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The Relationship Between Networks Accuracy and Duration of Session in Static GPS Method

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Abstract

In order to investigate duration of session in static GPS method, data from a network of 7 points, with baseline length of from 64 km to 358 km, were processed. The network were observed by Trimble 4000SSE and Trimble 4000SSi with duration of 24 hours. Data extracted from this session were processed as if they were measured in 3, 6, 9 ··· 21, and 24 hours session. The results (Baselines, Sloop Closures, Coordinates, and Standard errors of coordinates) of these sessions were compared to 24 hours one. Some conclusions were made, which seem to be useful in selection of duration for the same dimension GPS network for different purposes.

Keywards : duration of session, static GPS method, baseline, sloop closures

1. Introduction

Since 1980 the development of GPS technology has been created high abilities in surveying and mapping applications. The application of GPS must be considered in each particular task based upon technical steps such as: network design, survey markers construction, method of data collection, processing software in order to achieve desired accuracy. In these steps, beside the selection of session schedule, the decision related to duration of sessions is very important. In this paper we merely mention to the duration of sessions applied in static GPS method.

The duration of session refers to the time interval, which is calculated from the beginning to the ending of signal reception process of all survey receivers available in this session. The duration of session depends upon several factors: the dimension of baseline, the numbers of satellite, DOP of values, the kind of receivers. In those the baseline has most important role. Because all mentioned factors significantly influence to the duration of session, so that it is difficult to predict its precise value in quantity (Busics Gy. 2000). Therefore, investigation of the relationship between the network accuracies and the duration of session for different dimension networks is needed and has a practical significance.

In general, as duration of session is longer, accuracy of network is higher. In practice, because the cost limitation and required accuracy, so the duration of session associated with baseline should be studied and considered in several facets.

According to Nemeth Gy.-Busics Gy. (1993), to achieve an accuracy around cm, the duration of session associated with baseline is suggested in Table 1.

In GEODYSSEA project (with baselines of thousand km), in each point they measured continuously 5 sessions; after a session of 24 hours there was short pause for loading data, replacement of batteries, and then continued next one (Simons W.J.F at all, 1998).

Joo, I.(2000) proposed a duration of session should be equivalent 24 hours in the networks used in crustal movement survey. This process can reduce effect of the ionosphere, that was not be removed entirely, although dual-frequency receiver was used.

Kenyeres A.-Borza T.(2000) proposed duration of session with interval of 6-12 hours by using dual-frequency receiver in GPS heighting for 3rd order levelling.

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Table 1. Duration of Session Associated with Baseline

Length (km)	Duration of session (minute)
0.1-1.0	10-30
1.1-5.0	30-60
5.1-10.0	60-90
10.1-30.0	90-120

Hai, V.Q at all(1998) had posed a method to investigate duration of session for a particular network that can be able to apply in networks used for investigation movement. In a particular network for movement survey, at first measurement the duration (that is posed by experiences and references) can be chosen longer than normal periodic. With the results obtained in first measurement, the investigation can be proceeded to select the appropriate duration in order to suit required measurable level of crustal movement that predicted from geological data.

On the whole, the selection of appropriate duration for session seems not to be simple. In this paper, based upon a measured data obtained from particular Korean GPS network for movement investigation, we had calculated and compared the relationship between duration for session and other measured results to obtain some experiences to be able reference during application of GPS technique in surveying and mapping works.

2. Investigated Data and Data Processing

Investigated data are measured values of GPS network which governed 7 points with baseline length of form 64 km to 359 km; average of baselines is 180 km (Fig. 1). The data were received from all points by Trimble 4000SSE and 4000SSi receivers. The duration of session was 24 hours. The signals were received in L1, L2 phases, L1 C/A code, and L2 P code.

