Integrated geodetic infrastructure at the Geodetic Observatory Pecný, Czech Republic, in service of national and international GNSS projects

Pavel NOVÁK, Czech Republic

Key words: geodesy, reference systems, geodetic observations, GNSS, gravimetry

SUMMARY

Geodetic techniques provide both the reference frame for Earth system observations as well as observations of crucial parameters related to changes in the Earth's geometry, rotation and gravity field. To ensure a long-term stability of the terrestrial reference system at the relative accuracy level of 1E-9, interactions between different time-dependent influences of the Earth's system to the terrestrial reference system have to be considered. Therefore, necessary observations of different observation techniques must be available. To achieve reliable results, geodetic observations must be completed for meteorological parameters and environmental data of different kinds (ground water level, soil moisture etc.). The Geodetic Observatory Pecný, Czech Republic is an example of the integrated geodetic infrastructure which continuously provides time series of GNSS, gravity, seismic, environmental, climatologic and meteorological observations. The observatory also operates data and analysis centres of international scientific services within the International Association of Geodesy and participates at several national and international geodynamical and meteorological projects. The observatory serves as a reference station for a scientific and experimental GNSS network operated in the Czech Republic and supports the national reference GNSS network providing differential corrections to GNSS users (including monitoring stability of its stations).

Integrated geodetic infrastructure at the Geodetic Observatory Pecný, Czech Republic, in service of national and international GNSS projects

Pavel NOVÁK, Czech Republic

1. INTRODUCTION

The Earth is subject to a multitude of dynamic processes that cover a broad variety of spatial and temporal scales and are driven by various interior and exterior forces. The need for a global monitoring of the Earth has been recognized by UN which resulted in initiating several global observing systems. None of these systems explicitly includes a geodetic component nor it is directly connected to the Global Geodetic Observing System. Nevertheless, only geodetic techniques can provide both the reference frame for Earth system observations as well as observations of crucial parameters related to changes in the Earth's geometry, rotation and gravity field. To ensure a long-term stability of the terrestrial reference system on the accuracy level of 1E-9 in the global and continental scale, the interactions between different time-dependent influences of the system Earth to the terrestrial reference system have to be considered. Therefore, necessary observations of different observation techniques must be available. To achieve reliable results, observations must be completed with meteorological parameters and environmental data of different kinds (ground water level, soil moisture etc.).

A possible contribution of a regional geodetic infrastructure is illustrated by an example of the Geodetic Observatory Pecný, Czech Republic, which continuously provides time series of GNSS, gravity (based on absolute and superconducting gravimeters), seismic, environmental, climatological and meteorological (including radiometric atmosphere profiling) observations. Parallel to it, several data and analysis centers of the IAG international scientific services and of international geodynamical and meteorological projects are running at the observatory. The observatory is also a reference station for the scientific and experimental GNSS network operated in the Czech Republic and a part of the regional seismic network. Samples of time series of observations are presented.

2. GEODETIC OBSERVATORY PECNÝ

The Research Institute of Geodesy, Topography and Cartography (RIGTC) in Prague, Czech Republic, was officially established in 1954 but already before 1954 a small research group in Prague had investigated some problems of geodetic theory and surveying practice. In RIGTC this group tied in the applied research pursued in the Triangulation Office of the Ministry of Finance of Czechoslovakia. In accordance with economic and societal requirements of that time, the group started investigations of several theoretical and applied geodetic problems related to accomplishment of the Czechoslovak Triangulation and Astro-geodetic Networks, to analysis and re-observation of the Czechoslovak Levelling Network and its re-adjustment within a unique levelling network of East-European countries.

The incorporation of the Geodetic Observatory Pecný (GOPE) into the structure of RIGTC in 1965 stimulated an experimental research in geodetic astronomy, geodetic gravimetry, theory of measurement and geodetic instruments and linked RIGTC to international permanent (first astrometry, later also satellite and earth tides) observation services. GOPE had as an experimental facility a relatively high international standard in 1960's and in early 1970's, but it was slowly felling below later mainly due to morally obsolete instrumental equipment. At the beginning of 1990's (with political changes in the former Czechoslovakia) the observatory revived and joined again important international projects.

