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Geodetic Reference Frames in the Czech Republic 2002 - 2003 Progress Report

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1. Densification of EUREF in the Czech Republic

The densification process is reported in described in *(Kostelecký and Šimek, 1993, 1995),(Šimek and Kostelecký, 1994)* and *(Kostelecký et al., 1996, 1997, 1998, 1999, 2000, 2001)*. The beginning of the ETRF89 in the Czech Republic dates back to 1991 (campaign EUREF CS-H/91), followed by its full realization in 1991 - 1994 and implementation in 1995, *(Kostelecký, Dušátko, eds., 1998)*. The national reference frame is represented by 174 sites of the national GPS reference network DOPNUL. The coordinates of the DOPNUL stations were determined from a combined processing based on the data from several national densification campaigns - NULRAD, CS-BRD-93 and DOPNUL, see Figure 1.

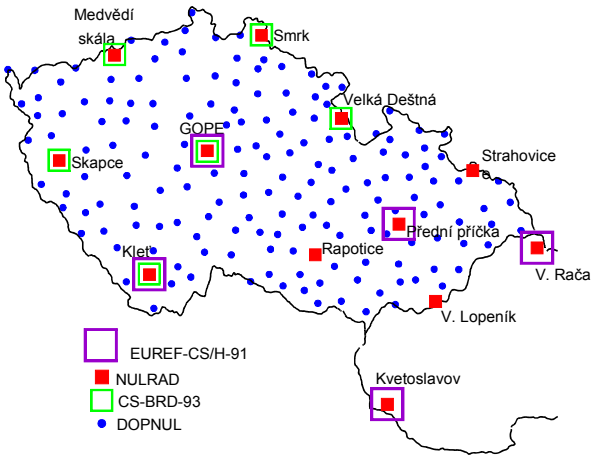

Figure 1

Since 1995 this national reference frame has been densified in two parallel ways. The first densification, carried out by the Land Survey Office, is called ”selective maintenance” and is aimed to GPS user community. It is based on the national GPS reference network DOPNUL. After the work is finished the total number of GPS stations will be 3,500 and the final density will be 1 station/24 km sq with an average spacing below 5 km. All these stations are identical with the triangulation stations of the national terrestrial triangulation network but they are equipped with a new monumentation and a special protection against damage. Until the end of 2002 1,768 stations were determined. Their coordinates are available in ETRF89 and in both the official national user system S-JTSK and an

improved user system S-JTSK/95. The improved system S-JTSK/95 has been realized in two variants. The first is represented by the official user system S-JTSK rectified only by the "precise" terrestrial system S-42/83, the second one is an amended version of the first created by incorporation of available GPS observations. The differences between the first and the amended variant of the S-JTSK/95 are displayed in Fig. 2, see also *(Kostelecký, Dušátko, eds., 1998)*. The standard deviation in horizontal position is 3.9 cm. The differences between the amended variant of the S-JTSK/95 and the original (still official) S-JTSK are represented in Fig. 3. In this case the horizontal standard deviation is 11 cm. Fig. 3 also clearly shows local systematic distortions of the user system S-JTSK.

