Development of the Czech National Geodetic Control

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1. Densification of EUREF in the Czech Republic, DGPS method

In the years 1991 – 1994 the ETRF89 was established in the Czech Republic by the extension of the EUREF to the territory of former Czechoslovakia, see e.g. (SEEGER et al., 1994) and by accomplishing two national densification campaigns, see e.g. *(*KOSTELECKÝ and DUŠÁTKO (eds.), 1998*).* Since 1996 the Land Survey Office has been performing further densification of the national ETRF reference frame aiming at the final density of about 1 point per 25 km sq. (total about 3,500 points for the Czech Republic) which should be reached in 2006. These GPS sites are identical with the national triangulation points and are equipped with a special protection. Their coordinates will be available in the "improved" civilian user system S-JTSK/95 (defined by both geocentric ETRF89 coordinates and planar coordinates of the national oblique conical conformal projection with sea level heights) and also in the official user system S-JTSK system. The connection of above mentioned network and GPS network of Federal Republic of Germany is planned in the year 2000.

The densification was launched in 1996, at present the coordinates of 853 new points are available, see Figure 1. The coordinates in ETRF89 have been used to check the accuracy of the realization of an improved national civilian reference frame S-JTSK/95, which is based on the national GPS reference network used for the transformation of the "precise" military reference frame S-42/83, see (KOSTELECKÝ and ŠIMEK, 1999). R.m.s. position error is 3.8 cm, r.m.s. error of the sea level height, computed with the combined quasigeoid VÚGTK 95 (GPS, levelling, gravity, vertical deflections) is 4 cm – see Figure 2. The relative error in position is 8 mm/km. A comparison of the coordinates of 853 new points with the official user system S-JTSK gives the r.m.s. position discrepancy of 11cm.

Since 1995 the Cadastral Offices (Departments of Cadastral Mapping) have been making an extensive densification of the detailed surveying control field using GPS techniques. The related GPS measurements are linked to the national GPS reference network DOPNUL. Almost 30,000 new points with both ETRF89 and S-JTSK (Czech National Terrestrial Reference System) will be established till 2004. The final density should be 1 point per 1 – 2 km sq. Due to the observation procedure used the position accuracy of these points will be of about 3 cm.

In the frame of the application DGPS technology for precise geodetic measurement (eg. densification of the reference frame) the post-processing DGPS method has been developed. The method is based on the network of permanent GPS stations with remote access of users via internet.

2. UELN 2000 – Related Activities

In 1998 – 1999 the activities have continued towards data collection and recomputation of the levelling loops of the 1st and 2nd order to the system of geopotential/levelling differences. This task was made for levelling from the time interval 1939 to 1955 and 1973 to 1992 respectively. Obtained results were transferred in December 1999 to the UELN2000 analytical center in BKG Leipzig.

The main characteristics of the Czech part of UELN2000 are as follows: 517 of 1st and 2nd order levelling lines, 188 levelling loops (134 closed), 384 levelling sites (56 common sites with neighbour countries). The total length of levelling lines is 9841 km.

3. Fundamental Geodynamical Network of the Czech Republic

The Fundamental Geodynamical Network of the Czech Republic (GEODYN), which consists of 32 stations – see e.g. (KOSTELECKÝ et al., 1999). Most of the geodynamical stations are realized through levelling bench marks with a special deep-borehole monumentation (so called height indication points). Since Spring 1995 five repeated GPS observation campaigns have been carried out in this network. In the period 1995 – 97 all geodynamical stations were re-levelled and in 1996 – 98 all stations of the network were connected by precise relative gravity measurements with links to the absolute gravity points.

After discussions with geomorphologists nine sites of the geodynamical network were selected for the sixth repeated observation in June 1999 – see Figure 3.

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4. Permanent GPS Observations at the IGS Station GOPE

In November 1999 the receiver Trimble 4000SSE, which has been operated at the IGS station GOPE since 1993, was replaced by the new Ashtech Z-18 to observe NAVSTAR and GLONASS satellites. The permanent GPS observations are going on in fully automated process. The NAVSTAR data are transferred to the regional data center Graz and further forwarded to the IGS data center BKG Frankfurt am Main, the GLONASS data to the IGEX data center in BKG Frankfurt am Main. In station reports weekly published by the IGS Central Bureau the prevailing evaluation of the station GOPE is 10-9 as to data quality and quantity, only the latency is usually 9. Since November 1998 hourly observation files have been produced in addition to traditional daily files to support the international pilot project aimed at ground-based GPS meteorology and at rapid orbits. Since March 2000 one-second data have been observed and collected to test the ability of the GOPE station to participate in future in the LEO (Low Earth's satellite Orbit) project. Since November 1999 meteo data – temperature, atmospheric pressure and relative humidity – have been observed and transferred to the above mentioned data centers.

