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TESTS OF SELECTED AUTOMATIC POSITIONING SYSTEMS IN POST-PROCESSING MODE

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Key words: GPS, on-line processing.

Abstract

GPS data post-processing is time consuming and sometimes difficult task, that must be performed after each static survey. To obtain good coordinates, one must perform baseline processing and adjustment of GPS vectors. This requires both time and dedicated software. To speed up the process and save some money, surveyors may use automated, on-line GPS data processing systems. In this paper, authors compare results obtained from three automatic on-line GPS processing systems (Polish ASG-Eupos, Australian AUSPOS and American APPS) with respect to accuracy, availability and performance.

TESTOWANIE WYBRANYCH SERWISÓW AUTOMATYCZNEGO POZYCJONOWANIA W TRYBIE POSTPROCESSINGU

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Słowa kluczowe: GPS, serwisy automatycznego opracowania obserwacji GPS.

Abstrakt

Opracowanie obserwacji GPS w precyzyjnym pozycjonowaniu jest zadaniem złożonym i czasochłonnym. Musi być przeprowadzone po każdym pomiarze statycznym. Uzyskanie poprawnych współrzędnych wyznaczanego punktu jest możliwe po wyznaczeniu składowych wektorów GPS i wyrównaniu sieci tych wektorów. Zadanie to jest czasochłonne i wymaga odpowiedniego oprogramowania. Aby zaoszczędzić czas i pieniądze, geodeci mogą skorzystać z bezpłatnych serwisów opracowania obserwacji GPS. W artykule autorzy porównują wyniki uzyskane z trzech internetowych serwisów automatycznego opracowania obserwacji GPS (polskiego ASG-EUPOS, australijskiego AUSPOS i amerykańskiego APPS) pod względem ich dokładności, dostępności i działania.

Introduction

There is a wide variety of on-line GPS processing systems available in internet (TSAKIRI 2008). Many of these are commercial, which means that one has to pay for the data processing or maintaining the account. Web search for "free + online + GPS + baseline + processing" gave three results – AUSPOS, JPL's APPS and ASG-EUPOS. This paper describes all three.

During a various GPS surveys, we got into situation, when most widely used GPS online processing system ASGEUPOS failed to process some baselines. This was usually caused by insufficient number of observations (too short observation session, obstructions etc.). We have decided to check if other systems that does not use ASG-EUPOS reference stations can provide sufficient accuracy for certain surveying tasks. The online GPS processing systems are gaining attention all over the world.

Listing those of major importance in Poland:
- ASG-EUPOS of GUGiK
- JPL's APPS (AUTO-GIPSY) of NASA
- AUSPOS of the National Mapping Division of GeoScience Australia
- CSRS-PPP of Natural Resources Canada
- SCOUT of SOPAC

We have compared three of those that use different positioning strategies.

Short description of the systems

For the convenience, the description of each system was put into tables.

Table 1

AUSPOS

Parameter	Description
Web adress	http://www.auslig.gov.au/geodesy/sgc/wwwgps/
GNSS systems and frequencies	GPS L1/L2 (requires both frequencies)
Send/receive data protocols	www, ftp, e-mail
Reference frame	GDA94 for Australia, ITRF 2005 at current epoch for the rest of the world.
Owner	The Australian Surveying and Land Information Group
Registration required	no
"Under the hood"	MicroCosm
Working time	24/7
Nominal results quality	σhorizontal <10 mm and σvertical <20 mm with 6 hours of data

Source: DAWSON et. al. (2001)

Table 2

APPS

Parameter	Description
Web adress	http://apps.gdgps.net/index.php
GNSS systems and frequencies	GPS L1/L2 (requires both frequencies)
Send/receive data protocols	www, ftp, e-mail
Reference frame	GDA94 for Australia, ITRF 2005 at current epoch for the rest of the world.
Owner	Jet Propulsion Laboratory (NASA, California Institute of Technology).
Registration required	no for basic usability / yes for advanced options
"Under the hood"	GIPSY-OASIS v.5
Working time	24/7
Nominal results quality	10 cm

Source: ZUMBERGE (1998)

Table 3

ASG-EUPOS

Parameter	Description
Web adress	http://www.asgeupos.pl/
GNSS systems and frequencies	GPS L1/L2 (requires both frequencies), GLONASS at some reference stations
Send/receive data protocols	www, e-mail
Reference frame	European ETRF89, Polish 2000, 1992 and 1965
Owner	GUGiK (Polish government)
Registration required	yes
"Under the hood"	no data
Working time	24/7
Nominal results quality	0.01 m – 0.10 m depending on survey conditions

Source: BOSY et al. (2007)

Comparison of the algorithms used by each system

Since each service uses different positioning approach, we provide a brief description of each systems positioning algorithm.

