant data and information volumes. ASCABOS is designed to strengthen the communication system ensuring flexible and operative infrastructure for data and information exchange between partners and end users.

ASCABOS aims to increase public awareness and to stimulate and motivate the utilization of operational oceanographic information in management and decision-making practices. In the same time, high level of the operational services must be built and retained. ASCABOS will support achievement of these crucial objectives by initiating an educational and training programme designed for young scientists and wide spectrum of end users.

Considerable work has been performed on compiling meta-databases on the Black Sea environmental data, information and research within previous international initiatives and projects. To support and to strengthen the exchange between scientists, governmental managers and other users ASCABOS is planning to combine experiences and instruments in order to develop a Black Sea information system, containing all available metadata, validated and efficiently updated through the Internet.

ASCABOS plans to organize a cost-effective VOS pilot programme, applying modern technologies and developments for data collection, transmission, storage, use and dissemination. The VOS programme will respond to the GOOS demand for long-term monitoring of the marine ecosystems.

SEADATANED - The proposed SEADATANET infrastructure is a Pan-European initiative by major ocean & marine data centres from 36 countries, bordering the European seas, to meet these identified user requirements. It aims at integrating and developing, in the context of new communication technology, past actions carried out to secure, standardize and make in a timely manner, available Pan-European metadata, data and data products. The overall objective is to develop and to provide an efficient Pan-European data management infrastructure for present and future ocean & marine monitoring and forecasting systems for European seas, supporting a large array of users. The specific project objectives are:

- To realise up-to-date catalogues, inventories and transparent access by internet to marine and oceanographic data & information, managed by partners and their national networks;
- To harmonize the quality, formats, access and exchange of these data & information, complying to international standards;
- To strengthen working relationships and improve data exchanges with research users, facilitating the use of available data for developing value-added regional data products;
- To promote the infrastructure and its services to users and to encourage adoption of protocols, standards and tools by other marine institutes.

MyOcean - MyOcean is project which basic goal is the development and pre-operational validation of the GMES Marine Core Service for ocean monitoring and forecasting. The goal will be achieved by providing the best information available on the Ocean for the large scale (worldwide coverage) and regional scales (European seas), based on the combination of space and in situ observations, and their assimilation into 3D simulation models: temperature, salinity, currents, ice extent, sea level, primary ecosystems, etc. The MyOcean service is orientated to a wide range of users in different applicative sectors: marine resources management, climate change, seasonal forecasting, coastal activities, ice sheet surveys, water quality and pollution, oil spill prevention, maritime security, etc. These are the foundation of MyOcean project.

ECOOP- European Coastal Sea Operational Observing and Forecasting System - funded by the European Commission's Sixth Framework Programme, under the priority Sustainable Development, Global Change and Ecosystems.

The goal of ECOOP is to build up a sustainable pan-European capacity in providing timely, quality assured marine service (including data, information products, knowledge and scientific advices) in European coastal-shelf seas. The activities will comprise: Ecosystem models, HAB warning systems, Oil spill and contaminant dispersion and forecast studies, Maritime ship routing applications.

SESAME - Integrated Project supported by the European Commission's Sixth Framework Programme, Sustainable Development, Global Change and Ecosystems.

SESAME aims to assess and predict changes in the Southern European Seas (Mediterranean and Black Sea) ecosystems and in their ability to provide key goods and services with high societal importance, such as tourism, fisheries, ecosystem biodiversity and mitigation of climate change through carbon sequestration in water and sediments. The Mediterranean and Black Sea, are unique and evolve rapidly with large interannual to decadal variability and abrupt fluctuations. For this reason, SESAME will merge economic and natural science in order to study the changes in the Western and Eastern Mediterranean and Black Sea. To this end, it will bridge the gap between natural and socio-economic sciences in order to assess the ability of the ecosystems to sustain these essential functions.

Euro-Argo – European Contribution to Argo program. Funded by the European Commission's Seventh Framework Programme, included in the ESFRI Roadmap

The Euro-Argo array is the European component of a world wide in situ global ocean observing system, based on autonomous profiling floats. The Argo objective is to develop a global array of floats throughout the ice-free areas of the deep ocean, inlcuding the European regional seas.

RIFI - Research Infrastructures: Foresight and Impact - Funded by the European Commission's Seventh Framework Program: Coordination and Support Action

The project aims to develop an integrated framework for the identification of Research Infrastructures (RI) investment opportunities and methods for Socio-Economics impact assessment of new and existing RI. The expected final result of this project will consist of a methodology for the evaluation of the socio-economic impact of investments in RI, whether this be for newly built ones or already existing RI that shall be upgraded or need other types of major investment.

Up-Grade of Black Sea SCENE - The Up-Grade of Black Sea SCENE is a follow-up of the Black Sea SCENE research infrastructure to stimulate scientific cooperation, exchange of knowledge and expertise, and strengthen the regional capacity and performance of marine environmental data and information management, underpining harmonization with European marine data quality control/assessment procedures and adoption of international meta-data standards and data-management practices, providing improved data & information delivery services for the Black Sea region at a European level. The main aim is 1) to improve on-line access to in-situ and remote sensing data, meta-data and products and 2) to adopt standardized methodologies for data quality checking to ensure the quality, compatibility and coherence of the data at Black Sea regional scale.

EUROFLEETS - Quality of infrastructure available for marine research directly affects Europe research results. Thus, marine research infrastructures are considered as key elements of the European strategy for marine research in construction. Coherent pan-European approach with enhanced partnership in investment, development and utilization of the fleet will have a significant impact on better meet the diverse needs of European marine research. EUROFLEETS aim is to bring together European research fleet owners to improve coordination and promote cost-effective use of their facilities. It will support research and monitoring services for the sustainable management of regional seas and oceans, and organize common access to all European scientists only condition for excellence. This will allow the EU to achieve ambitious goals to maintain the biodiversity of the ocean.

Geo-Seas - Geo-Seas will develop an infrastructure of 26 marine geological and geophysical data centres, located in 17 European maritime countries. European researchers will be able to locate and access pan-European, harmonised and federated marine geological and geophysical datasets and data products held by the data centres through a single common data portal. The new infrastructure will be promoted to research communities, and new data products and services will be developed following consultations on research requirements. Geo-Seas will adopt and adapt the existing SeaDataNet research infrastructure to handle marine geological and geophysical data, data products and services, creating a joint infrastructure covering both oceanographic and marine geoscientific data. Common data standards and exchange formats will be agreed and implemented across the data centres. Other geological and geophysical organisations will be encouraged to adopt the Geo-Seas protocols, standards and tools

MICORE - The general aim of the project is to develop and demonstrate on-line tools for reliable predictions of the morphological impact of storm events in support of civil protection mitigation strategies. This is evidently in line with the scientific and environmental interests of Topic: ENV.2007.1.3.1.1, which aims to analyze and map storm related risks in sensitive European regions taking into account intensity, spatial extent, duration, hazard interaction effects. The project is specifically targeted to contribute to the development of a probabilistic mapping of the morphological impact of marine storms and to the production of early warning and information systems to support long-term disaster reduction. A review of historical storms that had a significant morphological impact on a representative number of sensitive European sites will be undertaken. All data will be compiled into a homogeneous database of occurrence and related socio-economic damages. Monitoring of selected sites will take place for a period of one year to collect new data sets of bathymetry and topography using state-of-

the-arts technology (Lidar, ARGUS, Radar, DGPS). Numerical models of storm-induced morphological changes will be tested and developed, using commercial packages and developing a new open-source morphological model. The most important end product will be the production of risk indicators with defined threshold for the identification of major morphological changes and flooding associated vulnerability.

National Activities:

Bulgarian Black Sea Monitoring Programme - Bulgarian Black Sea Monitoring Programme was established to provide accurate description of the present state of the Western part of the Black Sea, provides analysis and forecasts of the sea state, and sets the basis for climate and environmental predictions. The programme started in 1991 with sampling a net of stations planed to cover both coastal zone and open sea and to review key marine physical, chemical and biological parameters. Main goal of the monitoring programme is to collect reliable data and to provide relevant information to the governmental agencies for taking decisions for protection and recovery activities and related to the sustainable development of the coastal zone and Bulgarian part of the Black Sea. As an element of the Global Ocean Observing System, Bulgarian Black Sea Monitoring Programme is a permanent system for observations, modelling and analysis of marine and ocean variables to support operational ocean services.

GALATA - Real-time in-situ meteorological and oceanographic data is exceedingly required for science, marine industry and safety at the see. This data allows assessing the actual seastate and improvement of modeling techniques and forecasts. A pilot open sea monitoring project was initiated by Bulgarian Institute of Oceanology and completed in the frame of public-private cooperation between the Institute of Oceanology and gas exploration company Melrose Resources Sarl. The project targets specific elements of regional monitoring system and the development of end-to-end observing capabilities providing internet access to both real time and historical data. Galata platform real time data is one of the most important sources of multi-parameter operational information in the Black Sea which will serve for monitoring, verification and improvement of modeling results and forecasts as well as for collecting long time series of data needed for climatic research. It also provides useful real time information for marine industry and safety.

POMOS - The operational marine observing system is a network of distributed sensors and centralized data collecting, processing and distributing unit. The system is designed to allow the real-time assessment of weather and marine conditions in the areas of the major Bulgarian ports: Varna, Burgas and Balchik. Real-time information is obtained using various sensors placed at thirteen strategic locations. All instruments are connected to communication system via intranet which provides direct intranet access to the sensors. The measured data are transmitted to the central collecting system, where the information is processed and stored in database. Access to database is through internet/intranet with the help of browsers. Actual data can be displayed on the computer screens using report server supporting thereby Maritime administration to secure safety navigation in bays, canals and ports. The system is developed in the frame of academic-government partnerships and represents an important resource to the Bulgarian ports.

