Web-based GNSS Data Processing Services as an Alternative to Conventional Processing Technique

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SUMMARY

In this study, commonly used web-based online GNSS processing services are compared to each other with respect to their accuracy. Within this frame, 24-hour data sets collected at one of the TUSAGA-Aktif Network, CORU, reference station were used. The 24-hour-data files were divided into several shorter sessions as; 24 consecutive 1 hour sessions, 12 consecutive 2 hour sessions, 6 consecutive 4 hour sessions, 4 consecutive 6 hour sessions, and 2 consecutive 12 hour sessions. All these observation files were processed with web-based online services by using Trimble RTX, AUSPOS and OPUS that utilize differential technique; and using CSRS-PPP, magicGNSS and APPS with the PPP technique. The findings reveal that these services can be used in many surveying applications including high-accurate studies with a cost-effective manner and very easily used without any knowledge of the GNSS processing software.

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1. INTRODUCTION

Until recent years, it was necessary to obtain positioning with GPS using at least two receivers, and the collected data should be processed for high accurate positioning by using the GNSS data processing software whether scientific or commercial. However, the usage of such software is also quite difficult because they generally require deep knowledge of the GNSS and experience in the processing. Furthermore, they mostly need a licensing fee.

Regarding the improvements in information technology and GNSS data processing methodology, many new opportunities have been offered to the users. In this respect, several institutions, research centres or organizations have developed web-based online GNSS processing services and they have started to become a strong alternative to the conventional data processing method. The only requirement for using these services which are generally provided free of charge with limitless usage, is a computer having an Internet connection and web browser. These services are designed to be as simple as possible for the user and with minimal input. Users of such systems have to perform uploading/sending of their collected RINEX data by using the web site of these services, e-mail or ftp sites to the system and selecting a few options such as static/kinematic modes, datum, antenna and etc. With these services, when the data is received to the service, processing starts and the results (together with the coordinates, process reports along with other necessary information for analysing the results) are sent to the user in a short amount time. Some of these services process not only the GPS but also the data of other systems, particularly those of GLONASS, and provide resilience and a higher accurate positioning service in certain cases to their users.

As of today, there are several web-based online GNSS processing services, in which some of them calculate the coordinates with a relative solution approach (e.g. Trimble RTX, AUSPOS, OPUS,); or with the PPP technique (e.g. CSRS-PPP, magicGNSS, APPS*)*. PPP-based services used the GNSS data collected with only a single receiver with precise satellite ephemerides and clock data by taking into account corrections like carrier phase wind-up, satellite antenna phase offset, solid and ocean tides. The services evaluated with the relative solution, use the fixed station points which relate to International GNSS Service (IGS) and/or CORS Networks as reference points and calculates the coordinates of the points with the relative method. The use of these systems saves time and labour by eliminating the need for a reference station and knowledge, training and usage of the GNSS processing software.

A brief overview including the main features of the common web-based online GNSS processing services that are used in this study are given below.

Canadian Spatial Reference System-Precise Point Positioning (CSRS-PPP): The service has been operated by Natural Resources Canada, Canadian Geodetic Survey since 2003. The online post-processing PPP service is free, but you need to register to the system. The user submits his/her GNSS data to the service via its easy-use web page with a valid e-mail address to which the processing results will be sent. After selecting some options (processing mode as static or kinematic, reference frame as NAD83 or ITRF, and if needed selecting the geoid model and import an Ocean Tidal Loading (OTL) file), service process, single or dual-frequency data from GPS and GLONASS (if available) satellites by using the best available ephemerides (final, rapid or ultra-rapid), and can process the data approximately 90 minutes after data collection. The results having not only the PPP-derived coordinates but also summary reports and graphical time series plots sent to the user by e-mail. The service is accessible at http://webapp.geod.nrcan.gc.ca/geod/tools-outils/ppp.php?locale=en

magicGNSS: The free online multi-constellation GNSS PPP service was developed by the Spanish GMV Aerospace and Defense Company, in 2008. This service supports not only GPS but also other GNSS satellites, i.e. GLONASS and GALILEO. Users can send the dual-frequency observation files via the service's web site or e-mail. The PPP-derived coordinates can be estimated in static or kinematic modes. The magicGNSS provides three different levels of usage as: a post processing service (for registered users), e-mail service (free) and real-time service. The results including coordinates and the reports are sent back to the users through e-mail. The service is accessible at http://magicgnss.gmv.com

