ANALYSIS OF MUTUAL POSITIONS OF GEODETIC OBSERVATION POINTS SITUATED ON THE ŚNIEŻKA MOUNTAIN BASED ON GPS AND TOTAL STATION TECHNOLOGIES

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ABSTRACT
On the Śnieżka mountaintop in the Giant Mts. there are situated three GPS points. The first one situated on the Polish side (SNIE), a former fundamental trigonometric station, is an epoch site maintained by the Department of Geodesy and Photogrammetry AU Wroclaw that has been used for geodynamic research connected with the EXTENDED SAGET, CERGOP and CEGRN international programmes for the past 10 years. Since 2001 two other GPS sites are located on the Czech side of the Śnieżka Mt. One of them (SNE1), placed on the Czech fundamental trigonometric point, serves for an occasional GPS epoch measurement point and the other one (SNEC) belongs to a permanent GPS observatory point maintained by the Institute of Rock Structure and Mechanics AS CR, Prague. Since GPS observations have been performed in 2001 and 2002 simultaneously within a few international research programmes, this fact enabled to transfer geodynamic observations from one site to another one, e.g. from the epoch site SNIE point to the permanent GPS observatory SNEC. From this viewpoint, several day observations were carried out at the same time on all three GPS points SNIE, SNEC and SNE1 in 2002. Afterwards range and angle measurements with precise Leica TCA 2003 Total Station were performed to verify and mutually link relative positions of all three GPS points.

KEYWORDS: geodynamics, GPS, SNIE and SNEC points, the Giant Mts, Sněžka, Śnieżka

1. INTRODUCTION

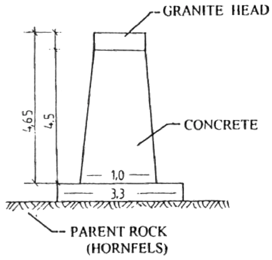
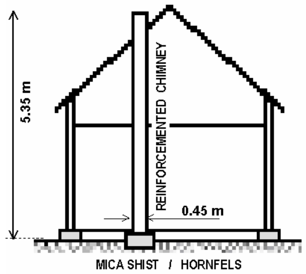
The Śnieżka station (SNIE) is one of six Polish points included, since 1994, in epoch observations within the CERGOP and CEGRN campaigns. A full cycle of satellite and geodetic observations were carried out simultaneously on the Czech permanent GPS observatory (SNEC) established nearby in a Post-Office building to collect data for linking both sites. The aim of the measurements concerned a possibility to transfer the GPS observations between both points in the most accurate way in future. There is an idea, the observations realized up to now on the SNIE epoch station transfer perfectly to the SNEC permanent observations station. It should be emphasised that both stations are positioned on a single hornfels block making up the Śnieżka mountaintop. Since on the Czech side of the mountaintop there is still another epoch GPS site (SNE1) situated on the top of 8 m high stone geodetic pillar established in 1824 as a fundamental trigonometric point of the Austrian-Hungarian monarchy, this site SNE1 was used as a transition station for the total station measurements between the SNIE and SNEC points (Fig. 1).

In 2002 GPS and geodetic total station measurements of all three points were carried out that was necessary for the accurate linkage of the epoch GPS measurements on the SNIE station realized since 1994 with the permanent observations on the SNEC observatory starting in 2001. The SNIE and SNEC site locations and their stabilisations are presented below. Preliminary results of GPS observations realized within the CERGOP and CEGRN, as well as the GEOSUD, KARKONOSZE and SUDETEN programmes are mentioned too. The both SNIE and SNEC stations took part in the CEGRN programme (June 16–21, 2003). The outcome of these observations allowed additional verification of the SNIE station transfer to SNEC point to be made.

2. DESCRIPTION OF THE LOCATION AND STABILISATION OF THE SNIE AND SNEC POINTS.

The SNIE and SNEC points are situated on the Śnieżka mountaintop in the Giant Mts. (the Karkonosze Mts. in Polish and the Krkonoše Mts. in Czech). Concrete block with a granite head has been chosen as the SNIE point location (Table 1, Fig. 1).