5. Activities of the EUREF Local Analysis Center GOP

Since January 1997 the Geodetic Observatory Pecny (GOP) in cooperation with the Department of Advanced Geodesy of the Czech Technical University in Prague has operated the EUREF Local Analysis Center (LAC) of the EUREF Permanent GPS network (DOUŠA, 1997).

Today GOP LAC subnetwork consists of 22 IGS/EUREF stations (June 2000) located in the whole Europe. The Bernese GPS software V4.2 is used for GPS data processing. Automated processing mode is realized by the Bernese Processing Engine (BPE) and it is controlled by a specially developed superstructure of shell scripts.

Apart from the production of the official results (SINEX solutions), GOP LAC has been performing several other activities: testing different aspects affecting the daily/weekly GOP solutions and investigating the method of velocity estimation from a long-period data combination of GOP results. All products and results of related analyses are available on URL: http://gama.fsv.cvut.cz/euref.

The GOP joined the pilot project of the Near-Real-Time GPS hourly data processing in Autumn 1998. The project should support the ground-based GPS meteorology and climatology studies. At the beginning the GOP work has been focussed on acquiring good stability in the evaluation of total zenith troposphere delays using predicted precise orbits. Different processing variants (absolute/relative estimation, elevation angle, a priori constrains, ambiguity fixing, gradient estimation etc.) have been investigated. During the year 1999 the processing routinely provided the total zenith delays for 14-20 sites both in hourly NRT mode (1-2 hours delayed, using predicted orbits) and in daily post-processed reference solution (18-36 hours delayed, using rapid orbits). The comparison with available radiosonde data resulted at the standard deviation for post-processed solutions of about 0.8 mm (in precipitable water vapour) and for NRT solutions of about 1-1.2 mm. In 2000 we have further tested the impact of subdaily orbit products.

Results of the routine NRT processing are available on the internet www address: http://pecny.asu.cas.cz /meteo.

In February 2000, GOP established the associated data center to support any type of NRT processing. The center nearly continuously mirrors the most internet ftp sources for important GPS data, reliable products and other useful information. It can be accessed at ftp://pecny.asu.cas.cz/LDC.

During the early 2000, GOP prepared and well tested the procedure of hourly based GPS orbit determination. Our new product should be available since August 2000 with 1-1.5 hour delay and it consists of 24 fitted and 24 predicted orbit arcs for complete set of available GPS satellites. The positive impact of the hourly GOP orbits was already tested in our NRT processing.

6. Detailed Quasigeoid for the Czech Republic and its Applications

The detailed quasigeoid constructed in 1996, see *(Šimek, 1996)*, was checked and improved by incorporation better gravity data. A new high-resolution (1´x 1.5´) gravimetric quasigeoid was computed in 1998/99 using terrestrial gravity data and the geopotential model EGM96. The "absolute" accuracy of this gravimetric model is estimated to be about 5 cm or better for the territory of the Czech Republic except for border zones. The accuracy of quasigeoid height differences is 2 cm and better for baselines 60 km and shorter. It was fitted to GPS/levelling data from the fundamental geodynamical network, see paragraph 3, by 3-parameter Helmert transformation. Influence of the dimension of the area of integration on the accuracy of the quasigeoid determination was tested in (PEŠEK, ŠIMEK, 1999)

An independent test of the gravimetric model was made by a number of local areas with a dense coverage by GPS/levelling data and by one large area, with GPS/levelling data coming from the densification of the national GPS reference frame described in paragraph 1. The r.m.s. discrepancy is 7.7 cm, see Figure 2. The result is, obviously, deteriorated by a systematic trend of differences in border zones. The differences reflect the "compatibility" of the national geodynamical network, national GPS-reference network, national levelling network and the gravimetric quasigeoid model.

7. Tidal and Absolute Gravimetry at GOPE station

Permanent observations of the gravity due to the reason to determine gravimetric tidal factors was continued at observatory by gravimeter Ascania Gs 15. No 228, using digital registration. Vertical gradient of the gravity at absolute point was observed by gravimeter LaCoste-Romberg 137G, and inhomogeneity of the local gravity field was determined. Warsaw University of Technology carried out twelve absolute gravity measurements at GOPE in September 1999 in the frame of the International Absolute Gravity Project UNIGRACE.

Acknowledgment

The works mentioned in this report were supported by Grant Agency of the Czech Republic, grant No. 103/99/1633.

