HUNGARIAN NATIONAL REPORT ON IAG 2007-2010

J. ÁDÁM[1]

This report outlines the activities of Hungary in geodesy for the period January 2007 to December 2010. It has been prepared for submission to the International Association of Geodesy (IAG) at its General Assembly in Melbourne, Australia during the XXVth General Assembly of the International Union of Geodesy and Geophysics (IUGG) on 27 June – 8 July, 2011. It is issued on behalf of the IAG Section of the Hungarian National Committee for IUGG.

Since the last XXIVth General Assembly in Perugia, Italy, July 2-13, 2007 there have been some minor changes in the list of members of the IAG Section of the Hungarian National Committee for IUGG. Currently the National Correspondent to the IAG is also the Chairman of the IAG Section. The members of the IAG Section for the period of 2007-2011 are as follows: J. Ádám (*Chairman*), L. Bányai (*Secretary*), Á. Barsi, P Biró, T. Borza, G. Csapó, I. Fejes, I. Joó (died in 2008), A. Kenyeres, Gy. Mentes, G. Papp, Sz. Rózsa, Gy. Tóth, P. Varga, L. Völgyesi, and J. Závoti.

Cooperating institutions in the field of IAG in Hungary are as follows: *a)* Department of Geodesy and Surveying, Budapest University of Technology and Economics (BME) (http://www.geod.bme.hu); *b)* Satellite Geodetic Observatory of the Institute of Geodesy, Cartography and Remote Sensing, Budapest-Penc (http://www.sgo.fomi.hu); *c)* Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences (HAS), Sopron (http://www.ggki.hu); *d)* Faculty of Geoinformatics, University of West-Hungary, Székesfehérvár (http://www.geo.info.hu); *e)* Eötvös Loránd Geophysical Institute of Hungary, Budapest (http://www.elgi.hu), and *f)* Mapping Service of the Hungarian Defence Forces, Budapest.

The national report has been divided into commissions corresponding to the new structure of IAG. The commission reports are compiled by the authors indicated in brackets, who are responsible for the content of their corresponding reports, namely I. Commission 1 „Reference Frames" (A. Kenyeres, T. Horváth, Gy. Grenerczy, S. Frey and T. Borza), II. Commission 2 „Gravity Field" (L. Völgyesi, G. Csapó and G. Papp), III. Commission 3 „Earth Rotation and Geodynamics (Gy. Mentes and P. Varga), IV. Commission 4 „Positioning and Applications" (Gy. Mentes, Sz. Rózsa and Á. Barsi), V. Inter-Commission Committee „Theory" (J. Závoti and L. Bányai) and VI. Communication and Outreach Branch (J. Ádám, Sz. Rózsa and Gy. Tóth). This report would not be possible without their efforts.

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I. Commission 1. (Reference Frames)

(Ambrus Kenyeres, Tamás Horváth, Gyula Grenerczy, Sándor Frey and Tibor Borza,
FÖMI Satellite Geodetic Observatory)

1. Geodetic infrastructure

The Hungarian GNSS reference station infrastructure and services have been established by the GNSS Service Centre (GSC) of the Institute of Geodesy, Cartography and Remote Sensing (FÖMI). The installation phase of the GNSSnet.hu reference station network development commenced in 2002. This process has come to an end in 2009, when all 35 Hungarian stations of the network became operational. In addition to the Hungarian sites, observation data of 19 stations from the neighbouring countries is collected and processed in real time to provide a truly nationwide coverage with homogeneous cm accuracy. The average inter-station distance is less than 60 km, enabling accurate modelling of distance-dependent errors like ionosphere, troposphere and orbits between the stations. All of the Hungarian stations and most of the integrated external sites are equipped with state-of-the-art GPS+GLONASS hybrid sensors and individually calibrated choke ring antennas. Some of the units are also Galileo ready.
The GNSS Service Centre uses the GNSMART network RTK software package of Geo++ GmbH to provide reference data for both real-time and post mission applications.

Real-time data is provided via the Ntrip protocol in various formats:

- single station DGNSS data in RTCM 2.1 and RTCM 3.0 formats,
- single station RTK data in RTCM 2.3, RTCM 3.0 and CMR formats,
- network RTK data in RTCM 2.3, RTCM 3.1 and CMR formats.

All major network RTK concepts (PRS, FKP and MAC) are supported.

RINEX and virtual RINEX data is provided for post-processing via the GSC website in RINEX version 2.11 format.

More than 660 organisations registered for FÖMI's GNSS services. In 2010 the number of registered user accounts exceeded 900. The majority of land surveying tasks in Hungary are carried out using real-time GNSS technique. The number of simultaneously connecting RTK and network RTK clients often exceeds 100.

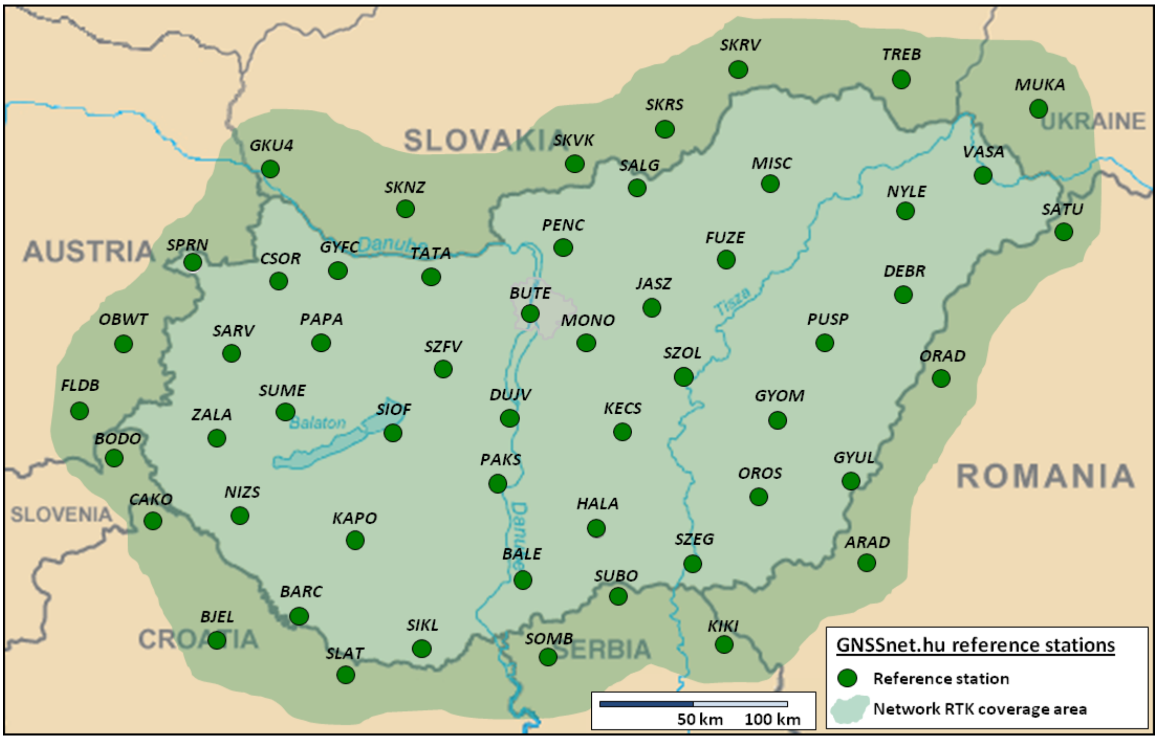

Fig. 1. Sites of Hungarian Active GNSS Network

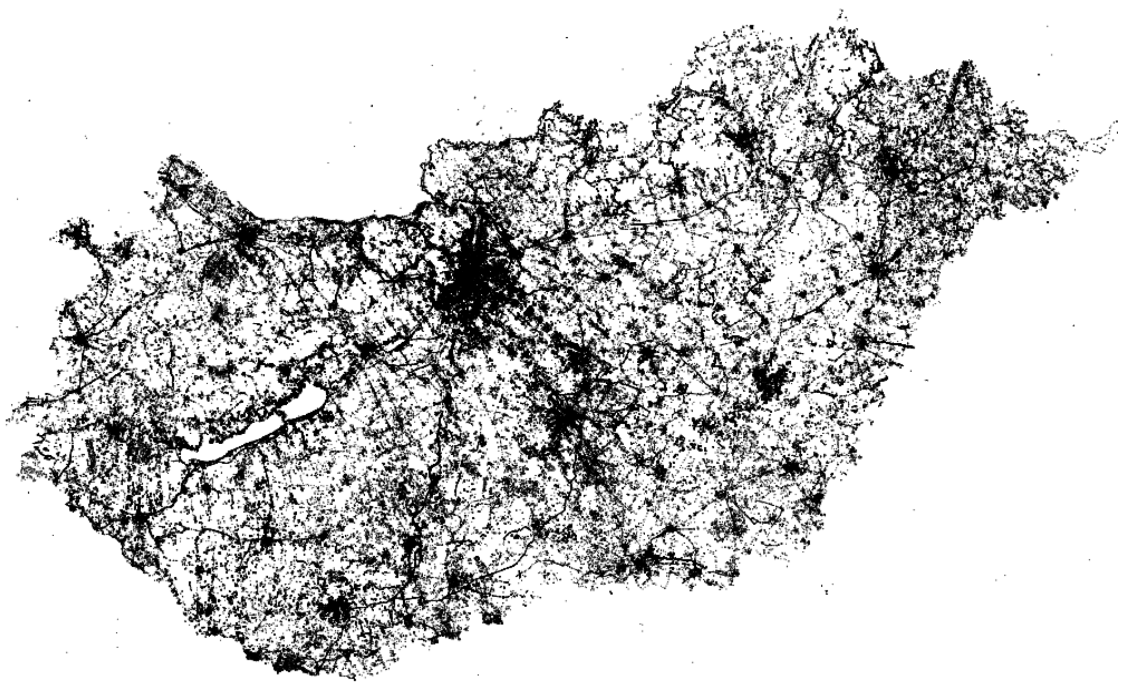

Fig. 2. Starting position of real-time connections in 2009-2010

GNSSnet.hu reference station coordinates are determined in ETRF2000 reference frame. Transformation to the Hungarian local grid (EOV) is supported in both real-time and post-processing mode. The desktop version of the official transformation application (EHT[2]) can be downloaded from the GSC website free of charge. The real-time version (VITEL) is available for most receiver brands as an extension of the RTK rover receivers' controller software. The transmission of transformation information via RTCM messages is also supported.