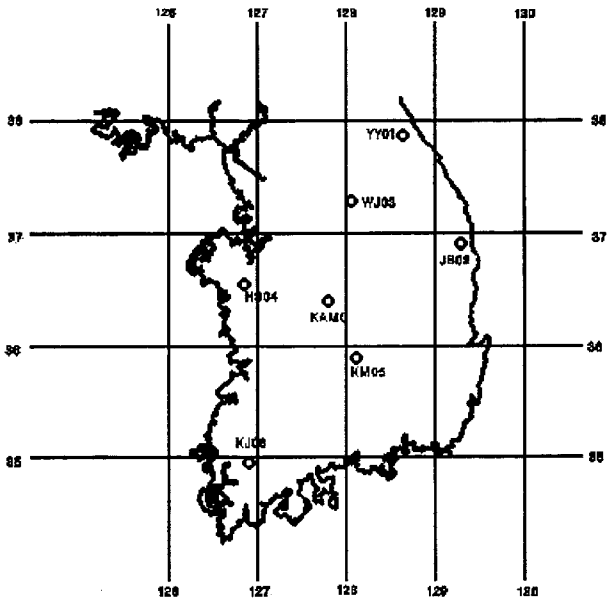
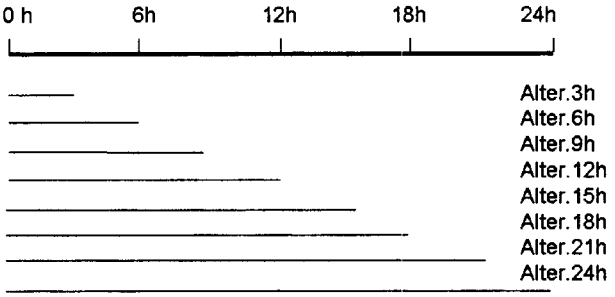


Fig. 1. Observation Network.

The results (baselines, sloop closures, coordinates and standard errors of coordinates) obtained from data of duration of 24 hours are considered as standard factor that are used to compare with one of shorter durations. The comparison can be conducted in following ways:

- comparison in baselines,
- comparison in sloop closures,
- comparison in coordinates adjusted,
- comparison in standard errors of coordinates.

There are several ways to choose data files of different duration, one of them is suggested in below diagram:



Data processing (baseline processing, adjustment) is conducted in corresponding to duration of 3, 6, 9 ··· 21, 24 hours successively. The results will be compared with those obtained in standard session measured in 24 hours. Thus some desired conclusions may be drawn out.

To increase the accuracy and the efficiency of comparisons process, in whole alternatives the root mean square (RMSE) of the deviations (related to baselines, sloop closures, coordinates, standard errors of coordinates) will be calculated. These RMSE values are foundation to draw out desired conclusions.

In some cases, statistical test may be used for RMSE values to obtain quantitative values that can support to above qualitative conclusions.

At the same time, the investigated results are also draw in graphics and function of regression lines of the RMSE values of baselines, sloop closures, coordinates, coordinate standard errors, corresponding to duration are calculated, too.

It is recommended that baseline processing and network adjustment should be implemented by using the same

inputs in all alternatives to achieve highest accuracy in comparisons.

3. Results

3.1 Comparison in Baseline

At baseline processing, using all baseline option, 21 baselines can be defined from the session of 7 points. Baselines are processed using GPSurvey Software, version 2.35. The strategy of base processing is summarized as follows:

- Use of precise ephemeris (IGS),
- Use of precise coordinates of fixed control station (KAMC),
- Choose Iono-free fixed for every baselines,
- Estimate zenith delay parameter every two hours.

The results derived from every particular alternative are discussed as follows:

- Alternative 3 h: Except to HS04-KJ06 baseline get Iono-free float solution (161400.307 m), the rest baselines have got fixed solutions. The ratio is able sufficient and reference variance values of almost baselines are approximately 1.
- Alternative 6h: Except to KJ06-KM05 baseline get float solution (169648.099 m), all other baselines have got fixed solution. The ratio is satisfied, reference variance values equal about 1.
- Rest alternatives (9-24 h): All baselines have got fixed solutions. The ratio is satisfied, reference variance values are mainly smaller than 1. These acquisitions prove that solutions in all baselines are qualified. The comparisons between 24 hours standard alternative with others are sum up in Table 2 in relation with each baseline respectively. It also shows the RMSE values correspondents to duration for session and to baseline for each alternative.

Based upon the results of baselines presented in Table 2 and Fig. 2 we have some following conclusions:

- Except 2 alternatives mentioned above, all baselines available in other alternatives get fixed solutions. Although float solution available in alternative 3 h on HS04-KJ06 baseline, however the deviation (bold, italic and underline numbers in Table 2) is mere 2 mm/ 161 km (scale 1:80,000,000) in comparison with standard case. In alternative 6 h, KJ06-KM05 baseline get float solution, but the deviation (bold, italic and under-

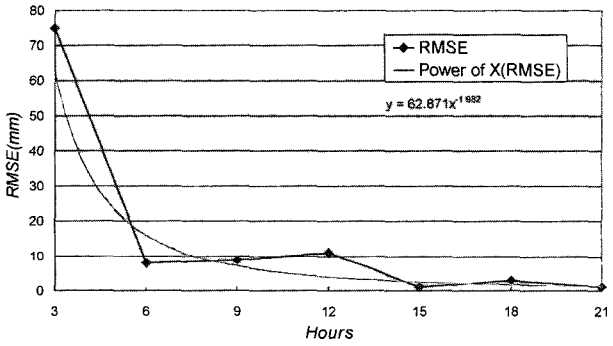


Fig. 2. RMSE-baselines.

