Accuracy Assessment of Different GNSS Processing Software

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Abstract: *This study investigate the accuracy of different free online GNSS processing software OPUS, AUSPOS, and CSRS-PPP, and offline software, of small scale geodetic network utilizing different Global Navigation Satellite System observations (GNSS) techniques such as static, precise point positioning, and rapid static, for different surveying applications.*

A series of field observations were carried out to indicate accuracy of the different GNSS processing software, with various of GNSS observations modes also, with varies observation periods time where, the observation time divided into (2,4,6,8, and 10hr) for processing online and 10 min for processing offline using practical software. It is importance to studying the characteristics of online GNSS processing services and the suitably for different GNSS applications. These online services OPUS, AUSPOS, and CSRS-PPP were used in this study.

The case study area located at Middle Technical University, Al-Zafaraniyah campus, with five points was selected on the roofs of building. The aim of this study is to evaluate accuracy three free processing software available online, OPUS, AUSPOS, and CSRS-PPP, as well as LGO v8.3 Offline commercial processing software. In order to carry out this evaluation, the unknown points were observed by using field surveying (traditional Surveying), where the total station instrument was used was to establish a closed traverse.

In case of using the OPUS and AUSPOS for processing GNSS data which, employ relative positioning technique, at least two receivers (or more) are required to determine the unknown positions, while in CSRS-PPP use precise point positioning technique, one receiver would be enough without depending on base station. The obtained results through comparison and analysis show that AUSPOS processing services accuracy are regular with the observation period when, the observations time longer the accuracy increase because of the network of IGS stations which consists of 12 stations is used for the processing as each time to this study. In general, the use of online processing services is easy; economic; simple and practical without needed to large field survey team and processing with available software.

The difference of Rapid Static (RS) techniques which are used commercial or practical software for processing GNSS data LGO v8.3, comparing with traditional surveying (total station) is at millimeter level.

Keywords: *GPS, GNSS, OPUS, AUSPOS, PPP, LGO.*

1. INTRODUCTION

Nowadays, Global Navigation Satellite System (GNSS) including the GPS, GLONASS, Galileo, BeiDou, and others, constitute the basis for modern positioning applications such as agriculture, mapping, public safety, military, surveying purposes and Geographical Information System (GIS) [1]. Some of these applications require a high accuracy geodetic observation that cannot be achieved with raw measurements. Therefore, the error sources such as (satellite system, receiver system, and signal path) errors in GNSS data must be eliminated. This can be achieved through an efficient algorithm of correction process can be taken place by implementing one of the standard procedures available for GPS data correction. The procedures can be divided into real-time based and post-processing based. The real-time based procedures, for instance differential GPS and the wide area augmentation system, use satellite-receiver intersystem communication to generate a differential GPS system. This type of DGPS is important in the applications that is requires instant results. The post-processing procedures apply the corrections after the GPS data has been collected. This type of procedure depends on recording the whole communication signal that is received from satellite by all receivers and sends this data to a one of the available online services for rectifications if using one receiver to determine unknown position or using scientific and commercial software. This type of corrections provides a higher accuracy comparing to the real-time procedures and therefore it has been widely used for surveying application.

The GNSS positioning and Total Station positioning have different accuracies. Thus, studying each positioning technique is necessary to evaluate its accuracy for different applications. In relative positioning, at least one or more reference stations are required to determine the unknown positions, while the Precise Point Positioning (PPP) just needs one receiver without base station. Some applications require meter level or centimeter level of accuracy and this depends on the required accuracy. The main objective of the proposed study is exploring this problem in terms of the coordinate's variation for each point and the relative relationships between points as a network. Therefore the study aims to find the quantity of the coordinate variation, the reliability of each available procedure, and to recommend the highest reliability available service. The technology of GNSS proved its strength in surveying Engineering applications. [2].

2. Statement of the Problem

There is numerous of GNSS observation correction services are available. However, it is not agreed which one of these services perform the best in terms of efficiency and precision. In addition, some studies argued that the service performance varies depending on the geographic position. None of the previous studies has discussed the best performance service for the objected study area. This study tries to fill this gap of knowledge for the study area and provides a procedure that can be generalized to be implemented for other areas.

