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# **Estimating the Adequate Observation Times of a Single GNSS Receiver by Utilizing Online Processing Services**

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Abstract. Global Navigation Satellite Systems (GNSS) have witnessed rapid developments in the field of online post-processing services and the abundance of continuously operating reference stations (CORS), which reflected on facilitating the tasks of surveyors, engineers and geoscientists. However, the sufficient time for observations to achieve a certain level of accuracy is still one of the main concerns for researchers and specialists. In this study, the geometry of a short-sides triangle has been employed to estimate the sufficient observing times of GNSS receivers throughout the online processing services. The short-sides triangle vertices were observed for 24 hours and partitioned into shorter periods of time, then GPS and GLONASS have been processed as well as GPS alone after filtering out the GLONASS observables. Datasets have been processed using online post-processing services, i.e. AUSPOS and CSRS-PPP. A number of propagation error models have been applied to investigate the station accuracy behaviour. the results have revealed that RMS errors of 1 cm can be achieved after two hours for horizontal component and three hours for the vertical component. Furthermore, including GLONASS satellites is playing a role to enhance accuracy especially in short observation times.

Keywords: GNSS, AUSPOS, CSRS, Online processing, Time estimation.

### **1. Introduction**

#### 1.1. Overview

Over the past ten years, many studies have been conducted to analyze the ability of the Global Navigation Satellite System (GNSS) online processing services for producing reliable positional accuracies. A significant part of those efforts has concentrated on estimating the accuracy as a function of the observation interval and satellite availability to inform surveyors how long to occupy a point in order to achieve a particular accuracy in the post-processing solutions. Previous studies have shown that session length is influenced by numerous variables, including which constellations are used, which online service is used, and the site conditions. This research paper has investigated the capability of GNSS online processing services from two different perspectives. First, particular attention was given for testing GNSS observations at 15-minute intervals between 1 and 2 hours (1:15, 1:30, 1:45) and; second, an equilateral triangle with known lengths from taping and levelling was used to validate the processing results. This study has utilized two GNSS processing services, AUSPOS and CSRS, to investigate the positional accuracies of GNSS receivers as a function of observing duration. Furthermore, the impact of including and excluding the GLONASS constellation during processing has been addressed to reveal the potential of this service.

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The study was conducted in Nasiriyah city - south of Iraq (Figure 1), where the GNSS techniques have been more in demand due to increased oilfield development projects in the region, which necessitates employing the most recent geomatics technologies to manage and accelerate executing such large-scale projects.



Figure 1. The study area location and the distribution of surrounding IGS Stations.

### *1.2. Previous studies*

Myriad of researches have been dedicated so far to investigate the adequate observing duration of GNSS receivers. This section describes the previous studies in brief. Ghoddousi-Fard and Dare [1] estimated the positional accuracy as a function of observation period length by employing eight GNSS station observations. However, only GPS data with a sampling interval 30-second were submitted for processing with the online processing services (CSRS-PPP, SCOUT, APPS, AUSPOS, and OPUS). The submission of the observation files was carried out for durations from 1 to 24 hours. Ghoddousi-Fard and Dare [1] found that the positional accuracy of observation sessions of less than six hours is a few centimeters. Whereas, the accuracies for observing session of greater than 6 hours was approximately stable in millimeter level. The accuracy of results is gained by comparing the station coordinates with the published ones, as they are active stations.

Dawidowicz and Krzan [2] conducted a study to reveal the quality of the results that are estimated from AUSPOS and CSRS-PPP services for short observing sessions of 0.5-6 hours. Three station observations, located in Poland, with different satellite visibility were utilized in the study. The study revealed that the GLONASS observations effect on the stations with limited satellite visibility improves the resulted coordinate accuracies.

Ocalan et al. [3] focused on analyzing the accuracy of popular online processing services, which are based on Differential GPS (DGPS) or Precise Point Positioning (PPP) approaches with respect to the scientific processing software, Bernese 5.0. This study concluded that the deviations between Bernese and the two approaches (i.e. DGPS and PPP) were 10mm and 20mm respectively.

Jamieson and Gillins [4] used static GNSS observations from six stations with various multipath environment in order to perform comparative analysis for the online processing services by involving impacting factors like (observation duration, satellite availability, multipath, and logging rate). The study has addressed that the horizontal and vertical accuracies are being stable after 5 hours of observation duration and satellite availability particularly affects the horizontal accuracy.