Table 2. Comparison in Baselines

Baselines	Length	24-3	24-6	24-9	24-12	24-15	24-18	24-21	RMSE
KAMC-HS04	64367.793	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
KAMC-KM05	96731.301	–0.064	0.003	0.001	0.001	0.000	0.000	0.000	0.024
WJ03-YY01	98845.400	0.000	0.000	0.000	0.000	0.000	–0.001	–0.001	0.001
KAMC-WJ03	118786.116	0.001	0.000	0.000	0.000	0.000	0.000	–0.001	0.001
YY01-JB02	134514.326	–0.001	0.000	–0.002	–0.001	–0.001	–0.001	0.000	0.001
WJ03-JB02	136856.024	0.001	0.001	–0.001	0.000	–0.001	0.000	0.000	0.001
JB02-KM05	141172.177	–0.002	0.000	–0.001	–0.002	–0.002	–0.002	–0.001	0.002
HS04-WJ03	142498.379	0.000	–0.001	–0.002	–0.002	–0.002	–0.001	–0.001	0.001
WJ03-KM05	144055.127	–0.093	0.000	0.001	0.001	–0.001	–0.001	–0.001	0.035
KAMC-KJ05	145179.690	–0.005	–0.003	–0.002	–0.002	–0.002	–0.002	–0.001	0.003
HS04-KM05	161091.160	–0.240	0.000	–0.001	–0.001	–0.001	–0.001	–0.001	0.091
HS04-KJ05	161400.307	–0.002	0.000	0.001	0.000	–0.001	–0.001	0.000	0.001
KJ05-KM05	169488.110	–0.004	0.007	–0.032	0.001	0.000	–0.001	–0.001	0.012
KAMC-JB02	199123.679	–0.127	–0.025	–0.004	–0.042	–0.003	–0.002	–0.002	0.051
KAMC-YY02	216713.609	–0.001	0.001	0.000	–0.001	–0.001	–0.001	–0.001	0.001
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Root M Square		0.075	0.008	0.009	0.011	0.001	0.003	0.001	

Table 3. Comparison in Sloop Closure

Unit: ppm

Loop	3h	6h	9h	12h	15h	18h	21h	24h
KJ05-KM05-JB02	0.2223	0.0593	0.3292	0.1095	0.1294	0.0617	0.0504	0.0714
KJ05-KM05-YY01	0.3089	0.0354	0.1805	0.0287	0.0318	0.0314	0.0283	0.0347
KJ05-KM05-WJ03	0.4252	0.0173	0.2062	0.0118	0.0173	0.0252	0.0173	0.0230
KJ05-KM05-KAMC	0.3413	0.0290	0.2850	0.0083	0.0166	0.0079	0.0088	0.0093
KJ05-KM05-HS04	0.4875	0.0420	0.2633	0.0223	0.0064	0.0031	0.0029	0.0111
KJ05-JB02-YY01	0.1593	0.0448	0.1099	0.0687	0.0857	0.0436	0.0311	0.0408
KJ05-JB02-WJ03	0.1999	0.0715	0.1360	0.0897	0.1011	0.0620	0.0334	0.0512
KJ05-JB02-KAMC	0.4609	0.1125	0.1195	0.0642	0.1444	0.0571	0.0625	0.0836
KJ05-JB02-HS04	0.4182	0.1019	0.1067	0.1346	0.1165	0.0527	0.0551	0.0722
KJ05-YY01-WJ03	0.0334	0.0304	0.0301	0.0281	0.0312	0.0334	0.0328	0.0333
KJ05-YY01-KAMC	0.0615	0.0210	0.0214	0.0233	0.0323	0.0284	0.0317	0.0395
KJ05-YY01-HS04	0.0674	0.0189	0.0723	0.0237	0.0244	0.0265	0.0271	0.0309
KJ05-WJ03-KAMC	0.0218	0.0240	0.0119	0.0058	0.0222	0.0310	0.0271	0.0285
KJ05-WJ03-HS04	0.0521	0.0278	0.0118	0.0050	0.0152	0.0253	0.0215	0.0263
KJ05-KAMC-HS04	0.0557	0.0051	0.0128	0.0016	0.0124	0.0061	0.0094	0.0072
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Root Mean Square	0.4169	0.0590	0.1160	0.0637	0.0473	0.0267	0.0237	0.0301

line numbers in Table 2) is only 7 mm/169 km (scale 1: 24,000,000).