3. The Research Objectives

The most widely used online services, and the accuracy analysis tests of them have been handled for accuracy researches. The objective of the proposed study is to compare between these services in terms of the coordinate's variation for each observed point and the relative relationships between points as a network. Therefore, the study aims to:

- Find the quantity of the coordinate variation, the reliability of each available procedure, and to recommend the highest reliability available service.
- Investigate the accuracy and convergence time of three online processing services (OPUS, AUSPOS, and CSRS-PPP).

4. Methodology

The research methodology includes four main parts. Firstly, established horizontal positions for five unknown stations using static GNSS positioning technique, based on the free online GPS services: Canadian Spatial Reference System (CSRS-PPP), Online Positioning Users Service (OPUS), AUSPOS Online GPS Processing Service. Those services used scientific software packages. In this method single receiver are used and the stations observation time were divided into different time (2, 4, 6, 8, and 10hr.). Secondly, established horizontal positions for the same unknown stations using Rapid Static (RS) for GNSS positioning technique, two receivers are used and processing raw data using practical software (Leica Geo Office v8.3). Thirdly, Total Station instrument type (Leica 1200) is used to observed unknown point and established closed traverse, the traverse calculation solved by (Traverse PRO) and then readjusted by (Leica Geo Office v8.3) software. Fourthly, compared and analyzing the results from two GNSS technique with total station traverse observation.

5. Online GNSS Processing Services

In the recent years a number of organizations have sophisticated online Global Navigation Satellite System (GNSS) for the processing services, which provide the users GNSS processing data to the use free of upload and with unlimited access. These processing services supply solutions for a user-submitted Receiver Independent Exchange Format (RINEX) file depend on differential technique with reference stations or precise point positioning technique using IGS Orbit Products [3].

5.1 AUSPOS

The Geo-science Australia [formerly the Australian Surveying and Land Information Group's (AUSLIG)] Online GPS Processing Service (AUSPOS) was officially launched in late 2000, and has been in uninterrupted since then processing geodetic data for dual frequency GNSS receivers positioned anywhere on earth. AUSPOS was designed and operated for the following purposes and objectives: It can be used easily web page interface, capability to process dual-frequency GPS geodesic data, The data is uploaded to the web-browser either directly or through ftp, The highest quality standards are used in the processing of data and the service is available to users throughout the day, fast processing turnaround, < 15 minutes/file, results Received by ftp server or email, Available anywhere in the world; and GDA94 which compatible for Australian users, ITRF elsewhere in the world. The AUSPOS used differential GPS positioning technique relying on the nearest three International GNSS Service (IGS) stations and uses the information of IGS precise orbit. The AUSPOS designed to be easy to use for different applications, includes: DGPS reference station positioning, very long baseline positioning, remote GNSS station positioning, GNSS connections to IGS stations; and high accuracy positioning [4]. This service is accessible via the Geo-science Australia website at: http://www.ga.gov.au [5].

5.2 OPUS

The United States' National Geodetic Survey is sophisticated the Online Positioning User Service (OPUS). The coordinates resulting from this service are based on a three stations CORS Continuously Operating Reference Stations. The resulting positions using this service are in consistent with the National Spatial References System of the users. The CORS sites are not selected according to the nearest but are choose according to the harmonization between the user data and the CORS site. Uploading the data to the OPUS Service requires five simple steps: firstly, data File of dual-frequency GPS (L1/L2) and full-wavelength carrier observables: Static data only; the receiver must remain unmoved throughout the observing session 15-minutes of data or more, up to 48-hours, 15-minutes of data or more, without crossing UTC midnight more than once, Files under 2 hours processed as rapid-static, RINEX data format, or many raw data formats. Secondly, antenna type selecting should be engage the appropriate antenna calibration model, to counter the unique measurement biases inherent in each antenna's design, While the wrong choice of antenna type leads to error more than 80 cm in height and 1 cm horizontal. Thirdly, antenna height enters the vertical height in meters of Antenna Reference Point (ARP) above the position, as expressed in the Plate (3.1). Fourthly, the Email address must be entered to receive for position solution. Fifthly, to customize the solution way for the button options must be performed or formatted [1]. This service can be found at: https://www.ngs.noaa.gov/OPUS/ [6].