Furthermore, many studies have been carried out to present the effectiveness of GLONASS observations on the final accuracies such as Anquela et al. [5], Yigit et al. [6], and Mohammed et al. [7]. All of these studies show that the final positional accuracies estimated from GPS+GLONASS observations are better than the ones obtained from GPS-only observations. Nevertheless, due to the remarkable advancement in the GNSS techniques and the constant updates to the GNSS online

processing services, the quality of results has changed slightly. Moreover, some of the previous studies mainly focused on active station data instead of data obtained from field surveys.

# 1.3. The online GNSS post-processing services

Several free online positioning services are available for GNSS users. These services include the precise point positioning (PPP) services like CSRS-PPP by Natural Resources of Canada [8] and APPS provided by JPL, based on the GIPSY-OASIS software [9]. Double difference (DD) positioning services such as AUSPOS Geoscience Australia (2011), and OPUS by National Geodetic Survey of USA [10][11] are also available. Many efforts have been made to compare the GPS/GNSS processing services such as the efforts of El-Mowafy [12], and Martin et al.[13].

CSRS-PPP is a free online tool for GNSS observations post-processing, which uses the PPP method and only requires data from one receiver, giving users the ability of computing high accuracy coordinates from their raw GNSS observation data. It is capable of processing both GPS and GLONASS observables as well as static and kinematic observations [14]. It utilizes the precise satellite orbit and clock to generate improved absolute accuracy of the position. Moreover, the CSRS-PPP output is referenced to ITRF or NAD83 reference frame.

AUSPOS is a popular free online positioning service that uses the DD approach, where baselines are needed to be directly connected to continuous GNSS stations e.g. IGS. A more realistic assessment method for coordinate uncertainties of AUSPOS solutions has been developed and the method has been implemented in version 2.1 of AUSPOS. The data analysis using the IGS08 and IGS08 + APREF reference frames, shows that a dense reference network can improve the ambiguity resolution success rate and coordinate uncertainties of AUSPOS solutions significantly, especially for short session lengths. Therefore, a dense regional reference network like APREF is very helpful for determining accurate AUSPOS solutions when processing short span data sets. Table 1 presents a general comparison between the two services (AUPOS and CSRS-PPP).

Service name	Positioning technique	Satellites	Minimum duration (recommended)	Fastest logging rate	Orbit source	Batch processing
AUSPOS	Relative	GPS only	1 h (6 h)	30 s	IGS	No
CSRS	PPP	GPS, GLONASS	None (> 2 h)	1 s	IGS and NRCan	Yes

Table 1. The main differences between AUSPOS and CSRS. [4]

The reasons behind adopting CSRS-PPP and AUSPOS in this study, are firstly the capability of these services for processing short observation intervals (i.e. 1-hour subset). Secondly, AUSPOS enables users to process observations referenced to up to 15 active stations (according to the detailed reports provided at the end of operation).

# 2. Methodology

# 2.1. Data Collection and management

Experiments started by establishing an equatorial triangle of 2 meters sides using a steel measuring tape to ensure as accurate as possible measurements (Table 2). The three triangle vertices (P1, P2 and P3) were occupied by a Leica Viva GS15 GNSS receiver for 24 hours. It is worth mentioning that the Leica GS15 is capable of tracking and recording signals from GPS and GLONASS constellations, which is of great importance for the sake of this study (Figure 2). The aim behind creating such short sides triangle is to validate the results obtained from online solutions as these short sides are relatively less affected by errors and do not require electro-measuring instruments.

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Table 2. Oround measurements of short side tringle.							
Measurement	<b>P1-P2</b> (m)	<b>P2-P3</b> (m)	P3-P1 (m)	AREA (m <sup>2</sup> )			
Slope Length	2.000 2.000		2.000	1 722			
Height Difference	0.018	0.006	0.024	1.752			

Table 2. Ground measurements of short side tringle

The observation sessions resulted in 24 hours, 30-second epoch, Receiver Independent Exchange (RINEX) format. Each 24-observation file has been partitioned into shorter time periods; i.e. (1, 2, 3, ..., 10) hours, which can be observed during the working day. In addition, the first two hours have been expanded into sub-periods, i.e. (1:15, 1:30, 1:45) to precisely monitor the improvement of accuracy during this critical period. Moreover, GLONASS constellation has been filtered out of the observation data using the TEQC tool. Figure (3) demonstrates the methodology followed in this research.