Automatic Precise Positioning Service (APPS): The service is operated by NASA Jet Propulsion Laboratory, California Institute of Technology. For basic service, there is no registration needed. User can send their observation files via web site, e-mail or service's ftp site. The PPP-based service provides static and kinematic processing modes by using JPL's GPS orbit and clock products. The service is accessible at http://apps.gdgps.net

Trimble CenterPoint RTX (Real Time eXtended): The free service provides a cm-level of accuracy positioning globally operated by Trimble. The service process, dual-frequency data collected in static sessions (at least 60 minutes of observation data should be collected after 14 May 2011). The Trimble CenterPoint RTX post-processing service provide solutions for not only GPS but also GLONASS, QZSS satellite systems. The GALILEO and BeiDou satellite data is used for testing purposes only because they have not been certified for commercial use. The positioning calculations are performed in ITRF2008 current epoch. Users can submit his/her dual frequency data files through the service's web page. When the processing is complete, a report will be sent via e-mail to the user. The service is accessible at http://www.trimblertx.com

AUSPOS-Online GPS Processing Service: This free online service provided by Geoscience Australia. Accepts only dual-frequency geodetic quality GPS data observed in static mode for more than 1-hour data span (preferably 2-hour). The service does not process kinematic data and other GNSS data. The data can be sent to the service through the web site or using ftp site. The service utilizes a relative method for positioning by establishing a network consisting of the nearest 15 IGS and APREF stations using the best available IGS products. That data is taken from Geoscience Australia's GNSS Data Archives. The report, in Adobe PDF format includes station coordinates computed in ITRF2008 and other information will be e-mailed to the user when the processing is completed within a few minutes. The service is accessible at http://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/auspos

Online Positioning User Service (OPUS): The service is operated by the US National Geodetic Survey (NGS). The user can upload their dual-frequency GPS data collected with a survey-grade receiver in static mode. The OPUS can process the data either as static or rapid-static modes depending on the data span. Files under 2 hour are processed as rapid-static whereas files between 2 hrs. and 48 hrs. are processed as static. This service utilizes relative positioning for positioning with respect to three nearby CORS stations. The solution will be sent via the introduced e-mail provided by the user within a few minutes. The service is accessible at http://www.ngs.noaa.gov/OPUS

More detailed information about the online services can be found in the Ghoddousi-Fard and Dare (2006), Tsakiri (2008), El-Mowafy (2011) and Gakstatter (2013), Guo (2015) and from the related web page of the services.

The main goal of this study is to make a comparison of the world-wide web-based online GNSS processing services with respect to accuracy as a function of the measurement time. The test procedures and obtained results, are given in the following sections.

2. CASE STUDY

In order to investigate the static accuracy performance of the common online GNSS processing services as a function of the measurement time, a 24-hour data set collected in the Çorum Province, of Turkey on December 03, 2014 (GPS Week: 1821; GPS Day: 337) at CORU was used. The CORU station (40^0. 57041 N, 34^0. 98220 E) is one of the 146 stations of Turkish RTK Continuously Operating Reference Stations Network (TUSAGA-Aktif). The interval of the observation data was 1-second. The CORU station was equipped with the Trimble NetR5 receiver and TRM55971.00 geodetic-grade antenna and situated on the roof of the Engineering Faculty at the Hitit University, in Çorum with a clear sky view as shown in Figure 1.

Figure 1. The CORU Station Location

The Trimble NetR5 is a multi-channel, multi-frequency GNSS receiver that supports the modernized GPS L2C and L5 signals as well as GLONASS L1/L2 signals.

Some information about the handled data is given in Table 1.

Table 1. Information about the Data Used in This Study

Station	Date & Start/End Time	Receiver Type	Antenna Type	Antenna Height
CORU	2014/12/03 00:00:00/23:59:30	Trimble NetR5	TRM55971.00	0.087 m

The 24-hour collected data was downloaded from the related Internet site of the TUSAGA-Aktif System. In order to investigate how long, it takes the online processing services' solutions to reach the best accuracy, the 24-hour data was divided into different shorter sessions as follows:

- 24 consecutive 1-hour sessions,
- 12 consecutive 2-hour sessions,
- 6 consecutive 4-hour sessions,
- 4 consecutive 6-hour sessions,
- 2 consecutive 12-hour sessions.