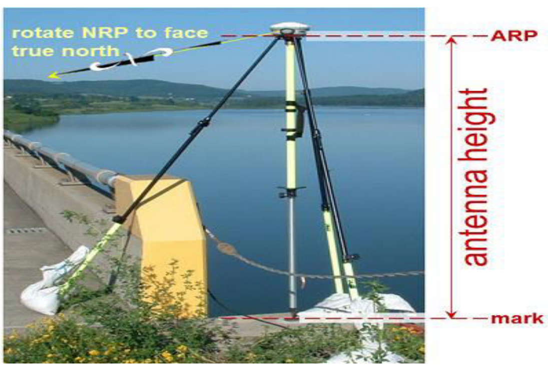

Figure (1): expressed antenna height and ARP [1].

5.3 CSRS-PPP

The Geodetic Survey Division (GSD), Canada, sophisticated the Canadian Spatial Reference System (CSRS) Precise Point Positioning (PPP) service. The CSRS-PPP service Provide post-processing position solutions of GPS observations data files which send by the users via the Internet. Precise position is estimated from PPP service either to the International Terrestrial Reference Frame (ITRF) or to the North American Datum of 1983 (NAD 83). The coordinates estimates of a single station are calculated either from kinetic or static observations utilizing precise GNSS orbits and clocks. The online (PPP) service is designed to be easy to use as well as providing the best position solution for the GNSS observation availability. Users need the following steps for the processing raw data:

- The email address of the user must be input as the processing results will be sent.
- The mode must be specifying for the processing static or kinematic.
- The frame of reference specifies should be for the data results to be processed either in ITRF or NAD83.
- The RINEX observation file (raw data) could be input by clicking on "Choose file [7].

This service is available via the GSD website at: http://www.geod.nrcan.gc.ca. [8]

5.4 SCOUT

The Scripps Coordinate Update Tool (SCOUT) was sophisticated by the Scripps Orbit and Permanent Array Center (SOPAC). The online SCOUT service also utilizes the three nearest IGS stations. However, this service allows the user to select up to four different IGS stations. The SCOUT service utilizes the GAMIT software for processing GNSS raw data [3]. The SCOUT service is accessible through the SOPAC website at: http://sopac.ucsd.edu. [9]

5.5 Auto-GIPSY

Auto-GIPSY is an e-mail/FTP interface to the GPS Inferred Positioning System (GIPSY) sophisticated by JPL. The Auto-GIPSY service performs one point positioning, and therefore it does not rely on closeness or availability of CORS/IGS data. The FTP address of user's data should be submitted by email to: ag@cobra.jpl.nasa.gov. For more information, which can visited the service's website at: http://milhouse.jpl.nasa.gov/ag/ [10].

6. Commercial processing software

6.1 Leica Geo Office (LGO v 8.3)

The LGO v8.3 is the processing software of GNSS from Leica Geosystems Company. This software is utilized for processing the GNSS data as post processing differential solution between a base station (reference) and unknown station (rover station), and can be considered as a commercial software package.

Leica Geo Office (LGO) has the ability to download the observation data (raw data) from the GNSS receiver and it is exported into RINEX file and other formats. Additionally, LGO can import the Leica DGPS format and other format such as the RINEX files.

7. Case study

The case study area is located at the Middle Technical University, Al- Zafaraniyah campus with five unknown stations which are selected precisely on the roofs of buildings to obtain a good visibility of observations between the points. These stations are selected on the basis of the visibility between the previous and subsequent stations, and avoid any effective obstructions like overhead obstructions that elevated from 10° to 15° above the horizon, reflecting the surfaces. These obstructions can be the reason of multipath effect, and prevented close electrical installations that can be interfere with the signal of satellite. Figure (2), shows the area of the case study from satellite image.

Figure (2): Study area , Middle Technical University, Al- Zafaraniyah campus [https://www.google.com.iq/maps; 15/11/2016 at 19:30 pm].

8. Field work

8.1 Static observations

In this study, Leica GS10 GNSS receiver is used for observe the unknown stations, as well as the duration of the observation for each point is divided into five periods (2^{hr}, 4^{hr}, 6^{hr}, 8^{hr}, and 10^{hr}). Figure (3) illustrates the use of a single receiver for raw data collection.

Figure (3): Single receiver set up. (station No.3 on the roof of the chemical industry department building)

8.2 Rapid static observations

In this work, the unknown point has been selected within the middle of the traverse, where the base receiver is set up over this point. The rover which is a Leica GS15 Antenna was moved from unknown point to another with observed time (10 min) for each point. Figure (4) represent the rapid static observations.