Table 1 Technical data on the SNIE and SNEC points

	SNIE	SNEC
WGS84 Coordinates	Latitude *50° 44' 11"* Longitude *15° 44' 24"* Height (a. s. l.) *1602 m*	Latitude *50° 44' 09"* Longitude *15° 44' 23"* Height (a. s. l.) *1611 m*
Type of monument	 *(All units are in meters)*	
Programme member	EXTENDED SAGET CERGOP / CEGRN, GEOSUD, KARKONOSZE	CEGRN, WEST SUDETEN
GPS observations	epochs 1994–2003	permanent since 2001

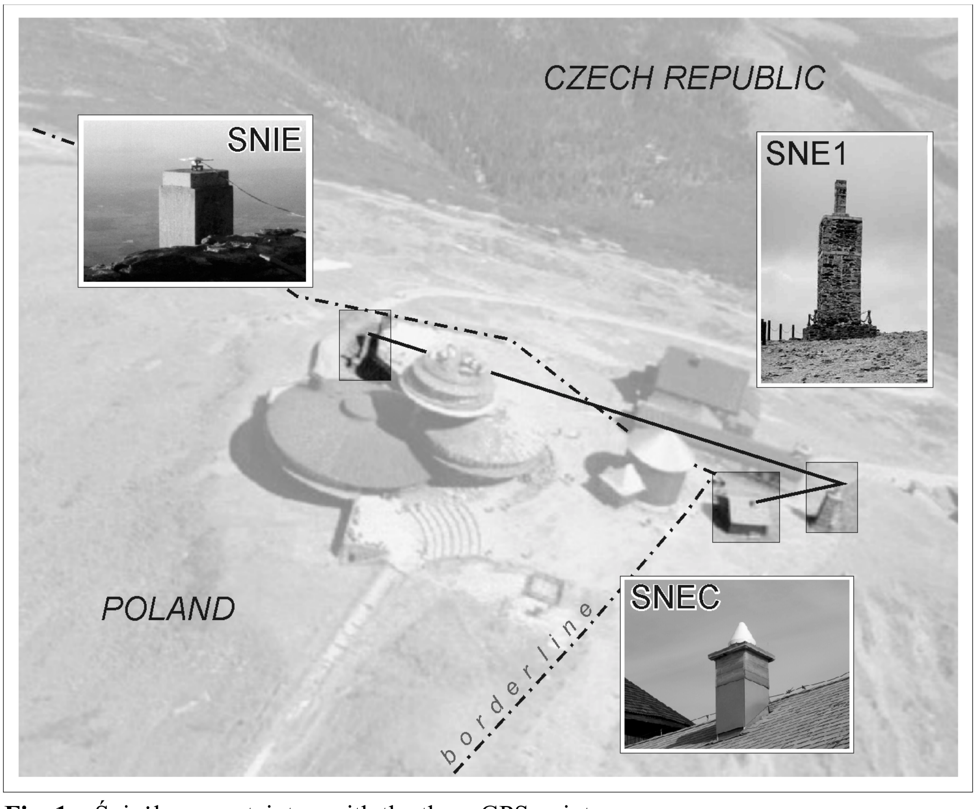


Fig. 1 Śnieżka mountaintop with the three GPS points

The point was used for angle observations in the German triangulation 1st order network (the beginning of the 20th century) and observations of the Polish astronomical-geodetic network (after year 1945). The permanent GPS observatory SNEC (formerly SNEZ) is located in a garret of the small Post-Office building (Schenk et. al., 2000a). Its antenna was placed firstly on the top stone geodetic triangulation pillar (SNE1), August 23 till October 12, 2001, and then on October 23, 2001, was moved on a reinforced building chimney filled by a concrete. The observatory SNEC is also incorporated into the regional geodynamic network WEST SUDETEN (Schenk et al., 2000b).

To make a linkage of the GPS measurements more precise the GPS measurements ran simultaneously in period September 6 to October 3, 2002, on the points SNEC and SNE1.

3. GPS OBSERVATION RESULTS ON THE SNIE AND SNEC POINTS

In last years a few movement vector assessments have been made for the epoch SNIE point and the SNEC observatory, respectively. Within the CERGOP activities, e.g. Becker et al. (2002) and Hefty and Duraciová (2003), velocity vectors of particular points were determined (Fig. 2). One of them was the SNIE point that movement velocity vector, however, displayed a bit greater value (to 4 mm/year) but considerably different azimuth than majority of neighbouring CERGOP network points. Several ideas seemed to explain this fact: (a) a regional movement of the Giant Mts. formations, (b) an effect of antenna changes within epoch observations and (c) any undetected movements of the observation pillars.

Since simultaneously other geodynamic projects within that GPS measurements were realized on the SNIE and/or SNEC points, their resulting vectors were taken (Tab. 2) to explain the disagreement mentioned above and, if possible, to find its origin. Other two velocity components and their RMS errors were calculated for the SNIE point from the GPS data recorded during epoch campaigns on the GEOSUD (Kontny, 2003) and the KARKONOSZE (Kontny et al., 2004) regional network measurements. Both velocity components were determined as local *intra-plate* ones because of a subtraction of continental plate velocities given by the APKIM2000 model (Drewes and Angermann, 2001). Even if another plate motion model, the velocity components differed substantially to the SNIE point velocity (3.64 mm/year) determined for the CERGOP measurements. Contrary to two previous determinations the GPS data monitored on the point SNEC during three epochs on the regional WEST SUDETEN network (Schenk et al., 2004) gave in reality a bit greater movements than those obtained from the CERGOP observations (Tab. 2).