The 24-hour-data including the sub-sessions were sent to the web-based online GNSS processing services via e-mail or the service's web page. All these observation files were processed in static mode with differential technique by using the Trimble RTX, AUSPOS and OPUS; with the PPP technique using CSRS-PPP, magicGNSS and APPS online processing services. The corresponding coordinates including some additional information about the processing retrieved via e-mail or placed into the service web site.

The coordinates were then compared with the reference coordinates, i.e. published coordinates values, to analyse the online processing service's accuracy performance. The obtained differences in position and ellipsoidal height are shown in Figure 2 for PPP techniques (i.e. from CSRS-PPP, magicGNSS and APPS), and in Figure 3 the differential solutions (i.e. from Trimble RTX, AUSPOS and OPUS).

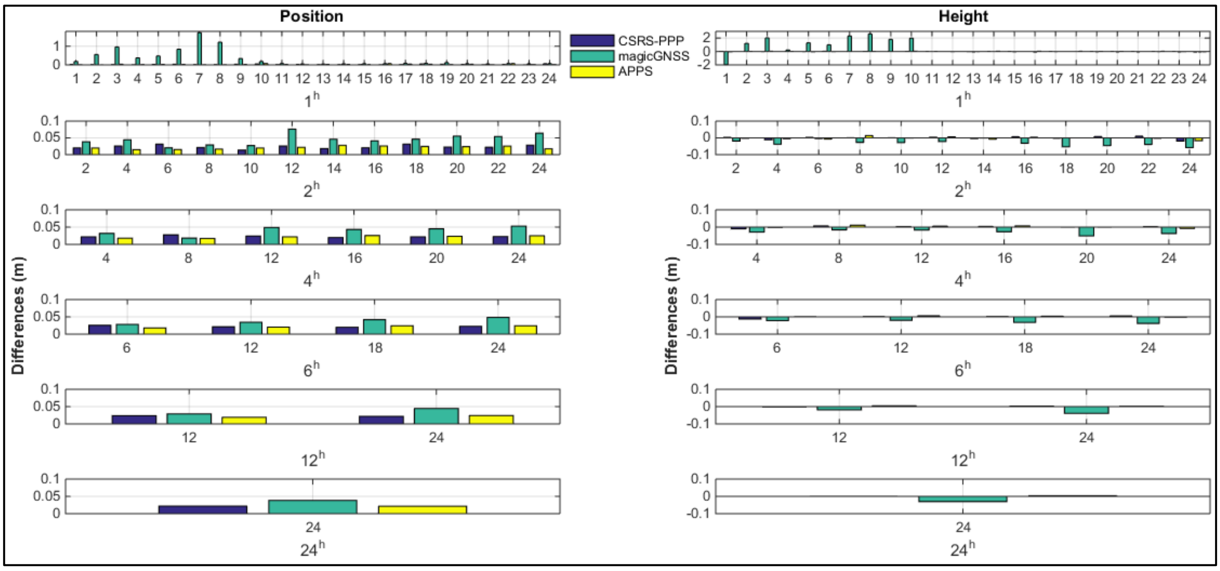

Figure 2. Differences between the PPP-derived solutions and Known Coordinates

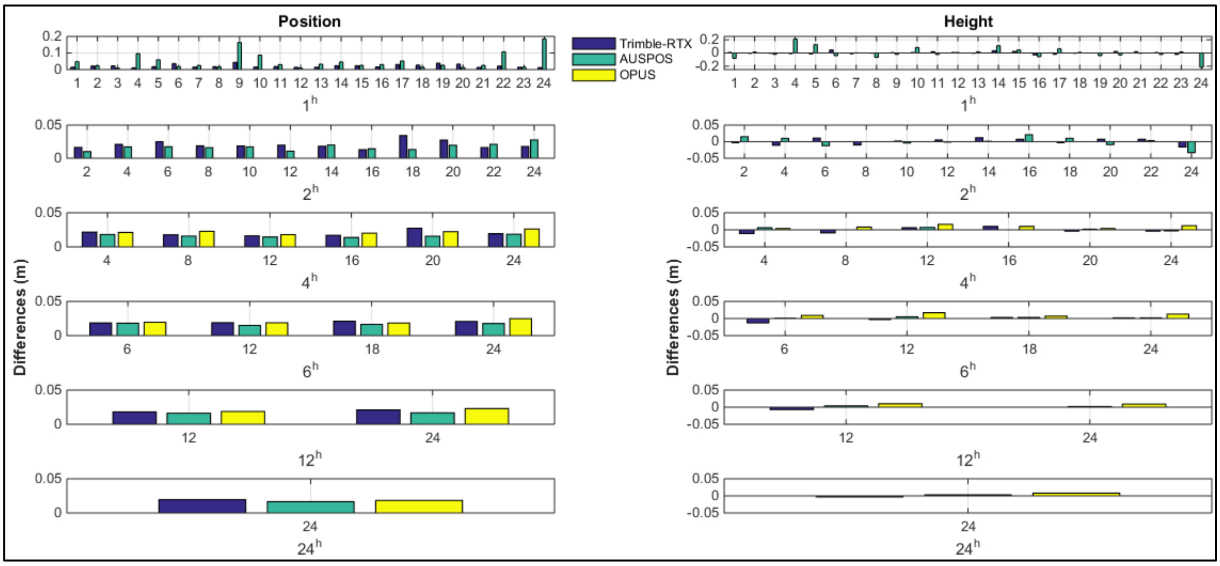

Figure 3. Differences between the Differential-solutions and Known Coordinates

Table 2 summarised some of the statistical information obtained differences.

Table 2. Some of the Statistical Information of Differences

		in Position (m)			in Height (m)		
		Min.	***Max.***	***Mean***	***Min.***	***Max.***	***Mean***
Data Span of Sub-sessions: 1-hour				**# of Sub-sessions**: 24			
with PPP technique	**CSRS-PPP**	0.01	0.07	0.03	-0.08	0.04	0.00
	magicGNSS	0.04	1.73	0.33	-1.99	2.62	0.50
	APPS	0.01	0.08	0.03	-0.05	0.05	0.00
with relative solution	**Trimble RTX**	0.01	0.04	0.02	-0.03	0.05	0.00