JPL APPS

This service uses the PPP (precise point positioning) method (ZUMBERGE 1999). It uses precisely estimated satellite transmitter parameters, such as satellite position and clock. These parameters are obtained from organizations such as NASA or IGS instantly. The method is well described in ZUMBERGE et al. (1997). In the processing the JPL final products were used.

AUSPOS

Auspos has a dual frequency geodetic GPS data processing capability. It uses double differenced phase observations positioning algorithm. Pseudo-range observations are used for receiver clocks only. The detailed description of the system can be found in (DAWSON et al. 2001). The system used the following nearby IGS GPS stations: bor1, joz2 and joze. The distance from the receiver to the reference stations were about 250 km.

ASG-EUPOS

Modern approach named BETA was used in polish system ASG-Eupos. It uses triple differenced phase observations with Schreiber differencing scheme (KADAJ, SWIETON 2009). As a control, standard double differenced solution is used. This algorithm is described in KADAJ, SWIETON (2009). The system used six reference stations (distances to each station in parentheses): GDAN (0.3 km), STRG (44 km), KOSC (50 km), WLAD (51 km), (ELBL 54 km), GRUD (97 km).

Baselines used in processing are depicted in Figure 1.

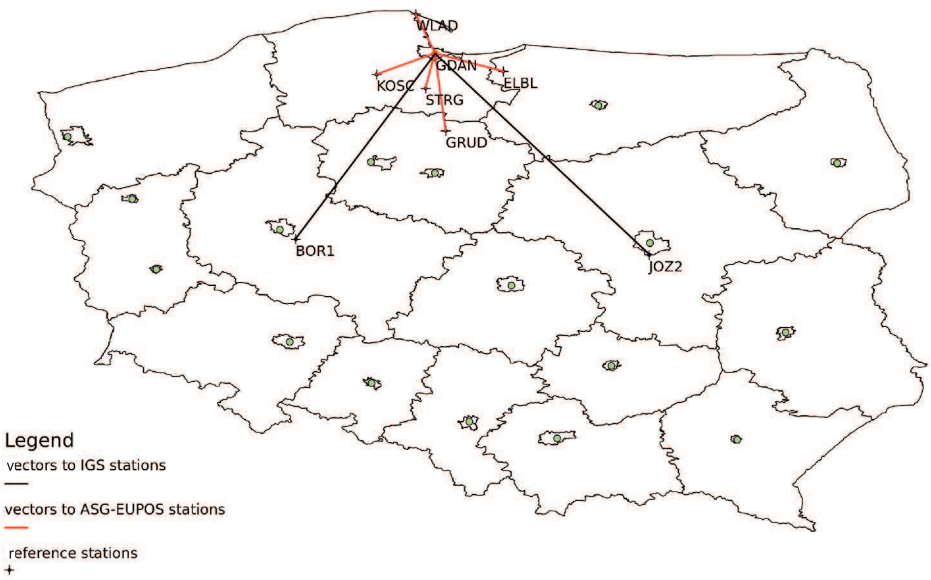

Fig. 1. ASG-EUPOS and IGS stations and the baselines analyzed in the experiment

Reference systems

AUSPOS returns coordinates in GDA94 reference frame for Australia and ITRF 2005 (current epoch) for the rest of the World, JPL's APPS works in ITRF 2005 (current epoch) and ASG-EUPOS works in ETRF89 (as it is a main system for Europe). For the purpose of comparison the coordinates must be transformed to one common reference system. Since all of the tests were performed in Poland we chose ETRF89. To obtain coordinates in ETRF89 all of the results from AUSPOS and JPL's APPS were transformed using the following scheme (NØRBECH et al. 2007):

1. Transformation from ITRF2005 epoch 2007.0 to ITRF2000 epoch 2007.0.
2. Apply the ITRF2000 Euler rotation velocities for Eurasia from epoch 2007.0 to epoch 1994.665.
3. Transformation from ITRF2000 epoch 1994.665 to ETRF2000.