Following the installation phase the GSC now concentrates its efforts and financial resources on quality improvement of its services. Besides the automatic quality control of the GNSMART software the GSC developed a number of real-time and post-processing quality monitoring tools for both internal use and information dissemination to the clients. The current status of the service can be monitored online via the GSC website: http://www.gnssnet.hu. A special monitoring tool has been developed for mobile phones. This enables users working on field to judge whether the system performs according to expectations.

The service availability level in the year 2010 was 99.74%. In order to further increase the availability and reliability a complete backup system of the central processing applications will be installed in the near future. This means duplicate hardware and software components and automatic switch between primary and backup upon failure.

A real-time fleet management system has also been developed for bigger organisations having numerous rover receivers. With the help of this system an operator of the organisation can monitor not only the actual position of the units belonging to the fleet but also rover position quality information (e.g., applied correction type, number of satellites, DOP values, RTK fix status, age of corrections, etc.).

In May 2010 a ministerial decree (Nr. 47/2010) has been released, which regulates he application, documentation, control, verification and acceptance of geodetic point positioning using GNSS technology.

The GNSS Service Centre is also contributing to EUPOS. EUPOS is the coordination body of the GNSS real-time networks being installed in the Central and Eastern European countries. The intention is the harmonization of the GNSS services and promotion of cross-border cooperation both on the user and service provider levels.

2. Integrated Geodetic Network (INGA)

Responding to the new trends in the use of the geodetic networks, in 2008 FÖMI in agreement with the academic institutions initiated the realization of the Integrated Geodetic Network, called INGA. At the INGA benchmarks GPS, levelling and gravimetric measurements are performed and their coordinates are expressed in all geodetic reference frames available in Hungary (EOV, ETRS89, EOMA). The points are primarily selected from levelling benchmarks, where undisturbed GNSS measurement is possible. The MGGA (National GPS Geodynamic Network) sites are part of INGA by default and also the suitable markers of the Hungarian Gravity Base Network will be incorporated. New markers are only installed where the network geometry cannot be guaranteed from existing sites. The INGA site separation is about 15-20 km, the country is covered by some 1000 benchmarks. The INGA sites will have enhanced physical and legal protection to ensure the long term existence of the network and the represented reference frames. The realization of the network is harmonized with the ongoing re-levelling of the 1st order EOMA network. This work was started in 2007 at the NE part of Hungary and planned to be finished in few years. At some feasible sites PS-InSAR reflector is planned to be installed to monitor the height variation. In the future repeated measurements are planned at the INGA sites to derive time variable reference coordinates.

3. SGO GNSS Analysis Centre

Since December 2001 the FÖMI Satellite Geodetic Observatory (SGO) is running a EUREF Local Analysis Centre (LAC). The SGO LAC is routinely processing the GNSS data of 35 EPN (EUREF Permanent Network), 35 GNSSnet.hu sites and 41 additional permanent stations from the neighbouring countries. The processed sub-network concentrates to the Central and East European region. The daily and weekly EPN sub-network solutions are submitted to the EPN Combination Centre acting at the BKG Frankfurt, Germany.
FÖMI SGO is also contributing to EUREF with the analysis of the EPN coordinate time series. The EPN Time Series Coordinator is acting at the SGO and provides the official EPN coordinate and velocity estimates, which is updated in every 15 weeks. Noise and harmonic analysis of the EPN time series is also routinely performed (see Fig. 3). All results are displayed on the EPNCB website (www.epncb.oma.be).

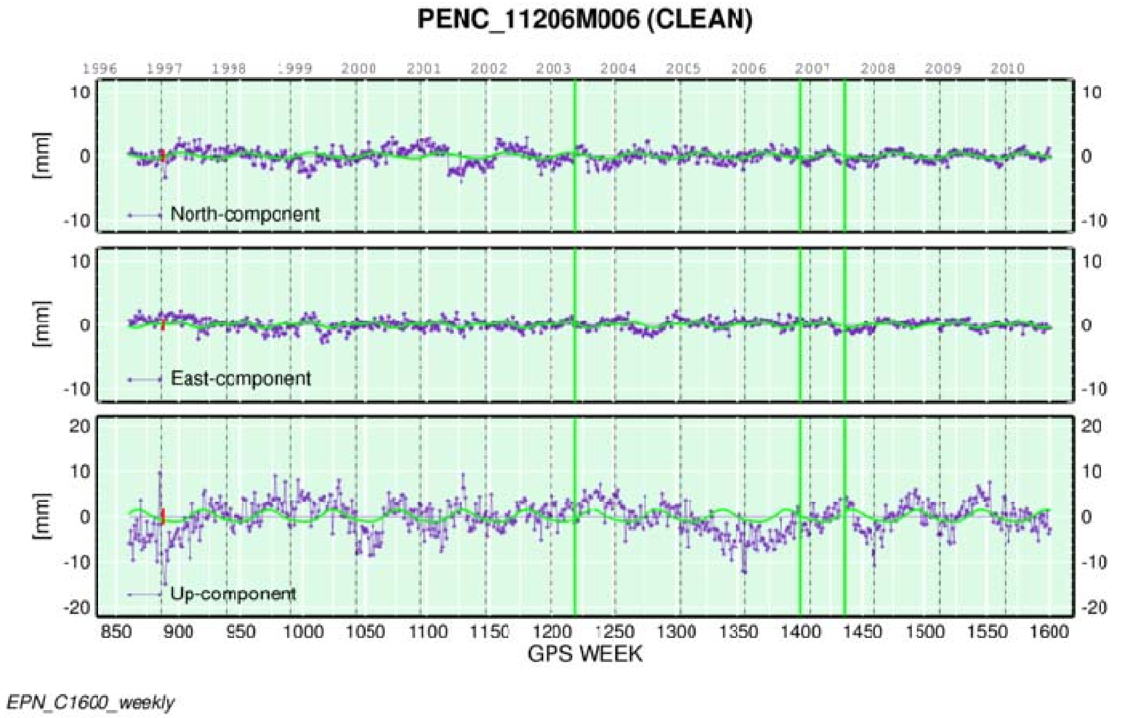

Fig. 3. The coordinate time series of PENC station, where the estimated annual signal is also indicated.

4. GPS geodynamics and PS InSAR

In this period of time at the FÖMI Satellite Geodetic Observatory we worked on several space and land based geodynamic projects on different spatial scales from global through regional, national to the smaller-scale local level using the Global Positioning System and the Synthetic Aperture Radar Interferometry techniques.
The Hungarian GPS Geodynamic Base Network –MGGA- was established in 2007 with special network integration resulting in a continuous monitoring history dated back to 1991. With this integration we successfully incorporated the soft sedimentary regions -covering more than half of the area of the country- into our GPS geodynamic research. Since then high precision country-wide GPS measurement campaigns are organized and their data are processed and analyzed.

Major large-scale deformation of the Tisza megaunit could be analyzed, and we could also better constrain the deformation of ALCAPA and its subregions. Relative motion of these megaunits and present activity of the Central-Hungarian shear zone were also studied, and the first conclusions have been drawn. With the cooperation of seismologists we compared the GPS crustal motions and present deformation rate with seismological data. In case of the Mur-Mürz zone analyzing the crustal motions and the resulting earthquakes and the seismic efficiency, we contributed to its earthquake hazard assessment. We also calculated these data for the central-Hungarian seismic zone and the ratio of aseismic deformation has been determined. We worked out an integrated GNSS geodynamic research plan for Hungary to meet all present need in precision and spatial resolution regarding the crustal motion and deformation map.

We participated in international cooperation in geodynamics. We coordinated surveys in the Central European geodynamic network with the participation of 14 countries. Several analyses have been done and all these international results were published. Gyula Grenerczy FÖMI-KGO was elected as secretary and also as governing board member of the CEGRN Consortium and later selected as its chairman.
We also carrying out several multisensor monitoring of land subsidence and hazards, and we are introducing and applying the Synthetic Aperture Radar Interferometry technique in Hungary. With our multi-technique investigations including PSI (Persistent Scatterer InSAR), GPS (Global Positioning System), leveling and gravity measurements we mapped various hazards (land slide, mining, water pumping, reservoir failure etc.) and performed extensive academic and research work with young scientists. Beside our research at four different locations we speeded up the InSAR technique related education and public information dissemination. We started to compile an InSAR guidebook in 2009 based on various information resources and our own results and experiences. We also created and continuing to maintain and update our web based InSAR information system. www.sgo.fomi.hu/InSAR/
Hungarian Academy of Sciences research group started its work in 2007 in the field of GPS geodynamics and InSAR. Two students and two researchers worked on selected topics.
We participated and presented our results in more than 20 international and domestic meetings and conferences.

5. VLBI activities

The International Celestial Reference Frame (ICRF) is defined by the positions of selected radio-loud active galactic nuclei (quasars) measured by Very Long Baseline Interferometry (VLBI). Over the last three decades or so, some of these positions proved variable. We studied the quasars' positional stability and its possible relation to their radio structure imaged with VLBI at milli-arcsecond angular scale, using a sample of nearly 70 objects (Frey & Moór 2009). While the direction of the apparent proper motions is close to the radio jet direction, there are exceptions from this general rule.
We took part in local densifications of the celestial reference frame, in order to serve the needs of future wide-field optical survey telescopes (Frey et al. 2007, Platais et al. 2007).
We continued simulation studies of Space VLBI as a potential new observing technique for applications in geodesy and geodynamics, which turns out to be a difficult task in practice in the foreseeable future (Wei et al. 2008, 2010).