GOPE is a research facility destined for an experimental geodetic research. It is located about 40 km south-east of Prague nearby the village Ondřejov close to a large campus of the Astronomical Institute of the Academy of Sciences of the Czech Republic. The observatory is a geodetic reference station of the Czech Republic including vertical and gravity reference points. It has a laboratory and a thermal chamber for testing gravimeters, geodetic instruments and GNSS receivers. Its LAN is linked to the Astronomical Institute and through it to the Internet. In the surroundings of the observatory there is a geodetic and photogrammetric test field and a calibration network for testing GNSS receivers.

2.1 Experimental Research

The permanent GNSS station GOPE started its operation in September 1993. Since September 1995 it has been regularly contributing to the *International GPS Service for Geodynamics* (IGS, today *International GNSS Service*). At the beginning the Trimble 4000SSE receiver was used. In November 5, 1999, the Ashtech Z-18 instrument was installed. This receiver was capable of simultaneous observations of both GPS NAVSTAR and GLONASS navigation signals. In 2009 a new GNSS receiver – Topcon CR-G3 – was installed; see Fig 1 (left). This receiver allows for observing the new L2C navigation signal of GPS NAVSTAR. The GNSS observations are supported by a Water Vapour Radiometer, see Fig. 1 (right), installed next to the GNSS antenna. It profiles the atmosphere and measures humidity of air masses above the station. These data are used to correct for tropospheric delays of measured navigation signals.

Figure 1: GNSS antenna (left) and Water Vapour Radiometer (right) at GOPE

The GNSS antenna is mounted in a metal plate with a forced centering embedded on the top of a concrete pier over the roof of the main observatory building. The pier is passing through the building and is embedded in its grounds. Around the upper part of the pier there is an observing platform containing a meteorological box with a sensor for recording local meteorological data (temperature, air pressure, humidity).

GNSS data are provided in both real-time and post-processing modes. Post-processing data are submitted in the RINEX format to international GNSS data centres (BKG, OLG, IGS CDDIS and NASA). Real-time data are provided with a small delay (few seconds) in the RTCM format. Hourly files with one second sampling rates are uploaded to data servers of CZEPOS – *Czech Permanent GNSS Array* – providing differential corrections to GNSS users in the Czech Republic. Real-time GNSS data from GOPE are used for CZEPOS as well as for the international project EUREF-IP. GNSS data series observed by GOPE were also used for establishment of the International Terrestrial Reference System (ITRS) 2008.

Earth's tides at GOPE are recorded by relative gravimeters OSG-050, Askania Gs15, LCR-G and ZLS Burris. Long-periodic gravity observations at GOPE allow for a detailed separation of various tidal waves. Long observation series of data from the superconducting gravimeter OSG-050, see Fig. 2 (right), then allow for a detailed tidal analysis. Data observed by OSG are provided to the *Global Geodynamics Project* (GGP) that organizes the international cooperation of SCG's operators worldwide.

Figure 2: Absolute (left) and superconducting (right) gravimeters at GOPE

The absolute gravimeter FG5, see Fig. 2 (left), installed at the observatory in 2005 is used mainly for epoch observations of gravity. These absolute recordings support permanent gravity observations acquired through relative meters; see Fig. 3. Gravity data are also used for determination of local hydrological effects at the observatory as well as for estimation of long-periodic effects that could be linked to seasonal variations of climate in Europe. Local effects are tested on time series of relative gravity changes measured by SCG.

