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I. Main duties of the research unit in 2014

Basic research in geodesy and geophysics is centered on observation, modeling and interpretation of the physical state and processes of the Earth system, furthermore elaboration and development of the theoretical basis and analytical tools. The main duties also include the operation of the Hungarian National Seismological Network and supporting services, continuous monitoring of the solid Earth and Earth's environment (geodynamics, geomagnetism, aeronomy), operation of permanent and temporal observation systems and participation in international observation networks and cooperation. In connection with the basic research, the institute contributes to the analysis of geological and geophysical natural hazards and risk assessment.

Funding, including the EURISGIC FP7, TAMOP project entitled "*Scientific analysis of Earth-system data and the popularization of knowledge with the help of information technology"*, furthermore the *MTA infrastructure* and *MTA support for EU and national grant proposals for research institute* grants provided the possibility to start new research projects in the institution. Outstanding projects focus on research on the deep structure of the solid Earth, effects of the Sun-Earth interactions on global changes, and development and geodynamic implication of the satellite-based radar interferometry technology.

II. Remarkable research and other results in 2014

a) Remarkable research and other results

Complex observations of geodynamic processes by surface and space geodetic methods. After the GNSS technology, the new generation techniques of the geodetic position determination and movement studies are the satellite techniques based on radar interferometry (InSAR – Interferometric Synthetic Aperture Radar). Vertical ground motion can be determined by centimeter precision by InSAR technique using the GNSS reference system. The new space geodetic tool in ground motion studies is the *ESA Sentinel-1A satellite.* The images acquired by the satellite became available to the public in October 2014.

The aim of the recently started radar interferometry research – supported by the MTA Infrastructure grants – is to build up an infrastructure where the classic high precision geodetic observations are supported by ascending and descending SAR observations. Subsequently, new routines are planned to be developed for the optimal processing of the acquired ascending and descending satellite distance variation and GNSS (or other geodetic) data.

Plans for the integrated geodynamic benchmarks were finished. This includes design of the geometric and electromagnetic parameters of the truncated, twin corner reflectors, which can be used in both ascending and descending satellite directions, furthermore additional (GNSS, classical geodetic, and gravimetric) survey markers are planned on the benchmarks. A local geodynamic network of four points was established near Sopron, in order to methodically

analyse the different analytical techniques. The average estimated errors of the parameters in the data processing were determined using the basic relations of interferometry. Satellite radar interferometry provides a high precision estimate on the line-of-sight variation, however, the reconstruction of the 3D movement cannot be adequately determined even by using two satellites.
The geometric information content of ascending and descending surface changes estimated by satellite radar interferometry was also investigated. A numerical method was developed to derive two components of the changes in observation plane which can be estimated unambiguously. Monte-Carlo simulation verified that the precisions of computed changes are not sensitive to one degree random error of positional directions. These 2D changes can be transformed into vertical and eastward changes, but they are biased if significant northward movement occur during the observation periods.

Gravity field modeling. Development of a digital zenith camera was started for the hexapod platform of the "Lendület" research group of the MTA CSFK Astrophysical Institute. The hexapod platform based camera is suited for the high precision determination of the normal vectors of the equipotential surfaces of the gravity field. The accuracy of tilt angles of the optical axis of the digital zenith camera were investigated as a function of the limited horizontal rotation (max. 60°) of the hexapod platform. Determinations of tilt corrections and normal points are proven to be $\leq \pm 0.1''$ accurate with the maximum rotation range of the hexapod platform, provided the accuracy of the tilt measurement is at least $= \pm 0.05''$. It is sufficient for the use of deflection of the vertical data in geodetic applications.
The spectral contribution of the horizontal gradients from Eötvös torsion balance measurements was investigated based on synthetic data processed in modified kernel solutions of gradiometric boundary value problems. Special attention was paid to the convolution integrals transforming horizontal gradients to vertical gradients, to gravity anomalies and to disturbing potential, analyzed both in space and frequency domain. For Hungary, the contribution of horizontal gradients is remarkable at medium and short wavelengths components ($300\ \text{km} \geq \lambda \geq 30\ \text{km}$) of the spherical harmonic composition of the Earth's gravity field.
Gravitational tide observations used for geodynamic constraints require high precision determination of the scale factor of the gravity meter. Therefore, the methodology of calibration of spring gravity meters in the tidal range was investigated by developing algorithms for the time and space dependent consistency check of scale factor of spring gravity meters. It was analyzed both for moving mass calibration and inter-comparison with synthetic tidal effect. Systematic effects were observed which currently make it difficult to determine the scale factor with an accuracy of less than 1%.

