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GLONASS-based Single-Frequency Static-Precise Point Positioning

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***Abstract*— Precise Point Positioning (PPP) has been used for the last decade as a cost-effective alternative for the ordinary DGPS-Differential GPS with an estimated precision sufficient for many applications. For many years, PPP systems are mainly based on GPS system for its reliability. GLONASS's contribution in PPP techniques is limited due to fail in maintaining full constellation. As GLONASS has reached its full constellation since a few years, GLONASS-based PPP systems could be implemented independent of GPS as well as PPP systems using combined GPS/GLONASS could be investigated. PPP using 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 precision varies based on observation type (GPS or GLONASS) and the duration of observations among other factors. This paper presents an accuracy assessment study of GLONASS-based Static-PPP using single frequency GLONASS observations from a station in Aswan city-Egypt. The observation residuals from GLONASS-based PPP are analyzed using single frequency observations. The paper also presents an evaluation study for the variability of GLONASS-based Static-PPP precision based on different observation durations.**

Keywords—GLONASS; GPS; single frequency; Precise Point Positioning; observation duration

Introduction

Precise point positioning (PPP) is an enhanced single point positioning technique for code or phase measurements using precise orbits and clocks instead of broadcast data. PPP became viable with the existence of the extremely precise ephemerides and clock corrections, offered by different organizations such as the IGS (International GNSS Service) [1 – 5]. The PPP technique [1] aims at correcting the observations errors and overcome the DGPS limitations.

Current PPP techniques are mainly based on GPS which considered the solely reliable system for many years, GLONASS limited observations could be integrated into GPS-based PPP to improve availability and precision [6 – 7]. As GLONASS reached its full constellation early 2013 [8], there is a wide interest in PPP systems based on GLONASS only and independent of GPS. Further, the investigation of GLONASS-based PPP will help the development of GPS and GLONASS combined PPP systems for improved precision and reliability [9].

Since dual frequency receivers still have very high cost compared with single frequency receivers, so PPP-positioning using 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.

Since few studies presented GLONASS-PPP systems [6], [9],[10]. This paper presents an accuracy assessment study of GLONASS-based single frequency Static-PPP. 16 hours of mixed observations were collected at a station (college of Engineering, Aswan University, Aswan, Egypt) using Leica viva GS15 instrument [11] (17/1/2017) (GPS day 19322) (5 sec recording interval & 10o mask elevation angle). The behavior of static-PPP using single frequency GLONASS system alone and single frequency GPS system alone could be investigated. The study presents also the precision variability with observation duration for static PPP using combined single frequency GPS/GLONASS.

I. Precise Point Positioning

PPP is an enhanced single point positioning technique for code or phase measurements using precise orbits and clocks instead of broadcast data. PPP became viable with the existence of the extremely precise ephemerides and clock corrections, offered by different organizations such as the IGS (International GNSS Service). IGS has been providing the most precise satellite ephemerides and clock corrections currently available [12]. To compensate for ionospheric effects (the largest source of error for GPS observations), dual frequency measurements are used for an ionosphere free combination. In the case of single frequency observations, some kind of ionosphere modeling has to be applied. For better accuracy, PPP users are advised with dual frequency measurements as it the most efficient way of mitigating ionospheric delay. PPP can provide positioning accuracy of centimeters or millimeters using un-differenced carrier phase observations where ambiguities are usually estimated as float values because the fractional cycle biases (FCB) contained in the carrier phase observations cannot be separated from the integer ambiguities.

The Canadian Spatial Reference System (CSRS) Precise Point Positioning (PPP) service provides post-processed position estimates over the Internet from GPS observation files submitted by the user. 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 online PPP positioning service is designed to minimize user interaction while providing the best possible solution for the given observation availability. Currently, users need only specify the mode of processing (static or kinematic) and the reference frame for position output (NAD83 (CSRS) or ITRF). CSRS-PPP service is processing both single & dual frequency observations from GPS and GLONASS [13].

II. TEST STUDY

To assess the performance of GLONASS-based PPP, a dataset of 16 hours of mixed observations were collected at a station (college of Engineering, Aswan university, Aswan, Egypt) (24.0889° N, 32.8997° E) using Leica viva GS15 instrument [11] (17/1/2017) (GPS day 19322) (5 sec recording interval & 10^{O} mask elevation angle). Figures 1 to 6 present variation of number of visible satellites and DOP values (HDOP, VDOP and PDOP) for constellations GLONASS, GPS and combined GPS/GLONASS respectively. Table 1 demonstrates the average number of visible satellites as well as the average DOP values for the tested station.

The observation residuals from single frequency GLONASS-based PPP are analyzed and compared to those from single frequency GPS-based PPP. The paper also presents an evaluation study for the variability of GLONASS-based Static-PPP precision based on different observation durations and comparison with GPS-based PPP. The different sets of observations were processed and the PPP solutions were estimated through Canadian Spatial Reference System (CSRS) Precise Point Positioning (PPP) service [13].

Table 1. The average DOP values & no. of visible satellites for tested station

Character	HDOP	VDOP	PDOP	Average number of visible satellites
GPS	0.979	1.716	1.986	8
GLONASS	1.246	2.683	2.999	6
Combined GPS/GLONASS	0.695	1.212	1.400	15

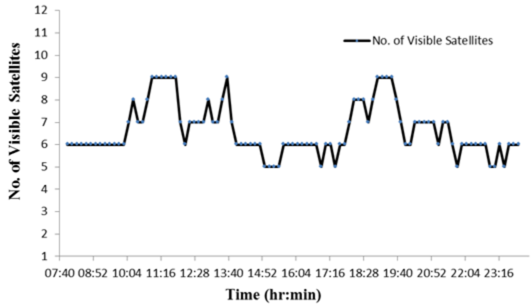

Fig.(1): Number of Visible Satellites (GLONASS constellation) During Observations Collecion Period.