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II. Commission 2 (Gravity Field)
Gravimetry, gravity field modelling, geoid determination

(Lajos Völgyesi, Budapest University of Technology and Economics, Géza Csapó, Eötvös Loránd Geophysical Institute and Gábor Papp, Geodetic end Geophysical Research Institute)

The Loránd Eötvös Geophysical Institute (ELGI) monitors the status of the national gravity network (about 500 points), reconstructs and re-observe the destroyed points of the network. During the last four years 4 additional absolute stations were established and observed in cooperation of Czech colleagues. Including the newly established stations the reference network provides the mGal standard of the country and ensures the compatibility with the United European Gravity Network (UEGN-2002). During the same period 9 absolute stations were re-observed. Based on the re-observed absolute data investigations of long-term regional and local changes of gravity were carried out (Csapó, 2007). In our country the vertical gradient of gravity can deviate from the normal (–0.3086) value by about 20-25 %. Because of this high variability for high accuracy investigations the real value of the vertical gradient should be determined. By the end of 2010 the vertical gradients were determined on 50 base points. In connection with the link to UEGN-2002 the national gravity network was re-adjusted (Csapó-Völgyesi, 2002). Due to the new absolute stations and the reconstruction of several base points the adjustment was repeated in 2010. The r.m.s. error of the network is $M_0 = \pm$ 0.014 mGal (Csapó-Koppán, 2010).

The ELGI's activities comprise theoretical and practical gravimetric researches oriented for geophysical problems as well. During the period between 2007 and 2010 we carried out detailed methodology research on the gravimetric signatures of structures with (meteorite) impact origin, furthermore defining and investigation of buried (possible) impact structures in Hungary based on the national gravity data base, maintained by the ELGI (Bodoky-Kis-Don-Kummer-Posgay-Sörés, 2007; Kis-Bodoky-Kummer-Sőrés, 2008). Besides, we dealt with the capabilities of micro-gravimetry and its distinctive methodology. We particularly analyzed cavity detection techniques, investigations of geohazard concerning abandoned mining structures, and urban measurements (e.g. waste deposit characterization). We also dealt with 2D modeling and inversion problems, carried out test investigations, and by means of that analyzed depth-to basement modeling and inversion, as well as interpretation of microgravimetric measurements.

Before the end of the 1960s approximately 60,000 torsion balance measurements were made in Hungary. The primary goal of about 60000 torsion balance measurements was domestic prospecting of mineral resources. Earlier theoretical investigations and geodetic torsion balance measurements made by Lorand Eötvös showed that these measurements are applicablefor gravity field determination as well and it is possible to generate all functionals of the gravity field by combining torsion balance with gravimetry (Csapó-Égető-Kloska-Laky-Tóth-Völgyesi, 2009). Recent research of their geodetic applications indicated the need for new observations. For that reason an Eötvös-Rybár (Auterbal) torsion balance, which has been out of operation for many decades, was reconstructed and modernized. The scale reading has been automated and its accuracy has been improved by using CCD sensors. Calibration and processing of field measurements were computerized to meet today's requirements. The first test measurements took place in the Mátyás cave (Budapest), including measurements on the main gravity reference point of Hungary, and the points of a gravity microbase created by the Eötvös Loránd Geophysical Institute. (Völgyesi-Égető-Laky-Tóth-Ultmann, 2008; Völgyesi, 2009a).

After more than 40 years of interruption new field observations have been made by an E-54 type torsion balance (TB). This original balance of the Loránd Eötvös Geophysical Institute was recently refurbished, and 30 TB stations have already been measured on the Csepel Island (Fig. 3) in addition to the repeated measurements of two old stations that have measurements dated back to 1950. A detailed topographic survey of each measured station was also carried out. These TB measurements were accompanied by a detailed gravimetric survey of each station with LCR gravimeters. Both vertical (VG) and horizontal (HG) gravity gradients were determined at each TB station for VG interpolation and reliability tests. We experienced an adverse effect of the observer's mass on the readings due to the sensitivity of the TB. This effect was captured by a video camera. The evaluation showed an effect of about 0.4 E (1E = 1 Eötvös Unit = 10^{-9} s^{-2}) for 1.5 minutes readout time and also a rapid increase with time. To eliminate this effect we plan to modernize the instrument for automated reading. Vertical gradient of gravity cannot be measured directly by the Eötvös TB. However, we successfully interpolated VG differences in the network of TB measurements following the idea originally due to Haalck (Tóth, 2007). Reliability tests by comparing HG and VG gravimetric and TB measurements were also performed (Csapó-Tóth-Laky-Völgyesi, 2008; Csapó-Laky-Égető-Ultmann-Tóth-Völgyesi, 2009). Torsion balance measurements will be important and indispensable data source for the determination of small wavelength gravity field and geoid features in Hungary. A group of professionals has been formed, who have the intention to continue the scientific efforts of Lorand Eötvös, to renovate and modernize historical, but still valuable instruments, and have the field experience to continue torsion balance measurements (Völgyesi-Csapó-Laky-Tóth-Ultmann, 2009)

Fig. 3. Torsion balance measurement by E54 instrument on the Csepel Island.

A new method was worked out for the inversion reconstruction of the 2D gravity potential. This method gives a possibility to determine the potential function and all of its important derivatives using the common inversion of gravity gradients and the first derivatives of the potential. Gravity gradients can be originated from torsion balance measurements, while the first derivatives of the potential can be derived from deflections of the vertical data. Different important derivatives can be originated from this reconstructed potential function at any points of the investigated area. Advantage of this method is that the solution can be performed by a significantly overdetermined inverse problem. This inversion algorithm is rather stable. Test computations were performed for the inversion reconstruction of gravity potential. In our test area there are 248 torsion balance measurements, 1200 gravity measurements and 13 points, where the deflections of the vertical are known. Gravity potential, the first and some second derivatives of the potential were determined by the suggested method. This method provides a useful geodetic application; deflections of the vertical based on torsion balance measurements can be determined for the whole area for each torsion balance stations (Dobróka-Völgyesi L, 2008).

Inversion reconstruction of 3D gravity potential based on each of the torsion balance and gravity measurements, deflections of the vertical and digital terrain model data have been solved by developing our former 2D solution. Applying this method the elements of the full Eötvös tensor including the vertical gradients, which are not directly measurable by torsion balance can be determined not only in the torsion balance stations, but anywhere in the surroundings of these points. Test computations were performed for the inversion reconstruction of gravity potential at the same test area, where the 2D solution was tested. The gravity potential, and all first and second derivatives of the potential were determined for the test area by this suggested method. This gives a simple possibility to transform the torsion balance measurements to different heights and the analytical determination of the equipotential surfaces of the gravity field. (Dobróka-Völgyesi, 2009a, 2009b, 2010).

A modification of Nettleton's original method (Papp, 2009)[1] has been successfully applied for the determination of average surface rock density in the Mecsek Mountains, south-west Hungary (Papp, 2007) to support the precise determination of gravity potential differences on a test area established there (Papp-Szeghy-Benedek, 2009).

Time variation of gravity influenced by the groundwater fluctuation was investigated too. Gravity effects of different types of moving vadose and groundwater were investigated. The magnitude of the time variation of non-tidal part of gravity was evaluated for the complete area of the Great Hungarian Plain based on the ground water fluctuation, which can reach a maximum of 60-70 μGal (Fig. 4). Reliability of measurements on the Hungarian national gravimetric calibration line was investigated in this respect. (Völgyesi-Csapó-Szabó-Tóth, 2007)

In order to make continuous gravity observations possible a CCD ocular and a PC based controlling and data processing system was developed for the LCR G type gravity meters not equipped with the so called CPI (Papp-Battha-Bánfi, 2009). It is now being operated in the Geodynamical Observatory of the Geodetic and Geophysical Research Institute, Sopron (please visit the website: www.ggki.hu) providing useful information about the time variation of the gravity field (e.g. gravity tides). It has been also successfully used either as a monitoring system for the investigation of seismic ("gradient") noise generated by ocean weather (waves) in the North Atlantic region or a device for the precise determination of instrumental effects (drift, barometric effect, etc…). The first results show that the gradient noise during a "silent" day is about ±2 μGal, whereas in stormy periods having 10 m - 12 m of significant wave heights it is increased up to ±(5-10) μGal in a distance of some thousands of kilometers away from the ocean. These "noisy" days are not suitable for gravity measurements requiring the highest (a few μGal) precision.

In satellite gradiometry the determination of the effect of topographic masses is crucial for validation and downward continuation of the gravitational signal. This investigation focuses on the determination of the effect of topographic masses on the second derivatives of the geopotential. During the investigations three methods have been applied. The first method is the direct numeric integration using planar approximation and mass prism topographic model, while the second one is the application of tesseroids. The third method is a mass prism topographic model using spherical approximation. The first two methods have been tested over the area of Europe, whereas the latter two have been used for global computations as well. For the continental and global studies the ETOPO5 digital elevation model has been used. The results show that the effect of topography is significant on the altitude of the LEO satellites, reaching the level of 10 Eötvös in all gravity gradients (Rózsa-Tóth, 2007).

[1] Because of erroneous handling of the manuscript during the printing process the original paper Papp G, (2007): Simultaneous determination of terrain correction and local average topographic density. Harita Dergisi, Special Issue N.18;360-365 had to be re-published in its correct content and form.