- The RMSE values associated with baseline progress toward standard value when duration for session increasing as show in Fig. 2.
- With the time of session equal 6 h, RMSE values are about 1 cm (10 mm) in comparison with standard alternative and corresponding to average baseline of 180 km (scale 1:18,000,000).
- The results derived in RMSE column show that it is impossible to constitute a linear relation between RMSE values and baseline length.

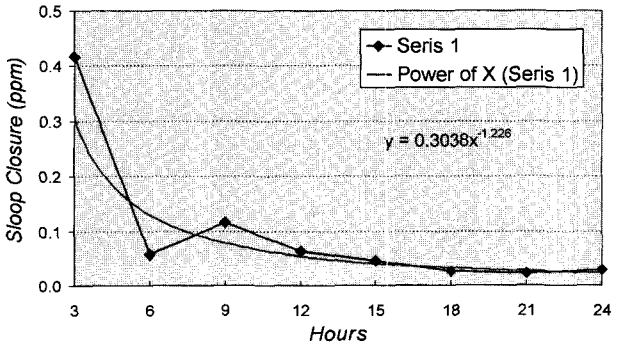


Fig. 3. RMSE of Sloop Closure.

3.2 Comparison in Loop Closures

In essential meaning, loop closures are real errors, refers to objective factor that estimate the accuracy of geodetic networks. Therefore, after calculation of baselines for each alternative, loop closures are estimated. In case of 7 points network, these errors are derived from 35 independent triangulars. RMSE values for 35 triangular corresponding to each alternative are calculated and presented in Table 3, too.

Statistical functions were established for 2 RMSE values including: $F^{1/2}$ = (Theoretical functions are: $F^{1/2}_{(0.95;35;35)}$ = 1.33. Empirical values correspond to 21 h, 18 h, 15 h respectively are $F_{24/21}$= 1.27; $F_{24/18}$=1.13; $F_{24/15}$=1.57.

Using data presented in Table 3 and the values obtained from statistical tests, considerations are figured out:

- RMSE values of loop closures relatively decrease from 0,4169 in 3 h alternative to 0,0590 when session is 6 h, then accuracy of network is improved (that is presented in sloop closure error values), however steep tendency of curve gradually decreases. These relationships can be seen clearly in Fig. 3.
- According to the statistical test for RMSE value, alternatives of 18, 21, 24 h seem to have equivalent accuracy.

3.3 Comparison in Coordinates

Coordinates of network points are calculated by using adjustment and based upon measured baselines. The adjustments are proceed with the same input respectively in all alternatives. The KAMC point (the point has precise coordinates) is selected to be fixed control point, fixed in 3 directions (Lat., Long. and H). The deviatons of coordinates between standard alternative and the other ones are pre-

Table 4. Comparison in coordinates (Unit: mm)

Points		3h	6h	9h	12h	15h	18h	21h
SH04	Lat	-3.28	1.98	1.70	2.01	1.08	0.71	0.34
	Long	7.80	0.74	0.92	0.37	0.62	0.40	0.17
	H	19.60	-3.40	-1.30	2.40	-1.20	2.90	1.80
JB02	Lat	20.90	-0.59	0.46	2.47	0.00	-0.19	-1.21
	Long	-22.63	2.69	-0.86	-2.05	-1.18	-1.14	-0.84
	H	39.50	15.50	2.00	3.90	-1.50	-3.80	-0.90
KJ05	Lat	14.75	3.65	1.24	2.07	1.86	1.18	0.25
	Long	-2.00	2.98	1.57	0.20	0.08	0.58	0.18
	H	6.40	0.30	-1.60	4.90	0.00	1.40	-0.20
KM05	Lat	44.56	-0.09	-0.06	1.05	1.02	0.68	-0.28
	Long	-98.21	4.47	0.37	0.67	0.52	0.22	-0.55
	H	-41.60	-4.00	-4.20	-1.70	-3.20	-1.90	1.20
WJ03	Lat	2.81	-0.09	1.33	0.80	-0.06	-0.19	-0.56
	Long	1.08	0.52	-0.93	-1.03	-0.32	-0.42	-0.52
	H	55.20	1.20	2.60	4.10	1.30	-0.30	2.00
YY01	Lat	2.60	0.87	0.19	0.53	-0.87	-1.11	-1.27
	Long	3.46	0.32	-1.02	-0.63	-0.05	-0.17	-0.61
	H	89.90	8.40	7.20	8.30	1.80	1.30	1.60
RMSE Hor		32.80	2.15	1.02	1.38	0.85	0.69	0.67
RMSE Ver		49.74	7.53	3.75	4.72	1.77	2.24	1.42