BulArgo - Funded by the Bulgarian National Scientific Fund

The purpose of the project is to develop a new national marine research infrastructure for *in situ* observation in the Black Sea based on autonomous profiling floats. This represents the Bulgarian contribution to the Euro-Argo network, which is a part of the Global Argo programme.

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Tsunami Commission (IAPSO / IAPSEI / IAVCEI)

IAPSO Activities

Institutions:
National Institute of Geophysics, Geodesy and Geography
University of Mining and Geology "St. Ivan Rilski", Department of Applied Geophysics
Institute for Space and Solar-Terrestrial Research

TSUNAMI INVESTIGATIONS – Assoc. Prof. Boyko Ranguelov

In the frame of IUGG tsunami commission the following tsunami research took part in Bulgaria during the time period of 2007-2011.
All activities have been executed according main objectives and tasks of several projects related to the tsunami investigations. Bulgaria activities have been related mainly to the:

- Investigations of the tsunami hazard in the Black Sea (collect data, cataloguing, etc.).
- Investigations of the tsunami event of 7th May 2007
- Investigations of the tsunami environment for establishment of the early warning system

Bulgaria representatives (B.Ranguelov, R.Radichev, G.Mardirosian, E.Rumenina, A Gikov. G. Jelev, V.Naidenova, St. Dimovsky, J.Krumova , et al.) took part in the following Projects:

The TRANSFER Project - Tsunami Risk ANd Strategies For the European Region – FP6 (2006-2010)

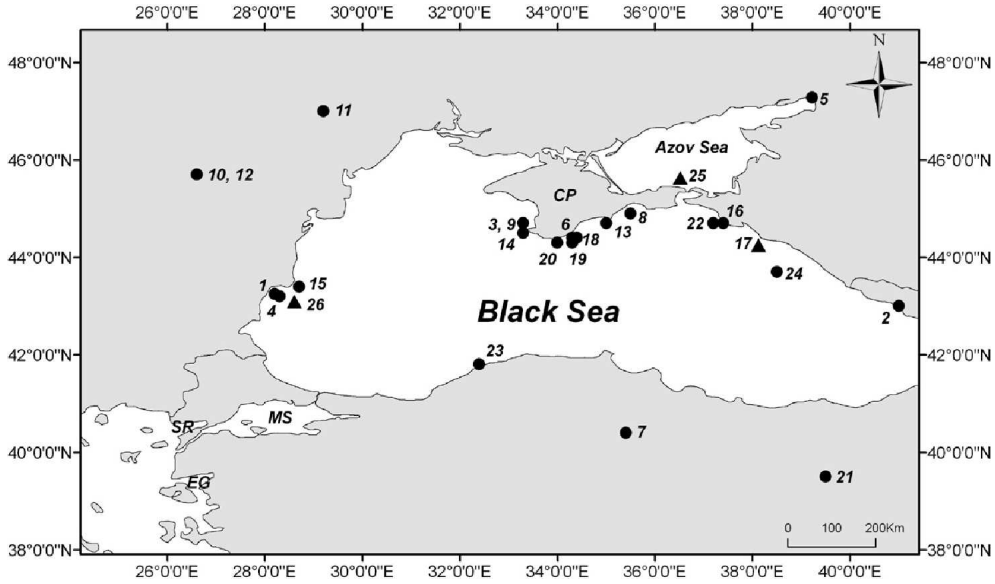
http://www.transferproject.eu/
The project main goal is to contribute to the understanding of tsunami processes in the Euro-Mediterranean region, to the tsunami hazard, vulnerability and risk assessment and to identifying the best strategies for reduction of tsunami risk. Focus was posed on the gaps and needs for the implementation of an efficient tsunami early warning system (TEWS) in the Euro-Mediterranean area, which is a high-priority task in consideration that no tsunami early warning system is today in place in the Euro-Mediterranean countries. The main items addressed by the project are summarized as follows. The present Europe tsunami catalogue is improved and updated, and integrated into a world-wide catalogue (WP1). A systematic attempt is made to identify and to characterize the tsunamigenic seismic (WP2) and non-seismic (WP3) sources throughout the Euro-Mediterranean region. An analysis of the present-day earth observing and monitoring (seismic, geodetic and marine) systems and data processing methods is carried out in order to identify possible adjustments required for the development of a TEWS, with focus on new algorithms suited for real-time detection of tsunami sources and tsunamis (WP4). The numerical models currently used for tsunami simulations are improved mainly to better handle the generation process and the tsunami impact at the coast (WP5). The project Consortium has selected seven test areas (one of them – the entire Black Sea). Here innovative probabilistic and statistical approaches for tsunami

hazard assessment (WP6), up-to-date and new methods to compute inundation maps (WP7) were applied. The Black Sea tsunamis have been modeled from different seismic sources and reasonable results obtained.

Bulgarian Activities:

- Contribution to the tsunami catalogue of the Black Sea (together with G. Papadopoulos and others (NOA-Greece)
- Contribution to the modeling of different seismic tsunami sources (together with Stefano Tinti and others (UniBo-Italy)
- Data set compilation about non seismic tsunami sources according the WP3 of the project

The following products are presented:
The revised tsunami catalogue for the Black Sea and Azov Sea and a map of the tsunami sources follow:



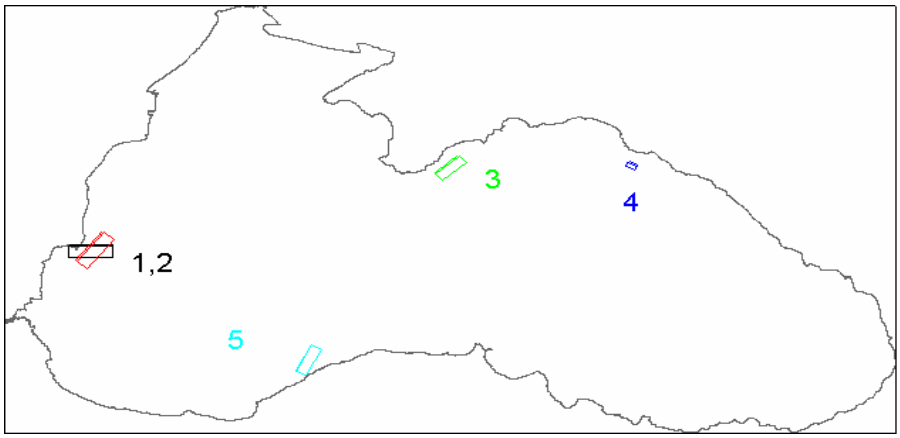
Sources of tsunami generation in the Black Sea and the Azov Sea (for data see the Table). Key: a solid circle is a seismic source, a solid triangle is a gravitative sliding source; CP = Caspian Peninsula, EG = Edremit Gulf, MS = Marmara Sea, SR = Saros Bay.

Table containing data about tsunami CATALOGUE in the Black Sea and Azov Sea is published in Papadopoulos et al., 2011.

These data and information are published in:

Papadopoulos, G. A., G. Diakogianni, A. Fokaefs, and B. Ranguelov., 2011. Tsunami hazard in the Black Sea and the Azov Sea: A new tsunami catalogue., Nat. Hazards Earth Syst. Sci., 11, 945–963, doi:10.5194/nhess-11-945-2011

Seismic tsunami sources and their parameters in the Black Sea:
According the analysis of the seismic catalogues and observed tsunamis several tsunamigenic seismic sources have been outlined and their parameters used for the tsunami generation and propagation have been accepted



Tsunamigenic Black Sea seismic sources and their parameters – next Table

Table of the seismic sources parameters used for the numerical modeling of tsunami generation and propagation.

L (m)	**58000**	**59000**	**41700**	**13200**	**43650**
W (m)	**23500**	**24000**	**20400**	**9120**	**18200**
Strike	**90°**	**40°**	**50°**	**115°**	**28°**
Dip	**40°**	**40°**	**50°**	**50°**	**38°**
Rake	**270°**	**270°**	**270°**	**270°**	**90°**
Slip (m)	**2**	**2**	**2**	**1**	**2**
Position, depth (km)	**28.7°, 43.4°, 2**	**28.7°, 43.4°, 2**	**34.5°, 44.5°, 2**	**37.5°, 44.5°, 2**	**32.17°, 41.9°, 2**
M	**7.2**	**7.3**	**7**	**6**	**7**
Fault №	**1**	**2**	**3**	**4**	**5**

Non-seismic tsunami sources (in this case coastal surface landslides, as potential tsunami generators) have been investigated and their data sumarised in a data base as a part of the activity – WP3 of the Transfer project.
The following Table presents an extract of the original one submitted to David Long (GB) – the coordinator of WP3.