Figure (4): Rapid static of GNSS observation. Base (fixed device on left), Rover (moved device on right).

8.3 Traversing

In order to evaluate the accuracy of the processing results of the GNSS data from the various processing software, a closed connected traverse was created using total station instrument type Leica FlexLine TS09plus with accuracy (1sec). This instrument is equipped with several advanced surveying programs, including a Travers POR, where it is used to create a high accuracy traverse. Fieldwork has been started from station (1), as shown in Figure (2) where its coordinates are imposed and the first direction is also assumed. Figure (5), reveals the field survey of the closed loop traverse.

Figure (5): The field observations to create traverse.

9. Data Processing

9.1 Static Observation Processing

The collected raw data from the static observations was processed using two of the previously mentioned online GNSS processing services OPUS, AUSPOS and CSRS-PPP.

9.2 Rapid static Observation Processing

After the field observations data are achieved, the raw data was downloaded to personal Computer (PC) from base and rover receivers, the base receiver observations data was submitted to the online OPUS processing service for processing this data in order to obtain accurate position. Finally, LGO v8.3 software has been used to processing the rapid static data as shown in Figure (6).

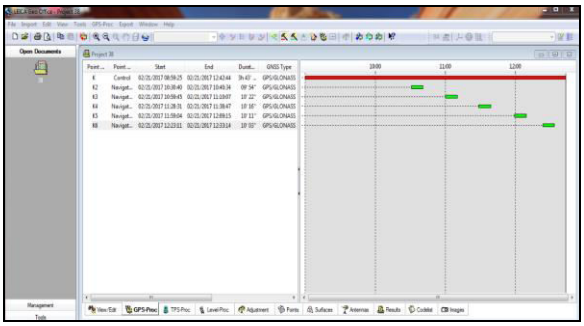

Figure (6): Raw data processing with LGO software.

10. Field Results Calculations (Analyzing and Comparing)

The calculations results for each side of traverse are given in the following tables where, the side's lengths were derived from the positions that obtained from three online processing software based on observations times also, the positions using LGO processing software and the positions estimated using total station. As well as calculation of the differences between the field measurements resulting from the use of the total station (TS) and the lengths of traverse side the outputs of the inverse computations using the coordinates of each processing software.The statistical validity of results derived can be assessed by considering the Root Mean Square Error (RMSE).

The root Mean Square Error, (RMSE) is a frequently used measure of the difference between values calculated by observation software and the values actually observed from the field. These individual differences are also called residuals, and the RMSE serves to aggregate them into a single measure of predictive power.

The RMSE of software observation with respect to the measured filed variable X_f is defined as the square root of the mean squared error:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{f,i} - X_{s,i})^2}{n}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where:

X_f; field values and

X_s; observed values at time/place *i*.

10.1 Analysis of Side Length

The first part of analysis refers to the results of 2^{hr} observations period. The analysis was based on differences in the lengths of each side of traverse.

Table (1): Traverse lengths calculated based on the observation within 2^{hr}period.

Side No.	Computed distance (m)								
	Field measured (TS)	Time span 2^{hr}						Rapid Static	
		OPUS	Difference (cm)	AUSPOS	Difference (cm)	PPP	Difference (cm)	LGO	Difference (cm)
	1	2	1-2	3	1-3	4	1-4	5	1-5
1	82.699	82.687	1.2	82.678	2.1	82.673	2.6	82.697	0.2
2	385.434	385.457	-2.3	385.453	-1.9	385.454	-2.0	385.433	0.1
3	259.066	259.025	4.1	259.053	1.3	259.039	2.7	259.066	0
4	238.561	238.580	-1.9	238.581	-2.0	238.588	-2.7	238.560	0.1
5	733.189	733.214	-2.5	733.202	-1.3	733.212	-2.3	733.189	0
RMSE(cm)		**2.6**		**1.8**		**2.5**		**0.11**	

The differences in lengths were very clear as illustrated in Table (1) ranging from 1.2 cm to 4.1 cm for OPUS processing services, 1.3 cm to 2.1 cm for AUSPOS processing service, and 2 cm to 2.7 cm for CSRS-PPP processing service. It can be seen from the computed results which the CSRS-PPP service gave the most consistently at level 2 cm while the OPUS service degradation in (side No.3) at level 4cm due to the selected two CORS stations located outside of Iraq and third locate in north region of Iraq(as reported in appendix B). This variance is shown more clearly by the Root Mean Square Error (RMSE) values where the AUSPOS was 1.9 cm, 2.5 cm for the CSRS-PPP and 2.7 cm, it can be concluded within the 2^{hr} period the AUSPOS was better than other online processing software which consider in this study. While the LGO was better than OPUS, AUSPOS, and CSRS-PPP at level 0.11 cm. These differences in distances can also be illustrated in the Figure (7).

