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EVALUATION OF INTEGRATION DEGREE OF THE ASG-EUPOS POLISH REFERENCE NETWORKS WITH UKRAINIAN GEOTERRACE NETWORK STATIONS IN THE BORDER AREA

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ABSTRACT. GNSS systems are currently the basic tools for determination of the highest precision station coordinates (e.g. basic control network stations or stations used in the networks for geodynamic studies) as well as for land, maritime and air navigation. All of these tasks are carried out using active, large scale, satellite geodetic networks which are complex, intelligent teleinformatic systems offering post processing services along with corrections delivered in real-time for kinematic measurements.
Many countries in the world, also in Europe, have built their own multifunctional networks and enhance them with their own GNSS augmentation systems. Nowadays however, in the era of international integration, there is a necessity to consider collective actions in order to build a unified system, covering e.g. the whole Europe or at least some of its regions. Such actions have already been undertaken in many regions of the world. In Europe such an example is the development for EUPOS which consists of active national networks built in central eastern European countries. So far experience and research show, that the critical areas for connecting these networks are border areas, in which the positioning accuracy decreases (Krzeszowski and Bosy, 2011). This study attempts to evaluate the border area compatibility of Polish ASG-EUPOS (European Position Determination System) reference stations and Ukrainian GeoTerrace system reference stations in the context of their future incorporation into the EUPOS. The two networks analyzed in work feature similar hardware parameters. In the ASG-EUPOS reference stations network, during the analyzed period, 2 stations (WLDW and CHEL) used only one system (GPS), while, in the GeoTerrace network, all the stations were equipped with both GPS and GLONASS receivers. The ASG EUPOS reference station network (95.6%) has its average completeness greater by about 6% when compared to the GeoTerrace network (89.8%).

Keywords: GPS, GLONASS, Precise satellite positioning, Cycle-slip loss rate

1. INTRODUCTION

Geodetic networks created using station coordinates in defined areas are tied to neighboring geodetic reference systems. Properly implemented geodetic control network provides a uniform reference system for the whole area it covers. This in turn constitutes the basic condition of correctness of execution of all the geodetic and cartographic works in the area. Nowadays, the basic, detailed and measurement geodetic control networks are being created with use of space and satellite techniques or their combination with classic techniques. In practice, these tasks are performed by the top class ground based permanent GNSS networks (primary, fundamental and basic). The permanent networks are sets of autonomously operating GNSS stations combined with advanced infrastructure for gathering, processing and redistribution of observations and their products.

GNSS permanent networks, depending on their coverage, can be classified as:

- Global networks – covering the whole globe (e.g. IGS)
- Regional networks – covering a continent or its significant part (e.g. EPN EUPOS)
- National networks – covering the area of a country (e.g. ASG-EUPOS)
- Local networks – covering a certain part of a national or regional network (e.g. MSPP - Malopolska Precise Positioning Sytem).

Thanks to the progress in the satellite measurement technology and in modelling geophysical phenomena happening on Earth and in its vicinity it became possible to create Earthly reference systems on a centimeter (1 – 2 cm) accuracy level for determination of coordinates and 1mm per year determination of their velocity. The main purpose of every such reference system (including EUPOS) is to provide uniform positioning in the whole coverage area, especially in the border areas, for the purposes of cross-border collaboration of neighboring countries. For this condition to be fulfilled, firstly, the network itself has to be uniform within its whole coverage and should meet the unified standards in the scope of data acquisition and exchange. In such case, the basic and necessary condition is the full integration of reference stations operating in different countries.

2. COMPARATIVE ANALYSIS OF SATELLITE RECEIVERS OPERATION IN PARTICULAR STATION COORDINATES OF THE EVALUATED NETWORKS

Daily variability of observed coordinates for a GNSS permanent station is a sum of various factors which directly or indirectly influences its operation. This is why analysis of GNSS observations, including those performed in local or regional networks, should be preceded with a quantitative and qualitative analysis of observation. The key element is the quality and number of real satellite observations obtained at a given station, which depends mainly on the degree of technological advancement of the measurement equipment as well as the location of the station itself. The evaluation of observation data quality for selected stations of the Polish reference station network ASG-EUPOS and the Ukrainian GeoTerrace network was performed on the basis of 24-hour observations made for seven days: 203-209 DOY 2016. The obtained results were analyzed for: data availability, cycle-slip loss rate, multipath effect and accuracy of the GNSS vectors obtained in the post processing.

Fig. 1. Reference stations covered by the study.

3. DATA AVAILABILITY

The evaluation of data availability was performed on the basis of the percentage indicator of the data completeness, calculated as a ratio of the number of actual observations to the number of the possible observations in the given time period, according to the following formula (1):

$$DCGO = \frac{D_A}{D_C} * 100 \tag{1}$$

where:
D_A – number of actual observations made during 24 hours,
D_C – number of all possible observations for the station during 24 hours.