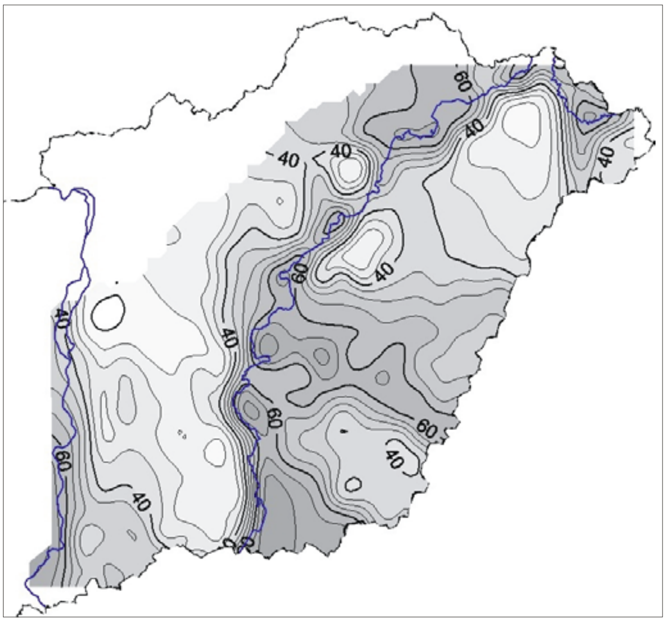

Fig. 4. The gravity effect caused by the fluctuations of the groundwater motions in the Great Hungarian Plane between years 1933 and 1953. Isolines are in μGal.

Variation of gravity gradients in different heights was discussed. Elements of the full gravity gradient tensor changes were computed on a regular grid for two models (one of them is the water mass of the Danube river in Budapest during the great flood in 2002; the other is the water mass of an urban water reservoir on Gellért-hill). Gravity gradients were computed on 10 different heights above the models by the software Mod3D. The gravity gradients change on height was found to be very sensitive to the actual distance of the point from the Earth's surface. (Völgyesi-Ultman, 2007)

The wide-spread use of the GPS in the geodetic practice demands the knowledge of precise and reliable geoid heights. Nowadays the determination of the precise, cm-accuracy geoid is one of the biggest challenges of the Earth's sciences. Development and problems related to the concept of the geoid were discussed (Völgyesi, 2009b). At the present state of the geoid determination the basic concepts of the geoid definition and all the driving factors leading to the time variation of the geoid were discussed.

A new quasigeoid solution HGTUB2007 (Fig. 5) was computed for Hungary using least-squares collocation technique for the first time by combining different gravity data sets. More than 380 000 point gravity data were interpolated onto a 1.5' × 1' geographical grid consisting of 26 478 values in the IGSN71 gravity system. The selected subset of these gravimetric data were combined with 138 astrogeodetic deflections and gravity gradients available at more than 25 000 points in the least-squares collocation procedure. Topographic information was provided by SRTM3 data at 3"×3" resolution. We have used the GPM98CR model and a GRACE GGM02-based combined model as a global geopotential reference to our new solution. Several solutions were produced and compared by combining different data sets. The final solution was chosen to fit to the national GPS/leveling network of Hungary with a very high weighting. As a quick evaluation of the solution with GPS/Leveling data shows, the obtained accuracy is about 2-4 cm in terms of standard deviation of geoid height residuals (Tóth, 2009a, 2009b).

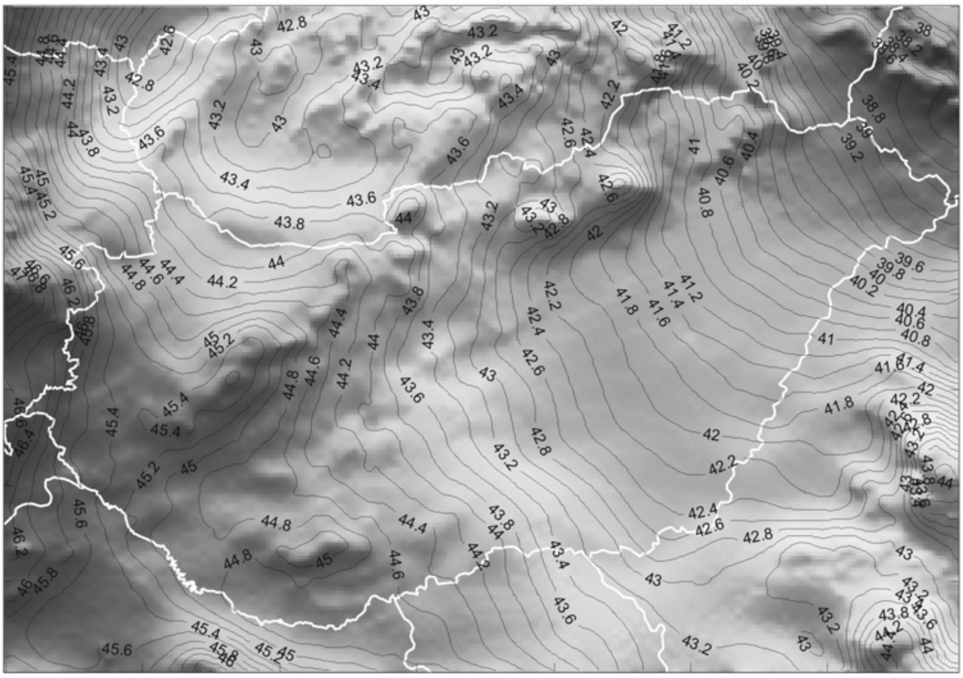

Fig. 5. The new quasigeoid solution for Hungary (Tóth, 2009a, 2009b)

Correction of the gravimetric geoid using GPS-leveling data was investigated. The time-consuming, labour intensive method of traditional levelling can be substituted by GPS-levelling, using a precise geoid model. The optimal geoid model is a combination of the GPS-derived and the gravimetrically-derived geoid undulations. The combined geoid can be constructed by adding a corrector surface to the original gravimetric geoid, which can be determined by using the GPS-levelling data. The combined geoid can be given in analytical form using a third-degree spline interpolation. Results are promising; fitting of the corrector surface can be performed by 1-2 cm accuracy. Attention is called to the importance of the homogeneous distribution of the GPS/levelling data, elimination of gross errors, and to the optimal separation of the learning and the test data set. (Zaletnyik-Paláncz-Völgyesi-Kenyeres, 2007)

Local GPS/levelling geoid undulations using Support Vector Machines (SVM) was modeled. Support Vector Machines with wavelet kernel has been applied to the correcting gravimetric geoid using GPS/levelling data. These data were divided into a training and a validation set in order to ensure the extendability of the approximation of the corrector surface. The optimal parameters of the SVM were considered as a trade-off between accuracy and extendability of the solution in order to avoid over-learning. Employing 194 training points and 110 validation points, SVM provided an approximation with less than 3 cm standard deviation of the error and nearly perfect extendability. (Zaletnyik-Völgyesi-Paláncz, 2008)

Combination of GPS/levelling and the gravimetric geoid by using the thin plate spline interpolation technique via finite element method was investigated. The purpose was to develop an improved local geoid model for Hungary combining GPS and levelling height data with a local gravimetric geoid model, via corrector surface, which accounts for datum inconsistencies, long-wavelength geoid errors and vertical network distortions. The improved model can be constructed by adding the corrector surface to the original gravimetric geoid. The corrector surface can be represented by means of a Thin Plate Spline Interpolation (TPSI) and finite element solution. In this work 194 GPS/leveling points with a local gravimetric geoid were used to calculate the corrector surface and the combined geoid model. To estimate the realistic error of the solution 110 GPS/ leveling points were used as external control points. Attention is called to the importance of the homogeneous distribution of the GPS/leveling data. The mean accuracy of geoid heights of the used 110 control stations was 1–2 cm after the surface fitting (Zaletnyik-Völgyesi-Kirchner-Paláncz, 2008)

Investigations for the determination of a transformation function between MGH-50 and MGH-2000 Hungarian gravity networks by means of surface fitting were made. In our case applying power series is not suitable due to a low number of common points given in the systems. Transformation by fitting two-dimensional surfaces to *g* values of networks was attempted to apply (Földváry-Völgyesi-Csapó, 2007).

Methods for deriving gravimetric data to determine the geopotential number of levelling benchmarks were also investigated. The optimal density of the gravimetric measurements have been investigated under different topographic conditions, i.e. considering plane, hilly and mountainous areas, and how rarefying of the data affects the determination of the geopotential number and of the metric height values has been analyzed. Based on the Hungarian gravimetric data base the *g* values have been interpolated in order to complement the sparse measurements. Interpolation errors have been determined at identical stations by comparing the measured and the interpolated Faye-anomalies. According to the results in the case of hilly regions 1.5–3 km for the density of the *g* measurements is sufficient, however at mountainous regions in some cases even the 1 km density is not eligible to match the accuracy requirements for the normal height. Finally the feasibility of the prism modelling (using a DEM and a density model) for interpolating gravity data for Hungary has been discussed considering the accuracy of the available models. According to these investigations the earlier instructions for the point density of the gravity measurements were found to be necessary (Csapó-Földváry-Tóth, 2010).

The re-observation of the first order levelling network of Hungary has been commenced in 2007 (Csapó-Tóth-Laky-Völgyesi, 2008). To provide the necessary gravity values for the geopotential data ELGI carried out gravimetric measurements on 300 points along the levelling lines (Mihály-Kenyeres-Papp-Busics-Csapó-Tóth, 2008). About the same number of point were observed by the Geodetical and Geophysical Institute of Academy (GGKI, Sopron) as well (Csapó, 2008).