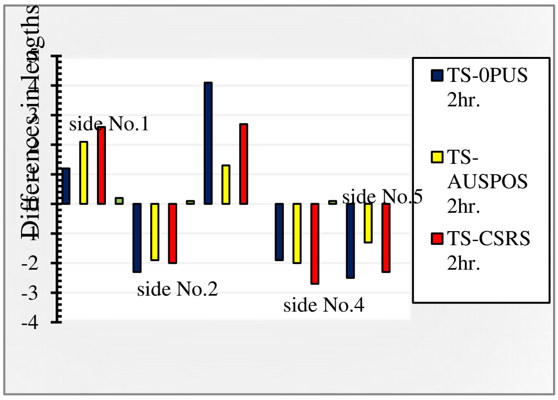

Figure (7): The differences in lengths (cm) for 2^{hr} time period observation.

The second part of the analysis refers to the results of 4^{hr} observation period. Similarly to the 2^{hr} data, solutions were also analyzed based on the lengths at individual traverse for each processing service.

Table (2): Traverse lengths calculated based on the observation within 4^{hr}period.

Side No.	Computed distance (m)								
	Field measured (TS)	Time span 4^{hr}						Rapid Static	
		OPUS	Difference (cm)	AUSPOS	Difference (cm)	PPP	Difference (cm)	LGO	Difference (cm)
	1	2	1-2	3	1-3	4	1-4	5	1-5
1	82.699	82.691	0.8	82.679	2.0	82.675	2.4	82.697	0.2
2	385.434	385.425	0.9	385.425	0.9	385.416	1.8	385.433	0.1
3	259.066	259.083	-1.7	259.078	-1.2	259.084	-1.8	259.066	0
4	238.561	238.581	-2.0	238.580	-1.9	238.586	-2.5	238.560	0.1
5	733.189	733.204	-1.5	733.201	-1.2	733.201	-1.2	733.189	0
RMSE(cm)		1.45		1.5		1.99		**0.11**	

Table (2) shows variations in traverse side length, those variations for OPUS processing service ranging from 0.8cm to 2.1cm, 1.2cm to 2cm for AUSPOS processing service, and 1.2cm to 2.5cm for CSRS-PPP processing service. It can be shown the results of the (side No.1) of OPUS is better than the rest and the reason for this is the choice two CORS station inside of Iraq and third CORS station outside of Iraq. It is also through the calculation of Root Mean Square Error (RMSE) that there is an improvement with time increase in the results shown in the Table (1) compared to 2^{hr} of observation where there was a clear convergence in the value of RMSE of OPUS and AUSPOS 1.45cm, 1.5cm respectively while RMSE-CSRS-PPP 1.99cm based on these values can be considered OPUS and AUSPOS better than CSRS-PPP in the 4^{hr} observation period. In addition, variations in lengths can be illustrated in the Figure (8).

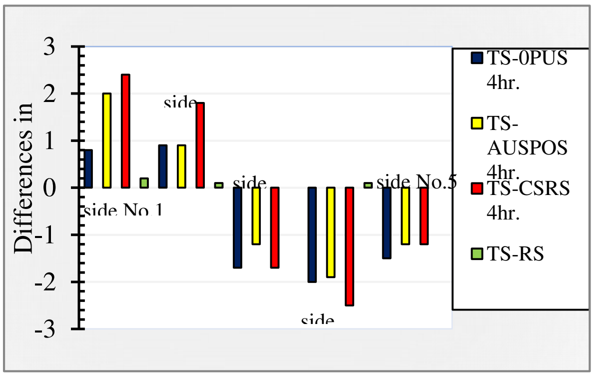

Figure (8): The differences in lengths (cm) for 4^{hr} time period observation.

The third part of the analysis refers to the results of 6^{hr} observation period. The solutions were also analyzed based on the lengths for each processing service.