Table 4

Transformation parameters at epoch 2000.0 and their rates from ITRF2005 to ITRF2000 (ITRF2000 *minus* ITRF2005)

Parameters	T_1	T_2	T_3	D	R_1	R_2	R_3
Units	mm	mm	mm	10^{-9}	mas	mas	mas
Parameters	0.1	-0.8	-5.8	0.40	0.000	0.000	0.000
Rates /year	-0.2	0.1	-1.8	0.08	0.000	0.000	0.000

Source: http://itrf.ensg.ign.fr/

Table 5

Estimation of ˙RYY

YY	$\dot{R}_1$	$\dot{R}_2$	$\dot{R}_3$
Rates	mas/y	mas/y	mas/y
94	0.20	0.50	-0.65
Rates	±0.021	±0.008	±0.026

Source: http://itrf.ensg.ign.fr/

Table 6

Transformation parameters and their rates from ITRF2000 to ETRF2000

Parameters	T_1	T_2	T_3	D	R_1	R_2	R_3
Units	mm	mm	mm	10^{-9}	mas	mas	mas
Values	54.1	50.2	-53.8	0.40	0.891	5.390	-8.712
Rates/year	-0.2	0.1	-1.8	0.08	0.081	0.490	-0.792

Basic transformation formula is:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}^{\text{sec ondary}} = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}^{\text{primary}} + \begin{bmatrix} T_1 \\ T_2 \\ T_3 \end{bmatrix} + \begin{bmatrix} D & -R_3 & R_2 \\ R_3 & D & -R_1 \\ -R_2 & R_1 & D \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}^{\text{primary}} \tag{1}$$

In the formula (1) each parameter for epoch EP:

$$P(t) = P(EP) + P \cdot (t - EP) \tag{2}$$

and Euler rotation formula:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}^{\text{ITRF 2005}}_{2007} = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}^{\text{ITRF 2005}}_{t_c} + (t_c - 2007.0) \cdot \begin{bmatrix} 0 & -\dot{R}_3 & \dot{R}_2 \\ \dot{R}_3 & 0 & -\dot{R}_1 \\ -\dot{R}_2 & \dot{R}_1 & 0 \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}^{\text{ITRF 2005}}_{t_c} \tag{3}$$

In the above formulas T_1, T_2, T_3 are translation parameters, D is scale factor, R_1, R_2, R_3 are rotation parameters and $\dot{R}_1$, $\dot{R}_2$, $\dot{R}_3$ are rotation velocities. All of the required parameters were obtained from ITRF website (http://itrf.ensg.ign.fr/trans_para.php).

Tests

The test procedure was performed in the following steps for each system:

1. Split the data from 8 h session into 4, 2 and 1 h long sessions.
2. Uploading the data to the online system.
3. Receiving the results.
4. Transformation of the results to ETRF2000.
5. Comparison of the results to the results obtained from Bernese v5.0.

Three features were considered:

2. Availability
3. Performance
4. Accuracy

All of the services were available for all the test time. Since the speed of network connection depends on the distance from one computer to another, Australian page was slightly slower then American and European (trace route showed much more steps to connect to server). Time that was needed to receive the results is presented in Table 8.

Table 7

Waiting time

System	Time [minutes]
AUSPOS	8 to 12
JPL's APPS	3 to 8
ASG-EUPOS	5 to 15

In order to test the performance and the accuracy, a sample of data was sent to each system. The test data consisted of 15 GPS data files in RINEX format. One eight hour long observation file was divided into 2, into 4 and into 8 files using teqc software. As a result 15 files were processed.

The survey conditions were good, there were not many obstacles and there was no problem with tracking satellites. Figure 2 depicts the satellite distribution during entire survey session.