Due to the re-measurement of the first order levelling network the importance of the research on precise determination of geopotential numbers and potential differences significantly increased. Among others the key questions in potential determination are the number and accuracy of gravity data providing information about the physical structure of the Earth's gravity field. In the classical approach the number of gravity data necessary for the desired accuracy is determined from classification of the topography along the levelling line. In order to eliminate the uncertainties and ambiguities of this method a new solution based on the joint application of measured and synthetic gravity data was developed and tested on a local levelling and gravity profile in a district of south-west Hungary having moderate (hilly) topography (Papp-Szeghy-Benedek, 2009). The average point distance for both data types was 34 m along a 4.3 km long line. Here also a detailed (20 m × 20 m) DTM and sufficient number of gravity survey points were available. The results show that the proposed method can be efficiently used to synthetically model the variation of gravity field along the line supplying accurate g values ($\sigma \leq \pm 0.1$ mGal) for all the 129 staff and base points using only one measured g data on the line. It provides a geometrical accuracy better then ±0.01 mm for the height difference between the start and end points of the line.

Beyond the practical considerations the method can be efficiently used to numerically analyse the fine structure (convergence/divergence) of the potential surfaces along the levelling line which makes the geometrical height differences (i.e. the Euclidean distance between the potential surfaces) obtained from staff readings ambiguous/erroneous eventually. This information can be used for the evaluation of the levelling lines and for the control of error accumulation.

The theoretical-mathematical background of the application of polyhedron volume elements (PVE) for gravitational field modelling was investigated extensively by Benedek (2009). The formulae of the gravitational potential of PVEs and its derivatives up to the third order were derived applying a uniform solution of Newton's integral and analysed systematically with special attention to their singularities and numerical behavior. PVEs can be efficiently used in a global Cartesian coordinate system for the modelling of the density distribution of the lithosphere and thus they can play very important role in both forward and inverse gravitational modelling (e.g. processing of satellite gradiometer data) as it was demonstrated by Benedek and Papp (2009)[2].

[2] Because of erroneous handling of the manuscript during the printing process the original paper Benedek J, Papp G, (2007): Geophysical inversion of on board satellite gradiometer data: a feasibility study in

Research related to the GRACE and CHAMP satellites has been performed at the MTA-BME Physical Geodesy and Geodynamics Research Group. Two gravity models have been determined using the energy integral approach using GRACE data. The first method employed the so-called baseline solution on 35 days of GRACE data with brute force method used for the adjustment. The second solution applied also microwave ranging measurements, solved for 4 months of GRACE data adjusted by the so-called PCGMA method. (Paizs-Földváry, 2007). The feasibility of the direct use of the Newtonian equation of motion for CHAMP data has been studied. Then numerical results for 2 years of CHAMP observations are presented. Though the method failed to provide the best CHAMP-only gravity field model, it has been found to be generally feasible, and worth for using for other gravity satellite data (Földváry-Bokor, 2010).

A comparison of an a priori GRACE mission simulation with the real observed results of the satellites has been performed. It turns out that the accuracy of the GRACE is an order of magnitude worst than it is in the baseline, and that more signal in the seasonal gravity has been detected than it was expected (Földváry, 2007b).

Kinematic orbits provide a time series of independent positions, which are a good base for gravity field recovery. Gravity field recovery using the energy integral requires numerical differentiation in order to get velocity information for kinetic energy. Several numerical differentiation methods have been investigated to test the most effective method for velocity determination of a LEO (Földváry, 2007a). Derivation of velocity has been found to be efficient when a reference gravity field is used during the processing. However the possibility of an error emerges that the reference field 'leaks' into the estimated velocity, which would harmfully affect the gravity field model solution in the subsequent step. The use of a gravity model demands a strict analysis in the Fourier-domain, which has been performed (Földváry, 2008). Further investigations on numerical differentiation of kinematic LEO orbits have been done for determination of both velocity and acceleration along the orbit. Tests were performed on a simulated GOCE orbit and on a kinematic CHAMP orbit as well (Földváry, 2007c).

The GOCE mission will produce gravity gradient data at satellite altitude and consequently contribute to more accurate determination of the gravity field. Previously we discussed formulas for the upward/downward continuation problem of second gravity gradients. The proposed approach was to use these gravity gradients in two combinations with special kernel functions. These kernel functions are infinite sums of Legendre functions of orders 0, 1 and 2. As a continuation of our previous study, several practical aspects of the proposed approach are addressed. First, the practical use of formulas in gravity field determination makes it necessary to evaluate these kernel functions in a band-limited setup. Second, the integration radius of gravity gradient data depends on the particular data combination, band-pass filter and altitude. Third, the upward/downward continuation problem can be extended to other gravity field functionals with appropriate kernel functions. These issues are investigated in the context of GOCE (Tóth-Földváry-Tziavos, 2007).

Records of the tide gauges detect a sea level rise between 1.0 mm/year and 2.5 mm/year. The rise is normally explained as effect of the melting ice caps, however these interpretations are not fully reliable. An outlook of the problem considering the Antarctic ice sheet, and an estimate of the ice melting based on monthly GRACE gravity field models has been provided (Földváry-Mészáros, 2009). This method has been later refined. In order to diminish the effect of large uncertainties in glacial isostatic adjustment (GIA) models, an approach has been developed to estimate the acceleration of the ice-sheet mass, assuming the presence of accelerated melt signal in the GRACE data. Though the estimate of accelerated melt does not provide an absolute value for the volume of the melting ice, it is a viable tool for characterizing the present-day ice-sheet mass balance (Földváry, 2010).

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III. Commission 3 (Earth Rotation and Geodynamics)

1. Earth Orientation (Earth rotation, polar motion, nutation and precession).

(Péter Varga, Geodetic and Geophysical Research Institute)

The determination of Earth Orientation Parameters (EOP) is one of the main tasks of geodynamics. Variations of Earth rotation due external (inter alia due tides and tidal friction) and internal forces generated by the redistribution of masses within the Earth are closely related to the deformation of the geometric shape of our planet and the temporal changes in its gravity field. One of the central questions of our researches during the period 2007 to 2010 was investigation of connection between the rotation vector of the Earth and different geophysical phenomena.

Connection of EOP with centred and eccentric geomagnetic dipole fields was investigated with the use of Gaussian coefficients for the epoch 1880-2000. The main tools of statistical investigation carried out were Laplace-type robust estimation (in case of Length Of Day - LOD) and the non-linear regression analysis (for Polar Motion -PM). On the basis of computations carried out statistical dependence was detected between the geomagnetic dipole moment M0 and ΔLOD both in case of centered and eccentric geomagnetic dipole field in decadal time-scale. The orientation and eccentricity of the geomagnetic dipole show also somewhat weaker correlation. The inference can be explained with toroidal circulation in the liquid outer core which leads to the temporal variations of the core angular momentum through frictional processes at the core mantle boundary. The dependence of ΔLOD on temporal variations of orientation of geomagnetic dipole and also correlation of PM and dipole moment M_0 suggest that beside the toroidal flow in the liquid outer core there are also spheroidal flows present what leads to the radial mass redistribution within the outer core (Varga et al., 2007, 2008). In geological time-scale it was found that M_0 grew from 3.5 Ga BP to our days to roughly one and a half or even more (Schreider et al., 2008, Varga 2009b, Denis et al., 2011).

Seismology is related to many problems of geodynamics. Due to the fact that the energy production of our planet is rather close to energy consumption of the Earth the energy balance can be disturbed significantly by processes much less as the main energy users of the Earth system. From this point of view was discussed in Varga & Denis (2010) the effect of tidal triggering by the study of tidal stress tensor components expressed in spherical system of coordinates.

Until now there is no unambiguous success to relate changes of Earth orientation parameters (EOP) with seismicity. Present day accuracy of length of day variations is not sufficient yet to detect spin variation generated even by the greatest earthquakes. The polar motion is probably more sensitive to earthquakes and there is a chance to detect polar displacements generated by seismic events (Varga & Denis, 2010).

Tidal friction is influencing through despinning of axial rotation the geometrical flattening. It was shown (Riguzzi et al., 2010, Varga 2009b) that this flattening variation causes stresses along the longitude and this phenomenon is closely related to seismic energy release.

A detailed examination of the energy household of the Earth showed that the global plate tectonics is significantly influenced by tidal despinning (Riguzzi et al., 2010).

The depth distribution of earthquake energy is also not uniform. The 90% of the total earthquake energy budget is dissipated in the first ~30km., whereas most of the residual budget is radiated at the lower boundary of the transition zone (410 km - 660 km). This proves that the slabs themselves do not provide elastic energy to drive plate tectonics. Finally, the mutual position of the shallow and deep earthquake energy sources along subduction zones indicates that they are connected with the same slab along the W-directed subduction zones, but they may rather be disconnected along the opposed E-NE-directed slabs, being the deep seismicity controlled by other mechanisms (Varga et al., 2010).

A new multidisciplinary geodetic-seismological method was suggested to assess on deterministic way the seismic hazard. A combined use of geodetic strain rate data and the seismic moment data set determined for past seismic events was suggested in Varga 2010b. Using a modified version of Kostrov's (1974) equation and the catalogue of seismic moments, the minimum return period of the strongest earthquakes of a source area is estimated with the use of geodetic strain rates. It was found that the return periods(Δt) in a given source zone in case of earthquakes $M_W \geq 9.0$ are of the order of some hundred years. For the large and medium earthquakes the expected Δt is well above some 10^3 year (Varga 2011a,b).

An attempt was made to the application of methods of geodynamics in planetology. For this purpose the study of significant volcanic activity of the brigtest celestial body in the solar system, the Saturn's moon Enceladus was used. The method discovered by Molodensky (1953) and Alterman, Jarosh, Pekeris (1959) was applied to calculate distribution of the normal and tangential stresses within Enceladus. It was found that due to the inhomogeneity within Enceladus (what distinguishes it from other Saturn moons), 85% of the tidal energy is generated in a volume that contains just 39% of its mass. In time intervals of 3.0×10^8 and 5.3×10^8 years the temperature increase in the relative depth range $0.70 \leq r/a_E \leq 0.90$ is approximately 270° and 370° Kelvin, respectively (Varga et al. 2009).