Table (3); Traverse lengths calculated based on the observation within 6^{hr}periode.

Side No.	Computed distance (m)								
	Field measured (TS)	Time span 6^{hr}						Rapid Static	
		OPUS	Difference (cm)	AUSPOS	Difference (cm)	PPP	Difference (cm)	LGO	Difference (cm)
	1	2	1-2	3	1-3	4	1-4	5	1-5
1	82.699	82.687	1.2	82.681	1.8	82.681	1.8	82.697	0.2
2	385.434	385.415	1.9	385.425	0.9	385.421	1.3	385.433	0.1
3	259.066	259.077	-1.1	259.073	-0.7	259.076	-1.0	259.066	0
4	238.561	238.579	-1.8	238.578	-1.7	238.580	-1.9	238.560	0.1
5	733.189	733.197	-0.8	733.199	-1.0	733.202	-1.3	733.189	0
RMSE(cm)		**1.42**		**1.29**		**1.49**		**0.11**	

Table (3) explain, the differences in lengths for each processing service, those differences for OUPS processing service from 1.2 cm to 1.9 cm, 0.7 cm to 1.8 cm for AUSPOS processing service, and 1 cm to

2.1 cm for CSRS-PPP processing service. The results achieved by the service of AUSPOS for processing is better at (side No.3) due to the network of IGS stations are the same used every time for processing in this study. It is also noted that there is deterioration in the (side No.1) and (No.2) in the results when compared with the 4^{hr} of observation and the reason that the processing was based on CORS stations outside Iraq(as reported in appendix B). Furthermore, when observing the values of the Root Mean Square Error (RMSE), the value of the OPUS 1.4 cm is very close to the value of the fourth hour observation. There is an improvement in the RMSE values with increase time observation for the AUSPOS at level 1.29 cm and CSRS-PPP at level 1.49 cm through, values of RMSE can say that AUSPOS is better than the OPUS, and CSRS-PPP of the online processing software. Figure (9), illustrates these differences in lengths.

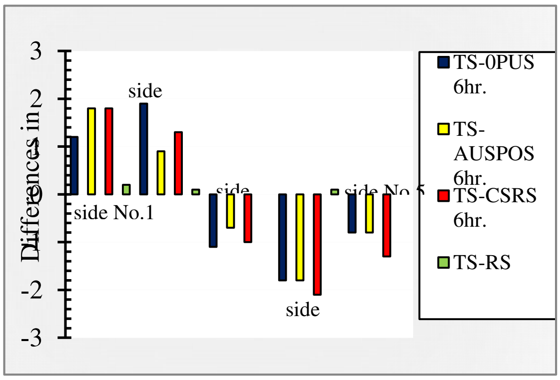

Figure (9): The differences in lengths (cm) for 6^{hr} time period observation.

The fourth part of the analysis refers to the results of the 8^{hr} observation period as well, analyzed on the basis of lengths for each processing service.

Table (4): Traverse lengths calculated based on the observation within 8^{hr}period.

Side No.	Computed distance (cm)								
	Field measured (TS)	Time span 8^{hr}						Rapid Static	
		OPUS	Difference (cm)	AUSPOS	Difference (cm)	PPP	Difference (cm)	LGO	Difference (cm)
	1	2	1-2	3	1-3	4	1-4	5	1-5
1	82.699	82.693	0.6	82.689	1.0	82.683	1.6	82.697	0.2
2	385.434	385.443	-0.9	385.442	-0.8	385.445	-1.1	385.433	0.1
3	259.066	259.076	-1.0	259.071	-0.5	259.067	-0.1	259.066	0
4	238.561	238.569	-0.8	238.575	-1.4	238.573	-1.2	238.560	0.1
5	733	73	-0.4	733	-0.6	73	-1.5	73	0

	.189	3.193		.195		3.204		3.189	
RMSE(cm)		0.77		0.92		1.22		0.11	

It can be shown from Table (4), the differences in lengths for each processing service, those differences for OUPS processing service from 1cm to 0.4 cm, 1 cm to 0.4 cm for AUSPOS processing service, and 1.6 cm to 0.1 cm for CSRS-PPP processing service. The results obtained from the comparison between field measurements and different processing software showed a clear fluctuation in CSRS-PPP values from 1 to 1.6 cm because of the depends on clocks and orbits products, the tropospheric, and ionospheric model [11] but in this study have been observed points at each individually using single receiver. While, the results of OPUS and AUSPOS are approaching the field measurements at the level less than one centimeter, the following Figure (9), shows those differences. As well as by calculating the Root Mean Square Error(RMSE) whose values was shown in the Table above, where it was as follows for OPUS 0.77 cm, for AUSPOS 0.92 cm and for CSRS-PPP 1.22 cm.These values gave an approximation of the OPUS and AUSPOS values of the field measurement values within the limits of less than centimeters. This gives an impression of marked improvement with increased observation time while, value of the CSRS-PPP was within the limits of the centimeter, due to the same reason mentioned above.

