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VARIATION OF STATIC-PPP POSITIONING ACCURACY USING GPS-SINGLE FREQUENCY OBSERVATIONS (ASWAN, EGYPT)

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ABSTRACT:

Precise Point Positioning (PPP) is a technique used for position computation with a high accuracy using only one GNSS receiver. It depends on highly accurate satellite position and clock data rather than broadcast ephemeries. PPP precision varies based on positioning technique (static or kinematic), observations type (single or dual frequency) and the duration of collected observations. PPP-(dual frequency receivers) offers comparable accuracy to differential GPS. PPP- single frequency receivers has many applications such as infrastructure, hydrography and precision agriculture. PPP using low cost GPS single-frequency receivers is an area of great interest for millions of users in developing countries such as Egypt. This research presents a study for the variability of single frequency static GPS-PPP precision based on different observation durations.

Keywords: Static, PPP, GPS, Single frequency, Observations duration

1. INTRODUCTION

Global Navigation Satellite Systems (GNSS) are satellite-based systems for navigation and positioning. It serves the human kind in different fields. The current two constellations are GPS and GLONASS. The near-future two constellations are (The European system) Galileo and (the Chinese system) BeiDou.

GNSS technology use different positioning techniques varying in cost and accuracy. "Point Positioning" is the basic positioning technique. However, because of the errors caused by satellite ephemeries, satellite clock, ionosphere, troposphere, multipath and others, the point positioning provides the user with a horizontal accuracy ≤13 m and a vertical accuracy ≤ 22 m (GPS-SPS, 2008). The Differential GPS (DGPS) positioning technique mitigate the errors by using the spatial correlation between one or more reference stations with known coordinates and the nearby rover GPS receiver station whose coordinates are to be determined to obtain higher accuracy down to the centimeter level (Abdel-salam, 2005). DGPS considers high-cost positioning technique for its limitations; the need for a reference station, the distance limitation (≤ 20 km) between the rover and reference station, and the need for simultaneous observations between the reference and rover stations.

PPP (Bisnath and Gao, 2008 & Soycan and Ata, 2011) is an enhanced single point positioning technique for code or phase measurements. PPP benefits from the existence of the extremely precise ephemerides and clock corrections, offered by different organizations such as the IGS (International GNSS Service) (IGS, 2017). To compensate for the largest source of error for GPS observations (ionospheric effects), dual frequency measurements are used for an ionosphere free combination. Since dual frequency receivers still have very high cost compared with single frequency receivers, so PPP-positioning using GPS single frequency receivers is a major area of interest for many engineering applications that requires high accuracy with less cost. Single frequency receivers are widely used in developing countries for many applications such as infrastructure projects. PPP could be used for static and kinematic applications and has been studied extensively in recent years (Zumberge et. al., 1997; Kouba and Héroux, 2001; Gao and Shen, 2001; Bisnath et al., 2002; Colombo et al., 2004; Bisnath and Gao, 2008; Chen et al., 2009; Geng et al., 2010; Soycan, 2012). Table 1 presents the PPP errors that have to be considered during PPP process (Rizos et al., 2012).

PPP accuracy improves with the length of the data collection period. A minimum period of good quality GPS data is required to permit convergence. The PPP convergence period is the duration of time required from a cold start to a decimeter-level positional solution is typically about 30 minutes under normal conditions and longer for converging to the few centimeter level (Bisnath and Gao, 2008). The convergence minimum period and the accuracy attainable will depend on the type of GPS receiver, the site's environment and atmospheric conditions. Extending the data collection past this minimum period should further improve accuracy, but more so with dual-frequency receivers than with single frequency receivers (Mireault et al., 2008).

Table 1. The errors considered during PPP process (Rizos et al., 2012).

The errors considered during PPP process		
Satellite dependent errors Satellite clock corrections Satellite ephemeries Satellite antenna phase centre variations Satellite antenna phase centre offset Satellite antenna phase wind-up error	Receiver dependent errors Receiver antenna phase centre offset Receiver antenna phase centre variations Receiver antenna phase wind-up error	Atmospheric modelling Troposphere delay Ionosphere delay (L1 only) Geophysical models Solid earth tide displacements Ocean loading Polar tides Plate tectonic motion

The single frequency PPP have been investigated in some studies such as; Choy, S. (2009), Marel and Bakker (2012) and Bakker and Tiberius (2016). PPP precision using single frequency observations could be investigated using medium cost or low cost receivers. The output precision is dependent on the quality of the used receiver and antenna (Choy, 2009). This research presents a study for single-frequency static GPS-PPP precision variation based on different observation duration using low cost receiver (ProMark3). The tested observations were collected in near-equatorial geographic region (24.0889° N) where the ionospheric activity has noticeable effect on the collected observations.