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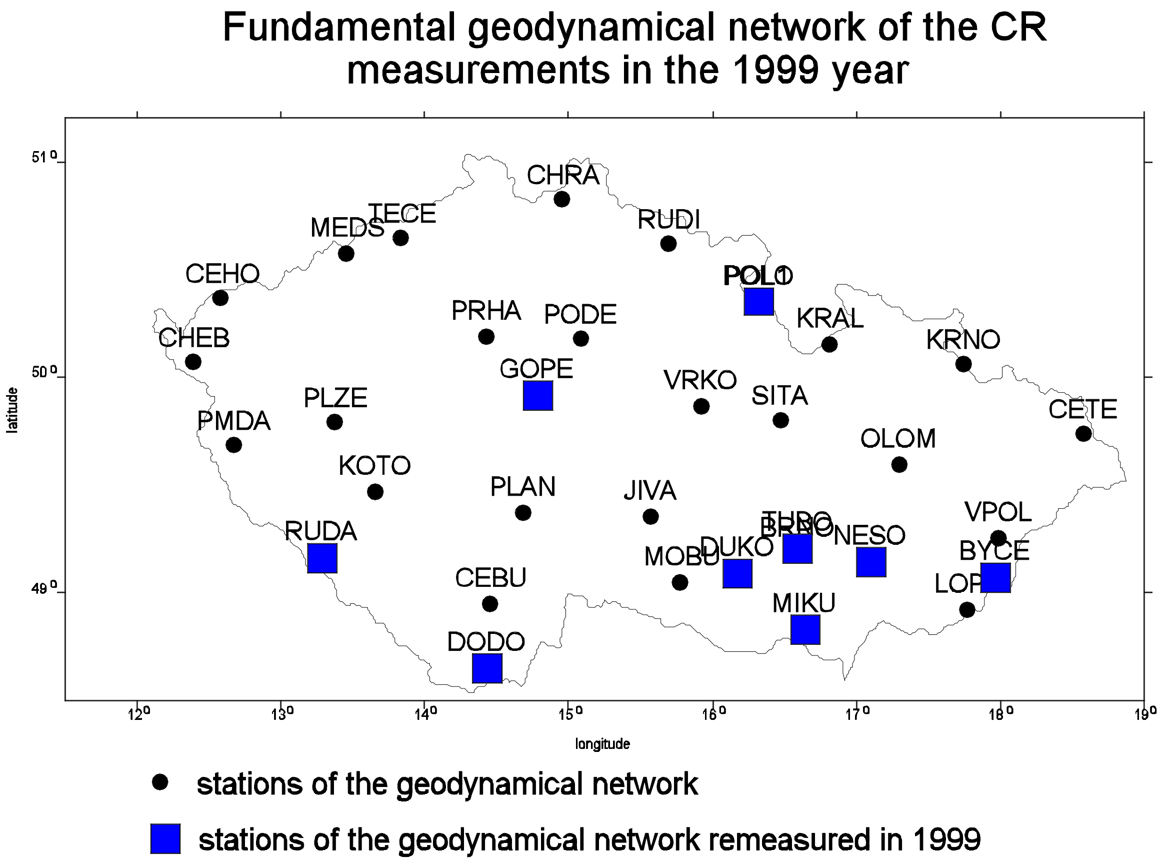
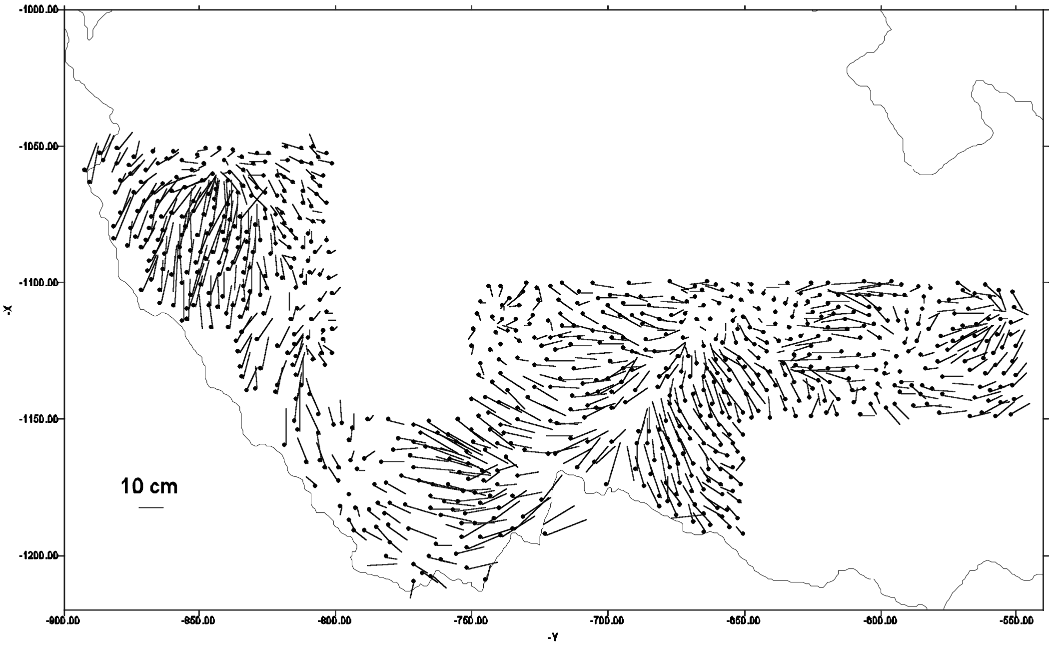