The parallelisms and common roots of the development of two important fields of earth sciences geodesy and seismology is discussed in Varga 2009a, 2010, Varga & Denis 2010. The connection is based on the fact that for early seismology the effective rigidity observed by earth tidal observations was of first order importance. The common interest in the study of rheological properties of the Earth remains hitherto. In addition to this seismology and geodesy used similar instruments observing directly accelerations due to gravitational forces or inertial accelerations due to ground deformations. Some examples of parallelism between geodesy and seismology in the field of instrumentation The famous LCR instruments were designed by L. LaCoste as a broad band vertical seismometer in 1932. The horizontal pendulum developed by Hengler was used for long time as a horizontal seismometer from the time of E. von Rebeur-Paschwitz (1889). The bar extensometer invented by H. Benioff in 1935 for study of surface waves and free oscillations of the Earth is still in use in earth tidal research (Varga, 2010).

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2. Observation of Earth tides and tectonic movements by extensometers.

(Gyula Mentes, Geodetic and Geophysical Research Institute)

Earth tides observations have been carried out by an 22m long quartz-tube extensometer at the Sopronbánfalva Geodynamic Observatory. For increasing the accuracy of measured tidal parameters the relationship between barometric pressure and extensometric data were investigated in detail. It was pointed out that barometric pressure had a seasonal effect on the measured tidal data (Mentes and Eper-Pápai, 2009) therefore the old barometric correcting methods (e.g. regression method) should be further developed. Now new correcting method is developed using neural networks.

Intensive research work was done to improve the in-situ calibration of the extensometers. A new calibration device was developed by means of which the accuracy of calibration was increased by one order of magnitude. The obtained accuracy is 0.01 nm (Mentes, 2008, 2010).

Since the quality of the extensometric measurements also strongly depends on the topography in the surroundings of the observatory and cavity effect, in addition to correction of the environmental parameters (temperature, barometric pressure) the observatory-instrument system was also investigated by coherence analyses between theoretical and observed tidal data as input and output data of the observatory-instrument system, respectively. As output data the uncorrected, temperature and barometric corrected measured extensometric data were used (Mentes, 2010). It was revealed that the Sopronbánfalva Geodynamical Observatory and the extensometer installed here are stable and reliable for tidal measurements and tectonic observations (Fig. 6). The thin curve was obtained in the case of uncorrected and temperature corrected data. It means that the temperature has no effect in the tidal band. The reason for the smaller coherence in the diurnal than in the semi diurnal tidal band is yet unknown. It is thought that the new barometric correction method will yield a higher coherence also in the diurnal band.

One of the longest continuous extensometric record in the world is obtained at the Sopronbánfalva Geodynamic Observatory (Fig. 7). Figure 7 shows that the rate of the tectonic movements is not constant. The rate of the contraction is continuously nonlinearly decreasing (Mentes, 2008). The seasonal effect seen in the curve is caused by the annual temperature variation. It means that the long-term temperature effect can not be neglected but it can be easy filtered from the data. The tectonic movements in the Pannonian Basin were investigated in cooperation with other observatories: Mátyáshegy Observatory in Budapest, Vyhne in Slovakia, Beregovo in Ukraine. Results are given by Mentes (2008).

A practical application of Earth tide phenomena was also found. Large objects (e.g. towers) as inverse vertical pendula can amplify tidal signals which can also be detected by low sensitive tiltmeters. This effect can be used for investigation of the connection between object and ground motions in the engineering surveying (Mentes, 2007).

In this period new research topics were also started: investigation of the connection between rock strain and radon emanation of the rock; searching earthquake swarms in extensometric data records.

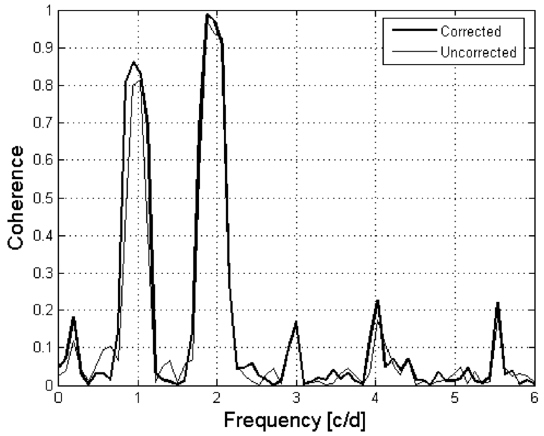

Fig. 6. Results of the coherence analysis

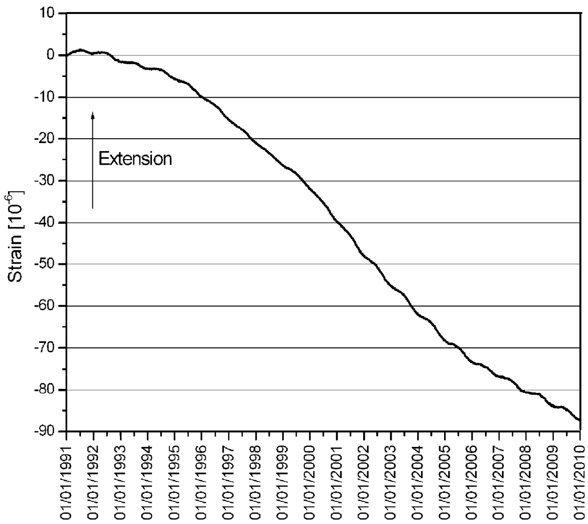

Fig. 7. Strain measured in the Sopronbánfalva Observatory from 01.01.1991 till 31.12.2009.

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IV. Commission 4 (Positioning and Applications)

1. Applications of geodetic positioning using three dimensional geodetic networks (passive and active networks), including monitoring of deformations. Activities at the Geodetic and Geophysical Research Institute

(Gyula Mentes, Geodetic and Geophysical Research Institute)

According to the research objectives of the international IAG WG 4.2.4: „Investigation of Kinematic and Dynamic Behaviour of Landslides and System Analysis" (Chair: Gyula Mentes) the Geodetic and Geophysical Research Institute was working

- on development of dynamic monitoring and data evaluation systems for landslide prone areas,
- on development of multi-sensor monitoring and alert systems for landslides,
- on study the interactions between landslides and geophysical, geological, geomorphological, hydrological, geomechanical, meteorological, etc. processes,
- on development of knowledge based systems for landslide risk assessment.

In the frame of international cooperation the institute laid a great stress on multi-scale monitoring landslide prone areas (Újvári et al., 2008, Mentes et al., 2009). For the investigations two test sites were used in Hungary (High Danube banks at Dunaföldvár and Dunaszekcső). On both areas a geodetic network was established for GPS and electronic distance measurements and precise levelling. The intermittent geodetic measurements were repeated in time intervals according to the rate of the movements. In addition to the geodetic measurements continuous tilt measurements were also carried out by highly sensitive borehole tiltmeters (Mentes, 2008a). At both test sites the precipitation, the ground water level and the water stage of the River Danube were also recorded. This complete measurement system is very suitable for the investigation of the kinematic behaviour of landslides and together with other (e.g. hydrological, meteorological, etc.) parameters for study the dynamics of landslides. On these test sites the influence of geological, geomorphological, hydrological, meteorological, etc. factors and their role in triggering landslides were investigated (Mentes, 2008b).

At the Dunaföldvár test site the effect of geology and tectonic movements was studied by tilt measurements in detail. For this reason gravimetric measurements were also carried out to study the features of the bedrock (Mentes et al., 2009).

In this period the most characteristic test site was the high loess bank of the Danube at Dunaszekcső. The high bank on this area was sliding slowly with increasing velocity since September of 2007 till 12 of February 2008. On this day there was an abrupt sliding. About 500.000 m^3 loess was slid toward to the Danube (Fig. 8). The whole sliding process was monitored. The study of the movement is a good possibility to understand the kinematics and dynamics of the slope (Újvári et al., 2009). The monitoring is continued after the large sliding to study the after-sliding processes. In 2010 a small sliding (about 200 m^3) was forecasted on the basis of the continuous tilt measurements.

At present new measurement methods applying accelerometers (Mentes, 2008c) and their mathematical background for detecting very small displacements are developed for early detection of landslides.

The results of the research activity in this field are continuously published.

Fig. 8. Oblique aerial photo of the large Dunaszekcső landslid on 12 February 2008. Photo was taken by László Körmendy on 17 February 2008.

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2. Further Activities in the Field of Positioning and Applications

(Szabolcs Rózsa and Árpád Barsi, Budapest University of Technology and Economics)

In the reporting period many developments and research activities were carried out in the field of Positioning and Applications. As the Global Navigation Satellite Systems (GNSSs) have become state-of-the-art observation techniques in surveying, the rapidly growing demand encouraged the development of the GNSS Infrastructure in Hungary as well as the research activities in GNSS positioning.

The GNSS Infrastructure

The Hungarian GNSS reference station infrastructure and services have been established by the GNSS Service Centre (GSC) of the Institute of Geodesy, Cartography and Remote Sensing (FÖMI). The installation phase of the GNSSnet.hu reference station network development commenced in 2002. This process has come to an end in 2009, when all 35 Hungarian stations of the network became operational. In addition to the Hungarian sites, observation data of 19 stations from the neighbouring countries is collected and processed in real time to provide a truly nationwide coverage with homogeneous cm accuracy. The average inter-station distance is less than 60 km, enabling accurate modelling of distance-dependent errors like ionosphere, troposphere and orbits between the stations. All of the Hungarian stations and most of the integrated external sites are equipped with state-of-the-art GPS+GLONASS hybrid sensors and individually calibrated choke ring antennas. Some of the units are also Galileo ready.

The GNSS Service Centre uses the GNSMART network RTK software package of Geo++ GmbH to provide reference data for both real-time and post mission applications.