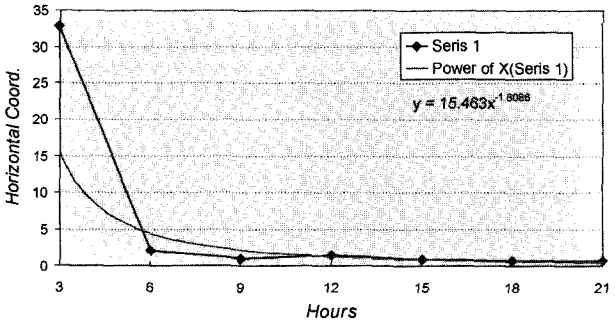


Fig. 4. RMSE Horizontal Coord.

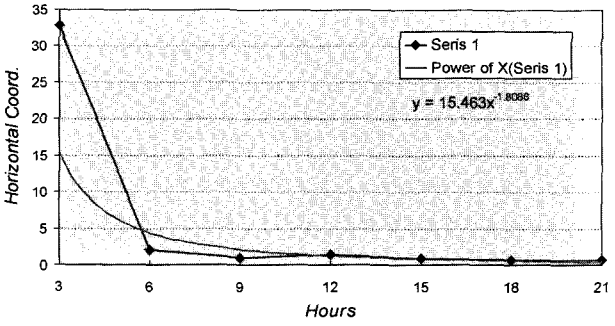


Fig. 5. RMSE Vertical Coord.

sented in Table 4.

Similar to baselines and loop closures comparison, RMSE values are calculated from deviations of coordinates in horizontal plain and vertical direction. Analyzing data in Table 4 and Fig. 4, 5 can provide following considerations:

The coordinates of points are more precise, when the duration of session is more long as showing in Fig. 4 (horizontal coordinate) and Fig. 5 (ellipsoidal height). RMSE values vary from 32.8 mm (in 3 h alternative) to 2.1 mm (in 6 h session), then decrease gradually to 0.7 mm (in 21 h alternative). With the baseline dimensions are about 180 km, RMSE values of horizontal coordinates are very small (1:90,000,000), when sessions are equivalent or longer 6 hours.

3.4 Comparison in Standard Errors of Coordinate

Standard errors of coordinates are quantity specified to the accuracy of geodesic network. Like to coordinate of points, coordinate errors can be derived from adjustment results. These errors are presented in Table 5. In those last two ranks represent RMSE values, which are calculated in horizontal plain and in vertical direction. It can be realised that, except 3 h alternative has significant error, the remained alternatives have small difference in comparison with standard alternative in term of RMSE value.

Ones again statistical test is used, in this case theoretical value is 1.64, while impractical value is $F_{6/24} = 1.636$ corresponding to horizontal plains error and $F_{6/24} = 1.579$ for ver-

Table 5. Comparison in Coordinate Errors (Unit:mm)

Point		3h	6h	9h	12h	15h	18h	21h	24h
HS04	Lat	17.1	1.4	1.9	1.3	0.9	1.1	0.9	1.0
	Long	14.1	1.5	1.6	1.4	1.0	1.1	1.0	1.1
	H	40.4	5.6	5.7	4.2	4.0	3.3	3.5	3.7
JB02	Lat	23.2	2.0	2.2	1.8	0.9	1.3	1.0	1.0
	Long	18.7	2.1	1.8	2.0	1.1	1.3	1.1	1.2
	H	52.0	7.5	6.4	5.3	4.3	3.4	3.6	3.9
KJ05	Lat	18.9	2.0	1.9	2.0	1.1	1.5	1.1	1.3
	Long	12.7	1.3	1.8	1.3	0.9	1.1	1.0	1.0
	H	40.0	5.6	6.1	4.3	4.2	3.4	3.5	3.8
KM05	Lat	30.0	1.5	2.0	1.4	0.9	1.2	1.0	1.0
	Long	24.9	1.6	1.8	1.4	1.0	1.1	1.0	1.0
	H	36.2	5.8	6.3	4.2	4.0	3.3	3.5	3.7
WJ03	Lat	16.2	1.8	1.7	1.6	1.0	1.2	1.0	1.1
	Long	11.8	1.4	1.6	1.3	0.9	1.1	0.9	1.0
	H	39.1	5.5	5.4	4.1	3.9	3.3	3.5	3.7
YY01	Lat	17.6	1.9	2.0	1.8	1.0	1.3	1.1	1.2
	Long	12.6	1.4	1.8	1.4	0.9	1.1	0.9	1.0
	H	39.6	5.6	6.3	4.1	4.0	3.3	3.5	3.7
RMSE.horizontal		18.9	1.7	1.9	1.6	1.0	1.2	1.0	1.1
RMSE.vertical		41.5	6.0	6.0	4.4	4.1	3.3	3.5	3.8