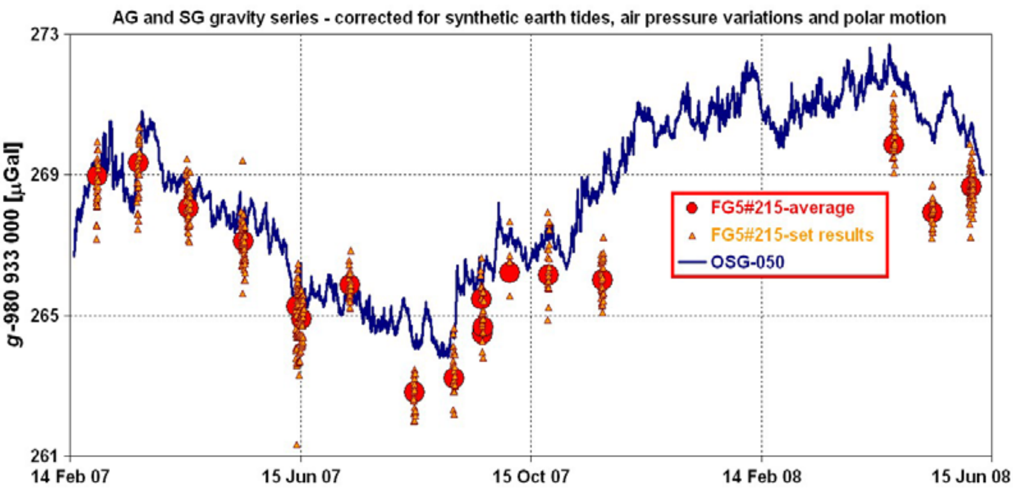

Figure 3: Gravity series of the AG and SG gravimeters at GOPE

Local hydrological effects on gravity at the observatory are also determined by collecting data about soil humidity around the gravimetric lab as well as about ground water changes below the observatory. In connection with a detailed DEM of the observatory and its neighbourhood they allow for evaluation of corresponding gravitational effects.

The astrometric time and latitude observations have regularly been performed at GOPE since 1957. At present only one instrument – a circumzenithal VUGTK 100/1000 – is occasionally being operated. A smaller model of this instrument – a circumzenithal VUGTK 50/500 – is used as a field instrument for determination of vertical deflections especially in mountainous regions. Observation data from circumzenithal observations were after on-site pre-processing supplied for further processing to international centres of optical astrometry, (BIH, Paris; Shanghai, China; Mendeleyevo, Russia). In the past photographic satellite tracking had continuously been performed during the period 1969 – 1990, satellite laser ranging was tested in 1970 and Doppler observations in 1984 – 1989.

2.2 Analysis and data centres

The observatory operates an official local GNSS data centre within the EUREF Permanent Network (EPN). The Local Analysis Centre (LAC) at GOPE contributes to EPN with the full spectrum of products – near-real time, fast and final. GNSS data processing operates fully automatically. LAC also participates at the international project *EUREF Re-processing* and processes routinely data from permanent GNSS arrays within the Czech Republic, see Fig. 4 (left). Time series of all products are freely available through ftp services including stability characteristics of GNSS permanent stations. Since 2010 GOPE has been operating a continuous service monitoring stability of permanent GNSS stations in the Czech Republic.

Times series of their coordinates reveal in specific cases some interesting temporal variations (periodic as well as secular), see Fig. 4 (right).