Mathematical problems of geodetic location determination. A global model for 3D, 7-parameter (Helmert) nonlinear similarity transformation was developed with several distinct solutions for the scale factor, and the Bursa-Wolf model is included as a special case. These results were obtained by applying different principles in order to solve the overdetermined system of equations obtained for the scale factor.
The restriction on the common points in the outer orientation problem of photogrammetry was eliminated, and a general mathematical model of the problem was also given. The main difference between the new and the conventional method is in the way the scale factor is treated: in the old method the scale factors are treated only indirectly (not used), but in the new method an individual scale factor is explicitly determined for every point. The new procedure developed for the outer orientation is more effective and faster, and it eliminates the

difficulties inherent in the conventional methods: it does not require Taylor-expansion, approximate values, and iteration.

Geophysical Inversion, Modeling. Several geophysical methods are used in the research of the Earth and near-Earth space by the institution. From a mathematical point of view, modeling means the numerical solution of a given partial differential equation. Geophysical inversion estimates the model parameters based on the measured data and derived parameters by assuming a particular model. Recently, two and three dimensional geophysical data processing techniques are more commonly used in case of complex structures. One dimensional inversions are considered as solved problems. However, in the study of inversion algorithms, it is worth to focus on 1D inversions, as some of the properties of the inversion can be better described in these cases. Qualitative analyses of the geophysical model parameters determined by linearized inversion were carried out in general. The inversion is based on the singular value decomposition of the Jacobi matrix. The mathematical parameters which help to determine the quality of the inversion are the correlation matrix, a resolution matrix, SVD eigenvalues and the standard deviation of the model parameters. The conclusions are relevant to 2D and 3D models as well.

Magnetosphere and Space Physics. In the frame of the EU FP7-Space "PLASMON" project, the automated whistler detector analyzer system (AWDANet) was installed on 16 stations around the globe. This complex system runs in real-time since the middle of 2014 and provides – for the first time and uniquely in the world – the electron density values of the Earth's plasmasphere. This data is crucial for describing and understanding the plasma physical processes of the near-Earth space, and in addition, this is fundamental in the real time observation of the space weather.
Satellite data (measurements from the THEMIS/ARTEMIS, Cluster and Geotail satellites) and the results of *magneto-hydrodynamic computer simulations* were used during the analysis of an event (recorded on 19th of November, 2010). During the event the solar wind pressure increased radically and its direction also changed. This combination of events led to a so-called forced reconnection in the geomagnetic tail. This kind of reconnection was predicted before based on theoretical basis but this is the first time when this kind of event was studied in such a detail.
The transition zone at the *Earth's bow shock* was studied in the framework of an international cooperation project. This is the location where the solar wind plasma meets the Earth's magnetosphere. Previous simulation results showed a fluctuation or pulsation of ion density distribution in the velocity space. These fluctuations could be detected in spacecraft data which means that the theory and simulations predicted a real phenomenon. This is the first time when this phenomenon was observed in satellite based data.

Aeronomy. Directions of lightning sources were determined based on ELF (extremely low frequency) transients recorded at Széchenyi István Geophysical Observatory and data recorded by WWLLN (global lightning detection network). Research on the difference between the directions showed that the magnitude of differences depends on the direction of the source and has diurnal variations in local time. The symmetry of the variations related to the source directions corresponds to the changes of the conductivity of the upper crust at the observing site. The variations in local time can be related to the changes of the ionospheric conductivity profile (~50-120 km).

Frequency (f_{min}) variations deduced from ionograms (Digisonde DPS4; Pruhonice) in June 20, 2013 were compared with lightning parameters (time, polarity, peak current) recorded by LINET network as well as the time points of the transient luminous events. It was concluded

that the short-term electron density anomalies in the D layer were related more to the red sprites formed above the thunderstorm than to the lightning discharges of the highest intensity.