The tests have shown significantly lower data completeness in the considered epochs for the Ukrainian GeoTerrace network. For the GeoTerrace network, the analyses have shown that the average completeness of the data acquired in the epochs for the analyzed 9 reference station (Table 2) was equal to 89.8%. This results come from two basic factors. Firstly, the Leica receivers elimination of reflected and disturbed signals. However,it is not a requirement of the EUPOS guidelines in this scope (Horváth, 2008, Bruyninx, 2015). Secondly, the shortages of observation data are caused by short interruptions in the operation of the stations due to frequent power outages they experience. Detailed results of research in this matter are presented in Tables 1 and 2. Two stations are unique. The first SULP station, located in Lviv at the Lviv Polytechnic National University, which is equipped with a Topcon TPSNET-GA3 receiver and a TPSCR.G5 THSP antenna. For this station the data completeness in the period of measurement was equal to 96.7%. The second station, RDVL located in Radyvyliv (Radziwiłów), is equipped with a Javad JPS E-GGD receiver and a Topcon TPSPG-A1 TPSD antenna. For this station, the data completeness in the period of measurements was equal to 94.2% (Table 2). In case of Polish ASG-EUPOS stations, the average 24-hour data completeness for the 11 analyzed stations (Table 1) in the Ukrainian border area was equal to 95.6%. The lowest data completeness of 90% was noted for the WLDW station. This station, located in Włodawa, was equipped with a Trimble NetRS receiver and a Trimble Zephyr

Geodetic antenna with a radome. On the other hand, the highest result of 99.6% completeness was noticed for the BLPD station, located in Biała Podlaska, which was equipped with a Trimble NetR5 receiver and a Trimble Zephyr GNSS Geodetic II antenna with a radome.

Table 1. Percentage of data completeness in epochs in selected station coordinates of the ASG-EUPOS network.

Data Completeness General Observations - DCGO [%]											
DOY	Station name										
	BILG	BPLD	CHEL	HOZD	HRUB	KROS	LUBL	MLCN	PRZM	USDL	WLDW
203	98.3	99.3	96.4	93.3	92.3	98.7	97.2	94.2	98.9	91.9	89.8
204	98.5	99.5	97.1	94.0	92.5	99.0	96.5	94.3	98.3	92.1	90.0
205	98.2	99.6	97.5	94.4	92.4	98.9	97.5	94.1	99.2	92.3	90.2
206	98.2	99.7	96.9	93.8	92.5	99.0	97.4	94.1	99.1	92.1	90.0
207	98.3	99.7	96.7	93.6	92.2	98.9	97.6	94.3	99.0	91.9	89.8
208	98.3	99.5	96.5	93.4	92.6	98.8	97.0	94.2	98.6	92.3	90.2
209	98.2	99.8	96.8	92.6	92.3	98.8	97.3	94.3	99.0	92.4	90.1
Average	**98.3**	**99.6**	**96.8**	**93.6**	**92.4**	**98.9**	**97.2**	**94.2**	**98.9**	**92.1**	**90.0**
Average	**95.6%**										

Table 2. Percentage of data completeness in epochs in selected station coordinates of the GeoTerrace network.

Data Completeness General Observations - DCGO [%]									
DOY	Station name								
	BRGN	CHER	MYKO	RDVL	SAMB	SKOL	SULP	VLVD	ZOLH
203	87.4	88.8	87.2	94.5	88.6	88.1	97.2	88.8	87.1
204	87.2	88.0	86.2	93.4	88.1	87.9	96.3	87.9	87.4
205	87.2	89.1	87.2	94.3	88.6	88.2	96.4	89.0	87.8
206	87.3	89.2	87.1	94.3	89.3	88.3	96.7	89.1	88.2
207	87.2	89.3	87.2	94.8	89.1	88.4	96.6	89.4	87.9
208	87.4	89.0	87.2	94.0	89.0	88.6	96.2	89.0	88.1
209	87.1	88.8	87.4	94.4	89.2	88.6	97.5	88.8	88.3
Average	**87.3**	**88.9**	**87.1**	**94.2**	**88.8**	**88.3**	**96.7**	**88.9**	**87.8**
Average	**89.8%**								

It should be stressed, that the insufficient number of observations does not make it impossible to determine hourly or other solutions during a day. Moreover, incomplete time series of observations of station coordinates may make impossible to reliably assess the coordinates accuracy.