	AUSPOS	0.01	0.19	0.05	-0.22	0.21	0.00
	OPUS	N/A	N/A	N/A	N/A	N/A	N/A
Data Span of Sub-sessions: 2-hour				**# of Sub-sessions**: 12			
with PPP technique	**CSRS-PPP**	0.01	0.03	0.02	-0.02	0.01	0.00
	magicGNSS	0.02	0.08	0.05	-0.06	0.00	-0.03
	APPS	0.01	0.03	0.02	-0.02	0.01	0.00
with relative solution	**Trimble RTX**	0.01	0.03	0.02	-0.02	0.01	0.00
	AUSPOS	0.01	0.03	0.02	-0.03	0.02	0.00
	OPUS	N/A	N/A	N/A	N/A	N/A	N/A
Data Span of Sub-sessions: 4-hour				**# of Sub-sessions**: 6			
with PPP technique	**CSRS-PPP**	0.02	0.03	0.02	-0.01	0.01	0.00
	magicGNSS	0.02	0.05	0.04	-0.05	-0.02	-0.03
	APPS	0.02	0.03	0.02	-0.01	0.01	0.00
with relative solution	**Trimble RTX**	0.02	0.03	0.02	-0.01	0.01	0.00
	AUSPOS	0.01	0.02	0.02	0.00	0.01	0.00
	OPUS	0.02	0.03	0.02	0.00	0.02	0.01
Data Span of Sub-sessions: 6-hour				**# of Sub-sessions**: 4			
with PPP technique	**CSRS-PPP**	0.02	0.03	0.02	-0.01	0.00	0.00
	magicGNSS	0.03	0.05	0.04	-0.04	-0.02	-0.03
	APPS	0.02	0.02	0.02	0.00	0.01	0.00
with relative solution	**Trimble RTX**	0.02	0.02	0.02	-0.01	0.00	0.00
	AUSPOS	0.01	0.02	0.02	0.00	0.00	0.00
	OPUS	0.02	0.02	0.02	0.01	0.02	0.01
Data Span of Sub-sessions: 12-hour				**# of Sub-sessions**: 2			
with PPP technique	**CSRS-PPP**	0.02	0.02	0.02	0.00	0.00	0.00
	magicGNSS	0.03	0.04	0.04	-0.02	-0.04	-0.03
	APPS	0.02	0.02	0.02	0.00	0.00	0.00
with relative solution	**Trimble RTX**	0.02	0.02	0.02	-0.01	0.00	0.00
	AUSPOS	0.02	0.02	0.02	0.00	0.00	0.00
	OPUS	0.02	0.02	0.02	0.01	0.01	0.01
Data Span of Sub-sessions: 24-hour				**# of Sub-session**: 1			
with PPP technique	**CSRS-PPP**	0.02	0.02	0.02	0.00	0.00	0.00
	magicGNSS	0.04	0.04	0.04	-0.03	-0.03	-0.03