No	Name of the area	lat	long	Area disturbed	Volume	Height in [m]	Depth [m]	Type of survey	Age	Frequency of repeation
1	Yajla	43,4316	28,5412	0,5	<0.1km3	36		geological,	Upper Pleistocene -> present	<10^2 years
2	Tauk-liman	43,4173	28,5167	1,2	<0.1km3	50	10	geological, geochemical	Upper Pleistocene -> present	<10^2 years
3	Kawarnenski	43,4188	28,3205	2,58	<0.1km3			geological,	Upper Pleistocene -> present	<10^2 years

3a	Kalkantepe	43,414	28,284	0,82	<0.1km3	65		geological,	Upper Pleistocene -> present	<10^2 years
4	Balchishki	43,4051	28,2211	7,79	<0.1km3			geological,	Upper Pleistocene -> present	<10^2 years
4a	Baluklar	43,412	28,267	0,6	<0.1km3	100		geological,	Upper Pleistocene -> present	<10^2 years
4b	Ikantuluk	43,406	28,215	1,05	<0.1km3	110	32	geological,	Upper Pleistocene -> present	<10^2 years
4c	Tuzlata	43,405	28,22	1,9	<0.1km3	100	32	geological,	Upper Pleistocene -> present	<10^2 years
4d	Djinibair	(43.4005)	(28.13554)	0,036	<0.1km3			geological,	Upper Pleistocene -> present	<10^2 years
4e	Susambair	(43.392)	(28.1213)	0,023	<0.1km3			geological,	Upper Pleistocene -> present	<10^2 years
4f	Sivritepe	(43.3829)	(28.1057)	(0.02)	<0.1km3			geological,	Upper Pleistocene -> present	<10^2 years
5	The palace	43,4039	28,1482	0,51	<0.1km3			geological,	Upper Pleistocene -> present	<10^2 years
6	Momchilsko	43,3972	28,1369	0,26	<0.1km3	140		geological, geodetical	Upper Pleistocene -> present	<10^2 years
7	Karamanli	43,3896	28,1199	1,19	<0.1km3	80		geological,	Upper Pleistocene -> present	<10^2 years

The SCHEMA Project - Scenarios for Hazard-induced Emergencies Management – FP6 (2007-2010)
http://www.schemaproject.org/

SCHEMA is a research effort which is carried out by a consortium including eleven organizations based in the EU, as well as in associated and MAGREB countries. The partnership aims at using earth observation data in order to develop a generic methodology suitable for helping experts to build vulnerability and hazard impact maps related with the occurrence of tsunamis. The project is coordinated by Geosciences Consultants. The main objective refers to the design and development of techniques for creating vulnerability maps based on intrinsic variables of the stakes facing the hazard (types of building, categories of inhabitants, …), spatio-temporal variables (location of buildings in old areas, access conditions etc) and organizational vulnerability variables, which determine the efficiency of the rescue operations. The hazard scenarios revisited together with end-users and operational personnel in countries recently stricken by coupled earthquakes/tsunamis events. The methodology that was created is based on the data of the Indian Ocean tsunami of 2004 and deployed in the five **SCHEMA** test sites in Portugal, Morocco, France, Italy and Bulgaria. The results of the methodology used GIS techniques, allow the users query the data base and analyze the geographic data sets. Thus realistic representation of the spatial and temporal patterns of vulnerability was obtained for the various coastal areas considered in the project.

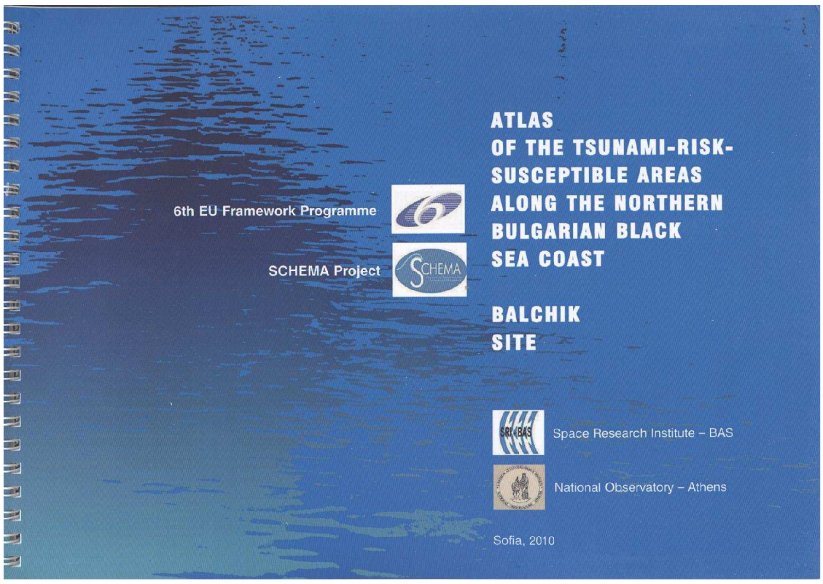
The results are integrated into existing hazard/ exposure analysis techniques in order to support tsunami and related phenomena risk evaluation.
The Bulgaria part includes the creation of an Atlas of the tsunami vulnerability and risk maps, for a test site (town of Balchik) which have been presented to the end-users – administration in Balchik and used in its prevention practice.

Bulgarian Activities:

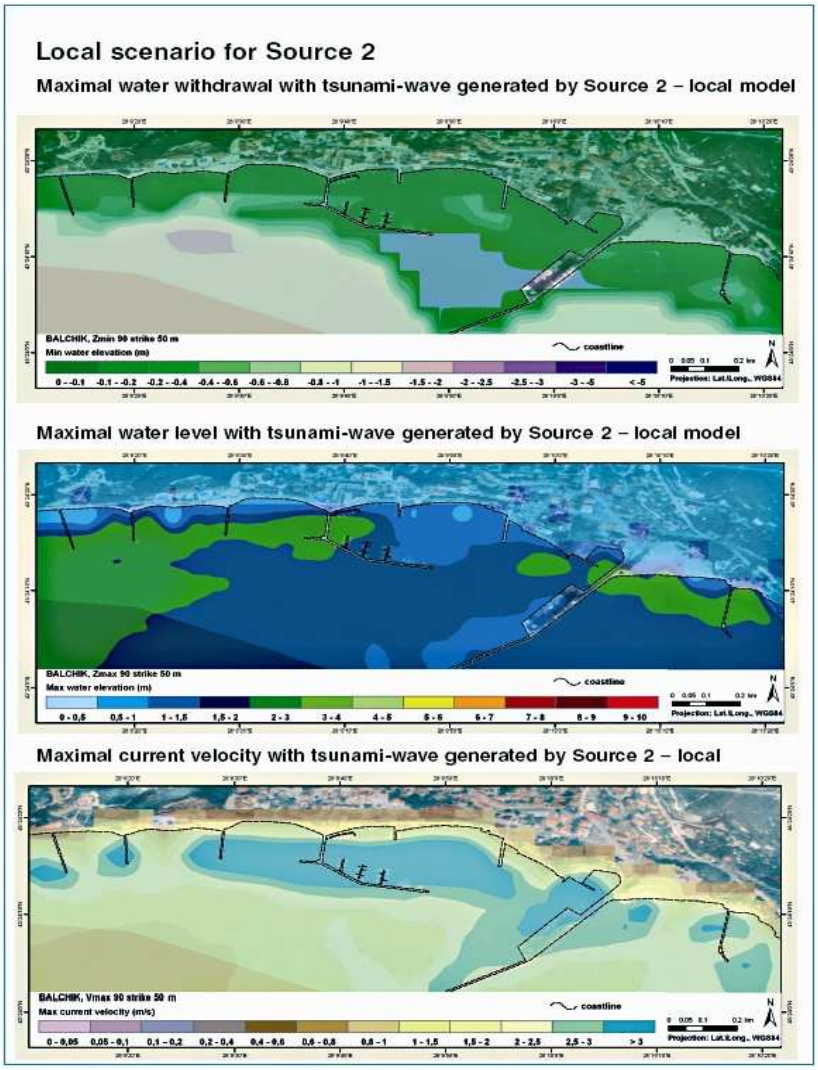
Main tasks:

- To provide sufficient information about the selected test-site of Balchik
- To create DEM in different scales for the tsunami inundation models
- To asses the vulnerability and risk according the accepted unified methodology
- To produce tsunami risk maps for the test site on regional and local level
- To present the created Atlas to the end-users.

All tasks were successfully executed and atlas produced and distributed among end-users: Local and regional authorities, Civil Defense service and scientific community.