3.1 Cycle slip of carrier phase

The cycle slips of carrier phase during GNSS phase observations have a disadvantageous influence on the positioning accuracy and create a significant problem during the analysis of such observations (Czarnecki, 2014). The cycle slip in static measurements occurs when the connection with a GNSS satellite is interrupted for a short period of time. This may happen due to short obstructions of the antenna by various obstacles (an airborne aircraft or static terrain obstacles that may appear between the moving satellite and the static antenna, e.g. a high mast or tower). Many of such observation defects increase the number of standard errors in measurements. Cycle slips result in an interruption of continuity of carrier phase, and every lost cycle may cause errors of about 20 cm for L1 measurements (Liu 2010). Therefore this problem has a significant impact on selection of locations suitable for GNSS receiver antenna especially for a reference station locations. The cycle slip problem regards the total number of phase cycles, the same for all of the satellites with which the connection was interrupted. The algorithms detecting the phase cycle slips usually use triple-differential phase observations. Based on the performed quality assessment tests it was found that this phenomenon occurs for both of the networks considered in this study. However, a significantly greater (over five times) number of cycle slips was noted for Polish reference stations of the ASG-EUPOS network (Table 3) compared to GeoTerrace network (Table 4). This can be partially justified by a generally smaller number of observations and their *smoothing* by the Leica receivers which took place in the case of stations of the Ukrainian network. However, the average number of cycle slips of 5258 in the analyzed period, for the Polish Horyniec Zdrój (HOZD) station may indicate significant disturbances in the operation of this station (Table 3).

Table 3.The number of cycle slips for the ASG-EUPOS stations

Total number of GPS+GLN cycle slips											
DOY	Station name										
	BILG	BPLD	CHEL	HOZD	HRUB	KROS	LUBL	MLCN	PRZM	USDL	WLDW
203	1894	586	497	5255	4746	1245	1123	2926	863	2187	935
204	2098	672	581	4782	4274	1182	1193	2910	910	2102	985
205	1979	685	593	3621	4179	1229	1208	3011	1043	2197	900
206	2231	701	609	5335	4020	1170	1219	2930	931	2209	912
207	2187	739	644	4707	4192	1306	1144	3008	1038	2067	992
208	2172	704	609	5227	4066	1232	1111	3063	935	2118	955
209	2164	683	589	7882	4365	1229	1198	3025	877	2114	925
Average	**2104**	**681**	**589**	**5258**	**4263**	**1228**	**1171**	**2982**	**942**	**2142**	**943**
Average	**2028**										

Table 4. The number of cycle slips for the GeoTerrace stations.

Total number of GPS+GLN cycle slips									
DOY	Station name								
	BRGN	CHER	MYKO	RDVL	SAMB	SKOL	SULP	VLVD	ZOLH
203	357	363	263	214	311	259	913	303	887
204	340	410	259	213	211	256	918	379	510
205	358	352	263	467	597	280	997	295	568
206	351	377	253	194	244	271	760	358	480
207	387	395	256	179	237	295	728	268	640
208	361	373	283	109	252	269	504	310	552
209	254	367	298	256	237	272	635	305	462
Average	**344**	**377**	**268**	**233**	**298**	**272**	**779**	**317**	**586**
Average	**386**								

3.2 Multipath effect – MP Parameter

A signal travelling from a satellite to a receiver antenna may be reflected by various obstacles, which in turn increases pseudoranges to this satellites. In such case, the antenna receives both desirable signals which come directly from satellites and reflected signals, which causes this pseudorange to be incorrect when the receiver is unable to distinguish and filter out the reflected signals. The multipath effect near the antenna may especially be caused by: uniform smooth surfaces, glass panes, water surface or different kinds of natural and artificial obstacles. The multipath effects are different for code and phase observations. Using a proper linear combination of L3-P3 phase and code observations, free from the ionosphere influence, it is possible to determine the values of systematic errors caused by the multipath effect. This study presents simplified characteristics of the multipath effect, developed for pseudoranges (code observations). It is known, that solutions developed on the basis of code observations are a reference point for precision solutions (phase or code-phase). Therefore, they have an influence on the accuracy of the final solution, whereas solutions based solely on code measurements are quite commonly used in land, maritime and air navigation. The elaboration presented in this study was developed on the basis of the analysis of observation files with use of TEQC and Leica SpiderQC software.
The calculated average multipath values of pseudoranges, for both frequencies depend on many factors. The values (MP1, MP2) calculated in the study and their changes are a faithful digital description of the stations' surroundings. The obtained values (MP1, MP2) for the ASG-EUPOS network (Tables 5 and 6) are relatively constant, except for the LUBL station. This station is equipped with a LEICA GR610 receiver and a LEIAR20 LEIM antenna. The Multipath Total parameter values for both frequencies significantly differ from the same parameters for other stations. The average multipath parameter value for the **LUBL** station in the analyzed period for frequency L1 was equal MP1=5.7cm, for frequency L2 was equal MP2=7.3cm, while for other 10 stations the calculated parameter were equal MP1=41.3 and MP2=40.9, respectively.