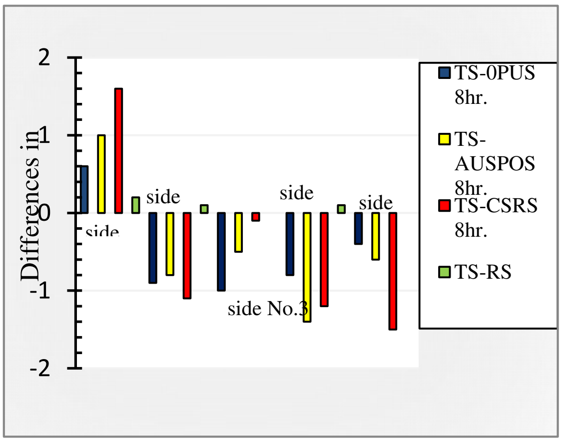

Figure (10): The differences in lengths (cm) for 8^{hr} time period observation.

The fifth part of analysis refers to the results of 10^{hr} observations period. The differences in lengths were small compared to other results, as shown in Table (5).

Table (5): Traverse lengths calculated based on the observation within 10^{hr}period.

Side No	Computed distance (m)								
	Field measured	Time span 10^{hr}						Rapid Static	
		OPUS	Difference	AUSPOS	Difference	PPP	Difference	LGO	Difference

.	(TS)		(cm)		(cm)		(cm)		(cm)
	1	2	1-2	3	1-3	4	1-4	5	1-5
1	82.699	82.697	0.2	82.698	0.1	82.697	0.2	82.697	0.2
2	385.434	385.433	0.1	385.435	-0.1	385.437	-0.3	385.433	0.1
3	259.066	259.060	0.6	259.061	0.5	259.061	0.5	259.066	0
4	238.561	238.567	-0.6	238.568	-0.7	238.563	-0.2	238.560	0.1
5	733.189	733.185	0.4	733.186	0.3	733.181	0.8	733.189	0
RMSE(cm)	**0.43**		**0.41**		**0.46**		**0.11**		

It can be noticed the length differences for each processing service as follows for OPUS processing service ranging from 0.1 cm to 0.6 cm, AUSPOS processing services ranging from 0.1 cm to 0.7 cm, and CSRS-PPP processing services ranging from 0.2 cm to 0.8 cm. The results show that all values for all processing software are close to field measurements in millimeters. These results were almost predictable because the observation period is relatively long. In addition to these differences, the values of the Table (5), where found that the values of the Root Mean Square Error (RMSE) are all at a level of less than one centimeter. This gives a clearer impression whenever, the longer the observation period, the closer the results to the truth values. Furthermore, these differences in lengths can be illustrated in Figure (11).

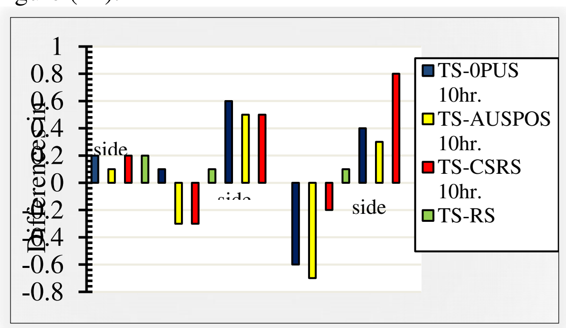

Figure (11): The differences in lengths (cm) for 10^{hr} time period observation.

10.2 Summary

To summarize the results obtained through online and offline processing software, depending on the results of Root Mean Square Error (RMSE) that appears in the previously mentioned Tables where it was collected here in one Table (5-6), and then prepare a brief to give an impression about software.