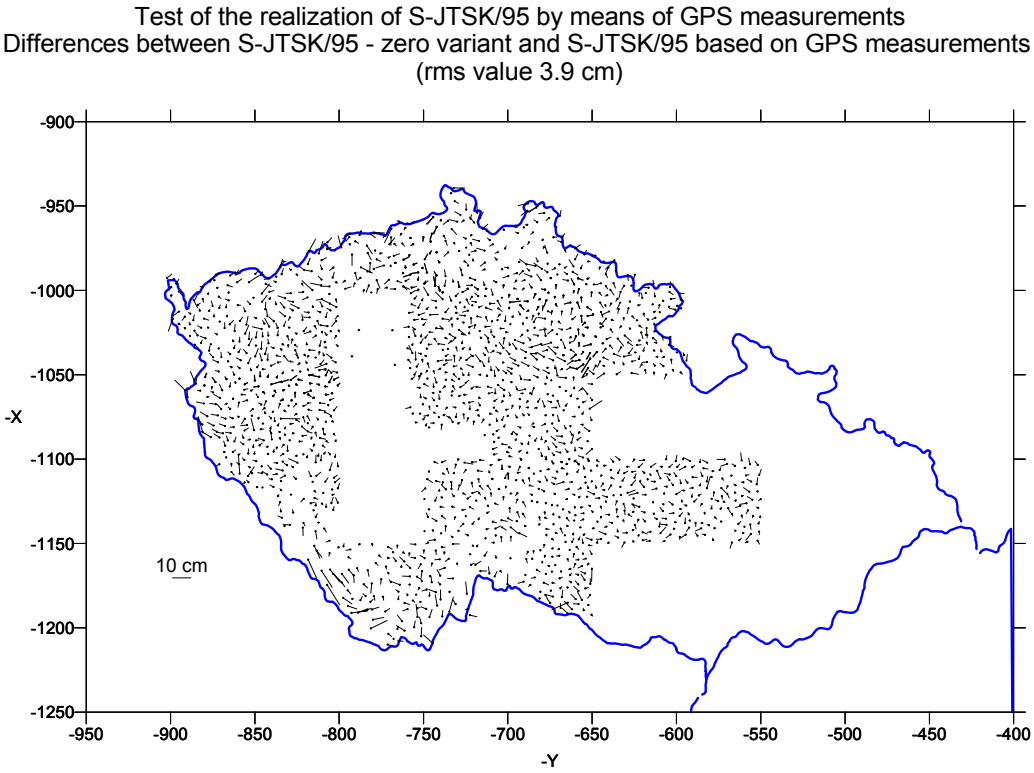

Figure 2

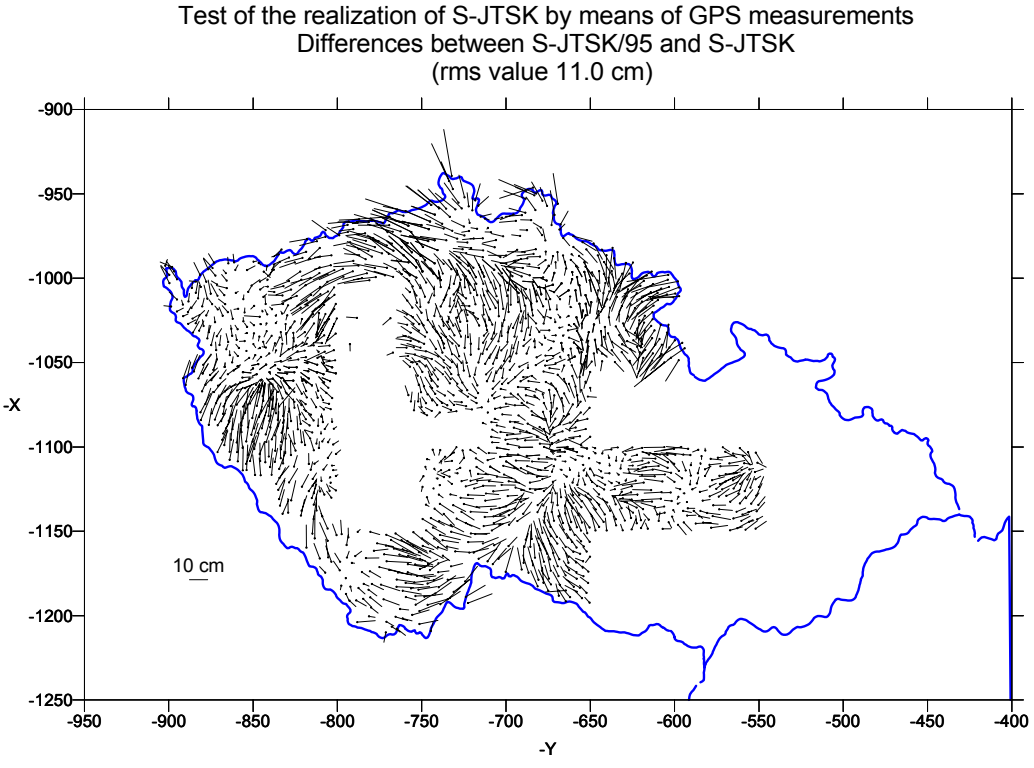

Figure 3

Parallel to the "selective maintenance" the other large scale GPS based densification has been carried out since 1995 by the regional cadastral offices (departments of cadastral mapping) under the title "Densification". The project will have been finished by the end of 2003. Unlike the "selective maintenance", where the GPS campaigns are carried out at existing triangulation stations, in this case it is about establishing a large number of new densification stations by GPS observations. The total number of these new stations should be over 30,000. At present preliminary ETRF89 geocentric coordinates tied to the national GPS reference network DOPNUL are being determined along with classical plane coordinates in the national user system S-JTSK. These coordinates are determined by transformation using local transformation formulas.

After the whole work is accomplished a new stepwise adjustment "by regions" is supposed to get final ETRF coordinates. A software for the adjustment of the large geodetic networks has been developed in the RIGTC for that purpose in 2000 *(Kostelecký, 2000)*. A test common processing of 1,841 stations determined by GPS fast static technique in South Bohemia region was performed in 2002. This subnetwork was connected to 10 stations of the DOPNUL network. The inner accuracy characterized by the r.m.s. errors is about 1.4 cm for the horizontal components and for the up component it is 1.2 cm.

The data from both densifications are archieved in the form of "database" files of the observation vectors. For the near future we suppose

- reobservation and reprocessing of the DOPNUL network
- reprocessing of the "selective maintenance" densification network in one block using archieved vectors connected to the DOPNUL network
- reprocessing of the network created within the frame of the "Densification" project computing one block for one region using the vectors connected to the stations of "selective maintenance".