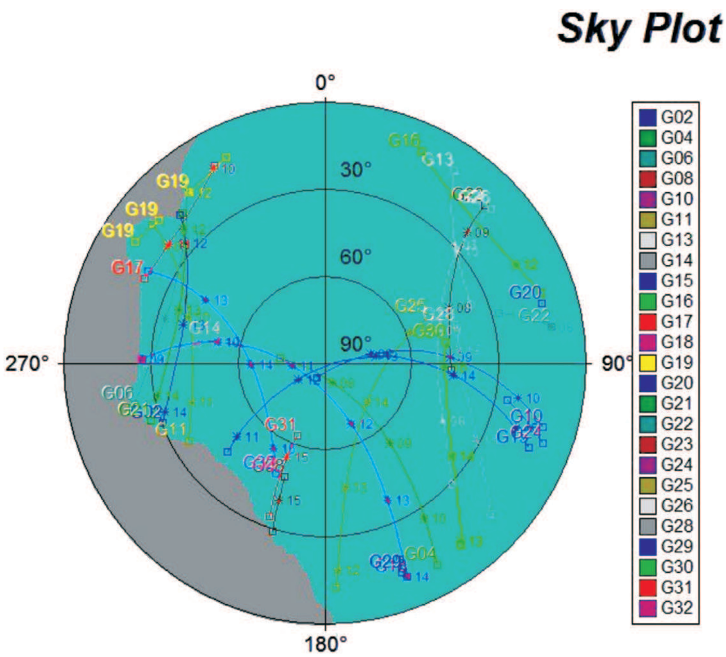

Fig. 2. Sky plot for 8h of observations

The Tables (8–10) below present which session was successfully processed by which system. Each cell in the table represents one session, the size of the cell represents its length. If the session was processed successfully the cell is marked “fixed” if not “failed”. The case where system processed the data but the results were significantly different from good coordinates (more then 20 cm) is marked “float”.

Table 8

Processed sessions for AUSPOS

<table>
<tr><td>1 h (fixed)</td><td>1 h (fixed)</td><td>1 h (fixed)</td><td>1 h (fixed)</td><td>1 h (fixed)</td><td>1 h (fixed)</td><td>1 h (float)</td><td>1 h (failed)</td></tr>
<tr><td colspan="2">2 h (fixed)</td><td colspan="2">2 h (fixed)</td><td colspan="2">2 h (fixed)</td><td colspan="2">2 h (failed)</td></tr>
<tr><td colspan="4">4 h (fixed)</td><td colspan="4">4 h (fixed)</td></tr>
<tr><td colspan="8">8 h (fixed)</td></tr>
</table>

Table 9

Processed sessions for JPL’s APPS

<table>
<tr><td>1 h (fixed)</td><td>1 h (fixed)</td><td>1 h (fixed)</td><td>1 h (fixed)</td><td>1 h (fixed)</td><td>1 h (fixed)</td><td>1 h (fixed)</td><td>1 h (fixed)</td></tr>
<tr><td colspan="2">2 h (fixed)</td><td colspan="2">2 h (fixed)</td><td colspan="2">2 h (fixed)</td><td colspan="2">2 h (fixed)</td></tr>
<tr><td colspan="4">4 h (fixed)</td><td colspan="4">4 h (fixed)</td></tr>
<tr><td colspan="8">8 h (fixed)</td></tr>
</table>

Table 10

Processed sessions for EUPOS

<table>
<tr><td>1 h (failed)</td><td>1 h (failed)</td><td>1 h (failed)</td><td>1 h (failed)</td><td>1 h (failed)</td><td>1 h (failed)</td><td>1 h (failed)</td><td>1 h (failed)</td></tr>
<tr><td colspan="2">2 h (fixed)</td><td colspan="2">2 h (fixed)</td><td colspan="2">2 h (fixed)</td><td colspan="2">2 h (fixed)</td></tr>
<tr><td colspan="4">4 h (fixed)</td><td colspan="4">4 h (fixed)</td></tr>
<tr><td colspan="8">8 h (fixed)</td></tr>
</table>

JPL’s APPS was able to process all of the data files with no outliers. AUSPOS failed in 2 sessions and results from one of the sessions were significantly different from the real coordinates.

Distribution of the satellites (Fig. 3 – DOP’s) during last hour is also good – nothing indicates why last two sessions, calculated by two services, failed.

ASG EUPOS failed in all 8 one-hour sessions and in one two-hour session. Strict limitation of minimum 720 GPS observation epochs caused that all of the one hour long data was neglected by the system. Last two hour long session was not computed by two systems which may indicate worse satellite distribution in that time.