	APPS	0.02	0.02	0.02	0.00	0.00	0.00
with relative solution	**Trimble RTX**	0.02	0.02	0.02	0.00	0.00	0.00
	AUSPOS	0.02	0.02	0.02	0.00	0.00	0.00
	OPUS	0.02	0.02	0.02	0.01	0.01	0.01

It can be seen from Figure 2 and Table 2 that, as expected, the PPP-based solutions from the 1-hour data sessions produce relatively larger differences than the longer observation data sessions, i.e. 2-hour or more of observation. The largest differences are obtained from the magicGNSS solutions that reach several meters for both the 2D position and height components. On the other hand, the CSRS-PPP and APPS services yielded very similar results good to a decimetre or better level of accuracy in the 2D position and height from the1-hour data sessions. When processing the 2-hour observation files, again CSRS-PPP and APPS services yielded very similar results within a few cm level of accuracy. Furthermore, it was found that the 2-hour solutions provide very similar results to the 4, 6, 12 and even 24-hour data solutions. The overall results show that, the CSRS-PPP and APPS services gives the best results very close to each other whereas, the magicGNSS gives very poor results from the 1-hour data sessions and slightly less accuracy for 2 or more hour data sessions. The whole results indicate that, at least 2-hour of observations are required in order to obtain a sub-decimetre to a couple of cm level of accuracy.

When considering the online services', the results utilize the relative solution approach (Figure 3), the results indicate that with the Trimble RTX's results, the differences in the 2D position and height agree with the reference coordinates within 5 cm or more. On the contrary, for these data sessions a low-level of accuracy, i.e. 2 dm-level of accuracy was obtained from the AUSPOS service. The OPUS service did not give any solution for the 1 and 2-hour data sessions. When processing the 2-hour observation files, the Trimble RTX and AUSPOS services provide very similar results within a few cm level of accuracy (3 cm as a maximum). It was found that the 2-hour solutions provide very similar results with the 4, 6, 12 and even the 24-hour data solutions and this results indicate that, in order to get a few cm of accuracy, the users are required to submit at least 2-hour of observation data.

3. RESULTS

In this study, the assessment for accuracy performance of common online GNSS processing services was carried out. When considering the PPP-based services, CSRS-PPP and APPS services produced very similar and the best results. The Trimble RTX and AUSPOS online GNSS processing services that make positioning with relative methods provide a very high-level of accuracy results even from the 1-hour data sessions. In general, according to the processing of the 24-hour lasting observation files and its sub-datasets consist of 1, 2, 4, 6 and 12 hour with different online GNSS processing services, it can be concluded that the services all can provide a cm-level of accuracy especially from 2-hour and more of observations. This attainable accuracy can be acceptable for a variety of precise surveying and several mapping applications.

The findings reveal that these services can be used in many surveying applications in a cost-effective manner and very easily without knowledge and training of any GNSS processing software. The use of these systems saves time and labour by eliminating the need for station points(s) and GNSS software. Online processing services with these advantages have become a significant alternative against the scientific and commercial GNSS software packages. Therefore, these services are very useful for users who do not have detailed knowledge of the GNSS method and the experience in commercial or scientific GNSS processing packages.

The study shows that, any user that collects GNSS data with only a single receiver, he/she can make positioning very accurate, easy and cost-effective with the online processing service which utilize the PPP technique or relative methods without requiring data from any reference stations for simultaneous observations. All usage of the services is very simple and user can process the collected data in the field, and process it with the different online services. This provides control of the calculated coordinates as well being a backup for each other. It should be noted that, outliers can always occur, so double occupations are strongly recommended, by using different services.

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BIOGRAPHICAL NOTES

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