Absence of the ionospheric sporadic E-layer was observed when red sprites occurred above the thunderstorm, which indicates the considerable decrease of electron density. This decrease can be related either to the gravity waves generated by thunderstorms or the attachment of the electrons to the meteoritic dust particles accelerated by the electrostatic field above the thunderstorms.

Determination of the Lithosphere-Asthenosphere Boundary (LAB) beneath the Carpathian-Pannonian region based on integrated geophysical and geochemical/petrologic approach. The LAB is defined by the changes of different geophysical parameters, such as the change in velocity of the seismic waves, the direction of the seismic anisotropy, the sudden increase of the electrical conductivity, and/or geochemical composition of the upper mantle. The Carpathian-Pannonian region is an excellent test area for LAB research, due to the five upper mantle xenolith-bearing Plio-Pleistocene alkali basalt locations. One of these locations is the Nógrád-Gömör Volcanic Field, which is located in the northern Pannonian Basin. The depth of the LAB beneath the Nógrád-Gömör Volcanic Field was determined by 1D inversion layer modeling of magnetotelluric (MT) data obtained at 14 MT stations. The LAB is estimated to be at ~65-80 km. 3D distribution of the seismic parameters (P and S wave velocities, S waves anisotropy) were determined, then subsequently were compared to SKS anisotropy data from the literature. Results show that not only the lithosphere, but also the asthenosphere is anisotropic.

Imaging of the ionospheric current fields, geomagnetism. The mathematical model of the ULF range surface electromagnetic variation as explicit function of the parameters of the source current system geometry, and using 1D subsurface electric conductivity distribution, was derived. It was proven that the variation of the source wavenumber within a realistic range has a significant influence on the relation between the primary and secondary fields.
Average daily polarization pattern of the geomagnetic and telluric fields was determined based on 4-year continuous registration of geomagnetic and geoelectric field at the Széchenyi István Geophysical Observatory. The polarization direction of the fields was determined as experimental function of the frequency and the local time (T=2-128min, LT = 0-24h). The interpretation of the results was provided in accordance with the well-known magnetospheric and ionospheric source mechanisms of Pc5-Pc6 period range.

Development of geoelectrical methods. While certain tensor invariants (ρ_{det}, ρ_{ssq}, ρ_{trace}, ρ_{I1}) are sensitive to the one-dimensional changes of the subsurface resistivity distribution (that is, to changes in one direction of the coordinate system) other invariants provide information about the changes in two (I_{2D}), or three directions (I_{3D}). They are called 1D, 2D and 3D invariants, respectively. It was shown that the anomalies become smaller and smaller both in their size and amplitude with increasing the number of dimensions of the tensor invariants, making their detection and interpretation more and more difficult. 1D invariants turned out to be the most invariant, while 3D invariants the least invariant during fieldwork. Even though most of the studied models was 2 or 3 dimensional, 1D invariants provided the best results. 2D invariants were the least useful according to the results of the study. However, as it was shown, interpretation of 2D and 3D invariants may provide further information of the study area, therefore it is recommended to include them in addition to the 1D invariants.

Environmental physical study of the Quaternary sedimentation. Results of the paleo-transport reconstruction history of the Austrian last glacial loess deposits is best described by a two-step model. The zircons in the loess deposits were first suffered fluvial transport then a subsequent secondary eolian reworking and transport in saltation. Consequently, the heavy mineral spectra of loess are strongly influenced by fluvial processes, their directions and zircon fertility of rocks drained by these rivers. At the same time, paleowind directions may have only a subordinate role in defining loess heavy mineral compositions. Thus, reconstructed paleo-transport routes primarily denote fluvial directions, while paleowind directions only subordinately. These latter directions should mostly be viewed as strongly hypothetic.

Seismotectonics, seismic hazard assessment. Determination of the amplitude of the paleo-earthquake induced peak horizontal ground acceleration was continued. The results of the previous, analytical calculations based on simplified modeling and parameters obtained by physical measurements of rocks were compared to new, finite element modeling, which allowed to consider the realistic shape of the stalagmite. The peak ground acceleration was examined by purely theoretical approach and also by functions based on real measurements.
Measurements of microseismic noise and active and passive seismic measurements were carried out for the seismic hazard assessment of Budapest. Applicability of the method based on cross-correlation of the noise on a local scale was examined. The resonance frequencies of different buildings were determined, and areas where ground-building resonance phenomenon might be expected were identified.
A complex method was developed for the separation of earthquakes and quarry blasts, which includes the hypocenter data, investigation of amplitude ratios of different phases, the waveform similarity, and the characteristics of spectra. The Mahalanobis distance was used to select the most suitable parameter combinations.