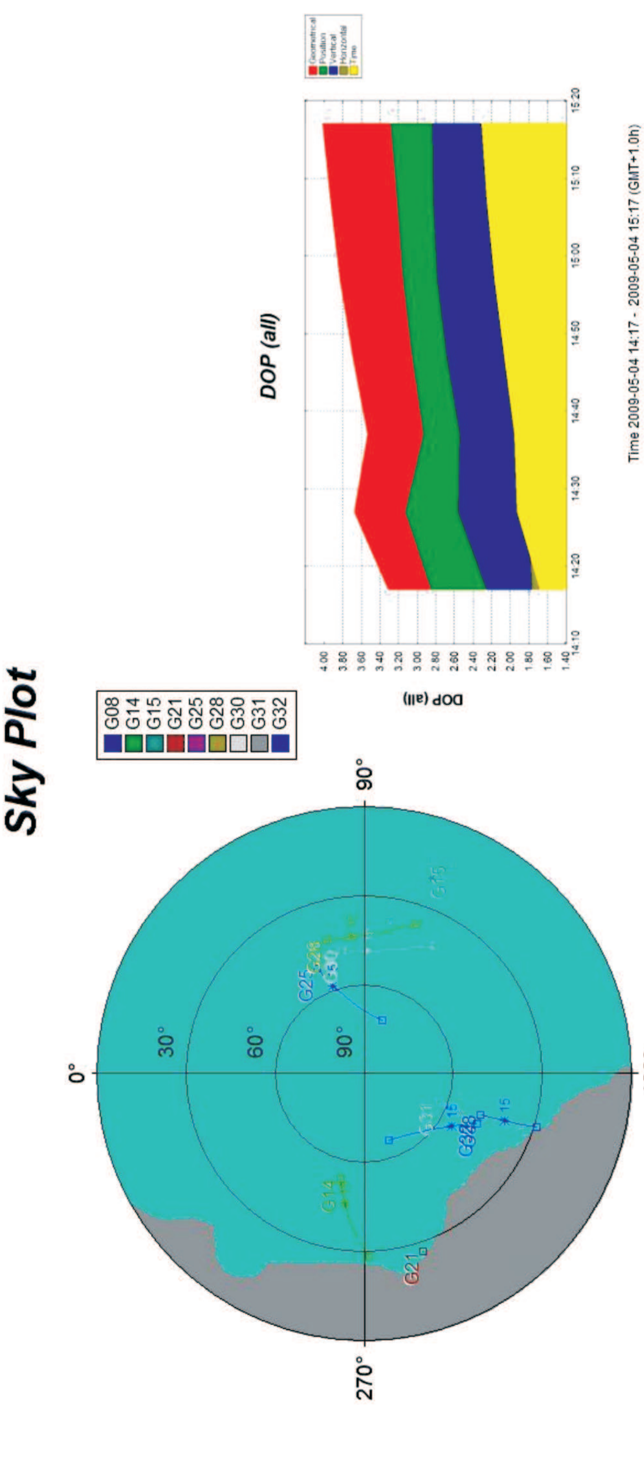

Fig. 3. Satellite distribution and DOP during last 1 hour session

Accuracy:

Coordinates calculated with Bernese v.5.0, from eight hour long session was considered to be "true" coordinates of the receiver. The differences in horizontal and vertical coordinates between "true" coordinates and results from each system are depicted in Figures 4 and 5. Table 11 presents standard deviations for each coordinate computed by these three systems.

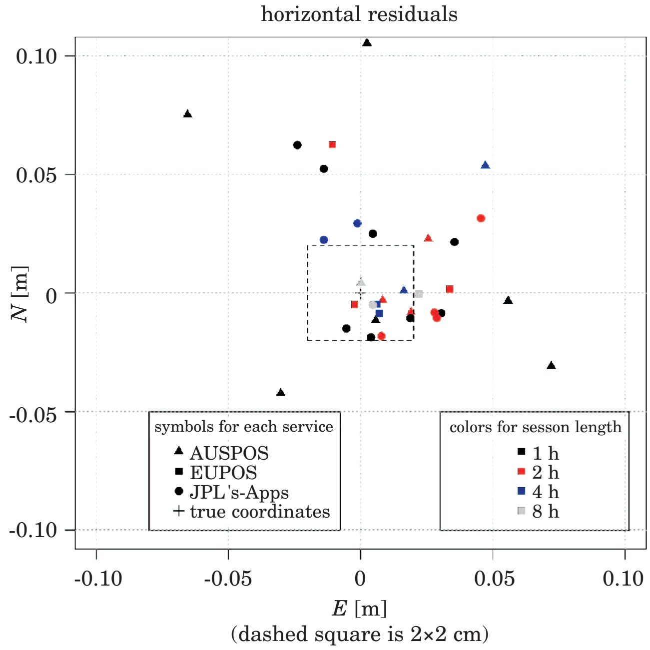

Fig. 4. Horizontal accuracy [in m]