Table 5. Multipath for frequency L1 for the ASG-EUPOS stations.

MULTIPATH TOTAL MP1											
DOY	Station name										
	BILG [m]	BPLD [m]	CHEL [m]	HOZD [m]	HRUB [m]	KROS [m]	LUBL [m]	MLCN [m]	PRZM [m]	USDL [m]	WLDW [m]
203	0.422	0.417	0.367	0.487	0.490	0.443	0.058	0.415	0.377	0.391	0.334
204	0.424	0.422	0.368	0.483	0.491	0.442	0.059	0.416	0.378	0.392	0.333
205	0.423	0.416	0.368	0.480	0.487	0.443	0.056	0.413	0.376	0.392	0.334
206	0.425	0.415	0.366	0.479	0.486	0.439	0.057	0.415	0.374	0.390	0.332
207	0.426	0.416	0.367	0.478	0.485	0.441	0.057	0.415	0.374	0.390	0.330
208	0.423	0.419	0.370	0.482	0.487	0.445	0.058	0.417	0.375	0.389	0.330
209	0.423	0.420	0.369	0.477	0.483	0.445	0.055	0.418	0.376	0.392	0.332
Average	**0.424**	**0.418**	**0.368**	**0.481**	**0.487**	**0.443**	**0.057**	**0.416**	**0.376**	**0.391**	**0.332**
Average	**0.413 m**										

Table 6. Multipath for frequency L2 for the ASG-EUPOS stations.

MULTIPATH TOTAL MP2											
DOY	Station name										
	BILG [m]	BPLD [m]	CHEL [m]	HOZD [m]	HRUB [m]	KROS [m]	LUBL [m]	MLCN [m]	PRZM [m]	USDL [m]	WLDW [m]
203	0.371	0.410	0.439	0.436	0.464	0.468	0.074	0.343	0.361	0.342	0.442
204	0.374	0.411	0.442	0.436	0.471	0.465	0.076	0.345	0.367	0.345	0.447
205	0.372	0.410	0.440	0.435	0.471	0.469	0.072	0.344	0.360	0.346	0.440
206	0.373	0.411	0.441	0.434	0.471	0.456	0.072	0.346	0.362	0.345	0.443
207	0.370	0.412	0.438	0.432	0.471	0.464	0.072	0.344	0.359	0.344	0.439
208	0.373	0.411	0.439	0.435	0.476	0.473	0.072	0.351	0.361	0.345	0.441
209	0.371	0.416	0.443	0.430	0.477	0.475	0.071	0.347	0.360	0.345	0.443
Average	**0.372**	**0.412**	**0.440**	**0.434**	**0.472**	**0.467**	**0.073**	**0.346**	**0.361**	**0.345**	**0.442**
Average	**0.409 m**										

During the analysis of the multipath values (MP1, MP2) for the Ukrainian GeoTerrace reference stations (Tables 7 and 8) it was found that they differ very significantly. Multipath for the L1 frequency measured by the Multipath Total parameter varies for the analyzed period from MP1=8.5 cm for **CHER** station to MP1=2.5 m for **RDVL** station. For frequency L2 and the same stations the minimum value MP2=9.3 cm while the maximum value was equal MP2=2.3 m. (Table 8). It should be also stressed, that the multipath values are periodic, where the period is equal to the sidereal day. These parameters are a source of significant information regarding the phenomena occurring in the surroundings of the station's antenna, resulting from the signal being reflected by terrain obstacles.

Table 7. Multipath for frequency L1 for the GeoTerrace stations.

MULTIPATH TOTAL MP1									
	Station name								
DOY	BRGN [m]	CHER [m]	MYKO [m]	RDVL [m]	SAMB [m]	SKOL [m]	SULP [m]	VLVD [m]	ZOLH [m]
203	0.100	0.083	0.177	2.805	0.183	0.207	0.517	0.097	0.216
204	0.095	0.083	0.178	2.100	0.185	0.210	0.525	0.098	0.209
205	0.097	0.082	0.177	1.870	0.188	0.211	0.521	0.100	0.212
206	0.097	0.086	0.175	3.245	0.187	0.209	0.527	0.099	0.209
207	0.095	0.088	0.175	2.353	0.188	0.206	0.527	0.101	0.212
208	0.097	0.086	0.176	2.378	0.188	0.206	0.526	0.100	0.216
209	0.102	0.085	0.176	3.066	0.188	0.210	0.525	0.104	0.208
Average	**0.098**	**0.085**	**0.176**	**2.545**	**0.187**	**0.208**	**0.524**	**0.100**	**0.212**
Average	**0.199 m**								

Table 8. Multipath for frequency L2 for the GeoTerrace stations.