The Atlas cover page

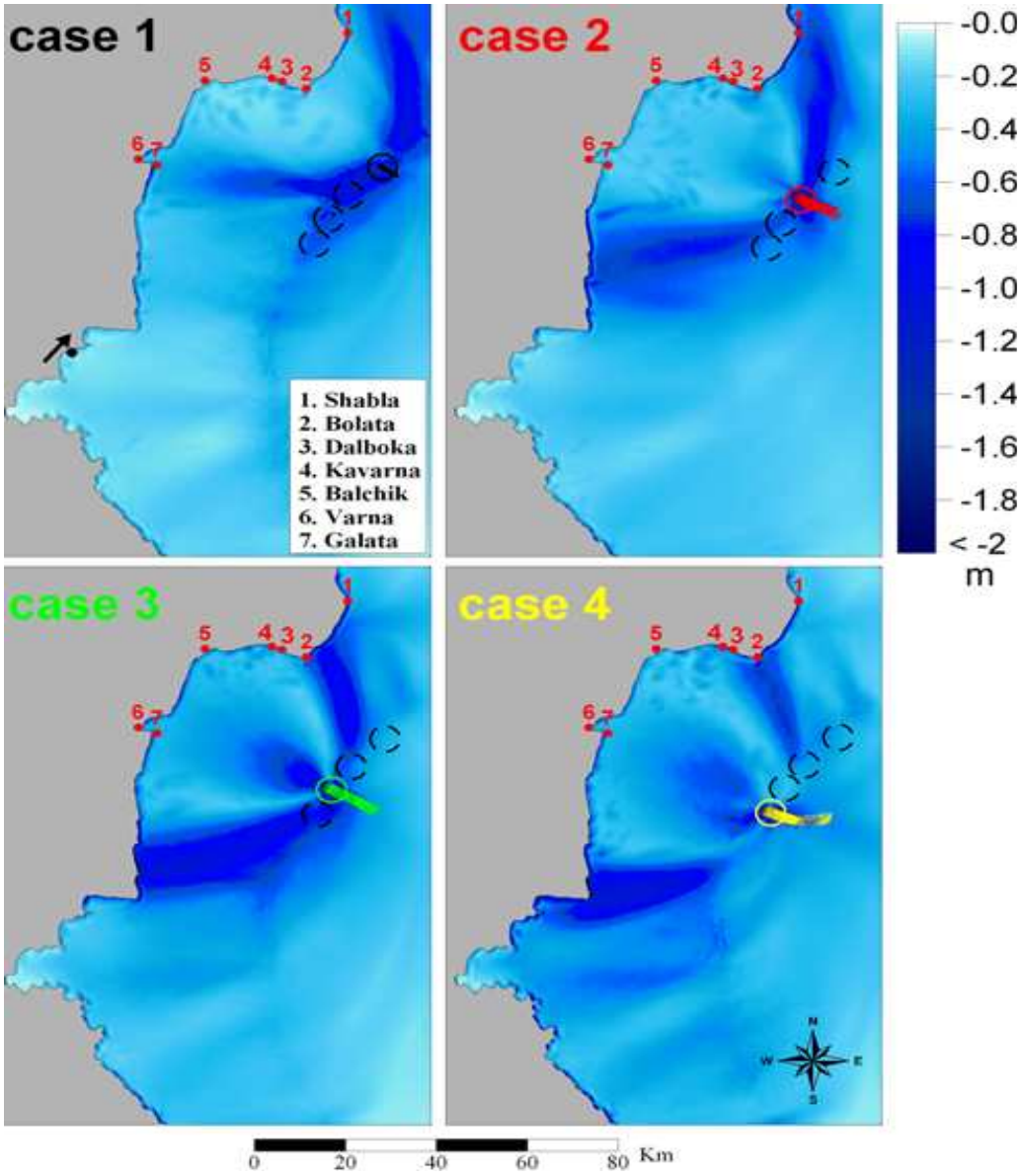


An example of the maps created for the town Balchik test-site - according to SCHEMA Project methodology

In parallel during the project execution a significant nonseisnic tsunami with amplitude of 2-3 meters of the water level occurred at the same test-site area and the investigation of its origin and effects was selected as of a primary Importance:

Nonseismic tsunamis related to the event of 7th May, 2007 have been modeled considering turbidities and meteorological origin. Both models show good correlation with the observations.

The turbidities possible origin was modeled together with the University of Bologna team (Prof. Tinti and collaborators) and results obtained are presented as follows:

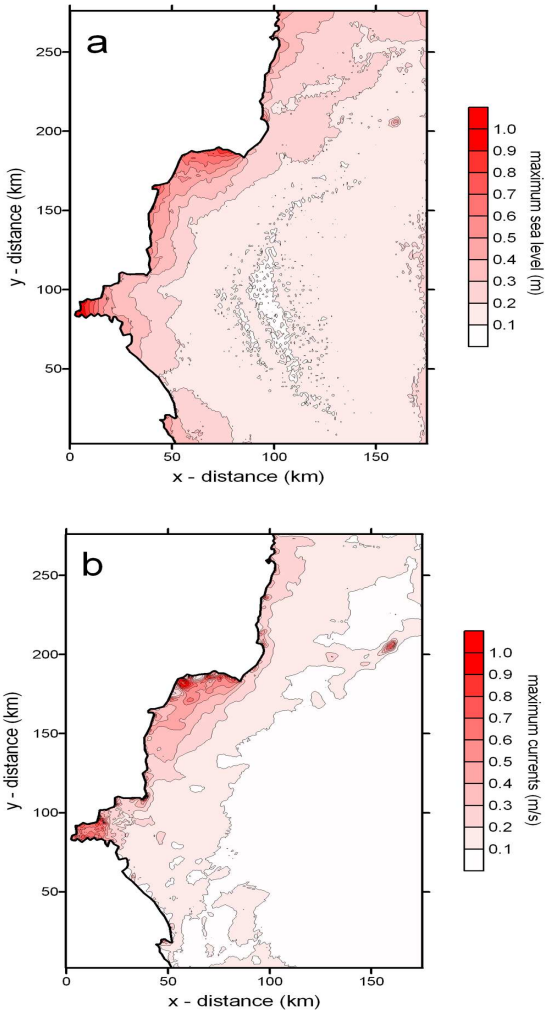


Four hypothetic case-studies and the tsunami heights modeled about the 7th May 2007 event

An interesting result obtained in this study is the beam like shape of the tsunami energy distribution dominated by the bottom and coastal geometry, which is the first case of such a behavior reported about the Black Sea.

The meteorological origin hypothesis was also explored using nonlinear approach to the waves' generation and numerical modeling about the propagation. Data about the synoptic environment were extracted from the satellite information and the bathymetry data from the GEBCO data-base.

The results obtained are presented as follows:



(a) maximal sea level heights and (b) maximal ocean currents about the observed sea level disturbances due to the event of 7th May, 2007.

Both approaches give reasonable results coinciding with the observations. Thus the clear separation of the origin of this interesting event was not possible to be done.

The MARINEGEOHAZARD Project

MARINEGEOHAZARD Set-up and implementation of key core components of a regional early-warning system for marine geohazards of risk to the Romanian-Bulgarian Black Sea costal area – Bulgaria-Romania Cross-boarder cooperation program Romania-Bulgaria 2010-2013, co-financed by the European Union through the European Regional Development Fund

http://www.geohazard-blacksea.eu/

Bringing together the expertise of the two countries – Bulgaria and Romania, the **MARINEGEOHAZARD** project aims for the establishment of a joint regional early-warning system and of a common decision tool, which can support in an efficient manner the emergency managers and decision makers in their activity related to protection of the local communities, environment and assets within the cross-border area, from consequences of natural marine geohazards.

- Project Coordinators: National Institute of Marine Geology and Geoecology – GeoEcoMar (Romania)
- Partners:
- Geological Institute Bulgarian Academy of Sciences (GI-BAS)
- Institute of Oceanology - Varna (IO-BAS)
- National Institute of Research and Development for Earth Physics (Romania)

General objective:

Implementation of an integrated early-warning system accompanied by a common decision-support tool, and enhancement of regional technical capability, for the adequate detection, assessment, forecasting and rapid notification of natural marine geohazards of risk to the Ro-Bg Black Sea cross-border area.

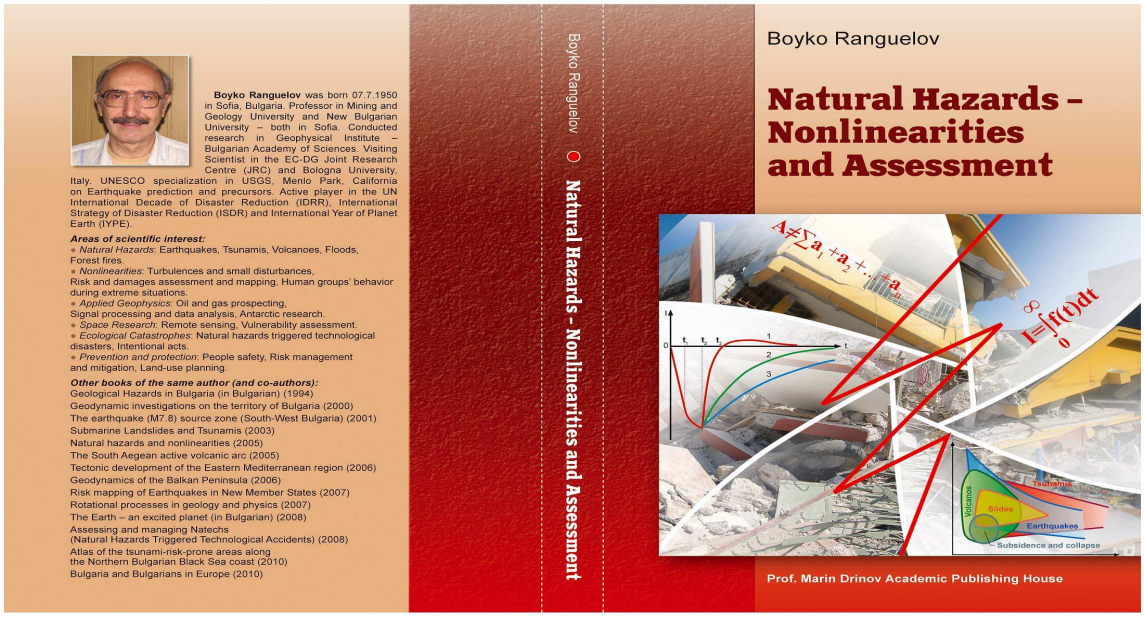
This is a first attempt for such a system creation in the area of the Black Sea thus having pioneer and pilot peculiarities:

Specific objectives*:*

- Define and implement a unified and integrated approach to assessment of marine geohazard of risk for the Romanian-Bulgarian Black Sea cross-border area.
- Install a real-time, fully automatic detection system comprising of deep Black Sea complex measurement stations (gauges), of on-shore marine seismicity monitoring and digitalized GPS stations.
- Implement a common decision-support tool (DST) by provision of unique forecast and assessment software package and development of a joint database of scenarios, to facilitate and support management and mitigation of marine geohazards.
- Create the regional technical capability to perform marine seismic measurements.
- Prepare joint, updatable databank by integrating the existing national data, the real-time data from deep-sea gauges and the on-line data from sea-level gauges, remote sensing and national seismographic networks and by performing coordinated marine geohazard investigations to fill-in the lacking data.
- Cluster and enhance the regional expertise by training the staff and establishment of data exchange platform between national institutions.