Theoretical seismology studies. The depth of the crust/mantle boundary (Moho) and the LAB was studied beneath the Nógrád-Gömör Volcanic Field using teleseismic data of three seismological stations, BUD (Hungary), PSZ (Hungary) and VYHS (Slovakia). Computations were carried out using P and S-wave data of teleseismic events with epicentral distances between 60° and 85°. Based on the IASP91 velocity model, the depths of the Moho and the LAB are given at 25 (+/- 5) km and 65 (+/-10) km, respectively.
The full moment tensors of 22 local earthquakes in Hungary were successfully estimated using a probabilistic waveform inversion procedure. Only strike-slip and thrust faulting events were found, hence supporting the hypothesis that the Pannonian Basin is currently experiencing a compressional regime of deformation. The azimuth of the sub-horizontal P principal axis varies from about NNE-SSW in SW Hungary through NE-SW well inside the basin to around E-W in the NE part of the country. Most of the analyzed earthquakes occurred on faults or sub-faults differently oriented than the main fault system.
Mantle convections. The effect of the Rayleigh number and the temperature and depth dependent viscosity on the properties of mantle plumes were studied by 3D numerical modeling. The plume radius decreases as a power law function of increasing Rayleigh number and temperature-dependence. Temperature anomaly decreases as the temperature dependence increases. The geoid anomalies as the function of Rayleigh number have a maximum, and the location of this maximum depends on the actual strength of depth and temperature dependence.

b) Dialog between science and society

Risk assessment, hazard prevention and forecast of vulnerable geological structures and the Sun-Earth physical connections, in addition seismotectonics are the basic duties of the GGI. Key tasks of the institute are the operation of the *Hungarian National Seismological Service* and diagnosis of the near-Earth space. Extreme variations, geomagnetic storms in the Earth's plasma environment caused by solar flares are becoming increasing risks to modern telecommunication technologies, navigation and energy transfer systems. The institute plays an important role in the EU project concerning the vulnerability of the integrated European critical infrastructures.
In addition to continuously providing up-to-date data and consulting with the National Directorate General for Disaster Management, the GGI has also been invited to participate in the work of the interdepartmental committee responsible for the completion of the national risk assessment. According to the agreement with the National Directorate General for Disaster Management, the GGI provided the risk assessment of events related to seismotectonics and space weather for the national report submitted to the European Council.
Residential reports and expert opinions are provided for the national damage prevention program, based on the cooperation between ORFK, MTA CSFK GGI and AEGON. The cooperation aims to reduce space weather and environmental physical, geological and geophysical hazards.
In addition to the social networking sites of the Kövesligethy Radó Seismological Observatory, a mobile application has also been developed. The app aims to reach the wider population in order to provide reliable information about the earthquakes in Hungary, and to collect more data for seismological research on the local effects of earthquakes.

III. A presentation of national and international relations in 2014

Conrad Observatory, Austria: collocated gravimetric measurements;
Massachusetts Institute of Technology: aeronomy, Schumann resonance research;
Ilmatieteen Laitos: geomagnetic induction, magnetotelluric deep soundings;
Natural Environment Research Council (BGS, Edinburgh): processing archive observatory recordings;
Polar Geophysical Institute of the Kola Scientific Center of Russian Academy of Sciences: geomagnetically induced currents in power transmission lines;
The Catholic University of America, NASA Goddard Space Flight Center: solar wind-magnetosphere coupling mechanism;
Thunderstorm effects on the Earth-Ionosphere System (TEA-IS) European Science Foundation Research Networking Programme: aeronomy, observation and analysis of electro-optical emissions appear in the upper atmosphere;
Laboratoire de Physique et Chimie de l'Environnement et de l'Espace (LPC2E) / CNRS; Institut de Recherche en Astrophysique et Planétologie, Université de Toulouse: magnetosphere and magneto-hydrodynamic research;
INTERMAGNET: international geomagnetic observatory network;
ETH Zürich: participation in the AlpArray project
ELTE TTK Lithosphere Fluid Research Laboratory: magnetotelluric deep sounding and study of mantle xenoliths in the framework of the lithosphere-asthenosphere boundary research.