MULTIPATH TOTAL MP2									
	Station name								
DOY	BRGN [m]	CHER [m]	MYKO [m]	RDVL [m]	SAMB [m]	SKOL [m]	SULP [m]	VLVD [m]	ZOLH [m]
203	0.117	0.091	0.210	2.588	0.218	0.257	0.356	0.102	0.247
204	0.102	0.097	0.212	1.580	0.228	0.262	0.361	0.108	0.242
205	0.099	0.092	0.211	1.878	0.225	0.261	0.356	0.106	0.243
206	0.103	0.092	0.210	3.022	0.227	0.259	0.360	0.108	0.243
207	0.100	0.092	0.210	2.118	0.226	0.259	0.359	0.106	0.248
208	0.104	0.093	0.211	2.123	0.227	0.256	0.357	0.105	0.248
209	0.108	0.091	0.209	2.828	0.227	0.257	0.356	0.106	0.246
Average	**0.105**	**0.093**	**0.210**	**2.305**	**0.225**	**0.259**	**0.358**	**0.106**	**0.245**
Average	**0.200 m**								

4. ANALYSIS OF VECTORS

The third stage of the analysis involved the diagnosis and evaluation of the determination accuracy of the free vectors obtained from post-processing of observations (RINEX files) from ASG-EUPOS and GeoTerrace reference stations.

The post-processing of GNSS observations consists of RINEX or binary format data recorded during a session or campaign. This processing involves pairs of synchronous observations which are Cartesian coordinate vectors (Δ X, Δ Y, Δ Z) along with their mean errors each component. The resulting set of vectors (pseudo ranges) is the basic material for the adjustment of the network coordinates. In this work daily synchronous satellite observations were subject to postprocessing for 11 ASG-EUPOS and 9 GeoTerrace stations, located in the border area of Poland and Ukraine. Observations were made with a sampling interval of 1 second from time span of seven days, denoted by GPS time Week Number: 19064 - 19073. The postprocessing was done using Trimble Business Center v3.70 software. The data elaboration was successful for all analyzed ASG-EUPOS stations and 8 GeoTerrace stations. For the Ukrainian RDVL reference station, which was characterized by the largest multipath errors (MP1 and MP2, tables 7 and 8), none of the solutions succeded to determine the precise fixed type vectors. Therefore, in this part of the study the RDVL reference station is not present. The actual obtained accuracy of the vectors for the first day (203 DOY, 2016) for analyzed observations, were presented in Figs. 2-7.

In total, 327 baselines were processed correctly (56 in GeoTerrace network, 95 in ASG-EUPOS, 176 common baselines). The results of processing of observational data for six consecutive daily solutions were very similar to each other. Therefore, the first solution was adopted as representative for the whole study. The subsequent Figures 2 to 7 show the precision of determination of individual GNSS vectors in directions: horizontal N (North) and E (East) and vertical U (Up). These parameters for each vector are presented on the basis: RMS 2D – (Root Mean Square) resultant standard deviation for horizontal components N and E 1σ (confidence level 67%) and RMS 1D – standard deviation for the height U 1σ (confidence level 68%).

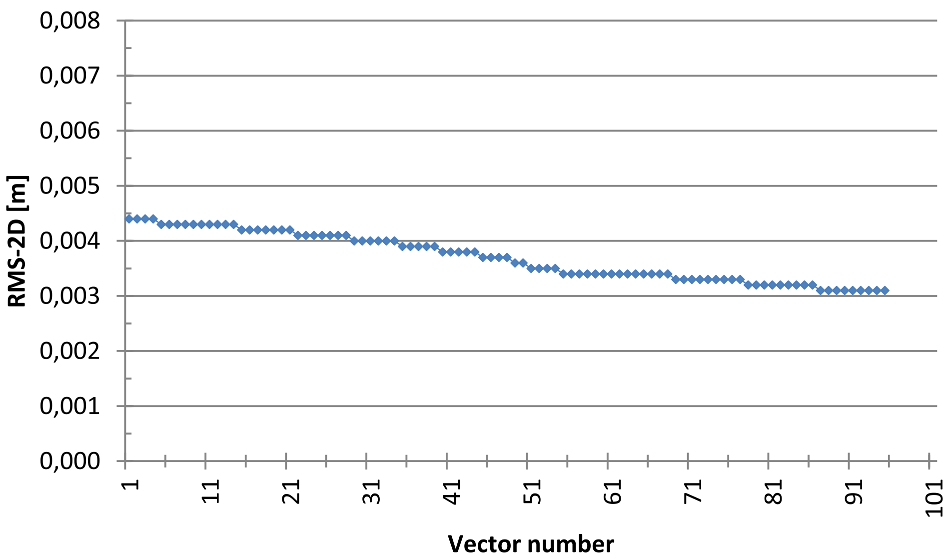

Fig. 2. RMS-2D for vectors of ASG-EUPOS network, GPS Week Number 19064.