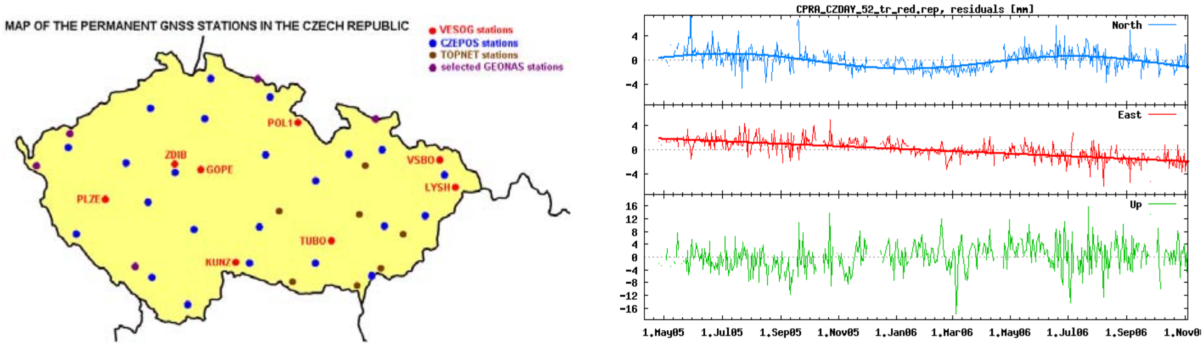

Figure 4: Permanent GNSS arrays in the Czech Republic (left),
temporal variations of coordinates at a selected permanent GNSS station (right)

Within the International GNSS Service (IGS) LAC GOP estimates precise orbits of GNSS satellites that are highly appreciated by the coordinator of IGS analysis centres. Namely ultra-rapid products are widely used in real-time applications of GNSS data. Their high quality and robustness leads to their increasing applicability in various commercial applications. Besides GPS NAVSTAR related products, LAC GOP also provides products based on combination of GPS NAVSTAR and GLONASS data. Recently, initial steps have been taken for real-time determination of clock corrections of GNSS satellites. The stations analyzed by LAC GOP are shown in Fig. 5. GNSS data are also used for GNSS meteorology, a relatively new concept of deriving atmospheric parameters from measured atmospheric delays of GNSS signals.

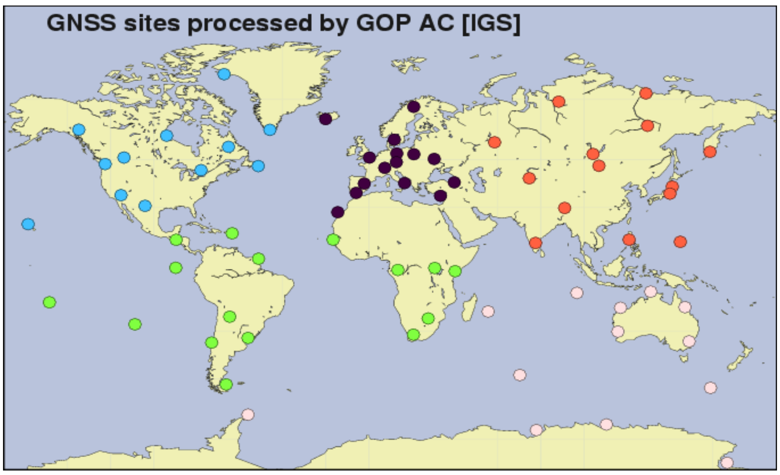

Fig.5: Permanent GNSS array processed by LAC GOP

GOPE also operates an analysis centre of DORIS data (DORIS is a French GNSS based on a system of ground transmitters and space receivers). The centre contributes to the International DORIS Service (IDS).

3. ANALYTICAL ACTIVITIES

Analytical activities of the department are mainly in the field of geodetic control networks, their update and integration within the modern European geodetic control. Recently a project of incorporation of the Czech Trigonometric Network into the European Terrestrial Reference System (ETRS) has been accomplished. In the past, the department participated in the extension of the new European Reference Frame (EUREF) to the Czech Republic, in the establishment of the Czech GNSS reference network and in its densification to the average density of 1 station / 400 km^2 as well as in the direct connection of the Czech GNSS reference network with similar reference networks of Germany and Austria. In the establishment of GNSS reference networks the department takes part by both observations and GNSS data processing by a scientific software package.

The department takes an active part in the process of incorporation of the Czech national geodetic control into the continental European geodetic control by participation in the international projects EUREF and EUVN. With the help of the national GNSS reference network, the national cartographic reference frame S-JTSK/95 has been improved. For Czech cadastral offices, local networks densified by themselves by GNSS techniques, are tied to the national GNSS reference network.