Bulgaria partners play equivalent role in the creation and functioning of a center in Varna – Bulgaria (and Constanta – Romania) about an early warning issue in case of marine hazards and risks development on the cross border region of the Black Sea. The Project is in its initial phase and the activities are under development.

The basis about the expected positive results is outlined in a new printed book:



Ranguelov B., 2011. Natural Hazards – nonlinearities and assessment. Acad. Publ. House (BAS), ISBN 978-954-332-419-7, 327 pp.

EU FUNDED INTERNATIONAL PROJECTS ON TSUNAMI RESEARCH WHERE SOME BULGARIA INSTITUTIONS TOOK PART

TRANSFER - Tsunami Risk ANd Strategies For the European Region – FP6 (2006-2010)
http://www.transferproject.eu/

SCHEMA - Scenarios for Hazard-induced Emergencies Management – FP6 (2007-2010)
http://www.schemaproject.org/

MARINEGEOHAZARD - Set-up and implementation of key core components of a regional early-warning system for marine geohazards of risk to the Romanian-Bulgarian Black Sea costal area – Bulgaria-Romania Cross-boarder cooperation program Romania-Bulgaria 2010-2013, co-financed by the European Union through the European Regional Development Fund
http://www.geohazard-blacksea.eu/

List of Publications:

Papadopoulos, G. A., G. Diakogianni, A. Fokaefs, and B. Ranguelov., 2011. Tsunami hazard in the Black Sea and the Azov Sea:a new tsunami catalogue., Nat. Hazards Earth Syst. Sci., 11, 945–963, doi:10.5194/nhess-11-945-2011

Ranguelov B., Mardirossian G., Getsov P., 2008. Tsunami investigations in the Black Sea (Bulgarian experience to the EU SCHEMA Project). Proc. Intl. Conf. Fundamental Space Research., Sunny Beach, 21-28 Sept., 11-14 pp.

Ranguelov B., S. Scheer, G. Mardirossian., 2009, Tsunami investigations – vulnerability and risk assessment to the Bulgarian Black Sea coast., Ann. of M&G University, Vol. 52, Part I, Geology and Geophysics., p. 184-188. ISSN 1312-1820

Krumova, Y., B. Ranguelov, G. Mardirossian., 2010. RISK MAPS PREPARATION AND ATLAS COMPILATION ABOUT BULGARIAN BLACK SEA TSUNAMI ZONES. Proc. Intl. Conf. Geography and regional development., Sofia 2010, pp. 465-472.

Mardirossian G., B.Ranguelov, Y.Krumova., 2010. The Bulgarian participation in the EU SCHEMA Project., Ecological Engineering and Environment Protection., vol.3-4, pp. 92-98. ISSN 1311-8668

Ranguelov, B., S. Tinti, G. Pagnoni, R. Tonini, F. Zaniboni, and A. Armigliato (2008), The nonseismic tsunami observed in the Bulgarian Black Sea on May, 7th 2007. Was it due to a submarine landslide?, Geophys. Res. Lett., vol.35, L18613doi:10.1029/2008GL034905.

Vilibić Iv., Šepić J., Ranguelov B., Mahović N.S., Tinti S., 2010. Possible atmospheric origin of the 7th May 2007 western Black Sea shelf tsunami event, J. Geophys. Res., vol. 115, C07006, 12 pp., 2010, doi:10.1029/2009JC005904

Ranguelov B., 2010. Atlas of the tsunami risk susceptible areas along the Northern Bulgarian Black Sea coast – Balchik site. 25 p. ISBN 978-954-9531-15-2.

Ranguelov B., 2011. Natural Hazards – nonlinearities and assessment., Acad. Publ. House (BAS), ISBN 978-954-332-419-7, 327 pp.

International Association of Seismology and Physics of the Earth's Interior (IASPEI)

IASPEI Activities in Bulgaria
2007 – 2011

National Correspondent: **Assoc. Prof. DSc. Dimcho Solakov**
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Institutions

- **National Institute of Geophysics, Geodesy and Geography**
- **Geoplogical Institute "Strashimir Dimitrov"**
- **University of Mining and Geology "St. Ivan Rilski"**
- **Institute for Space and Solar-Terrestrial Research**

SEISMOLOGY

The National Institute of Geophysics, Geodesy and Geography (NIGGG), http://www.geophys.bas.bg, is the only institution for seismology in Bulgaria, responsible for the earthquake monitoring over the territory of the country and basic and applied researches in seismology. It was established in 2010 as an organization of four former institutions of Bulgarian Academy of Sciences. NIGGG is coordinated by the Bulgarian Academy of Sciences, being budgetary organisation.

Seismological department is a part of NIGGG. Before 2010 Seismological department was a part of Geophysical Institute of BAS, established in 1960. Seismological department includes 23 researchers (8 PhD), 38 technicians and 4 PhD students. It has a wide background in earth sciences research, with focus on seismic source and seismotectonics, lithosphere structure and dynamics, seismic hazard assessment, site effects and microzonation, engineering seismology, assessment and mitigation of seismic risk.

The seismological activities in Bulgaria during the 2008-2011 time interval has been focused on the following main domains:

1) monitoring of natural and induced seismicity;
2) rapid earthquake location, earthquake impact evaluation and information to the responsible governmental and state organization;
3) seismic source modeling;
4) seismotectonics;
5) seismic hazard assessment.

Since Bulgaria is an earthquake prone area, it is of crucial importance to obtain quantitative information needed for seismic risk mitigation and related public policies and seismic safety measures.

NIGGG operates the national seismic network, consisting of 14 stations and two local networks (6 stations) connected in real time with the National Data Center at NIGGG (Figure 1). Continuous digital acquisition of the seismological data has been carried out since 1996 (VTS station). In 2005 all stations have been upgraded with digital aquisition systems. The seismic network has 13 stations equipped with broad-band or very-broad-band seismometers, 7 equpped with short-period seismometers and additionally strong motion instruments are installed at 6 stations (Table 1). The data are collected and transmitted in real time to the National Data Center in Sofia. Three stations (VTS, PLD and JMB) are integrated in the European virtual network. Real-time data exchange is realized with neighbor, other European countries and NEIC-USA.

Data from the national seismic network are collected in real-time using RefTek RTPD protocol and processed with SNDPsoftware (http://www.reftek.com). Real-time data exchange is performed using SeisComP/SeedLink software.

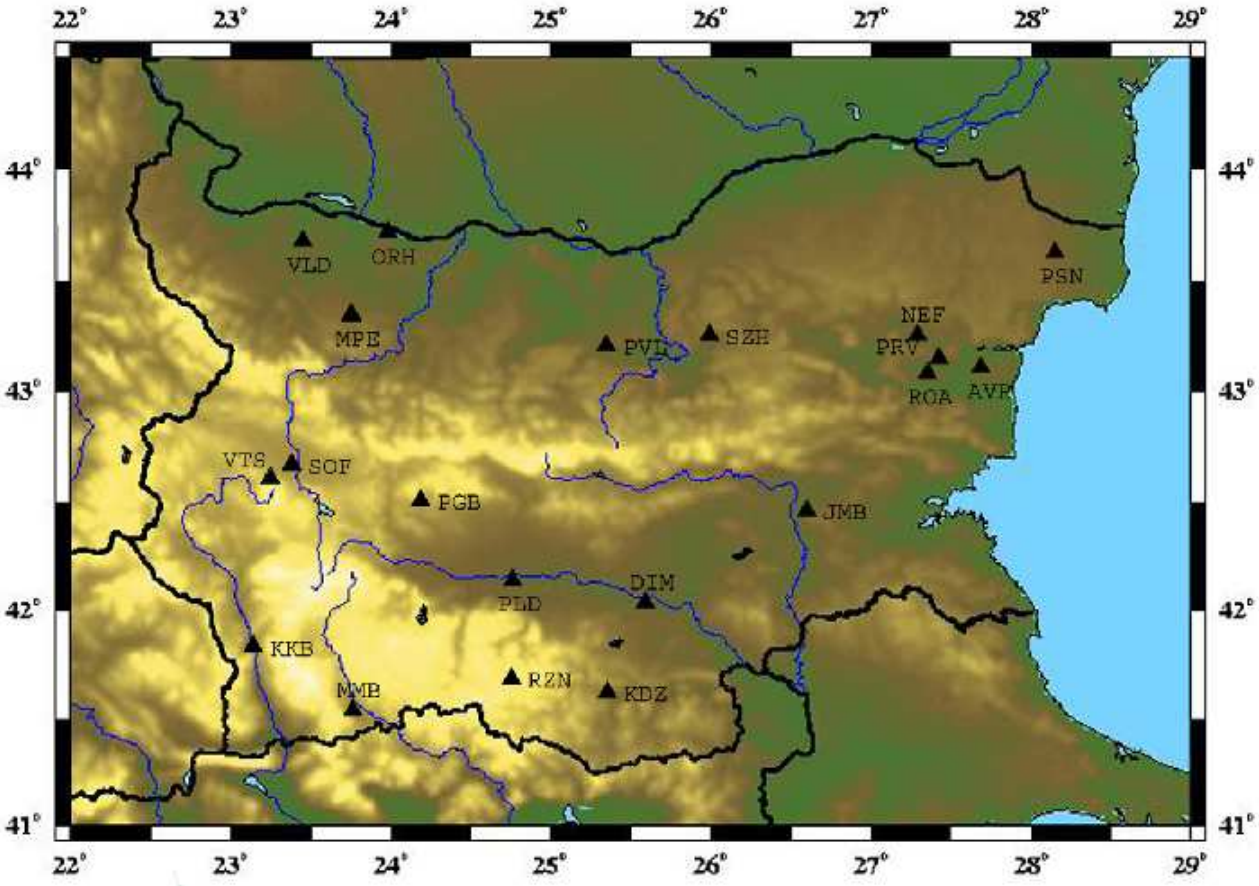

Fig. 1 Map of the current seismological network.