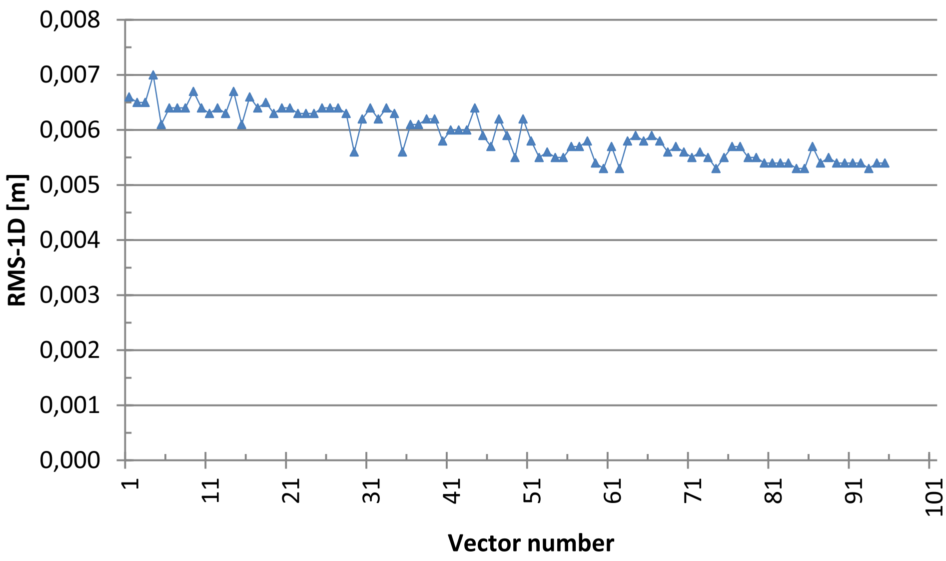

Fig. 3. RMS-1D for vectors of ASG-EUPOS network, GPS Week Number 19064.

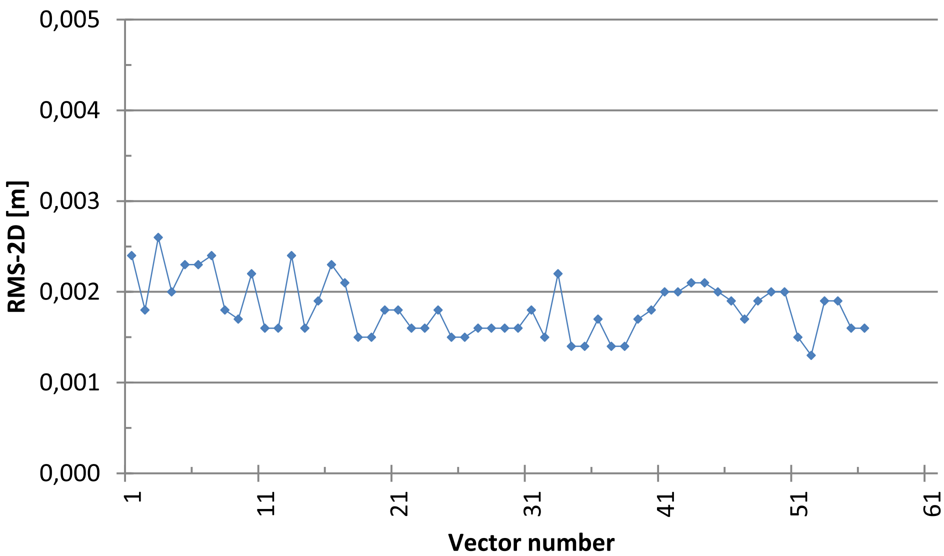

Fig. 4. RMS-2D for vectors of GeoTerrace network, GPS Week Number 19064.