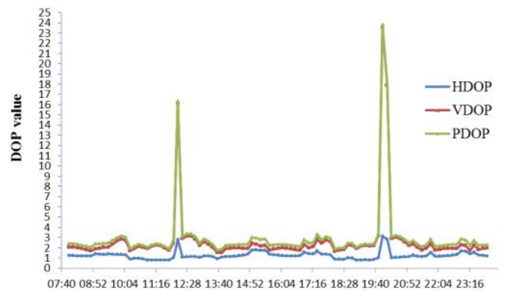

Fig. (2): Variation of GLONASS-DOP values (HDOP & VDOP & PDOP) During Observations collection period.

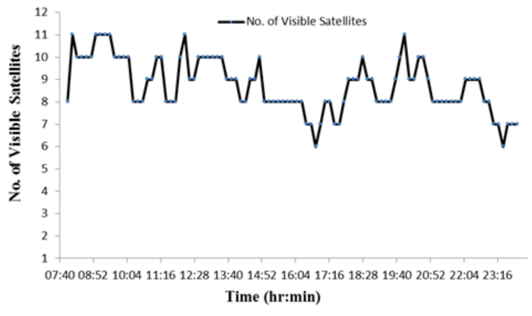

Fig.(3): Number of Visible Satellites (GPS constellation) During Observations Collecion Period.

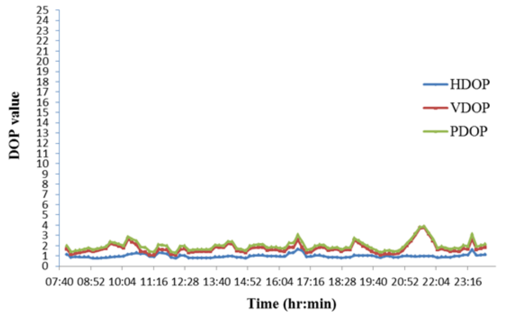

Fig. (4): Variation of GPS-DOP values (HDOP & VDOP & PDOP) During Observations collection period.

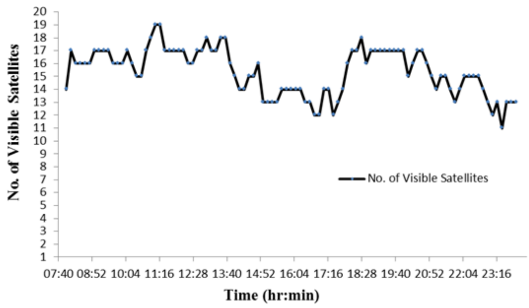

Fig.(5): Number of Visible Satellites (GPS/GLONASS combined constellation) During Observations Collecion Period.

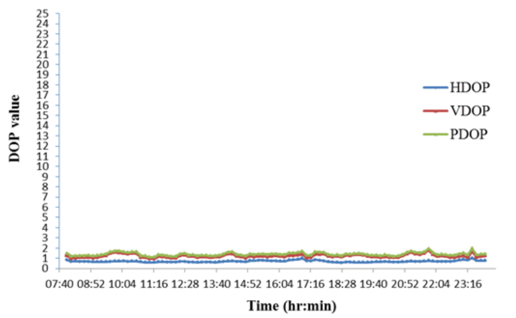

Fig. (6): Variation of (GPS/GLONASS combined)-DOP values (HDOP & VDOP & PDOP) During observations collection period.

III RESULTS & DISCUSSION

Tables 2,3 present Static-PPP accuracy from the systems GPS & GLONASS individually using single frequency observations for tested station. Table 4 presents Static-PPP accuracy from both systems GPS & GLONASS combined using single frequency observations for tested station. Figures 7, 8 and 9 present static-PPP accuracy using single frequency observations from GLONASS, GPS and combined GPS/GLONASS constellations respectively.

Table 2. Static-PPP accuracy variation with observation duration from Single frequency GLONASS observations.

Duration of observations	Static-PPP accuracy variation		
	Sigma (95%) Latitude (m)	Sigma (95%) Longitude (m)	Sigma (95%) Ellipsoidal height (m)
10 min.	2.435	2.879	8.846
20 min.	1.724	1.944	6.177
30 min.	1.406	1.513	5.015
45 min.	1.154	1.166	4.153
1 hour	1.015	0.971	3.749
1.5 hour	0.847	0.788	3.253
2.0 hours	0.735	0.718	2.654
2.5 hours	0.657	0.677	2.268
3.0 hours	0.602	0.644	1.989
4 .0 hours	0.530	0.582	1.562
6.0 hours	0.443	0.501	1.241
8.0 hours	0.384	0.439	1.065
10.0 hours	0.340	0.375	0.994
12.0 hours	0.316	0.358	0.898
14.0 hours	0.300	0.339	0.849
16.0 hours	0.295	0.326	0.833

Table 3: Static-PPP accuracy variation with observation duration from single frequency GPS observations

Duration of observations	Static-PPP accuracy variation		
	Sigma (95%) Latitude (m)	Sigma (95%) Longitude (m)	Sigma (95%) