Report to IAG

Ladislav Brimich
IAG National Correspondent

POSITIONING AND APPLICATIONS

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

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

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

GENERAL THEORY AND METHODOLOGY

Development of new techniques for inversion and interpretation of gravity data

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

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

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

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

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

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

GEODYNAMICS

Earth rotation

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

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

Reference frames

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

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

Interpretation of temporal gravity changes and surface deformations

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

Earth tides research

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

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

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