Guest scientists from abroad:
Andrew Hooper, Leeds University;
Karsten Spaans, Leeds University;
Markku Poutanen és Hannu Ruotsalainen, Finnish Geodetic Institute;

Christian Hirt, Curtin University, Australia;
Alexandru Szakacs and Agnes Gal, Sapientia Hungarian University of Transylvania and Universitatea Babes-Bolyai;
Vincent Courtillot, IPGP, Paris Diderot University;
Earle Williams, Massachusetts Institute of Technology.

A total of 15 research scientists spent 5 months in the institute.

Scientists of the institute working for a longer period abroad:
Postdoctoral fellow: 1 scientist.
Within the framework of research cooperation 5 scientists of the institute spent a total of 6.25 months abroad.

Organisation of local scientific program
KLIR – Energy budget constraints on the greenhouse effect; lecture session at MTA, May 21, 2014;
III. KP-LAB (Carpathian-Pannonian Lithosphere-asthenosphere boundary) workshop in Sopron, October 8, 2014;
KLÍR - Dangerous global warming: myth or reality? On scientific discovery, consensus and debate: a personal experience. Lecture session by Prof. Vincent Courtillot at MTA, October 29, 2014;
IX. Geomatika Seminar, Sopron, November 13-14, 2014;
Closing conference of the TAMOP project entitled “Scientific processing of the Earth system data and socialization of the results using up to date IT methods”: NYME Ligneum Visitor Center, Sopron, November 26, 2014.

Organisation of international scientific programs
InSAR – Theory and application worshop by prof. Andrew Hooper on March 17-21, 2014
Atmospheric Electricity: Exploitation of the Global Circuit for Climate and Space Physics workshop by prof. Earle Williams - 4 sessions on October 14, 21, 28, and November 4, 2014.

Activities in higher education in Hungary (not on a regular basis):
Habilitation board; PhD board of examiners: 5; OTDK – adjudicator: 1, opponent: 3.

Activities in higher education in Hungary (on a regular basis):
ELTE TTK: 15 courses on theory;
NyME (EMK, KTK, FMK): 24 courses on theory, 7 courses on practice;

Lecturing in universities abroad:
BBTE, Klasenburg/Cluj: 2 course on theory, 1 course on practice.

Regular staff member in a doctoral school:
NyME EMK Pál Kitaibel Doctoral School of Environmental Sciences: 2 scientist;
NyME József Cziráki Doctoral School of Wood Sciences and Technologies: 1 scientist;
NyME KTK István Széchenyi Management and Organisation Sciences Doctoral School: 1 scientist.

Teaching in a doctoral school:

BME Pál Vásárhelyi Civil Engineering and Earth Science Doctoral School: Internal Structure of the Earth, Geophysical Data Processing.

ELTE Doctoral School of Earth Sciences: Study of space weather processes by ULF-VLF electromagnetic waves.

NyME József Cziráki Doctoral School of Wood Sciences and Technologies: Measure theory; Digital image processing.

NyME EMK Pál Kitaibel Doctoral School of Environmental Sciences: Modeling of Geodynamical Processes, Application of GNSS systems to environmental sciences, Measurements of Environmental Movements, Methodology of the Scientific Research, Solar Activity and Weather, Geomagnetism; Space weather and climate; Atmospheric electrodynamics; Earth structure and processes.

NYME KTK István Széchenyi Management and Organization Sciences Doctoral School: Theory of statistical analysis.

Supervising (TDK study):
NYME GEO: 1 student;
ELTE TTK: 1 student.

Supervising (BA, BSc diplomas):
ELTE TTK: 5 students;
BME EOK: 1 student.

Supervising (MA, MSc diplomas):
ELTE TTK: 5 students;
BME EOK: 1 student
NYME: 1 student
PTE: 1 student.

Supervising (PhD dissertation):
ELTE TTK Doctoral School of Earth Sciences: 4 students;
NYME Doctoral Schools (EMK, KTK, SKK): 8 students.