GNSSnet.hu reference station coordinates are determined in ETRF2000 reference frame. Transformation to the Hungarian local grid (EOV) is supported in both real-time and post-processing mode. The desktop version of the official transformation application (EHT^2) can be downloaded from the GSC website free of charge. The real-time version (VITEL) is available for most receiver brands as an extension of the RTK rover receivers' controller software. The transmission of transformation information via RTCM messages is also supported.

The GNSS Service Centre is also contributing to EUPOS. EUPOS is the coordination body of the GNSS real-time networks being installed in the Central and Eastern European countries. The intention is the harmonization of the GNSS services and promotion of cross-border cooperation both on the user and service provider levels.

The service availability level in the year 2010 was 99.74%. In order to further increase the availability and reliability a complete backup system of the central processing applications will be installed in the near future. This means duplicate hardware and software components and automatic switch between primary and backup upon failure.

A real-time fleet management system has also been developed for bigger organisations having numerous rover receivers. With the help of this system an operator of the organisation can monitor not only the actual position of the units belonging to the fleet but also rover position quality information (e.g., applied correction type, number of satellites, DOP values, RTK fix status, age of corrections, etc.).

Remote sensing the atmosphere using GNSS

Hungarian scientist were active in the field of remote sensing the atmosphere using GNSS techniques, too.
The accuracy of GNSS tropospheric models were thoroughly controlled using two weeks of balloon data in Hungary (Banyai 2008). It was recognised that during the meteorological fronts the hydrostatic equilibrium state is disturbed and in that case no the Saastamoinen nor the Hopfield models are sufficient. It may be very disadvantageous if GNSS observations are used to predict the integrated water vapour content. Therefore, modified Hopfield model with three variable parameters (scale, height and power) was introduced and fitted to the balloon data. The modified Hopfield model with time-interpolated parameters can be used to detect the meteorological fronts and to compute the proper tropospheric delays (dry and wet component).

Since the active GNSS network had reached the spatial resolution of ca. 60 km, therefore the application of this network for monitoring the atmospheric water vapour became feasible. Rózsa et al. (2009) estimated the integrated water vapour from GNSS observations and compared the results with radiosonde observations. The two observation set agreed remarakbly well in the studied winter period, and showed a good agreement during the stormy summer period, too. Nowadays the operational GNSS processing system is being created and validated (Rózsa et al. 2010), and in the near future the zenith tropospheric delays stemming from the Hungarian Active GNSS Network could be included in the European GPS Based IWV estimations made in the frame of the EUMETNET E-GVAP programme.
As a byproduct of this research a local tropospheric model has been developed (Rózsa, 2010). Tuchband and Rózsa (2010) showed that this local tropospheric model models the seasonal variation of tropospheric delays better than the well known tropospheric models (Hopfield or Saastamoinen models).
Tuchband (2010) made a comparative study of the accuracy of various tropospheric models, including the one used by the EGNOS system, too.

Galileo local element augmentation system development

In the frame of a former Galileo Joint Undertaking (now GSA) contract the researchers of the Department of Geodesy and Surveying of the Budapest University of Technology and Economics participated in the development of methodology and algorithms and the their validation for the improvement of the positioning accuracy and integrity of the Galileo positioning system (Falzini et al. 2008). As a result of this project (GALILEA) a system has been developed for the local augmentation of the Galilea positioning services, thus a greater accuracy and higher integrity could be achieved.

Precise Point Positioning

With the emerging of the precise IGS orbit and clock products, and an accurate modelling an handling of the systematic errors affecting the GNSS observations, the absolute point positioning could be achieved with a few cm accuracy. Tuchband and Rózsa (2010) used the PPP approach for testing various 'a priori' tropospheric models, while Tuchband (2010) studied the feasibility of cm accuracy precise point positioning during archeological surveys in Egypt. The study concluded that a few cm horizontal and a bit worse vertical accuracy can be achieved after the convergence of the results. Thus surveying accuracy can be achieved even in remote areas, where no geodetic control networks exist.

Application of satellite based and airborne imaging systems

In the reporting period several space and land based geodynamic projects were carried out at the FÖMI Satellite Geodetic Observatory with different spatial scales from global through regional, national to the smaller-scale local level using the Global Positioning System and the Synthetic Aperture Radar Interferometry techniques.
The institute made several multisensor monitoring of land subsidence and hazards (Grenerczy et al. 2008; Oberle, 2009; Grenerczy et al. 2009; Grenerczy et al. 2010), and they were active

in applying the Synthetic Aperture Radar Interferometry technique in Hungary. With the multi-technique investigations including PSI (Persistent Scatterer InSAR), GPS (Global Positioning System), leveling and gravity measurements various hazards (land slide, mining, water pumping, reservoir failure etc.) have been mapped. An extensive academic and research work with young scientists has been initiated in this field, too.
Beside the research at four different locations, the InSAR technique related education and public information dissemination have been speeded up. An InSAR guidebook has been started to compile in 2009 based on various information resources and Hungarian results and experiences. A web based InSAR information system at http://www.sgo.fomi.hu/InSAR/ has also been created and maintained in the reporting period.
Researchers from the BUTE Dept. of Geodesy and Surveying, HAS-BUTE Research Group for Physical Geodesy and Geodynamics, and The Ohio State University have been developing algorithms and methodology for full waveform topographic LiDAR data processing (Laky et al. 2010a, 2010b; Toth et al. 2010, Zaletnyik et al. 2010). This includes data compression methods, classification using neural networks, and advanced peak detection algorithms.

Application of terrestrial laser scanning in engineering surveying

Researchers at the Deptartment of Photogrammetry and Geoinformatics studied the application possibilities of the state-of-the-art terrestrial laser scanners in the field of engineering survey, especially in the field of deformation measurement. Laboratory investigations and on-site measurements were done as well in order to prove that this novel data acquisition technology could be considered as a useful supplementary technique in engineering survey projects (Berényi et al. 2009a, 2009b; Lovas et al. 2008a, 2008b).

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V. Inter-Commission Committee (Theory)

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The book of Awange et al. (2010) presents modern and efficient methods for solving geodetic and geoinformatics algebraic problems. Numerous examples are illustrated by Mathematica software using the computer algebra techniques of the ring, polynomials, Gröbner basis, resultants (including Dixon resultants), Gauss-Jacobi combinatorial and Procrustes algorithms, as well as the homotopy methods. While these problems are traditionally solved by approximate methods, this book presents alternative algebraic techniques based on computer algebra tools. This new approach meets such modern challenges as resection by laser techniques, solution of orientation in robotics, transformation and bundle block adjustment in geoinformatics, densification of engineering networks, analytical solution for GNSS-meteorology and many other problems. For mathematicians, the book provides some practical examples of the application of abstract algebra and multidimensional scaling.

The similarity transformation can be used not only to switch from (global) GNSS frames to the national grids (local frames) and back, but it can be used to study the relative position and orientation of the local frames with respect to the more precise global frames, too. In that case the different available geoid solutions have a very important role. The local astro-geodetic geoids are not accurate enough and the global geoid solutions cannot be transformed to the local frame exactly – just in the lack of the unknown parameters – therefore a new concept was outlined. Taking into account the features of the different geoid solutions and the local reference frames the concept of the simultaneous spatial similarity transformation and local geoid estimation as nuisance parameters was suggested by Bányai and Gyimóthy (2009).

In geodesy and surveying the directions from the points with known coordinates are measured toward the unknown (new) points. The measured angles are used to compute the coordinates of the new points. The relationship between angles and lengths lead to a system of non-linear equations. Two different direct (non-iterative) solutions are discussed: one is based on the Sylvester determinant of the resultant, the other on the Gröbner-basis. Battha and Závoti (2009a) show that in the general case both methods lead to the same equations with one variable and four degree, but in a special case the equations obtained by the Sylvester-determinant are of second degree. As a numerical example, three known points and one unknown point were selected in the city of Sopron. The space angles were used to compute the X, Y, Z coordinates of the unknown point.

In another publication Battha and Závoti (2009b) obtain that the direct solution of the 2D similarity transformation leads to the same result as the application of Gröbner-basis.

The paper of Jancsó and Závoti (2007) demonstrates that the modified cross-correlation methods can be used to detect height errors of DTM points which are determined on the basis of stereo-pairs of aerial images. The usual cross-correlation method is extended by means of dynamic dimensioning and different structures of the correlation matrix. A texture coefficient is also introduced which makes the auto-correlation procedure more robust. Before starting the cross-correlation procedure the accuracy of the exterior orientation elements is checked by application of a direct analytical space resection in conjunction with effective grosserror detection. Moreover the paper points at the importance of the possibility examination of median difference filter. This filter is applied for detection of "sensitive" areas on the digital terrain models. The procedure can be used to visualize and separate the areas where thorough checking procedures would be necessary. Some experimental results are demonstrated which were produced for checking of TDM points.

Jancsó (2008) presented an algorithm for automated quality control of digital terrain models. Before checking the DTM points, we should firs check the control points. If gross errors exist among the control points and the exterior orientation elements were calculated by the control points, we should check and revise the exterior orientation elements, as well, since these errors cause absolute positional errors in the DTM points. These elements should be checked by recalculation. The recalculation and the gross error detection of control points are done by means of a direct analytical method. The paper distinguishes two approaches for image matching: 1. Image matching means the matching of left image points with the right image. The search area on the right image is determined by the location of the right image point which is calculated from the back projection by the collinear equations. After the image matching we gain a new image point on the right image. 2. During the checking of DTM points we can follow the way where the X,Y coordinates of the examined DTM point are fixed and the appropriate back-projected points are calculated at different Z coordinates. This procedure assumes that the area based image matching is executed several times and we will choose the Z coordinate from the case in which the cross-correlation coefficient reaches the maximal value. After this we can calculate the difference of Z coordinates comparing the original Z coordinate of the DTM point with the gained Z coordinate corresponding to the maximal cross-correlation coefficient.