A reference quasi-geoid model was computed for the territory of the Czech Republic with an accuracy of about 5 cm which allows for easy determination of sea level heights from GNSS observations at any place of the state territory. The stability of the reference frame is continuously monitored by evaluation of GNSS observations of a cluster of European IGS stations. For calibration and processing of the GNSS receivers, a calibration network was established at GOPE. In the field of the geodetic control networks the department collaborates with the Land Survey Office and with the Department of Advanced Geodesy of the Faculty of Civil Engineering of the Czech University of Technology in Prague.

4. SELECTED GNSS PROJECTS

The department is involved in several international GNSS projects. LAC GOP routinely contributes with its GNSS-based products to the international project *EUMETNET – GPS Water Vapour Programme* (E-GVAP). GOP products in the area of tropospheric monitoring are highly appreciated and supported financially by the project. In close co-operation with the *MetOffice UK* a global tropospheric model has been developed and tested. This product is still unique in Europe. Tropospheric parameters are estimated from about 100 globally-distributed GNSS stations in a near-real time mode.

In October 2010 GOPE joined the national project *CzechGeo/EPOS – Distributed system of observatory and field observations of geophysical fields in the Czech Republic – development and maintenance of a national component of the European project EPOS*. The main goal of the project is to create a unified observing system operated by Czech geosciences institutions. The frame of the CzechGeo project is based on permanent observatories (such as GOPE) that are linked with international data centres for data upload in real time. Permanent observatories are located at selected locations important for geophysical research. They can be extended for local mobile sensors that measure on demand data at selected points.

The international consorcium *CEGRN – Central European Geodynamics Reference Network* has been operating since 2001. The network was established already in 1993. The consorcium is oriented on coordination of GNSS observations, analysis of GNSS data and geophysical intrepretation of derived products. In the frame of this international co-operation many interesting and important results in the field of geophysical research at the teritory of Central Europe were achived.

GOPE also actively participates in the *European Position Determination System (EUPOS)* – an international initiative and cooperation of national operators of active GNSS systems. Its main goal is to establish a uniform DGNSS-based infrastructure over Central and Eastern Europe for multifunctional regional applications of DGNSS. A network of active reference stations providing the position accuracy at the level of 1 cm will be established on the basis of the common reference frame ETRS89, unified data formats and international standards. The EUPOS should meet requirements of a wide spectrum of GNSS users.

5. CONCLUSIONS

The contribution of a regional integrated geodetic infrastructure to global geodetic monitoring of the Earth and to GNSS projects was illustrated by activities at the Geodetic Observatory Pecný (GOPE), Czech Republic. This observatory continuously provides time series of GNSS, gravity, seismic, environmental, climatological and meteorological observations. Parallel to it, several data and analysis centers of international scientific services and of international geodynamical and meteorological projects are running at the observatory. The observatory also serves a reference station for scientific and experimental GNSS networks operated in the Czech Republic.

BIOGRAPHICAL NOTES

Pavel Novák obtained his PhD degree at the University of New Brunswick in 2000. He is a professor of geodesy at the University of West Bohemia, a Scientific Director of the Research Institute of Geodesy, Topography and Cartography and the Head of its Department of Geodesy and Geodynamics. Pavel Novák is a Chairman of the FIG National Committee of the Czech Republic, an Elected Fellow of the IAG, Vice-President of IAG's Inter-Commission Committee on Theory, author or co-author of 65 publications and over 120 presentations.

CONTACTS

Pavel Novák
Research Institute of Geodesy, Topography and Cartography
Ústecká 98
250 66 Prague-East
CZECH REPUBLIC
Tel. +420 728 383 486
Fax +420 377 632 602
Email: pavel.novak@vugtk.cz
Web site: http:/www.KMA.zcu.cz/Pavel.Novak