2. CANADIAN SPATIAL REFERENCE SYSTEM (CSRS) - PPP SERVICE

The Canadian Spatial Reference System (CSRS) Precise Point Positioning (PPP) service (CSRS-PPP, 2017) provides post-processed position estimates from GPS/GLONASS observation. Precise position estimates are referred to the CSRS standard North American Datum of 1983 (NAD83) as well as the International Terrestrial Reference Frame (ITRF). Single station position estimates are computed for users operating in static or kinematic modes using precise GPS orbits and clocks. The observations processed are selected from the submitted RINEX file in the following order:

1. L1 and L2 pseudo-range and carrier phase observations
2. L1 pseudo-range observation

An Ionospheric model is required for correction ionospheric delays from single-frequency observations. The source of ionospheric corrections selected for the L1 processing by the on-line application are the combined global ionospheric maps produced at 2-hour intervals in IONEX format by IGS with an accuracy of ± 2-8 TECU-level (range errors in the order of 30 cm to 1 m) (Huber and Heuberger, 2010). The L1&L2 processing uses the L1&L2 ionospheric-free combination of the code& phase observations and does not require input of an external source of ionospheric information. Table (2) shows Processing algorithms for CSRS-PPP online service.

Table 2. Processing algorithms for CSRS-PPP online service.

Reference system	ITRF2008
Coordinate format	LLH/XYZ
Satellite orbit and clock ephemeris	IGS
Satellite phase centre offsets	IGS ANTEX
Receiver phase centre offsets	IGS ANTEX
Tropospheric model	**Dry model**: Davis (GPT) (Global Pressure and Temperature data) **Wet model**: Hopfield model (GPT) (Global Pressure and Temperature data)
Mapping function	GMF (Global Mapping Function)
Ionospheric model	Second-order linear ionospheric combination (for dual frequency observations) IGS combined global ionospheric maps (for single frequency observations)
Min. Elevation angle	10^o
GNSS System	GPS/GLONASS
Software	CSRS-PPP
Observation Data	Single/dual frequency Static/kinematic
Ocean tide loading	FES 2004 (Finite Element Solution)

3. TEST STUDY

GPS static- single frequency observations (65 minutes in total) was observed on (10/9/2015-18614 GPS day) at college of Engineering, Aswan University, Aswan, Egypt. Aswan is a city sited in south Egypt (24.0889° N, 32.8997° E) using single frequency ProMark3 receiver (ProMark3, 2005) with 5 sec observation recording interval and 10^o elevation mask angle. The PPP solutions for different datasets were estimated through CSRS-PPP service (CSRS-PPP, 2017).

4. RESULTS & DISCUSSION

Fig. 1&2 show the variation of the number of visible satellites and Dilution of Precision (DOP) values; Horizontal DOP, Vertical DOP and Position DOP (HDOP&VDOP&PDOP) during observations collection period. Table 3 presents the average number of visible satellites and average GDOP value during observations collection period.