Figure 3

Test of the realization of S-JTSK by means of GPS measurements
Differences between S-JTSK/95 and S-JTSK
(rms value 11.0 cm)



Test of the realization of S-JTSK/95 by means of GPS measurements
Differences between S-JTSK/95 - zero variant and S-JTSK/95 based on GPS measurements
(rms value 3.8 cm)

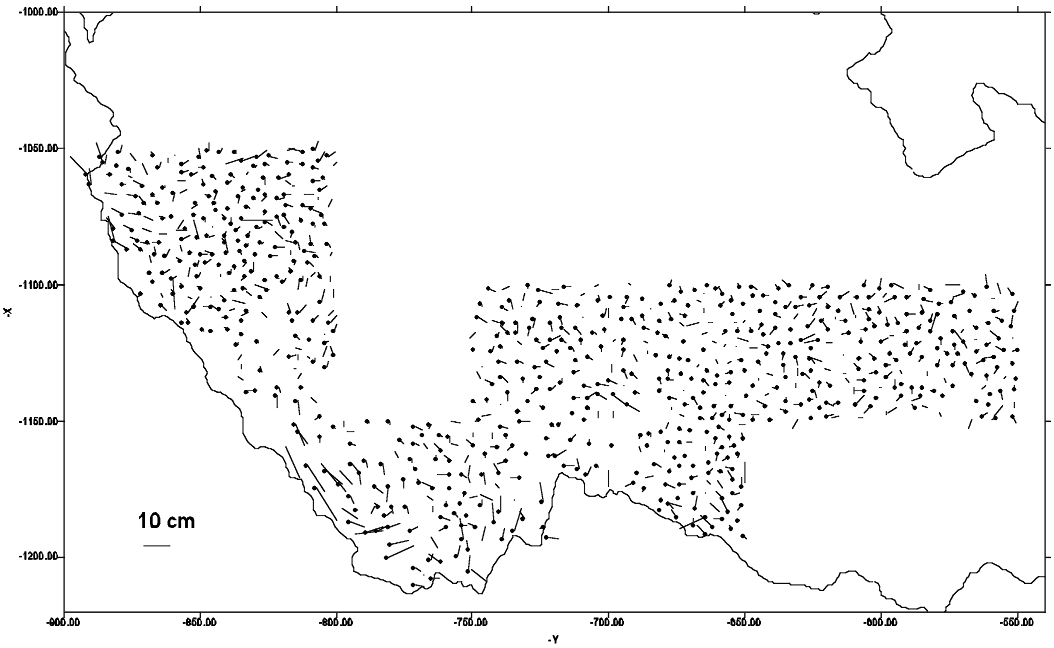
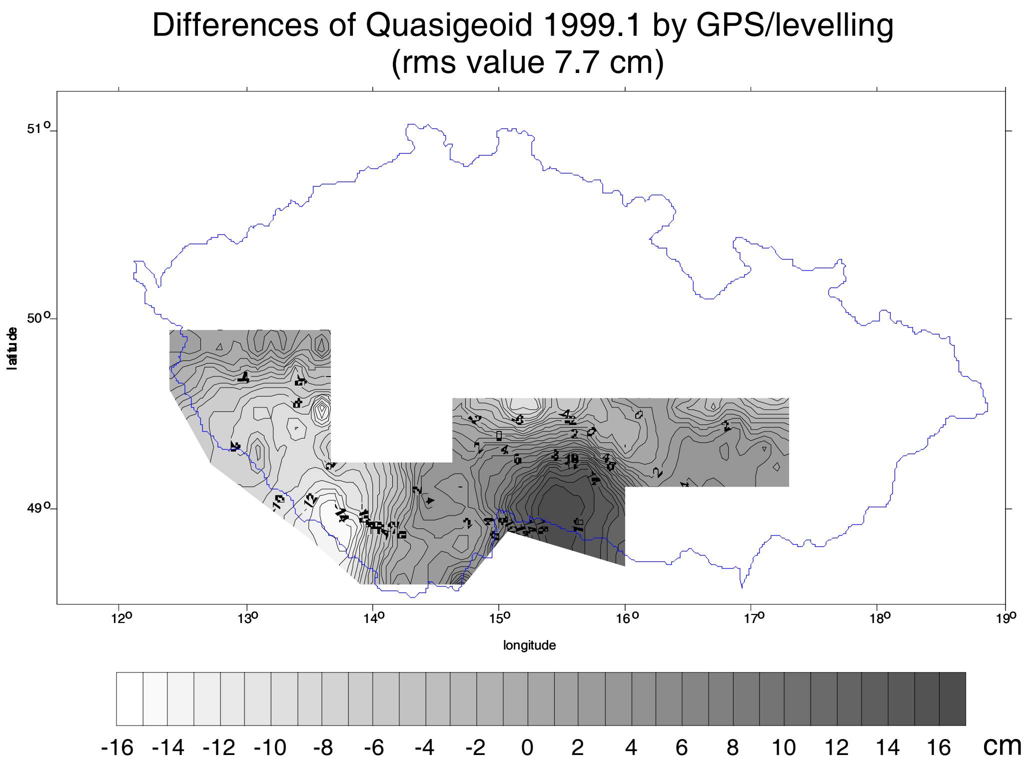