Figure 3. The adopted mmethodological framework.

## 2.2. Online Data Processing

Datasets have been processed with two online processing services; AUSPOS and CSRS-PPP where the final IGS product was adopted for the processing with the two services. The processing pipeline was accomplished through three stages as:

- 1. Only GPS data with AUSPOS service.
- 2. Only GPS data with CSRS-PPP service.
- 3. GPS+GLONASS data with CSRS-PPP service.

#### 2.3. The 24-hours Sessions

In this study, the 24-h observations were considered to be the Most Probable Value (MPV) as it is the longest session that could be processed on AUSPOS and CSRS-PPP [3]. To assess the obtained solutions, corresponding computed lengths from adjacent vertices were compared to the ground truth measurements measured using a steel tape. The resultant errors are shown in (Figure 4) which demonstrates an accuracy at the 1 mm level was achieved from the 24-h sessions.



Figure 4. 24-h sessions errors compared to tape measurements.

## 3. Results and discussions

#### 3.1. AUSPOS versus CSRS-PPP

While AUSPOS considers only GPS signals when processing GNSS observations, CSRS-PPP implements both constellation signals to produce robust solutions. Thus, to ensure an equal/fair comparison between the two services, the GPS signals included in observation files have been isolated from the GLONASS constellations to have GPS-based solutions from both services.

The solutions of each observation subset obtained from the two services were compared to the corresponding MPV to have the horizontal RMS errors and vertical RMS errors by adopting equations (1) and (2) respectively.

$$HRMS = \sqrt{\frac{(N_{mpv} - Ni)^2 + (E_{mpv} - Ei)^2}{n}}$$
(1)

$$VRMS = \sqrt{\frac{(Z_{mpv} - Zi)^2}{n}}$$
(2)

Where

 $N_{mpv}$ ,  $E_{mpv}$ ,  $Z_{mpv}$ ; the coordinates obtained from 24-h observations. Ni, Ei and Zi; the coordinates of each observation subsets, i.e. 1h, 2h,...10h.

INI, EI and ZI, the coordinates of each observation subsets, i.e. III, 21,... Ion.

The resultant RMS errors of each point obtained from AUSPOS and CSRS-PPP are demonstrated in figure 5.



Figure 5. HRMS and VRMS for P1, P2, and P3 based on CSRS versus AUSPOS solutions using only GPS data.

The performances of CSRS and AUSPOUS can be outlined as follow:

- 1. RMS values for the solutions from AUSPOS are nearly always much greater than 5 cm, whereas the values from CSRS-PPP are 1-5 cm in both the horizontal and vertical components.
- 2. At the 2-hours duration, a noticeable convergence in the solutions' accuracy from both services in the horizontal domain, which is less than 1 cm. Whereas the AUSPOS solution's accuracy has increased rapidly after the 2- hours duration.
- 3. The vertical accuracy of the solutions that are obtained from both the online services has been increased to 1 cm at the 3-hours observation duration.
- 4. After the 3-hours duration, the RMS errors of solutions obtained from both services have stabilized in both horizontal and vertical domain.

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# 3.2. The Potentials of CSRS-PPP Service

This section is dedicated to investigate the potential issues of CSRS-PPP service based on three testing levels; point, side and area as illustrated below.

# 3.2.1. Point-Based Test

CSRS-PPP has been deployed to process GPS+GLONASS as well as GPS alone after filtering out the GLONASS observables. This was done to point out the advantages obtained from including GLONASS service. The point-based testing has employed the same equations of section 3.1 to examine the solutions uncertainties (i.e. HRMS and VRMS) of each point with respect to the 24-h session as shown in figure (6).



Figure 6. HRMS and VRMS for the P1, P2, and P3 based CSRS solutions using GPS only versus GPS+GLONASS data.

