Testing of GPS Equipment Trimble 5700 and Trimble GeoExplorer CE in the Czech National Trigonometric Network

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SUMMARY

This contribution deals with the evaluation and analysis of measurements obtained by two different GPS instruments of the Trimble company, namely the surveying apparatus 5700 and the data acquisition device of geographical information systems (GIS) GeoExplorer CE. Both devices were employed repeatedly in a test network of dimensions approx. 8x9 km, formed by ten points of the Czech National Trigonometric Network during the year 2003. The Trimble 5700 instrument ran repeatedly in the rapid static mode with various time periods. The GeoExplorer CE device used the phase and code measurement method. In both cases the effects of parameter settings such as the elevation mask and the density of data recording intervals on the precision of measurements were investigated.

ANOTACE

Příspěvek se zabývá vyhodnocením a rozborem dosažených výsledků měření dvou rozdílných GPS aparatur firmy Trimble, geodetické aparatury 5700 a soupravy pro pořizování dat geografických informačních systémů (GIS) GeoExplorer CE. Obě aparatury byly v roce 2003 opakovaně použity v testovací síti rozměru cca 8x9 km, tvořené deseti body České státní trigonometrické sítě. Aparatura Trimble 5700 pracovala rychlou statickou metodou opakovaně s různou dobou seance. Přístroj GeoExplorer CE používal fázové a kódové měření. V obou případech bylo ověřováno působení různého nastavení parametrů elevační masky a hustoty intervalu záznamu dat na přesnost měření.

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1. INTRODUCTION

The aim of the work presented in this paper was to verify the behaviour and especially the analysis of measurements obtained from two different Navstar GPS equipment: Trimble 5700 and Trimble GeoExplorer CE, when employed in various external conditions and settings. This research, carried out within the framework of the grant project of CR, can be seen as a preliminary stage to the eventual deployment of both sets of equipment to observe the slope earth-slides and provide geological survey data at localities of large-scale reclamation of crater slopes at the sites of former open-cast mines.

2. TEST NETWORK

2.1 Positioning of the Survey Net

The site chosen in 2003 for the parallel testing of both sets of equipment was a survey net with dimensions 8 x 9 km. Approximate co-ordinates of the centre of the network in the system ETRS-89 are B=49°51´, L=14°25´. This site is located at the uplands near Dobříš in Central Bohemia, about 20-35 km south of the capital Prague. The locality has a fairly rugged terrain with altitude varying from 272 to 475 m. The dominant feature of the site is the Vltava river with its left-hand tributary called Kocába.

2.2 Points of the Survey Net

The survey net comprises eleven points in total and one of them was selected as the base station. Taking account of the terrain eight points were chosen as the observation points, one as the network densification point and another as the witness mark of the horizontal control in CR. Official geodetic figures of individual points were obtained by means of the free web service DATAZ (1), which is provided by the Czech Surveying and Cadastral Board (ČÚZK). Full numbers and names of the points follow: 0009 2102 0400 Na klínku, 0009 2103 0090 Hniva, 0009 2103 0340 V Kopcích, 0009 2222 0420 V Jabloních, 0009 2222 0620 Keřek, 0009 2222 0640 Na Ovčičkách, 0009 2222 0650 Na plazích, 0009 2223 0040 Nad homolí, 0009 2103 2120 U Nevady, 0009 2222 0651. In the further discussion, only the so called proper numbers of the points are used (i.e. the nonzero figures from the last four digits of the twelve-digit code).

The position of the base station was marked by an iron bar positioned close to the centre of the network in the Kocába river valley and was denoted by R. Determination of the co-ordinates was carried out by the GPS device Trimble 5700 according to the specifications in (2) and (3). In (2, clause 11.12) the mean co-ordinate error of the densification point is stipulated as $m_{xy} = \sqrt{0,5\left(m_x^2 + m_y^2\right)} = 0,02m.$ The requirements for creating the detailed minor control using GPS are defined in provision (3). The calculated average co-ordinates of the point in S-JTSK (Datum of Unified Trigonometric Cadastral Network) and in vertical datum Bpv (Baltic Vertical Datum-after Adjustment), defined by statutes of CR, are: Y=749 060,215 m, X=1 069 597,220 m, Z=235,376 m. The accuracy rating, characterised by the mean co-ordinate error m_{xy}=10,1 mm, satisfies the criterion quoted for establishing a densification point according to (2).