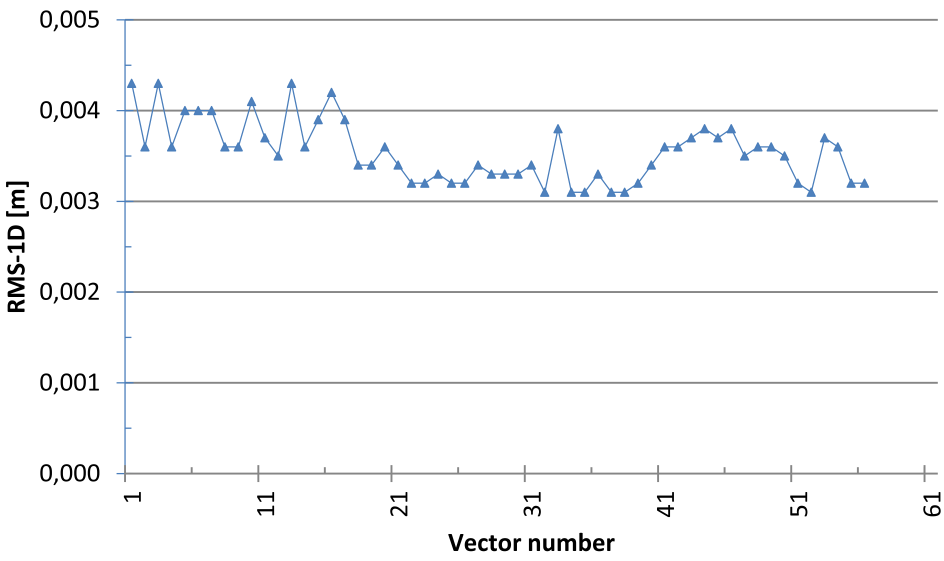

Fig. 5. RMS-1D for vectors of GeoTerrace network, GPS Week Number 19064.

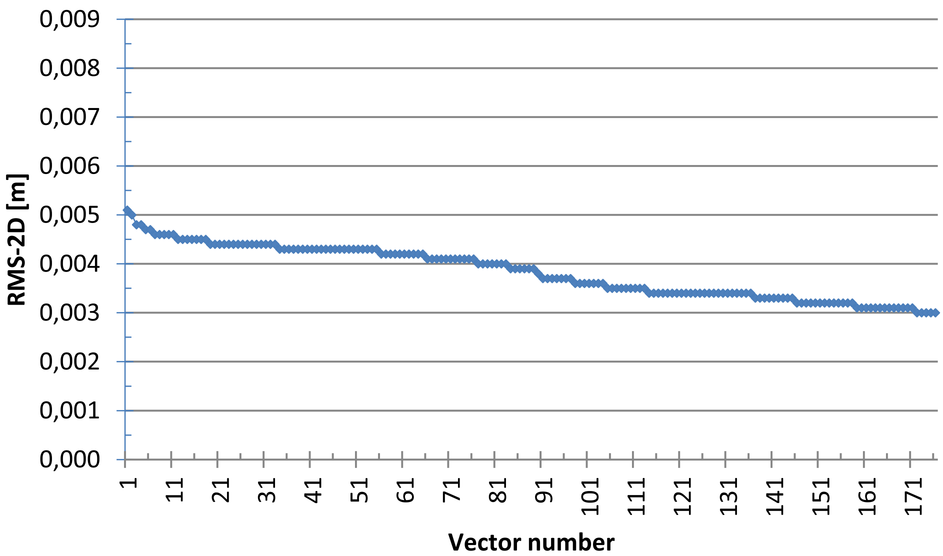

Fig. 6. RMS-2D for common vectors of ASG-EUPOS and GeoTerrace networks, GPS Week Number 19064.

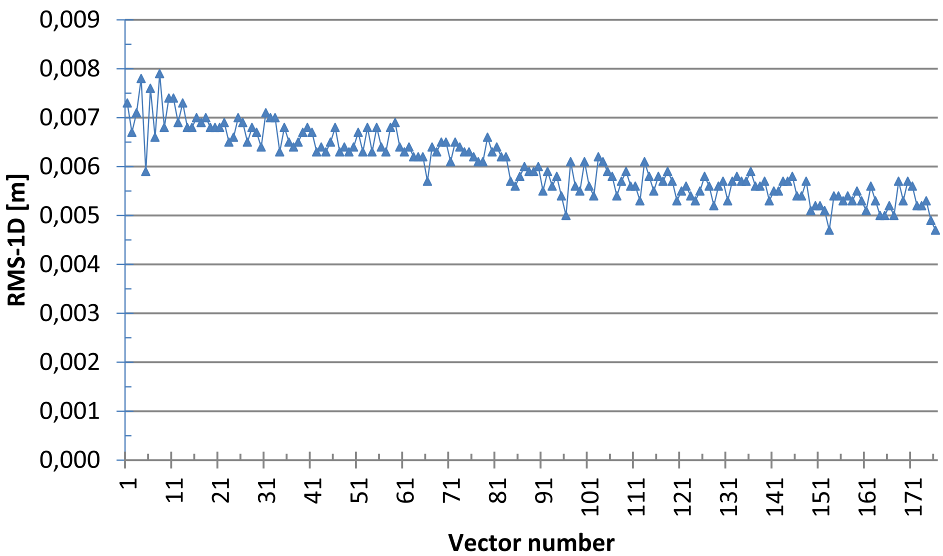

Fig. 7. RMS-1D for common vectors of ASG-EUPOS and GeoTerrace networks, GPS Week Number 19064.