Table (6): Root Mean Square Error (RMSE) of all lengths for each traverse in (cm) based on observation period.

Observation Period Time (hr)	RMSE of the lengths for each traverse (cm)			
	OPUS	AUSPOS	PPP	LGO
2	2.6	1.8	2.5	
4	1.45	1.5	1.99	
6	1.42	1.29	1.49	0.11
8	0.77	0.92	1.22	
10	0.43	0.41	0.46	

Through the values of the calculated Root Mean Square Error (RMSE) shown in the Table (6), showing that the LGO software used in the Rapid Static (RS) technique is the closest software in terms of convergence of values with field measurements (TS) and also show that the time factor is an important factor when using free online processing software where The time of observation was longer and the results were closer to the true values. It is also noted that the software OPUS gives better results when relying on the points located in Iraq, while the program CSRS-PPP was expected to give better results, but in this study was used one GNSS receiver to observation each point separately. It is also noted that the results were graded with the time when using the AUSOPS software because; the same IGS network is used in this study for the purpose processing. In general, the results were good when using online processing software, which can be used in various survey purposes in addition to being an easy and economical method and do not need high experience in using this software.

The following Figure (12), shows the variance of values when Root Mean Square Error (RMSE) value.

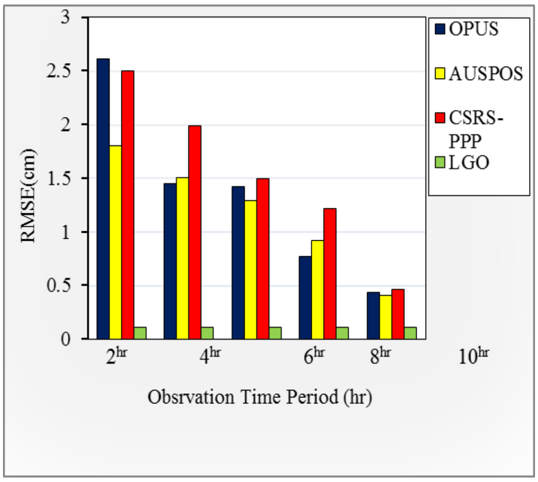

Figure (12): RMSE in (cm) for different GNNS software based on observation periods.

11. Conclusion

In this study, different positioning techniques for different accurate applications are used and three free online processing services, OPUS, AUSPOS, and CSRS-PPP, are considered and processing data with services scientific software. Those used services scientific of processing software in addition, to LGO v8.3 practical software are used for processing GNSS data. Furthermore, this study has allowable of a comparison analysis to be done by utilizing a large dataset based on different observations time period.

The following conclusions can be reached: -

1. Online processing services does not need to buy expensive processing software that does not require high processing experience compared to commercial software that require high-level experience.
2. There is no association between processing results at the same point for different free online processing services. Though, there is not uniformity between results processing, but the result are mostly perfect at the (0.41–2.6) cm level.
3. The degradation in accuracy of the OPUS solutions is evident in data spans. This is likely due to the long baselines and selected CORS stations for processing are irregular such as when using three CORS stations outside Iraq. Where those points are located in Tehran, Bahrain and Cyprus or Ankara. This degradation in accuracy may reach to 4cm.
4. The obtained results through comparison and analysis show that AUSPOS processing services accuracy are regular with the observation period when, the observations time longer the accuracy increase because of the network of IGS stations which consists of 12 stations is used for the processing as each time to this study.
5. Although the results of data processing through online processing service depend on several factors, users can expect reliable results during observation time period 10^{hr} at a millimeter level.

7. In general, the use of online processing services is easy; economic; simple and practical without needed to large field survey team and processing with available software.
8. The difference of Rapid Static (RS) techniques which are used commercial or practical software for processing GNSS LGO v8.3, comparing with traditional surveying total station is at millimeter level.

12. Recommendations

Depend on the results that have been concluded in this study, the following ideas may be examined for future work:

1. Preferably use of CSRS-PPP processing service to establish Ground Control Points (GCP) in remote areas which no available communication and references stations there.
2. To create a small ground control network do not exceed the length of the base lines one kilometer, rapid static positioning technique has been useful to this task.
3. Accuracy assessment of positions in the event that the constellation of European satellites is fully operational.
4. Calculating the parameters of translate from WGS84 coordinates system to localized coordinate system for Iraq that can produce coordinates of GNSS better

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