In the case of spatial similarity transformation even three common points result an over-determined system of equations. During the solution the gross errors are spreading out by the least-squares adjustment method. Jancsó (2009) shows an alternative adjustment method that can avoid the spreading out of the gross errors. The process is based on the weighted mean calculation. This method gives the same result as the adjustment method by iterations. At the same time the points having gross errors can be detected before the adjustment. For the detection we need a null-hypothesis comparison of the expected and calculated root-mean-square errors. The root-mean-square errors are calculated from the spatial similarity transformation using the points in every combination on the basis of groups of three points.

If sufficient data storage capacities are available, the today's full-waveform LiDAR systems are able to record and store the entire laser pulse echo signals. This provides the possibility of further analysis of physical characteristics of the reflecting objects. However the size of the captured data is enormous and currently not practical. Therefore a data compressing is needed. Laky et al. (2010) have developed a method to efficiently compress waveform signals using a lossy compression technique which is based on the discrete wavelet transform. Land classification itself is also a non-trivial task. They have implemented an unsupervised land classification algorithm, requiring only waveform data (no navigation data is needed). For the classification the Kohonen's Self-Organizing Map (SOM) has been used. Finally, the effect of the information loss caused by the lossy compression scheme on the quality of the land classification is studied.

The development of star cameras started in the 1970s. Their purpose was the determination of astronomic position. Using photogrammetric method the fieldwork could be carried out quickly. In spite of the fact that the accuracy was reduced – compared to the traditional methods –the overall time needed for measurement and processing was decreased drastically. In the 2000s, some of these instruments were fitted with CCD sensors. Automatised data processing methods were developed, which provided superior speed and accuracy. Recently, the development of a simplified star camera system has been started in Hungary. In the paper of Laky (2010) some key steps of the processing are outlined. Many of these steps can be regarded as optimization problems. For this purpose, the Differential Evolution was chosen as a fitting algorithm.

Evolutionary algorithms are numerical methods for solving multivariate optimization problems. Mimicking the natural evolution of populations, they mutate and combine possible solution vectors to give birth to a next generation of solution vectors that drives the population closer to the global optimum of the objective function (besides satisfying the given conditional equations). Geodetic application of evolutionary-related algorithms is not completely novel: for example, they have been used to optimize the surveying of GPS networks, and to solve the first order network design problem. In the work of Laky (2009) differential evolution, a relatively new algorithm is proposed as a solution to the free network adjustment problem.

In Paláncz et al. (2008a) a linear homotopy solution is given for GPS N-point navigation problem. The overdetermined polynomial system has been solved without initially guessed values by using natural start system that provides real solutions.

Paláncz et al. (2008b) proposed the Dixon resultant as an alternative to the Gröbner basis or multi-polynomial resultant approaches for solving systems of polynomial equations usually applied in geodesy. Its smallness in size, high density (ratio of the number of non-zero elements to the number of all elements), speed, and robustness (insensitive to combinatorial sequence and monomial order, e.g., Gröbner basis) makes it extremely attractive compared to its competitors. Using 3D-intersection and conformal C7 datum transformation problems, they compare its performance to those of the Sturmfels's resultant and Gröbner basis. This highlights the robustness of the Dixon resultant (i.e., the capability to use both absolute and relative coordinates with any order of variables) opposite to the Gröbner basis, which only works well with relative coordinates, and is sensitive to the combinatorial sequence and order of variables.

A fundamental task in geodesy is solving systems of equations. Many geodetic problems are represented as systems of multivariate polynomials. A common problem in solving such systems is the proper choice of the starting values for iterative methods. It may lead to the solutions with no physical meaning, or to the convergence that requires global methods. Though symbolic methods such as Gröbner basis or resultants have been shown to be very efficient, i.e., providing solutions for determined systems such as 3-point problem of 3D affine transformation, the symbolic algebra can be very time consuming, even with special Computer Algebra Systems (CAS). The study of Paláncz et al. (2010) proposes the linear homotopy method that can be implemented easily in high-level computer languages like C++ and Fortran which are faster than CAS by at least two orders of magnitude. Using Mathematica software, the power of homotopy is demonstrated in solving three nonlinear geodetic problems: resection, GPS positioning, and affine transformation. The method that enlarge the domain of convergence is found to be efficient, less sensitive to rounding of numbers, and has lower complexity compared to other local methods like Newton–Raphson.

Variational spline functions have already been successfully applied for deriving Digital Terrain Models. In the paper of Varga et al. (2008) a method have been constructed which is based on variational spline functions and the multigrid principle, for optimization of the stereographic measurement of a human face. The solution is interested in medical applications and facial reconstruction. This method has subsequently been elaborated by redefining the validation procedure through changing the convolution mask suitable for a more realistic point distribution, and as its consequence, by redefining the whole parameterization (Varga et al. 2009).

The paper of Zaletnyik et al. (2008) is a contribution to the previous work of Awange and Grafarend (2010) where Gröbner basis and Dixon resultant are available as the engine behind Computer Algebra Systems (CAS). The authors demonstrate how 3D GPS positioning, 3D intersection, as well as datum transformation problems are solved 'live' in Mathematica, thanks to modernization in CAS.

The 9 parameter 3D affine transformation is the generalization of the 7 parameter Helmert transformation where instead of one scale parameter 3 different scales are used according to the 3 coordinate axes. In the study of Zaletnyik et al. (2009) the symbolic solution of this transformation is given in case of the minimally required 3 known points. From the 9 variable nonlinear system of 9 algebraic equations, a quadratic univariate polynomial and the positive real roots are deduced which give the solution of the transformation problem. Different methods are demonstrated and the analytical form of the solutions for the 9 parameter is given. The main advantage of this result is that we do not need linearization or initial guess values of the 9 parameter, which is necessary in the case of the traditional solution of the nonlinear equation system. The result can be useful in the solution of the N-point case also, using Gauss-Jacobi combinatorial method, or using this solution as initial value for a local numerical solver.

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VI. Communication and Outreach Branch

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1. Introduction

The period of 2007-2011 is the second term in the operation of the Communication and Outreach Branch (COB) hosted at the Department of Geodesy and Surveying of the Budapest University of Technology and Economics (BME) with the MTA-BME Research Group for Physical Geodesy and Geodynamics of the Hungarian Academy of Sciences (MTA), Budapest, Hungary.
The Communication and Outreach Branch is one of the components of the Association. According to the new Statues (§5) of the IAG, the COB is the office responsible for the promotional activities of the IAG and the communication with its members.
The Terms of Reference and program of activities of the COB, and a short report on the IAG website ("IAG on the Internet"), were published in The Geodesist's Handbook 2008 (Ádám and Rózsa, 2008; Rózsa, 2008), respectively.
In the past period of the second term (since the 2007 IUGG General Assembly in Perugia till July, 2009) the COB's Steering Committee held a meeting in Vienna, Austria, 18 April, 2008. Helmut Hornik IAG Assistant Secretary General visited us at the COB office in Budapest in 25-26 February, 2009 in order to update and synchronize the database of the IAG Individual Members. An other meeting of the COB's Steering Committee is planned for June 2011 in Budapest (or in Melbourne).

2. The IAG Website

The Communication and Outreach Branch maintained the IAG Website. The website has been operational, no significant downtime has been experienced in the service. A regular update of the content has been carried out using the material provided by Association and Commission leaders, conference organizers and other members of the Association.

In the second half of the period the website has been redesigned after a consultation with the IAG Office and the Steering Committee members. A new section has been introduced, where the actual topics in Geodesy can be highlighted ("Topic of the Month"). Moreover a section introducing Geodesy to the wider public has been added to the website, and all the printed information material can be downloaded, too.

3. The IAG Newsletters

Altogether 46 IAG Newsletters have been published from March 2007 till December 2010 and can be accessed on the IAG new website in HTML, HTML print version and in PDF formats. We strive to publish only relevant information by keeping the Newsletter updated on a per-monthly basis. The IAG Individual Members, IUGG and JB GIS Presidents and Secretaries as well as interested persons mainly in developing countries received it in PDF and/or text attachments, with a link in the e-mail message to access the actual HTML Newsletter on the IAG website. Selected content of the electronic Newsletters were compiled and have been sent regularly to Springer for publication for 35 issues of the Journal of Geodesy (Vol 81/5 – 84/12). Starting from the double issue 82/11-12 the volume of the

Springer IAG Newsletters is limited to 3-4 pages due to a change in the editorial policy to improve the impact factor of the journal. Hence we strived to publish only new and/or relevant material as a service to the IAG community.

4. Outreach Activities

The COB has been active in the publishing of information material in the reporting period. A new brochure has been published (16 coloured pages), which targets the wider public and decision makers by introducing Geodesy in general as well as the role of the Association to the readers (Ádám and Rózsa, 2009). It has a chapter on the Global Geodetic Observing System, and provides information on the IAG components (Commissions, Inter-Commission Committee, Services, etc.).

Another shorter version of the brochure has been published for the JB GIS, too (Rózsa and Ádám, 2010). Both of the brochures can be downloaded from the opening page of the IAG website, together with the updated IAG leaflet (Ádám and Rózsa, 2007).

J.Ádám (2008) prepared a summary on “Update of the History of the International Association of Geodesy”.

5. Summary

In sum, the following activities were done:

a) the IAG website was updated, improved and continuously maintained;
b) the IAG Newsletter was regularly issued monthly and distributed electronically, and selected parts of them were prepared to publish in the Journal of Geodesy as IAG News;
c) new version of the IAG Leaflet was prepared, printed and distributed at different IAG meetings;
d) the large IAG Brochure was finalized through a long review process;
e) one short 4 pages IAG booklet was prepared for the Joint Board of Geoinformation Societies (JBGIS);
f) some works were made in preparation and for finalizing The Geodesist’s Handbook 2008 (Drewes et al., 2008), and
g) many e-mail correspondences to the community as part of the outreach activities.

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