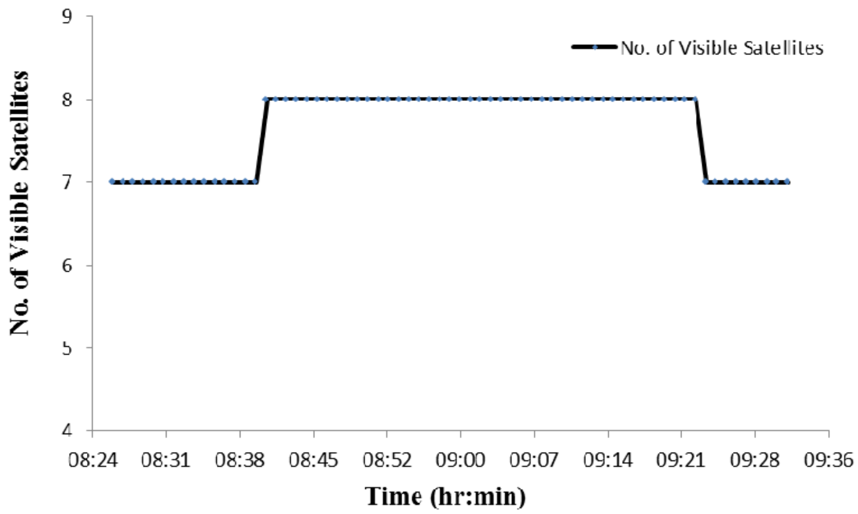

Fig. 1. Number of visible satellites during observations collection period

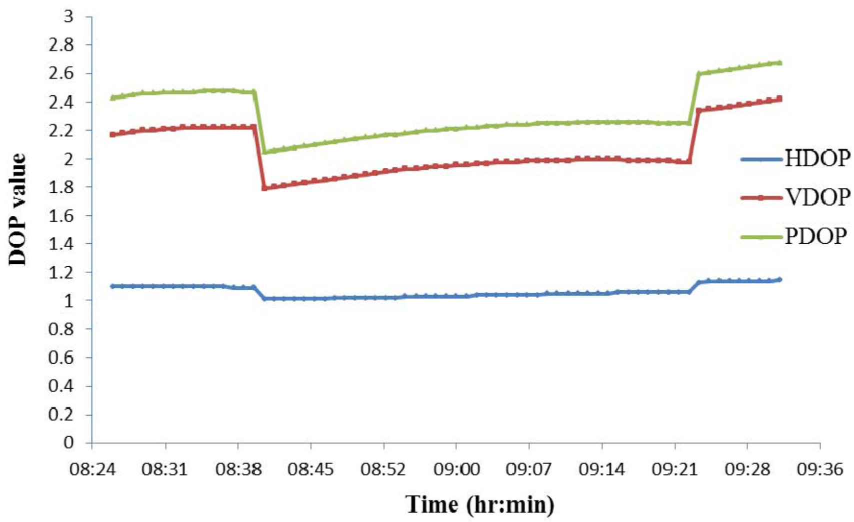

Fig. 2. Variations of DOP values (HDOP & VDOP &PDOP) during observations collection period

Table 3. The average no. of visible GPS satellites and average DOP values during observations collection period.

Average no. GPS visible satellites	Average HDOP	Average VDOP	Average PDOP
7	1.064	2.058	2.317

The quality of the observations file was checked using the software "Translate, Edit, Quality Check" (TEQC) (TEQC, 2017). The observations file was divided into 13 observation sessions (5 min. to 65 min. with 5 min. interval). The different sets of observations were processed through CSRS-PPP service (CSRS, 2017).

Table 4 and Fig. 3&4 present PPP-Static precision variation with observation duration for GPS single frequency measurements. Table 5 presents percentages of improvements in Static-L1-PPP accuracy variation with observation duration using GPS observations (with respect to 5 min. observation session)

Table 4. Static-PPP precision variation with duration of collected observations using GPS single-frequency observations.

Duration of observations (minutes)	Sigma (95%) Latitude (m)	Sigma (95%) Longitude (m)	Sigma (95%) Height (m)
5	1.776	1.614	4.298
10	1.267	1.143	3.056
15	1.053	0.934	2.559
20	0.920	0.807	2.234
25	0.828	0.720	1.995
30	0.758	0.655	1.813
35	0.704	0.605	1.669
40	0.660	0.564	1.547
45	0.622	0.530	1.440
50	0.589	0.501	1.350
55	0.561	0.477	1.274
60	0.535	0.455	1.210
65	0.514	0.438	1.159