2.3 Environment Effects

The positions of the points in the test network were also selected so that there was a variability of terrain in their immediate surroundings. This was done to ensure that the environmental effects of immediate surroundings on the precision of GPS measurements can be assessed. Using some simplification it can be said that:

- Points with numbers 4, 9, 62 and 65.1 are placed on high terrain sites, where the shading of the antennas by conifer, broad-leaved or self-seeding trees reaches 50% - 15% from one or more sides, for point no. 34 it reaches almost 95%.
- Points with numbers 40 and 42 are positioned in a field in open flat landscape, but very close to a long-distance high-voltage power line.
- Points with numbers 64, 65 and 212 have no visible jamming elements in their immediate surroundings, if we discount a protecting metal fence at the point no. 64.
- Point R is situated approximately a third way up a hillside of the river valley, i.e. about 14 m above the Kocába river level. A hardwood stand near the antenna was removed.

3. TERRAIN OBSERVATION

3.1 The Equipment Used

Trimble 5700 is classified as a geodetic apparatus. The factory and type numbers of individual parts of the apparatus are given in Table 1.

Device	Serial number	Type number
Receiver5700	0220267051	40406-00
Receiver5700	0220267048	40406-00
Aerial Zepthyr geodetic	11890114	41249-00DC4146
Aerial Zepthyr	11889481	39105-00DC4137
Controller TSCe	00012756	45185-00

Table 1: Serial and type numbers of Trimble 5700

GPS GeoExplorer CE (factory number 4243B14156, type number 46475-10) belongs to the category of compact GIS-GPS equipment. Detailed description of both models can be found in Hánek (2003) (4) and (5).

3.2 Equipment Set-up and Methods of Observation

The antennas of GPS receivers were fastened on a stand and carefully focused by a centering device to the observed point. The average height of antennas above ground level was 1,5 m for the base station and 1,7 m for the mobile equipment. The fast static method was used for measurements with the Trimble 5700 device while with the GeoExplorer equipment the phase and code measurements were recorded. The setting for receiving of EGNOS corrections was at all times turned to the maximum value of 15 sec. Measurements were organised in such a manner that it was possible to use the data obtained at the base station (which was one of the Trimble 5700 devices) for post-process evaluation of measurements by the GeoExplorer.

Measurements were carried out on the following six days: 22.9., 24.9., 28.9., 29.9., 30.9. and 1.10. 2003. Both sets of equipment were limited by setting of the maximum value of PDOP to six for the duration of the measurements.

3.2.1 Set-up of Trimble 5700

The receivers elevation masks were set to 15° on three days: 22., 24. and 28. of September. On the other three days of measurements the elevation masks were set to 13°. Intervals of data recording are shown in Table 2. The pre-set values of the length of observation on individual days given the different numbers of satellites observed are given in Table 3.

Date	22.9.	24.9.	28.9.	29.9.	30.9.	1.10.
Mobile station (s)	5	5	1	5	5	1
Base station (s)	5	1	0,2	5	1	1

Table 2: Intervals of recording in receivers Trimble 5700

Number of satellites observed	Date					
	22.9.	24.9.	28.9.	29.9.	30.9.	1.10.
	Time (min.)					
6 and more	10	10	10	8	8	8
5	20	20	20	15	15	15
4	25	25	25	20	20	20

Table 3: Lengths of observation by Trimble 5700

3.2.2 Set-up of GeoExplorer CE

The elevation mask of GeoExplorer was set to 15° on the four days 22., 24., 28. and 29. in September and on the other two days (30. 9. & 1. 10.) it was set to 13°. Two modes of measurement at a point were used. The code measurements were taken for three minutes and the phase measurements for five minutes. Intervals of recording for the code and phase modes are presented in Table 4.