Table 9. Extreme values of vectors' parameters, obtained on the basis of 7 daily solutions (part one)

Parameters of vectors determined in ASG-EUPOS network					
Value of parameter	**RMS_2D**	**RMS_1D**	**PDOP**	**SVS**	**Length of the vector**
	[m]	[m]	-	-	[m]
MIN	0.0029	0.0050	1.73	11	41721.52
MAX	0.0044	0.0070	4.80	20	291998.40
AV (average)	0.0037	0.0059	2.55	17	129296.18
SD (standard deviation)	0.0004	0.0004	1.16	4	
Parameters of vectors determined in GeoTerrace network					
Value of parameter	**RMS_2D**	**RMS_1D**	**PDOP**	**SVS**	**Length of the vector**
	[m]	[m]	-	-	[m]
MIN	0.0012	0.0029	1.78	16	34774.99
MAX	0.0026	0.0043	5.05	19	208051.04
AV (average)	0.0018	0.0035	2.35	19	102751.27
SD (standard deviation)	0.0003	0.0003	1.07	1	

Table 9. Extreme values of vectors' parameters, obtained on the basis of 7 daily solutions (part two)

Parameters of vectors determined in ASG-EUPOS + GeoTerrace networks					
Value of parameter	**RMS_2D**	**RMS_1D**	**PDOP**	**SVS**	**Length of the vector**
	[m]	[m]	-	-	[m]
MIN	0.0028	0.0045	1.74	11	32811.75
MAX	0.0051	0.0079	5.05	20	334288.75
AV (average)	0.0038	0.0060	2.51	17	161586.27
SD (standard deviation)	0.0005	0.0007	1.14	3	

Table 9 summarizes basic parameters of vectors obtained from 7independent daily solutions, the aim of which was also to determine the degree of integration of the investigated reference stations. On the basis of them, we conclude that the Ukrainian part of the network for which fixed solutions were obtained, is characterized by better parameters of determined vectors in horizontal directions N and E (RMS_2D) and vertical U (RMS_1D). It means that the total number of recorded observation data collected in the measuring epochs has less influence on the accuracy of the determined vector when compared to the actual number of observations recorded for a greater number of vector observations. As it follows from tables 1 and 2, the average number of measuring epochs recorded at Polish stations was about 10% higher than the total number of measuring epochs recorded in Ukrainian network. However, because all GeoTerrace stations enable tracking GPS and GLONASS satellites the number of observations for them is greater than for ASG-EUPOS stations. The elaboration of such observations gave a better accuracy effect, to the elaboration of observations, of which part was based on two positioning systems, and a part based on only one system (GPS). The second reason may be the average vector length which for the ASG-EUPOS network is 26 km greater than for the GeoTerrace one. However, these conclusions should be considered at the present stage as preliminary test results, for a single case study presented for wider discussion and requiring confirmation in subsequent studies of this type.

5. CONCLUSIONS

1. Integration of GNSS measurements in neighboring reference stations networks from different countries is very important from the point of view of obtaining more accurate station coordinates in border areas, what is beneficial for ensuring homogeneity of the reference stations networks with a greater territorial coverage.

2. The two networks analyzed in work are characterized by similar parameters in terms of hardware. In the ASG-EUPOS reference stations network, in the analyzed period, 2 stations (WLDW and CHEL) used only one system (GPS), however, in the GeoTerrace network, all the stations were equipped with GPS and GLONASS receivers.

3. Average completeness of observations in the ASG EUPOS reference station network (95.6%) is about 6% greater than in the GeoTerrace network (89.8%). This may cause that in some shorter time intervals (e.g. 1h, 2h) in the Ukrainian network some reference stations may not deliver enough observations.

4. Analysis of vector errors determined in the postprocessing, on the basis of daily observations in the interval of 1 second showed that this errors represented by RMS-2D and RMS-1D are smaller in the Ukrainian network than in the ASG-EUPOS one. This is due to two reasons. The first is that the average distance between stations in the Ukrainian network was smaller than in the network of Polish stations. Secondly, all analyzed stations in the GeoTerrace network were observing GPS and GLONASS satellites, while some of the ASG-EUPOS stations were equipped with GPS only.

5. Another issue is that not all the GeoTerrace reference stations have determined precise coordinates, what disqualifies these stations as reference once belonging to homogeneous reference system. For such stations as VLVL, RDVL, the administrator of the network does not provide coordinates at all.

6. In addition, studies have shown the incomplete effectiveness of the Ukrainian RDVL station to operate in a precise reference network due to errors caused by multipath effects.

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