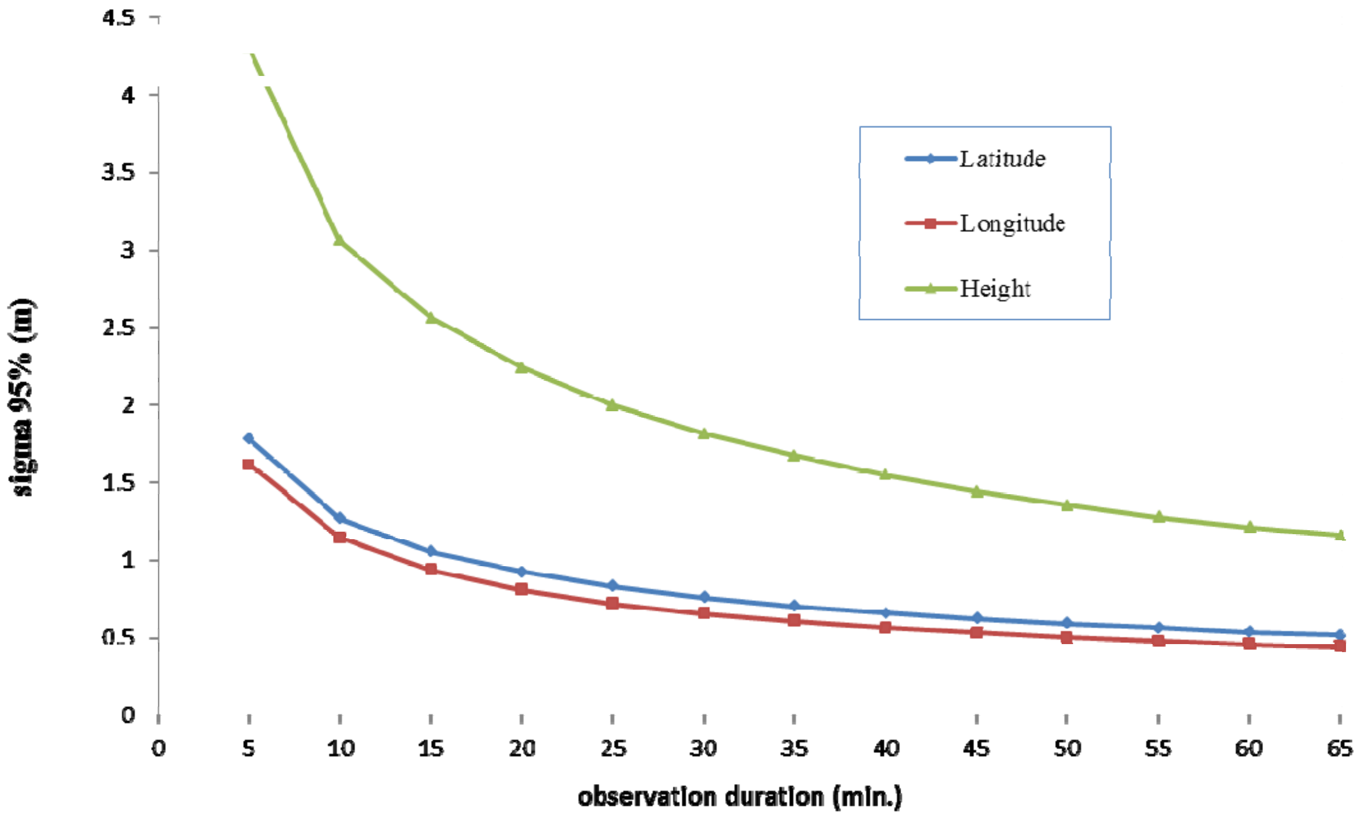

Fig. 3. PPP Positioning precision as a function of observation duration for single frequency GPS static observations