Date	22.9.	24.9.	28.9.	29.9.	30.9.	1.10.
Interval of recording (s)	5	5	1	1	5	5
Mode of measurement	code	phase	code	phase	code	phase

Table 4: Modes of measurement and recording intervals using the GeoExplorer CE device

4. EVALUATION OF GPS MEASUREMENTS

4.1 Trimble 5700

Different settings of the parameters before each individual session had no obvious effect to the precision of evaluation of a point. On the other hand, the change of setting of the elevation angle from the original value of 15° down to 13° and at the same time reducing the time from 10 to 8 minutes in case of visibility of six and more satellites were shown to be favourable. Because of this change it was possible to reduce the overall time spent at some network points. It appears that a suitable setting for the interval of recording is 5 seconds at both receivers or 1 second at the receiver of the base station and 5 second at the mobile receiver. For these intervals of recording we generated fairly large data files (circa 1MB at a mobile station and up to 25MB at the base station).

The equipment obtained excellent results even at such points where the surroundings were not ideal. Especially at the point no. 34 the conditions could be described as inappropriate for GPS. In spite of this the equipment was able to measure at the point for four days out of six. Generally, it can be said that the surroundings of the antennas had no major effect to the precision of results. The actual values of the mean co-ordinate error (M. C. E) m_{xy} are given in Table 5.

Point no.	4	9	34	40	42	62	64	65	65.1	212
M.C.E (mm)	18,6	9,8	5,3	7,3	21,0	15,3	11,0	9,4	37,6	7,1

Table 5: Values of m_{xy} for points sighted by Trimble 5700

The measurements at the points no. 4, 9, 34, 40, 62, 64, 65, 212 satisfied the condition for accuracy of the mean co-ordinate error to be within the 0,02 m, which would enable the establishing of a densification point according to (2) with quadratic mean-value error 0,011 m. The value achieved at point 42 overstepped this criterion by a very small margin. The least favourable co-ordinate error was recorded at point 65.1, which could then be used according to (2, paragraph 11.12) only as a so-called extra point of minor horizontal control with the mean co-ordinate error less than 0,06 m. This value of error was probably caused by a small number of visible satellites (four), due to the shading of the antenna from one side by high forest trees. In spite of this the value of PDOP at the point varied from 2,0 to 3,9 during the time of measurement. Comparison of average co-ordinates obtained by GPS measurements with the co-ordinates S-JTSK from geodetic data leads one to conclude that there is a good agreement. The average difference $\delta_Y = 0{,}03$ m, $\delta_X = 0{,}02$ m a $\delta_Z = 0{,}07$ m.

The altitude precision of a point is characterised by the value of standard deviation 35,3 mm (n=55). For this situation there is no criterion set out in (2). It was again observed that the determination of altitudes has a lower precision than the position measurements.

On the basis of these results it can be stated that the accuracy of the Trimble 5700 equipment satisfies the requirements for creating, renewal and densification of a minor horizontal control and hence for all work where the position precision of discrete points is required to comply with the same or less strict criteria – for example derived from a level of detectability of shifts (change of position) at measurements carried out in stages.

4.2 Trimble GeoExplorer

Values obtained by the GeoExplorer were analysed in two parts. The first set of calculation does not employ the corrections from the base station and the second set investigates the effect of implementation of the difference corrections. Both sets of results are presented for all measurements taken together as well as for the phase and code measurements separately.

4.2.1 Calculation without the implementation of corrections

Based on observed characteristics for the accuracy of determination of co-ordinates of a net-point achieved in both sets of results we can deduce that the phase measurements provide better accuracy in the open terrain, while on the other hand the code measurements yield higher accuracy at points with worse reception. An exception is a pair of points no. 34 and 212, when the quality of the accuracy was interchanged.

The Trimble GeoExplorer CE equipment with EGNOS signal reception turned on can be advantageously employed for locating the survey control points. In this manner it is also applicable to various special-purpose mappings with scales 1:5000 and less, provided that the accuracy of altitude components determination is not of primary importance.