Table 1. Bulgarian Network Stations

Station Name	Code	Lat, N	Long, E	Elev [m]	Sensors	Components	Data acquisition system/sampling rate	Data Transfer
Dimitrovgrad	DIM	42.046	25.577	180	S-13	3C	Reftek 130-01/ 100 sps	RT on VPN
Yambol	JMB	42.491	26.530	246	CMG-40T Reftek 131 - Accelerometer	3C	Reftek 130-01/6 100 sps	RT on VPN
Kurdzhali	KDZ	41.630	25.339	378	CMG 3ESPC	3C	Reftek 130-01/ 100 sps	RT on VPN
Krupnik	KKB	41.842	23.129	476	CMG-40T Reftek 131 - Accelerometer	3C	Reftek 130-01/6 100 sps	RT onVPN
Musomishta	MMB	41.547	23.750	640	STS 2 Reftek 131 - Accelerometer	3C	Reftek 130-01/6 100 sps	RT on VPN

Station Name	Code	Lat, N	Long, E	Elev [m]	Sensors	Components	Data acquisition system/sampling rate	Data Transfer
Panagyurishte	PGB	42.514	24.173	554	CMG-40T	3C	Reftek 130-01/ 100 sps	RT on VPN
Plovdiv	PLD	42.147	24.749	176	CMG-40T	3C	Reftek 130-01/ 100 sps	RT on VPN
Provadia	PRV	43.160	27.410	162	CMG-40T	3C	Reftek 130-01/ 100 sps	RT on VPN
Preselentsi	PSN	43.637	28.136	161	KS 2000 M Reftek 131 - Accelerometer	3C	Reftek 130-01/6 100 sps	RT onVPN
Pavlikeni	PVL	43.217	25.333	97	CMG 3ESPC Reftek 131 - Accelerometer	3C	Reftek 130-01/6 100 sps	RT on VPN
Rozhen	RZN	41.694	24.739	1771	CMG-40T	3C	Reftek 130-01/ 100 sps	RT on VPN
Sofia	SOF	42.683	23.350	546	S- 13	3C	Reftek 130-01/ 100 sps	RT on VPN
Strazhitsa	SZH	43.265	25.976	355	CMG 3ESPC Reftek 131 - Accelerometer	3C	Reftek 130-01/6 100 sps	RT on VPN
Vitosha	VTS	42.616	23.235	1345	STS-1(VBB) CMG 3ESPC	3C	Quanterra 380/ 20sps Reftek 130-01/ 100 sps	RT on VPN

Table 2 Bulgarian Network Stations (Kozloduj local network)

Station Name	Code	Lat, N	Long, E	Elev/Dept [m]	Sensors	Components	Data acquisition system/sampling rate	Data Transfer
Malo Peshtene	MPE	43.356	23.740	347	CMG 3ESPC	3C	Reftek 130-01/ 6 100 sps	RT on VPN
Malo Peshtene	MPEP	43.355	23.72	329	S-13	Z		RT by cabel to MPE
Valchidrum	VLD	43.690	23.436	77/210	S-13	Z	Q330 100 sps (local recording)	RT analogue radio-link to MPE
Oriahovo	ORH	43.726	23.966	231	S-13	3C	Q330 100 sps (local recording)	RT analogue radio-link to MPE

Table 3 Bulgarian Network Stations (Provadia local network)

Station Name	Code	Lat, N	Long, E	Elev [m]	Sensors	Components	Data acquisition system/ sampling rate	Data Transfer
Avren	AVR	43.121	27.666	170	GS-11D	3C	Reftek 130-01/ 100 sps	RT on radio-link to PRV
Nevsha	NEF	43.267	27.274	320	S-13	3C	Reftek 130-01/ 100 sps	RT on radio-link to PRV
Roiak	ROA	43.095	27.382	332	GS-11D	3C	Reftek 130-01/ 100 sps	RT on radio-link to PRV

Three layer network is developed in the data center for real-time acquisition, processing and archiving of the data and for real-time international data exchange (Fig. 2):
1) first layer-real-time data acquisition from all Bulgarian stations and data processing of all data, including foreign station data;
2) second layer- near real-time processing and data storage,
3) third layer - real-time international data exchange.

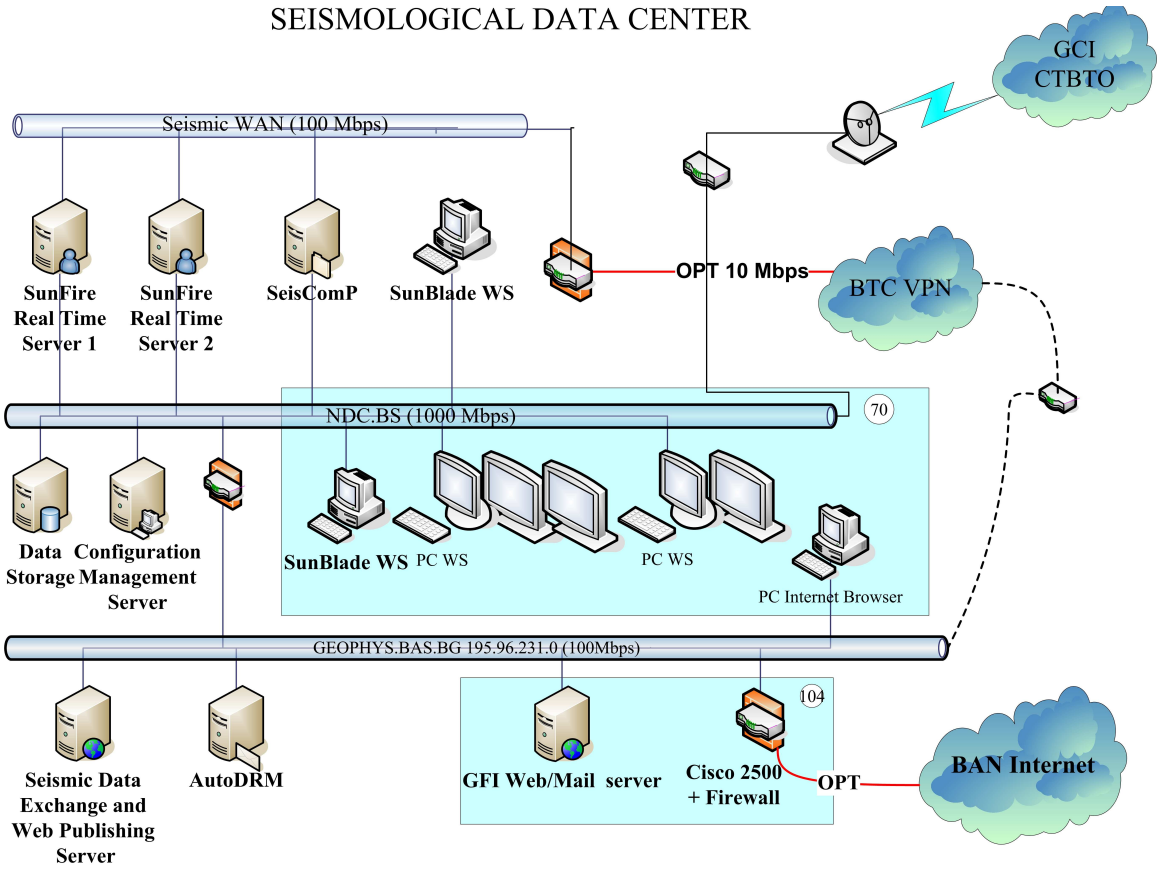

Fig. 2 Scheme of the network for acquisition, processing and exchange of seismological data

Monitoring of natural and induced seismicity

Among the significant achievements in the past years we mention:

- A fully automated and networked system dedicated to digital acquisition and real-time processing of seismological data, as well as to rapid exchange of earthquake information has been implemented. At present, NIGGG participates with 2 BB and 1 VBB stations to the Virtual European Broadband Network. Bilateral real-time data exchange with other national seismological data centers.
- Daily manual reprocessing of the data and preparing of bulletins and catalogues.
- Reliable data arhiving.
- Field investigations of microearthquakes and earthquake sequences.
- Research on natural and induced seismicity.
- Seismic noise evaluation.