Figure 1


Differences of Quasigeoid 1999.1 by GPS/levelling
(rms value 7.7 cm)
latitude
longitude
cm

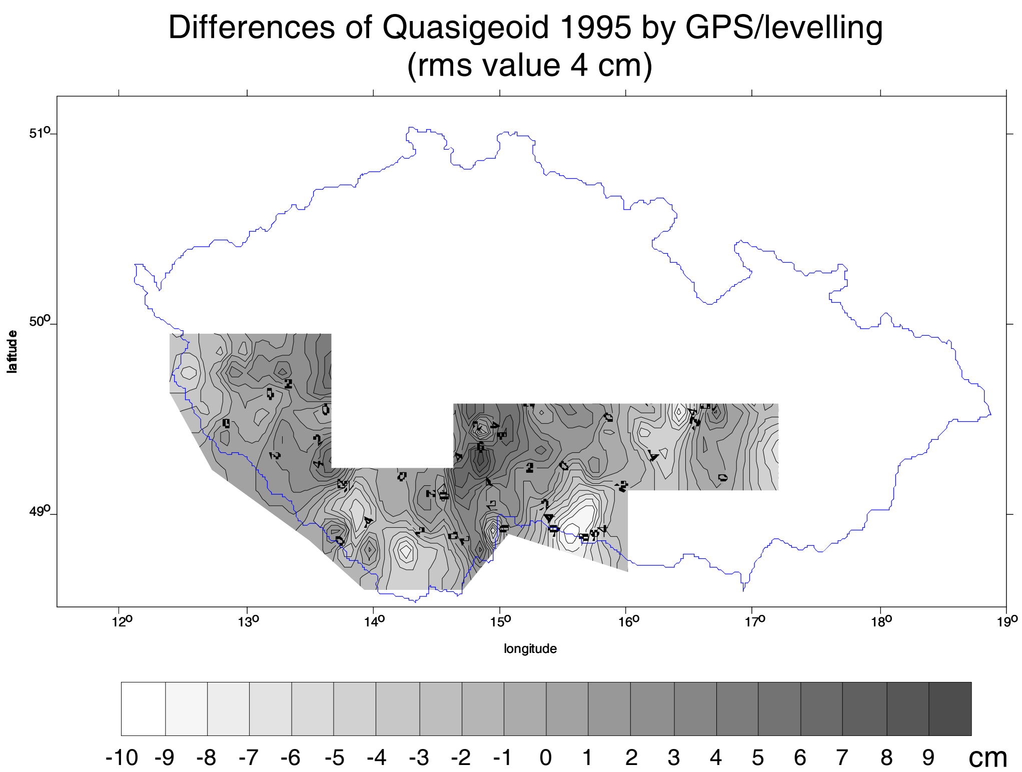

Differences of Quasigeoid 1995 by GPS/levelling
(rms value 4 cm)
latitude
longitude
cm

Figure 2