The mean co-ordinate errors m_{xy} of the measurements without implementation of corrections are given in Table 6. The mean difference at a co-ordinate by comparison with the co-ordinate values given by geodetic data is $\delta_Y = 0{,}86$ m, $\delta_X = 0{,}71$ m a $\delta_Z = 0{,}96$ m.

Mode of measurement	Point no.										
	R	4	9	34	40	42	62	64	65	65.1	212
Code & Phase	1,68	1,5	0,96	1,59	0,70	0,59	1,05	1,05	0,78	1,14	1,98
Code	1,58	1,18	1,05	1,51	0,82	0,51	0,81	0,91	0,79	1,22	1,53
Phase	2,03	2,13	0,73	1,09	0,14	0,46	1,02	1,57	0,73	1,24	2,57

Table 6: Values of m_{xy} for points sighted by GeoExplorer CE without corrections (m)

4.2.2 Calculation with post-process corrections

For this evaluation the data files already presented in the above paragraph were augmented by the data obtained at the base station R with the Trimble 5700 equipment. Evaluation on a PC demonstrated a complete mutual compatibility of both sets of GPS equipment (produced by the same company but differing in their parameters).

The mean co-ordinate errors m_{xy} after post-processing are shown in Table 7.

Mode of measurement	Point no.									
	4	9	34	40	42	62	64	65	65.1	212
Code & Phase	0,81	0,57	0,76	0,62	0,46	1,00	1,08	0,81	0,80	0,41
Code	1,12	0,87	0,45	0,84	0,42	0,58	1,01	0,46	1,82	0,18
Phase	0,68	0,35	0,73	0,49	0,53	0,87	1,07	0,93	0,33	0,54

Table 7: Values of m_{xy} for points sighted by GeoExplorer CE with corrections (m)

The mean difference at a co-ordinate in comparison with the co-ordinate values given by geodetic data is δ_Y = 0,37 m, δ_X = 0,62 m and δ_Z = 2,66 m.

Comparing the mean co-ordinate errors in the data file of the points measured we can conclude that the code-mode measuring is more precise (6 cases out of 10). However, when comparing the numerical values of these errors we see that lower values are obtained by the phase-mode measuring: scattering for the code-mode measuring is 0,18 – 1,82 m, and for the phase-mode measuring 0,33 –1,07 m. Afterwards it was found on the Trimble company's web information pages that the minimal duration of observation in the post-processing phase-mode for the evaluation to reach maximal inaccuracy of 30 cm is 10 minutes. Even if this were done the use of this equipment would still primarily be only for special-purpose mappings. If the data on accuracy stated above were valid then the equipment could also be used (under the conditions stated) for mapping from the scale 1:2000. However, it would be necessary to consider whether the method remains economically viable. The possibility of unique identification of points on measured objects (e. g. geological dividing lines, terrain snags etc.), visibility when measured by a total station etc. play a role in decision-making.

4.2.3 Measuring without corrections vs. post-processing evaluation

The comparisons of both types of evaluation described above show that the possibility of introduction into the calculations of the pseudo-distance giving the corrections from a local base station makes the result more precise as to position, but it makes the altitude component worse. If the distinction were to be considered important, then there would be an advantage to use its own base station even for this less expensive and uncomplicated equipment.

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BIOGRAPHICAL NOTES

František Bubeník lectures in numerical methods and carries out research work on applications of mathematics in geodesy, surveying and other branches at the Dept. of Mathematics, FCE, CTU, Prague. He has participated in a number of significant research projects. F. Bubeník is an author of many publications, both in his home country and abroad, including research papers and contributions to international conference proceedings, some with Pavel Hánek and other co-authors. He is a member of the Union of Czech Mathematicians and Physicists.

Pavel Hánek jr. is a young research worker who graduated in geodesy and is at present a PhD student at the Dept. of Maths of FCE CTU Prague. He specialises in engineering surveying techniques and GPS technologies. Already as an undergraduate P. Hánek started to participate in a series of research projects and to date has published some significant papers and contributions to conference proceedings either as an author or as a co-author, both in the Czech Republic and abroad.

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