Information about stations (coordinates, sketches, etc.) are collected in ORACLE type database maintened by the Land Survey Office in Prague. The internet access to this database is supposed within two years.

The following table 1 gives a brief summary of the GPS related reference frames in the Czech Republic.

Table 1: GPS-related reference frames in the Czech Republic

Status of station	No of stations/ average distance	Coherence with the EUREF data base	Coordinates based on the campaigns	Maintenance/ availability	EUREF stations
EUREF stations	3 / 150 km	in database	EUREF-CS/H-91	periodical check/ database	yes
zero-order network - NULRAD	10 / 90 km	no	NULRAD92	periodical check/ database	no
national GPS reference network - DOPNUL	174 / 21 km	no	NULRAD92 CS-BRD-93 DOPNUL	periodical check/ database	no
"Selective maintenance network"	1,950 / < 5 km in 2002 3,500 / < 5 km in 2007	no	"selective-maintenance" campaign connected to DOPNUL stations (1996 – 2007)	no strategy yet/ database	no
"Densification network"	30,000 /< 2 km in 2005	no	"densification" campaigns 1995 - 2003	one revision planned/ database	no

New gravimetric and levelling ties of the EPN station TUBO (TU Brno) to national networks were made by the Land Survey Office, Prague.

2. EPN Based Geodynamics

The analysis of the time series of coordinates of 20 EPN stations in Central Europe with respect to GOPE station was performed. The results - secular changes of coordinates - were used for regional geodynamics studies in Central Europe – see *(Kostelecký (jr)., Kostelecký, Kalvoda, 2003)*. The same analysis was also performed for 143 EPN stations and the tools of continuum mechanics were applied to determine the deformation tensors and vertical shifts in the European part of EURA tectonic plate – see *(Kostelecký(jr.),Kostelecký, 2003)*. The results were presented at AGU-EGS-EUG Joint Meeting in Nice, April 2003.