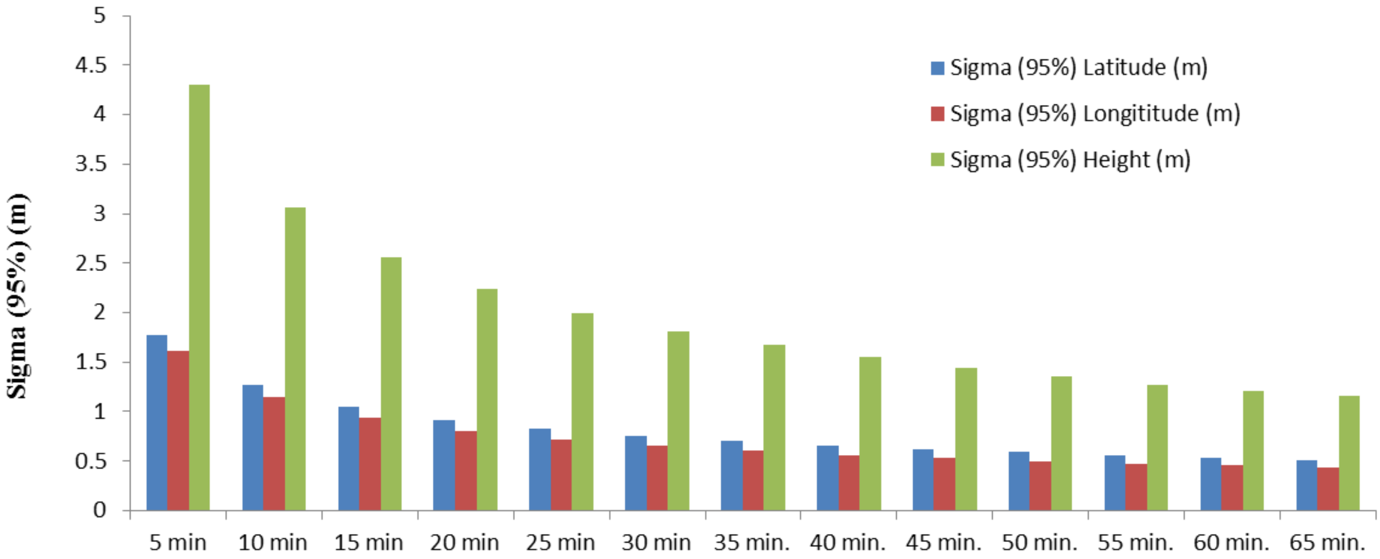

Fig. 4. Static-PPP accuracy variation with observation duration using GPS single-frequency observations

Table 5. Percentages of improvements in Static-L1-PPP accuracy variation with observation duration using GPS observations (with respect to 5 min. observation session)

Duration of collected observations (minutes)	**percentage of improvements in Static-L1-PPP accuracy variation with observation duration using GPS observations (with respect to 5 min. observation session)**		
	Sigma (95%) Latitude (m)	**Sigma (95%) Longitude (m)**	**Sigma (95%) Height (m)**
10	**28.7**	**29.2**	**28.9**
20	**48.2**	**50.0**	**48.0**
30	**57.3**	**59.4**	**57.8**
40	**62.8**	**65.1**	**64.0**
50	**66.8**	**68.9**	**68.6**
60	**69.9**	**71.8**	**71.8**
65	**71.0**	**72.9**	**73.0**

This research presents an accuracy assessment study for static-PPP solutions using single frequency GPS observations. The average cost of single-frequency receivers is 50% the cost of dual-frequency receivers so, single frequency receivers are used extensively in developing countries for its low cost. The average no. of visible satellites was 7 satellites with average PDOP of 2.3 as shown in Fig. 1 & 2 and table 3.

The L1-static PPP accuracy depends on observation duration and proportionally increases with increasing in observation duration as shown in Table 4 and fig. 3. It can be concluded that using 20 minutes of observations improves the accuracy with 50 % in average with respect to 5 min. observations accuracy. The percentage of improvement is 63 % in average when using 40 min. of observations. The percentage of improvement settles at 70 % when using 60-65 min. of observations.

It can be concluded also that using only 5 min. of observations gives an accuracy of about 1.65 m for horizontal coordinates and about 4 m in height. Using 20 min. of observations improves the accuracy to sub 1 meter for hz. coordinates and around 2 m for height coordinate. Using 50 min. of observations improves the accuracy to about 50 cm in hz. coordinates and 1.35 m for height coordinate. The accuracy provided using 60-65 min. of observations using static-GPS-L1 observations is appropriate for many civil engineering applications with dramatic safe in cost and time.

5. CONCLUSIONS

This research presents an accuracy assessment study for static-PPP solutions using single frequency GPS observations under favorable observation conditions; minimum of 7 visible satellites and minimum PDOP value of 2.3. The accuracy obtained using 1 hr of observations is 50 cm for hz. coordinates and 1.20m for height coordinate. This research's results are in agreement with (Choy, 2009). Static-PPP using GPS-single frequency observations provide sufficient accuracy for many applications in civil engineering such as preliminary leveling process, planning process, soil exploration process and earth geology exploration with enormous safe in cost and time for users in developing countries. Such Accuracy is suitable for hydrography and precision agriculture applications.

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