Rapid earthquake location, earthquake impact evaluation and information to the responsible governmental and state organization

Very important activity of NIGGG is the rapid earthquake location. At the NIGGG is organized 24 hour duty of 2 specialists (one seismologist and one technician). In case of felt earthquake the information about location, magnitude (in 20 minutes) and macroseismic effects (in 1 hour) are reported to the responsible governmental and state organizations. Annually more than 30 reports are

Seismic source modeling

Modelling the earthquake source is one of the main task with the long-term goal to construct a quantitative physical model for the entire earthquake process, including tectonic stress accumulation, nucleation of rupture, and the dynamics of the rupture propagation and cessation. Integration of the multiple aspects of the earthquake phenomena, from the small scale-scale to large-scale processes is becoming of increasing interest for many researchers.

An important issue is the physical interpretation of the spatial, temporal and size distributions of earthquakes, their clustering and scaling properties. All the information obtained on source parameters and scaling has been used to characterize the main properties of the seismogenic zones of Bulgaria as input data for seismic hazard assessment.

Following one of the main targets of the NIGGG, considerable amount of work has been carried out to model the influence of the seismic source on seismic hazard distribution and to simulate the strong ground motion characteristics in dense-populated areas of Bulgaria.

Seismotectonics

Focal mechanism solutions were analysed in order to determine the stress field and to correlate with the seismicity. The seismotectonic models are implemented in seismic hazard evaluation and drowing up seismic scenarios for some Bulgarian towns.

Seismic hazard

The territory of Bulgaria represents a typical example of high seismic risk area in the eastern part of the Balkan Peninsula. Bulgaria contains important industrial and urban areas that face considerable earthquake risk. Moreover, the seismicity of the neighboring countries, like Greece, Turkey, former Yugoslavia and Romania (especially Vrancea-Romania intermediate earthquakes involving the non-crustal lithosphere), influences the seismic hazard in Bulgaria.

Over the centuries, Bulgaria has experienced strong earthquakes. Some of the Europe′s strongest earthquakes in 20-th century occurred on the territory of Bulgaria. Impressive seismic activity developed in the SW Bulgaria during 1904-1906. Along the Maritza valley a sequence of three destructive earthquakes occurred in 1928. The 1986 earthquake of magnitude M_S=5.7 occurred in the central northern Bulgaria is the strongest quake after 1928.

In the considered period are produsedthe first seismic hazard maps for Bulgaria in terms of peak ground acceleration (PGA) in agreement with EC8. As recommended in EC8, the maps are calculated for a 475 years return period (probability of exceedance of 10% in 50 years) and for a 95 years return period (probability of exceedance of 10% in 10 years). All

information is implemented in GIS. This task dominated the seismological investigations in Bulgaria in the considered period.

Participation of the Bulgarian specialists in working groups involved in national and international projects or programmes

In the past four years the Bulgarian seismology has been actively contributing to:

Framework Programs

EC – 6FP, Project SCHEMA

EC – 6FP, Project TRANSFER

EC – 6FP, Project "CoSEESNet", INTAS

EC – 6FP, Project "SEE-ERA.NET" INTAS

EC – 7FP, Project "Balkan GEO Network – Towards Inclusion of Balkan Countries into Global Earth Observation Initiatives"

International projects – bilateral

Euro-Mediterranian historical macroseismic data arhive - Italy

Study of tectonics and seismicity in strong earthquake zones – Russia

Comparison between modern investigations of surface waves on the Balkan peninsula and Bohemian massive: data, methods, techniques, results – Czech

Danube Cross-border Sustem for Earthquakes Alert" – DACEA – Transboarder cooperation program Romania-Bulgaria 2007-2013, co-financed by the European Union through the European Regional Development Fund

National projects

Members of the Seismological department took an active part in a lot of national projects. The most important is:

Seismic zoning of Bulgaria in accordans with requirement of Eurocode-8 – Seismic zoning maps concerning seismic hazard for the territory of Bulgaria – funded by Ministry of Regional Development and Public Works;

EMIRA: Environmental Monitoring Implement for Risk Assessment of natural and man-made hazard – funded by National Science Fund, Ministry of Education and Science;

PROMIRA – System for monitoring of Provadia salt body – way for evaluation and reduction of natural and technogenic risk – funded by National Science Fund, Ministry of Education and Science.

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Scientific Results of Geological Institute "Strashimir Dimitrov"

Seismicity, neotectonics and active tectonics of Bulgaria and Balkan Peninsula. Paleoseismisic traces in karstic caves.

For the first time in Bulgaria traces of seismic events are established in karstic areas. Eleven targets have been investigated which makes this study one of the largest study of this type in the world. A complex methodology was applied. The results show that in most cases the caves are located in the hanging walls of some faults. Radiometric dating of the events has also been applied.

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UNESCO Project: ***Seismo-hydrogeological vulnerability of the geological environment and the society in the Balkan region***

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Project: ***Structural frame of the Neogene basins of Granada (Spain) and Sofia (Bulgaria) and recognizing of the active faults and their seismic potential*****.** - Joint project with the University of Earth sciences of Andalucía, Spain

Selected Publications:

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Project : ***Segmentation of active faults and seismic hazard in the Thracian low land*** **-** Joint Project with the Royal Observatory of Belgium

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Project: ***Active deformations in the mountain front of the Garvala Himalayas*** **-** Joint project with India.

Project: ***The Burgas - Alexandroupolis oil pipe – estimation of the seismic hazard*** **-** Study ordered by ILF Consulting Engineers (Munich, Germany)

Project: ***Evaluation of the seismic hazard along the gaze pipe NABUKO***

"MARINEGEOHAZARD" - Set-up and implementation of key core components of a regional early-warning system for marine geohazards of risk to the Romanian-Bulgarian Black Sea coastal area - EU collaborative program between Bulgaria and Romania.

Dangerous slope processes related to fault structures 3-D monitoring of active tectonic structures.

Monitoring and prognostic of dangerous geological processes.

Selected Publications:

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Tsunami Commission (IAPSO / IAPSEI / IAVCEI)

IASPEI Activities

Institutions:
National Institute of Geophysics, Geodesy and Geography
University of Mining and Geology "St. Ivan Rilski", Department of Applied Geophysics
Institute for Space and Solar-Terrestrial Research

(TO) Seismic source modeling

Studies of the seismogenic and tsunamigenic abilities of the Sumatra, Chile and Japan seismic sources – Assoc. Prof. Boyko Ranguelov

Two general tasks have been studied especially after the strong earthquakes in Sumatra, Chile and Japan
A) Study of the seismogenic potential of sources generated strong earthquakes – Sumatra, Chile, Japan
B) Study of the tsunamigenic potential of the same sources

A) The comparative analysis done about the sesimogenic and the tsunamigenic potential of the two strong earthquakes (Sumatra 2005 and Chile 2010) near continental plate boundaries – Indian and Sunda plates (Sumatra Island-Indonesia) and South America and Nazca plates (Chile coast) is made concerning their seismogenic and tsunamigenic potential. In the frame of the recent geotectonics, epicenter and hypocenter positions, depths of the seismic events, rupture process and the other parameters considered the explanation about the plate movements is outlined. The first giant earthquake (Mw9.1) generated a huge transatlantic tsunami, which kills more than 200 000 people in many countries around the Indian Ocean, thus appeared one of the greatest catastrophes during the mankind history. The second one (Mw8.8), located to the Chilean east coast produced a very small tsunami (which is absolutely unusual for such size of magnitude), but brought large destructions and more than 1000 deaths on the coastal cities. To know the potential of the subduction seismic zones to produce huge earthquakes able to move suddenly continental plates or parts of them appears of essential importance in view of the recent geodynamics. The geodesy data and information is of primary importance to asses the limitations due to the underwater sources of the earthquakes. The huge areas and volumes of earth's crust destruction delineated by a sequence of the very powerful and numerous aftershocks can help to understand the destructive processes - their size and generic potential. The same methodology incorporatated the Japan 11 March (Mw9.0) earthquake as well as.

The results obtained discover that during the recent years the GPS measurements can help to detect the whole (or the part) continental plate displacements due to the very large earthquakes located in subduction zones. After the discovery of the free oscillations of the Earth, the observations of the effects of big parts of the plates' displacements are the second very great result to confirm the plate movements due to the sudden disturbances. The decrease of the measured GPS horizontal displacements with the distance (for example clearly visible to the Chile earthquake) shows that it is rather difficult to explain the continental pure elastic bodies which have nonlinear behavior. (Ranguelov et al, 2010). The observed attenuation of the displacements observed on far field zones in South America shows that the movements far

from the epicentral area are smaller thus proving the nonlinear behavior of the continental displacements – fact not very frequently considered during the large scale models of the Earth crust and geodynamics.

B) The calculated models about the tsunamigenic effects are presented on the following table:

Date	M	H [km]	H water [m]	E-q-e mech.	H tsu max [m]	Location	Rupture length [km]	Rupture width [km]	Displ. water [km^3]	Energy released [J]
26.12. 2004	9.1	30	500-750	Thrust	37	3,316°N 95,85°E	1200-1300	270	210938	3.35×10^{18}
27.02. 2010	8.8	30	250-300	Thrust	3.7	35 89°N 73 04°E	650-700	100	20719	1.21×10^{18}
11.03. 2011	9.0	25	600-1200	Thrust	15	38 29°N 142 48°E	600-650	500	307190	2.73×10^{18}

The detailed investigations of the results obtained show that the main reason of the tsunami heights differences are the source mechanisms - for all events “trust type”, the water volume displaced (respectively the water depth over the seismic source) and the magnitude (respectively the energy release) of the main shock.