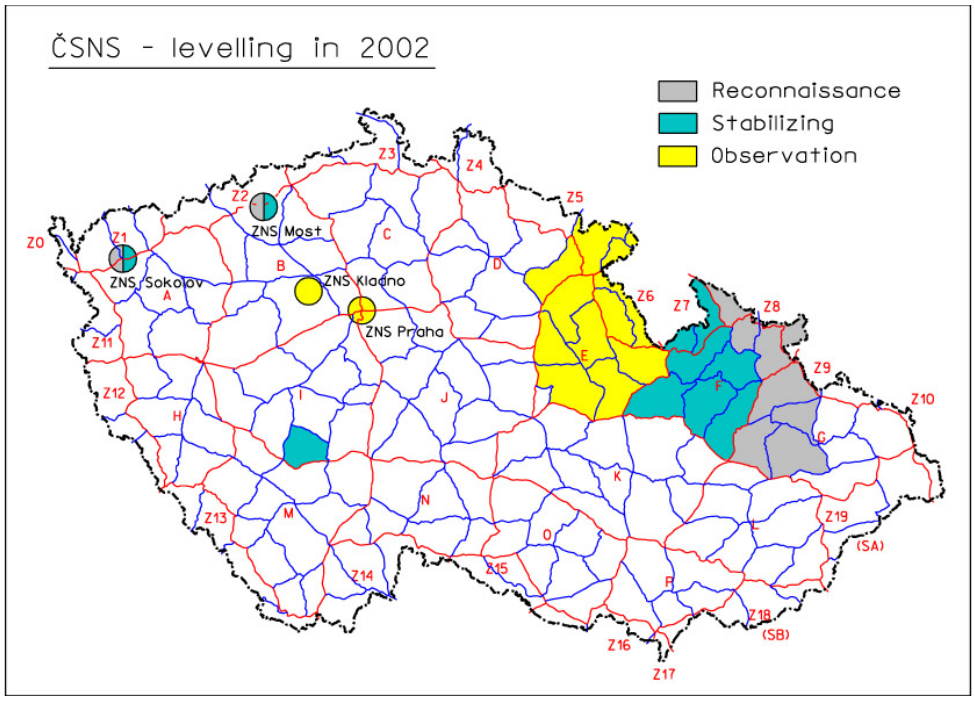

Figure 4

3. UELN 2000 and UEGN 2002 Related Activities

In 2002 the relevelling in the 3rd order Czech National Levelling Network (CNLN) was ongoing by the measurement of 650 km levelling lines. Besides, 210 km of levelling lines in the Special Levelling Network (SLN) Praha, and the SLN Kladno were observed – see also Fig. 4. The field inspection was performed in the SLN Most and SLN Sokolov. At the end of 2002 the Czech National Levelling Network included 82,681 levelling bench marks connected by levelling lines of total length of 24,814 km.

The evaluation of the connection of the Czech and Slovak levelling networks was finished in November 2002.

The Czech part of the Unified European Gravimetric Network (UEGN) was completed by new results from absolute and relative measurements performed in 2001. The Research Institute of Geodesy, Topography and Cartography (RIGTC) in cooperation with the Land Survey Office carried out the absolute gravity measurements at the new stations Liberec and Rožnov p./R., and repeated measurements at Litoměřice and Benešov n/Č stations. The measurements were made by the absolute gravimeter FG 5, No.215 of the RIGTC.

4. Permanent GPS Observations

The two Czech EPN stations GOPE (Geodetic Observatory Pecný) and TUBO (Brno University of Technology), both operated by the RIGTC, have been providing the data from global satellite navigation systems along with meteorological data. At present the following data files are being provided on a routine basis:

- 30 sec NAVSTAR and GLONASS (GOPE only) daily and hourly data files regularly transferred to the IGS/EUREF data centers in Graz and in Frankfurt/Main,
- 5 sec NAVSTAR 5 minute data files stored at the observatory server and used for DGPS experiments,
- 1 sec 15 minute data files (GOPE only) in support of IGS LEO Pilot Project,
- real time data (GOPE only) via Internet for real-time DGPS experiments

The station GOPE has been involved in IGS, EUREF and LEO projects, TUBO in EUREF, and both stations also in projects oriented to the GPS ground based meteorology (COST716, TOUGH).

Two "pseudo-permanent" stations were established by the Institute of Rock Structure and Mechanics of the Academy of Science of the CR within the frame of "Center of Earth's Dynamics Research". These stations are located in Sudeten – the first at "Snezka" mount, the other at "Biskupska Kupa" mount. Both stations are occupied by Ashtech Z-18 GPS instrument observing in permanent mode, but no on-line data transfer is available. The connection by modem and mobile operator is used for maintenance only. Further three "pseudo-permanent" stations are in preparation in West and South Bohemia.