Table 2 SNIE / SNEC point velocities given by various GPS network solutions

Network	CERGOP	GEOSUD	KARKONOSZE	WEST SUDETEN	
GPS point	SNIE	SNIE	SNIE	SNEC	
Period of observation	1994–2001	1996–2002	2000–2003	2001–2003	
ITRF	1997	1997	2000	2000	
V_{East} [mm/year]	-2.9	-1.0	-0.7	-4,2	-3.7
RMS V_{East}	0.8	0.5	1.0		
V_{North} [mm/year]	-2.2	-0.1	-2.6	-1.7	-3.0
RMS V_{North}	0.5	0.6	1.2		
V_{Up} [mm/year]	-2.2	-0.8	—	0.1	0.1
RMS V_{Up}	5.0	0.7	—		
V_{horiz} [mm/year]	3.6	1.0	2.7	4.5	4.7
V_{total} [mm/year]	4.3	1.3	—		
Geographic Azimuth [º]	233	264	195	248	231
Processing Correction	NNR NUVEL1A	APKIM 2000	APKIM 2000	NNR NUVEL1A	APKIM 2000

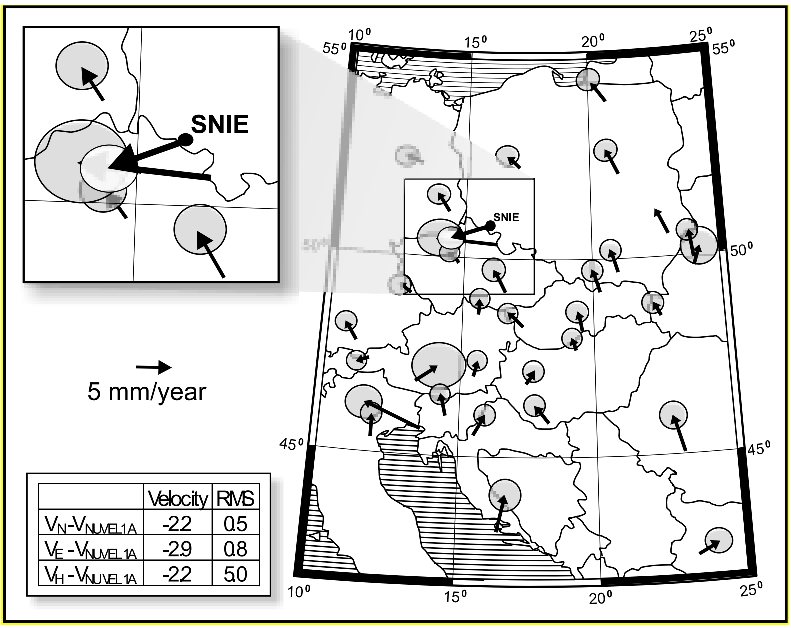


Fig. 2 Horizontal and vertical velocities from the CERGOP campaign 1994-2001 (Becker et al., 2002; Hefty and Duraciová, 2003)

Table 3 Mean components of the measured GPS vectors (WGS84) from daily solutions

Period	Reference	Rover	dX [m]	dY [m]	dZ [m]	GPS Distance [m]
10.-15.9.2002	SNEC	SNIE	-59.936	10.243	36.886	71.117
	SNE1	SNIE	-68.796	-1.070	43.631	81.472
	SNE1	SNEC	-8.860	-11.313	6.746	15.874

Table 4 Comparison of the lengths measured by GPS and Leica TCA 2003 electromagnetic range finder

Reference	Rover	GPS Distance [m]	Measured Distance [m]	Difference [mm]
SNEC	SNIE	71.117	---	---
SNE1	SNIE	81.472	81.471	-1
SNE1	SNEC	15.874	15.872	+2

To clarify the obtained results we followed to check and to test individual steps applied in GPS data processing of investigated data sets. Among the realized tests it was found one linkage that had an influence to the resulting velocities determined for the SNIE and SNEC points.