(TO) Seismotectonics

A) **Study of the European and Mediterranean Seismotectonics – Assoc. Prof. Boyko Ranguelov**

A) The Euro-Mediterranean seismotectonic model and its fractal properties have been studied to reveal the fractal properties and coefficients of the seismogenic zones in the Mediterranean Region. The area is divided into several seismotectonic provinces in accordance with the corresponding fragmentation and the specific seismogenic properties of the Earth crust for the separate zones. The Mediterranean seismotectonic model (MSM) is presented by M. Jimenez et al., 2001. The separate zones can be characterized by their specific seismogenic properties which may exert different seismic impact on buildings and constructions. In that way this analysis provides the opportunity for zone identification and comparison between different provinces, each of them being most probably characterized by specific seismic hazard.

To study the fractal properties (distributions and dimensions) we have used the methodology described by Ranguelov earlier.

The classical example of a fractal object is defined by Mandelbrot (1961). If the length of an object P is related to the measuring unit length by the formula

$$P \sim l^{1-D} \qquad \textbf{(1)}$$

then P is a fractal and D is defined as the fractal dimension. This definition was given by Beno Mandelbrot in the early 1960-ies. His ideas support the view that many objects in nature can not be described by simple geometric forms, but they have different levels of geometric fragmentation. It is expressed in irregularities of different scale – from very small to rather big ones. This makes the measuring unit extremely important because measuring of the length,

the surface or the volume of irregular geometric bodies is strongly dependent on the smallest measuring unit in a way that the parameter value changes vary from hundred to thousand orders. This fact was first determined when measuring the coastal line length of West England and it gave Mandelbrot the idea to define the concept of a fractal.

In geology and geophysics it is accepted that defining the different 'fractals' as real physical objects is most often connected to fragmentation. This reveals that each measurable object has length, surface or volume, which depends on the measuring unit and the object's form irregularity. The smaller the measuring unit is, the bigger is the common sum for the linear dimension of the object, and vice versa. The same is valid for 2D and 3D objects.

Another definition of a fractal can be made in terms of the relation between the serial number of measuring to each of the measuring units and the object dimensions. If the number of the concrete measuring with a chosen linear unit is bigger than r, then it may be presented by:

$$N \sim r^{-D} \qquad \textbf{(2)}$$

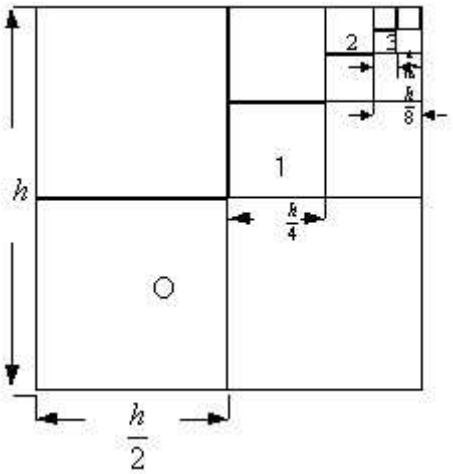
and the fractal is completely determined by D as its characteristic fractal dimension. By applying this definition for the elements of faulting and faults fragmentation, some authors depict formal models of the Earth crust fragmentation (citing foreign authors), which indicate the level of fracturing of the upper earth layers.

The theoretical approach for the linear case and for the 2D and 3D cases was developed by Turcotte et al. (1978). They focused attention on the relations between the smallest measuring unit and object's size in analyzing linear, 2D and 3D objects (illustrated on the Figure).

If l is the measuring unit and with m we denote the obtained value for N at each measuring cycle, then the common sum of the lengths N at level m is:

$$N_m = (1 - p_c)(1 + \frac{n}{m} p_c + [\frac{n}{m} p_c]^2 ... [\frac{n}{m} p_c]^m) \qquad \textbf{(3)}$$

where Pc denotes the probability for measuring each length for the corresponding cycle of measuring.



2D fractal scheme

By using formulae 1 and 2 of Turcotte, we obtain the formula:

$$\frac{N_{m+1}}{N_m} = 2^D \qquad \textbf{(4)}$$

and

$$\frac{N_{m+1}}{N_m} = \left(2^2\right)^D \qquad \textbf{(5)}$$

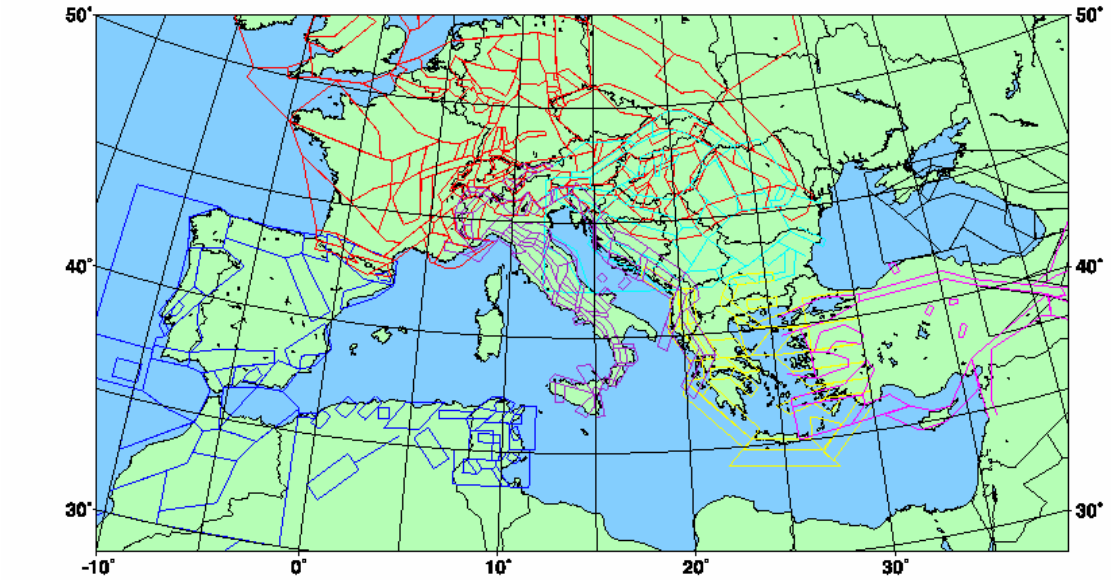
On the basis of this approach, we studied and analyzed the elements of the Mediterranean seismotectonic model and compared them with the Balkans seismotectonic model. The existence of different geometrical objects of similar type like the different seismic hazard zones in various Mediterranean areas makes it suitable to use such an approach when determining the fractal features of the considered seismotectonic models.

To study the fractal features of the Mediterranean seismotectonic model offered by M. Jimenez et al. (2001), we have used data from the map (Seismicity Source Regions for the Mediterranean Region). The map scale is 1:28 000 000.

We have determined the number and the size of all lines delineating each of the surface elements of the model. The error in determining the size is less than 5%. The authors of the map have divided the region into several seismotectonic provinces (we follow their denoting):

- The Adriatic (AD)
- Central and West Europe (CWE)
- The Pyrenees and West Africa (PWA)
- Greece (GR)
- Bulgaria and the Northern Balkans (BG NB).

Each province was considered separately at first. Finally some general studies have been made for the whole Mediterranean region.



The Euro-Mediterranean seismotectonic model (acc.Jimenec, 2002)

The lengths of the delineating elements for each seismotectonic zone vary between 100–500 km (very rarely they are bigger, but the number of such cases is small enough). Cumulative plots have been developed in order to calculate the fractal dimension of each zone.
The obtained results for the different provinces (zones) are presented on the next Table:

Fractal dimensions about the linear (D_L) and surface (D_S) elements of the investigated seismotectonic model are presented at the following table:

Zone	$D_{(L)}$	$D_{(S)}$
AD	2,71	1.67
CWE	1,12	0.41
PWA	1,18	0.24
GR	0.94	0.40
BG NB	1.20	0.25
All zones	1.23	0.38

Same approach has been performed about the Balkan Seismotectonic model and similar results obtained.

(TO) Seismic hazard

A) Practices and measures for the reduction of natural disasters risk – Assoc. Prof. Boyko Ranguelov

Some specific measures decreasing seismic hazard have been developed as a product of an EU Project, *Identification and collection of implementation-oriented technological and organizational practices and measures for the reduction of natural disasters risk (2008)*. Many examples are presented in table format, including different types of useful information – from physical properties and possible negative consequences, through research and implementation bodies, up to the cost of the respective prevention measure.

The main attributes included are:

- hazard name;
- impact elements (impact mechanism, impact effects);
- hazard measuring scales (units, ranges of impacts);
- destructive potential;
- time duration;
- impacted area;
- some important web sites containing essential information.

The specific measures and practices considered include:

- data and information about the type of the prevention, description;
- source of information;
- positive and possible negative effects;
- availability and applicability of the measure/practice;
- case studies;
- target groups (end-users);
- expert opinions and publications;
- future development and international perspectives.

All parts comprise tables, explanatory texts, illustrations. Web-based platforms including similar and/or more detailed information are sometimes incorporated at the respective positions.

The information can be used by the decision makers, Civil Protection Service managers, local and governmental authorities in EU and worldwide.

Measures and implementation practices on earthquake risk reduction have been compiled and synthesized.

To facilitate understanding and for the sake of a common approach, the respective hazard information is presented separately, too.

Each measure expresses the synthesized knowledge and experience of the international community acquired and used in different countries.

The terminology used makes the information easily acceptable by end users – Civil Protection authorities, regional and local administrations, the population.

International Project:

JRC-Contract No 252334 "Identification and collection of implementation-oriented technological and organizational practices and measures for the reduction of natural disasters risk", 2007.

List of Publications:

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