Since March 2003, the GOP is participating in the EUREF-IP special EPN project. The site GOPE operates as a broadcaster for the RTCM messages (actually 1,3,16,18,19,22,31,36) using the ASHTECH Z-18 receiver including the GLONASS corrections.

5. EUREF Local Analysis and Data Center GOP

The Geodetic Observatory Pecny analysis center (GOP AC) makes a regular processing of 37 EPN sites. Starting from 2001 the GOP has also been delivering troposphere products in TROSINEX format in addition to the standard weekly product for maintaining the reference frame. This activity is a contribution to the EPN Special Project "Troposphere Parameter Estimation".

The function of the GOP data center (DC) (ftp://pecny.asu.cas.cz/LDC) was completely re-designed in early 2003. The goal was to provide extended services along with decreasing latency. It has been reached by minimizing redundancy of the downloads, increasing efficiency of the whole procedure, simplifying configuration of the data together with a special data handling for different projects, maintaining a data base of all DC activities for monitoring etc. More details are given in *(Douša, Souček, 2003)*.

The GOP analysis center also participates in other projects mostly concerning routine hourly GPS data analysis. These are COST Action 716 European project ("Exploitation of the ground based GPS for climate and numerical weather prediction applications", 1998-2004) [e.g. Van der Marel, 2002] and TOUGH ("Targeting Optimal Use of GPS Humidity measurements in meteorology") project of the 5-FP EU (2003-2005), http://tough.dmi.dk. Within the COST-716 Near Real-Time Demonstration campaign (2001-2003), the GOP AC routinely provides a solution of hourly ZTD's for approx 50 sites, which are regularly delivered for the testing GPS data assimilation into the numerical weather models and the use for the numerical weather predictions. The routine monitoring of the results is available on the web: http://www.knmi.nl/samenw/cost716/. The TOUGH project is more or less successor of the COST Action 716 and its goals were presented in *(Vedel, 2003)*.

Additionally, GOP analyses a global NRT GPS solution for determining sub-daily precise orbits updated every 3 hours, *(Douša, 2003)*. Within the global solution, the troposphere delays are also estimated and are contributing to non-official IGS near real-time troposphere product.

More information of the GOP activities can be found at http://pecny.asu.cas.cz/gop.

6. Detailed Quasigeoid for the Czech Republic

The older version of a quasigeoid model for the Czech Republic "CR 2000" – see *(Kostelecký et al., 2001),* was compared with the quasigeoid heights determined for 640 GPS/levelling sites from the systematic ETRF densification from the period 1998 to 2002 described in paragraph 1. The r.m.s. error of the height component of these stations is estimated to be 1.5 - 2 cm. The differences between the new quasigeoid model and GPS/levelling results for these stations are illustrated in Fig. 5. The standard deviation is 3.5 cm. Thus, the method of GPS heighting in the Czech Republic can at present give an accuracy of about 3 cm or better over the most part of the territory.