The velocity calculations in the Table 2 can be divided into three groups with respect of a number and mainly of an areal extend of reference EPN stations used for the velocity evaluations: (a) the greatest velocity determined from the WEST SUDETEN network data (Schenk et al., 2004) had been calculated by means of the EPN stations from MATERA to RIGA and from BRUSSELS to LVOV, (b) a little bit smaller but still great velocity displayed the CERGOP network data calculation (Becker et al., 2002; Hefty and Duraciová, 2003) that investigated stations are located between PADOVA and LAMKOWKO and HOHENBUENSTORF and LVOV, and (c) the smallest velocity were evaluated from the GEOSUD (Kontny, 2003) and the KARKONOSZE (Kontny et al., 2004) regional network data in which the EPN stations from an area WETTZELL, BOROWIEC and PENC were used.

This fact detects a significant feature of the standard GPS data processing that can lead to inaccurate assessments of geodynamic site movements if a lot reference stations are used for linkage of network sites. Since processing algorithms of the BERNESE software try to find an optimal solution for all GPS points involving into a calculation, it brings following effect: the more EPN stations and/or greater area covered by EPN stations, the greater velocity of the SNIE and SNEC points with respect to these EPN stations.

The analyses and tests mentioned above leads us to conclusion that the Giant Mts. formations have to move in a slightly different direction than standard EPN and the CERGOP stations, respectively.

4. JOINT GPS AND TOTAL STATION OBSERVATIONS ON SNIE, SNEC AND SNE1 POINTS

For six days in September 10–15, 2002, GPS measurements were realized on the SNIE, SNEC and SNE1 points. Three Ashtech Choke Ring type antennas were used with Ashtech recorders Z-12 (SNIE) and Z-18 (SNEC and SNE1). Then on October 3, 2002, the total station angle and distance measurements with Leica TCA 2003 tachymeter in a 10 measurement series were realized. The SNIE-SNEC distance could not be measured directly because of optical barrier between the points. Table 3 contains the mean GPS vector components and vector lengths from daily solutions.

The measured angle and spatial distance values have been adjusted in the Ashtech Office Suite v. 2.11 software together with the GPS vectors computed with precise satellite ephemerides. The adjusted vector components were determined at the 0.3–1.0 mm accuracy level. The accuracies of determined point positions are within 0.1–0.5 mm and 0.9–1.2 mm ranges for the horizontal and vertical coordinates respectively. The mean GPS vector lengths (Tab. 3) were compared with distances measured by precise tachymeter obtained from average values of 10 measurement series (Tab. 4). The results of combined adjustment of GPS and total station data (error ellipses and distances) are presented in Fig. 3.

CONCLUSIONS

The analyses of satellite GPS epoch observations realized on the Polish point Śnieżka (SNIE) within the CERGOP/CEGRN, GEOSUD and KARKONOSZE epoch campaigns and Czech point Sněžka (SNEC) have shown ambiguous results concerning the movements of these points. Comparison of movement velocities of both points detected a possible influence of the

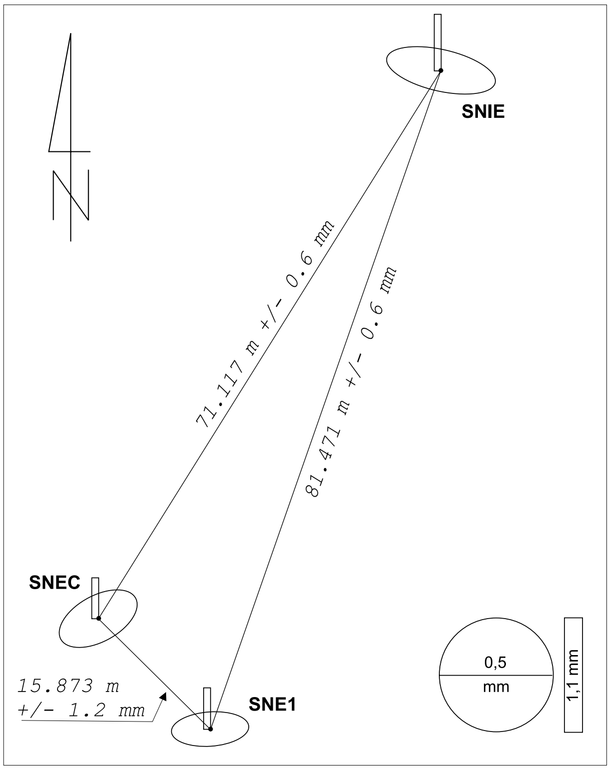


Fig. 3 Local satellite-geodetic network of GPS points on the Śnieżka mountaintop

EPN stations used as reference points to evaluation of the SNIE and SNEC points. It was concluded that the Giant Mts. formations move in a slightly different sense than other Central European geological units.

Further, the satellite GPS and geodetic total station measurements realized in 2002 in the local network of SNIE, SNE1 and SNEC points defined and verified conditions for the mutual transferring of individual GPS observations.

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