IV. Brief summary of national and international research proposals, winning in 2014

Participation in the AlpArray international project (Support for EU and other international and national grant proposals for research institutes). Budget: 60.993 MFt, acquisition of seismological stations required for participation.
The Alp Array is the largest geophysical project in the past few decades. The project was proposed by ETH Zürich, and several leading European institutes participates. The aim of the project is mapping the deep structure of the Alps and its surrounding by seismological network with high station density. The expected results are the geodynamic and seismotectonic models of the region.

Preparation for the *European Gravitational Wave Infrastructures Integration* proposal (Support for EU and other international and national grant proposals for research institutes). Budget: 16.8 MFt, acquisition of analytical instruments for geophysical environmental study.

Support for consortium building for*H2020-PROTEC-2015: Protection of European assets in and from space* proposal (Support for EU and other international and national grant proposals for research institutes). Budget: 4.127 MFt.
Inversion module for the AWDANet international whistler observatory network(MTA Infrastructure Funding). Budget: 3 MFt.

Multisensory monitoring of tectonically active areas (MTA Infrastructure Funding). Budget: 14.7 MFt
Focused, regional and local scale observation of tectonically active areas by development of the current infrastructure.

GEOMAGICA – Geomagnetic Induction in the Alps (Austrian Scientific Research Fund). Budget: 10 kEUR.

V. List of important publications in 2014

Bányai L, Mentes Gy, Újvári Gy, Kovács M, Czap Z, Gribovszki K, Papp G: Recurrent landsliding of a high bank at Dunaszekcső, Hungary: Geodetic deformation monitoring and finite element modeling. GEOMORPHOLOGY 210: 1-13. (2014)
http://real.mtak.hu/10279/

Eper-Pápai I, Mentes Gy, Kis M, Koppán A: Comparison of two extensometric stations in Hungary. JOURNAL OF GEODYNAMICS 80: 3-11. (2014)
http://real.mtak.hu/18894/

Hirt C, Papp G, Pál A, Benedek J, Szűcs E: Expected accuracy of tilt measurements on a novel hexapod-based digital zenith camera system: a Monte-Carlo simulation study. MEASUREMENT SCIENCE AND TECHNOLOGY 25:(8) Paper 085004. (2014)
http://real.mtak.hu/13777/

Klimov S, Ferencz C, Bodnár L, Szegedi P, Steinbach P, Gotlib V, Novikov D, Belyayev S, Marusenkov A, Ferencz O, Korepanov V, Lichtenberger J, Hamar D: First results of MWC SAS3 electromagnetic wave experiment on board of the Chibis-M satellite. ADVANCES IN SPACE RESEARCH 54:(9) 1717-1731. (2014)
http://real.mtak.hu/20598/

Szalai S, Lemperger I, Metwaly Mohamed, Kis A, Wesztergom V, Szokoli K, Novak A: Multiplication of the depth of detectability using gamma 11n arrays. JOURNAL OF APPLIED GEOPHYSICS 107: 195-206. (2014)
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http://real.mtak.hu/19889/

Újvári G, Varga A, Raucsik B, Kovács J: The Paks loess-paleosol sequence: A record of chemical weathering and provenance for the last 800ka in the mid-Carpathian Basin. QUATERNARY INTERNATIONAL 319:pp. 22-37. (2014)
http://real.mtak.hu/18812/

Viljanen A, Pirjola R, Pracser E, K Juri, W Magnus: Geomagnetically induced currents in Europe Modelled occurrence in a continent-wide power grid. JOURNAL OF SPACE WEATHER AND SPACE CLIMATE 4:Paper A09. (2014)
http://real.mtak.hu/20470/

Z Vörös, G Facskó, M Khodachenko, I Honkonen, P Janhunen, M Palmroth: Windsock memory COnditioned RAM (CO-RAM) pressure effect: forced reconnection in the Earth's magnetotail. JOURNAL OF GEOPHYSICAL RESEARCH A - SPACE PHYSICS 119:(8) 6273-6293. (2014)
http://real.mtak.hu/20121/

Wéber Z, Süle B: Source properties of the 29 January 2011 ML 4.5 Oroszlány (Hungary) mainshock and its aftershocks. BULLETIN OF THE SEISMOLOGICAL SOCIETY OF AMERICA 104:(1) 113-127. (2014)
http://real.mtak.hu/17244/