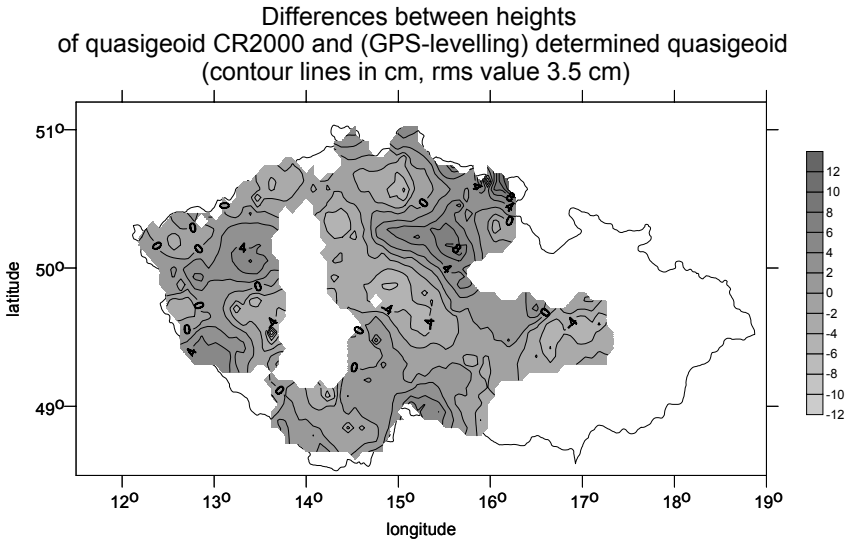

Figure 5

7. Gravimetry

Gravimetric earth tides have been continuously recorded by the tidal gravimeter Askania Gs15 No. 228 equipped with the digital feedback *(Brož et al., 2002)*. Since 2001 the upgraded gravimeter LaCoste & Romberg G No. 137 equipped with the MVR feedback has also been employed. The standard deviation of an hourly ordinate from a tidal analysis was for both gravimeter better than 1 nm s^{-2}. The gravimeter LaCoste & Romberg G No. 137 was also used for detailed measurements of the vertical gravity gradient above the absolute gravity point, for precise calibration of the MVR feedback signal with the help of the measuring screw *(Pálinkáš, 2002)* and for experimental investigations of magnetic and temperature effects on the gravimeter reading *(Pálinkáš et al., 2002)*.

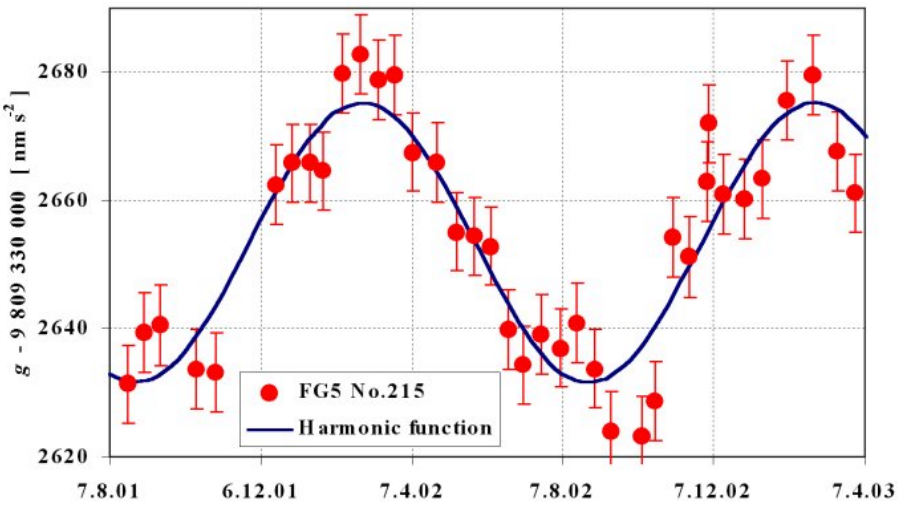

Figure 6 – Absolute gravity at GO Pecný mesured by gravimeter FG5, No 215 of Research Institute of Geodesy, Topography and Cartography

The absolute gravimeter of the Research Institute of Geodesy, Topography and Cartography FG5 No. 215 was installed at the GO Pecný in August 2001. Since that time the regularly repeated absolute gravity measurements have been carried out at this station in approximately two-week-intervals *(Pálinkáš, Kostelecký (jr.), 2002)*. Altogether 40 absolute gravity campaigns were carried out till mid May 2003. From the time sequence of the results (see Figure 6) we can infer that gravity at the observing site is not constant. The change of gravity can be represented by a harmonic function with the period of 1 year. The amplitude of this change was estimated to be about 22 nm s^{-2} and the maximum is at turn of February and March. The detected variation of gravity might be caused by changes of ground water masses around the observing site. For evaluation of the hydrological effects on the gravity the height of the ground water level, precipitation and soil moisture have been monitored around the observatory.

The results of repeated absolute observation campaigns were used for computing and checking the calibration coefficients of the tidal gravimeters running at the observatory. The calibration coefficients were determined on the accuracy level of 0.05 %.

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