To sum up the results of this test, the following remarks can be observed from figure (6):

- 1. The GPS-only and GPS+GLONASS solutions obtained from CSRS-PPP at duration 1-hour have dissimilar accuracies in horizontal and vertical ranges. The GPS-only RMS errors are around 1- 5 cm, whereas GPS+GLONASS errors are less than 1 cm for horizontal and vertical components.
- 2. At the 2-hours interval, a convergence in the accuracy (i.e. RMS errors) of both GPS-only and GPS+GLONASS solutions is noticeable in the horizontal component, which is less than 1 cm.
- 3. At the 3-hours interval, the horizontal RMS errors of GPS-only and GPS+GLONASS solutions are around 5mm.
- 4. The stability of vertical RMS errors was dramatically fluctuating and it has required longer time than HRMS errors to become stable. Though, the peak in the upper right subplot is still an unexpected and vague behaviour.

## 3.2.2. Side-Based and Area-Based Tests

The relative (side-based) and average (area-based) RMS errors are estimated based on the error propagation equations (3 and 4), which represent an indication for the horizontal accuracy coherence of the points processed with CSRS solutions. Based on the result shown in Figure (7), it is obvious how the horizontal RMS errors of the triangle geometry (area and side-lengths) are consistent with the points stand-alone (point-based) errors which confirms the set of findings of this study.

## Side-based error propagation model;

$$\left(\sigma D_{ij}\right)^2 = \left(\sin^2 \alpha i j\right) * \left(\sigma E_j\right)^2 + \left(-\sin^2 \alpha i j\right) * \left(\sigma E_i\right)^2 + \left(\cos^2 \alpha i j\right) * \left(\sigma N_j\right)^2 + \left(-\cos^2 \alpha i j\right) \\ * \left(\sigma N_i\right)^2$$

$$(3)$$

Where:

 $\sigma D_{ij}$ : The standard error in the distance between Pi and Pj.

 $\sigma E$ : the standard error in Easting component.

 $\sigma N$ : the standard error in Northing component.

 $\alpha ij$ : the direction from Pi to Pj.

Area-based error propagation model;

$$(\sigma A)^{2} = \frac{1}{2} D_{ij} D_{ik} \sin^{2} \theta_{jik} * \left[ \left( \frac{1}{D_{ij}} \right)^{2} \left( \sigma D_{ij} \right)^{2} + \left( \frac{1}{D_{ik}} \right)^{2} (\sigma D_{ik})^{2} + (\cot^{2} \theta_{jik}) \left( \sigma \theta_{jik} \right)^{2} \right]$$
(4)

Where:

 $\sigma A$ : Represents the standard error in area.  $\theta_{iik}$ : Represents the angle between jik.





Figure 7. HRMS for (P1-P2, P2-P3, P3-P1) sides and the area of triangle based CSRS solution using GPS only versus GPS+GLONASS data.

#### 4. Conclusions

- 1. It has been seen that the positional accuracies of short-period observations are comparatively more reliable when adopting CSRS-PPP solution than that of AUSPOS. In addition, CSRS-PPP includes GLONASS observations for processing, which were noticeably beneficial to reduce the RMS errors.
- 2. The one-hour observations using GPS constellation only could achieve less than 5 cm horizontal RMS errors if processing conducted by CSRS, and this is considered a good and economic choice for many applications which does not require a high level of accuracy. While a 1 cm- RMS errors can be achieved when including GLONASS constellation.
- 3. Two hours observing period is sufficient to achieve horizontal RMS errors of less than 1 cm when processing GPS only or GPS + GLONASS regardless of the implemented solution.
- 4. Observing for 3 hours, RMS errors of less than 1 cm could be achieved in the vertical and horizontal components when occupying GPS only. Adding GLONASS observations has led to improve the vertical RMS errors to less than 5 mm.
- 5. For both services (CSRS and AUSPOS), observing for more than 3 hours is adequate to produce stable solutions with less than 5 mm RMS errors for both components.
- 6. In summary, this study has been dedicated to supplying the GPS community (particularly surveyors) with experimental results that demonstrate which processing service is sufficient for their works. The comparison between AUSPOS and CSRS-PPP has revealed how the latter is superior in terms of achievable accuracies for short period sessions and the potentiality of integrating GPS and GLONASS signals to produce robust solutions. Thus, for those who are totally reliant on double-difference online services like AUSPOS, CSRS-PPP is a reliable and cost-effective alternative solution that could facilitate survey missions.

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