Table 11

Standard deviations

Session length	1 h			2 h			4 h		
Standard deviation	sd N	sd E	sd H	sd N	sd E	sd H	sd N	Sd E	sd H
Eupos	-	-	-	0.003	0.015	0.014	0.074	0.018	0.022
AUSPOS	0.051	0.060	0.075	0.009	0.016	0.037	0.022	0.037	0.050
JPL's APPS	0.021	0.032	0.028	0.015	0.022	0.041	0.009	0.005	0.040

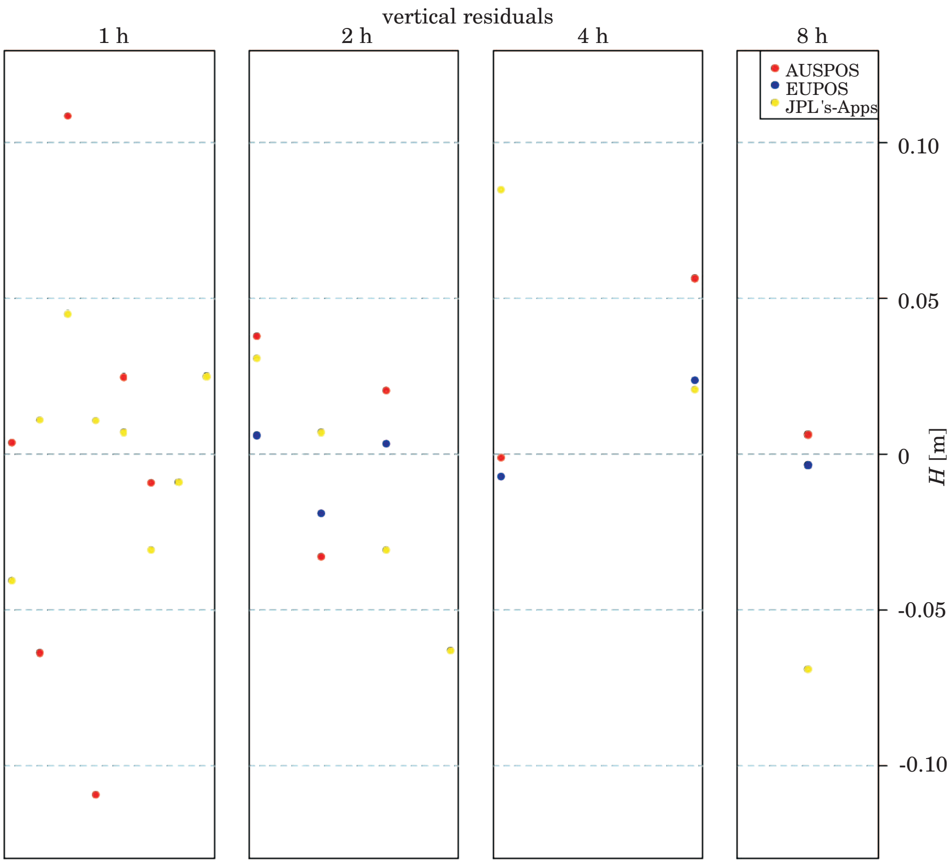

Fig. 5. Vertical accuracy [in m]

Conclusions

– ASG-EUPOS gave good accuracy using it's own reference stations. The main disadvantage is the necessity to provide long observation session (more than 720 epoch).

– JPL's APPS and AUSPOS give also good results using IGS reference stations. If for some reason survey sessions are shorter than 720 epochs, AUSPOS or JPL's APPS may be used, but in order to obtain results in ETRF89 the separate transformation procedure is necessary.

– Each of described systems may be used to process data from static GPS sessions. The resulting accuracy is in 10 cm level, which is satisfying for certain tasks.

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