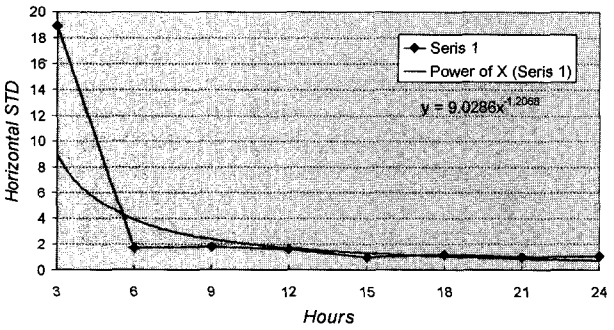


Fig. 6. RMSE Horizontal STD.

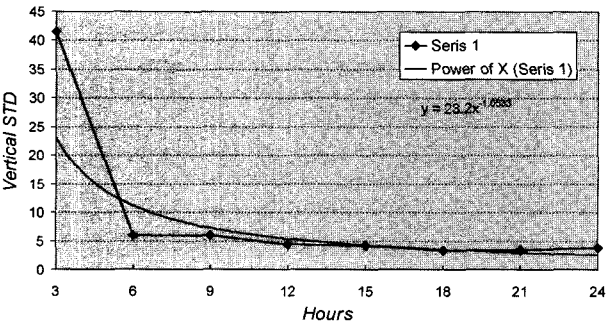


Fig. 7. RMSE Vertical STD.

tical dimension. Those suggest a conclusion: Coordinate errors in alternatives with session equal or longer 6 hours is in the same level with the standard alternatives one.

4. Discussions

With results presented above, some conclusions are proposed:

1. As the duration of session is longer, the accuracy of network is more improved. The relation of those with time presents in Fig. 2-7, in which the investigated data, the related curves and mathematical functions are determined. The relationship between networks accuracy and duration for session is nonlinear. It significantly increases within 3 to 6 hours, then it seem to be more modest when the session increasing longer 6 hours.

2. The baselinesolution is acceptable when duration for session at least 3 hours for the networks, which with their dimensions are similar to those had investigated. Although there still are float solutions available in 3 h and 6 h alternatives, but deviations in comparison with standard value are small and furthermore they probably can transfer back to fixed solution (as because of limitation and scope of this paper, it is not proceeded).

3. RMSE values of standard error of coordinates seem to be small (as in 6 h alternative it is 1.7 mm in horizontal and 6.0 mm in vertical) and RMSE values of standard errors derived in 6h and afterward are to be in the same level. It is very remarkable, because it relates to the session selection for the networks that have similar dimensions but are used

for different purposes. In cases they are merely control surveying or cadastral surveying networks, the duration for session can be reduced, while filling accuracy-requirement. By these ways, related expenditures and labors can be saved. Mathematical functions received in previous sections can apply as references in selecting duration of session for similar networks, which correspond to the varied technical characteristics.

4. Base upon data had been discussed, it is acceptable to observe the network investigated above for crustal movement surveys with duration of 24 hours. Data of Table 4, 5 and graphic presented in Fig. 4-7 shows that coordinate as well as its error after 15 th hours change very little (about few 0.1 mm).

5. As mentioned above, the selection duration for session is complicated process that should be studied further. The results obtained from surveying particular network mentioned above can be as a reference for specialists who apply GPS in their works.

6. We have been experienced with duration for session of networks that have short baselines (about 10 km). The network mentioned in this paper has baselines of hundreds km. By using this proposed method we probably investigate to the networks that have baselines of some tens km. This expectation will be conducted in the future.

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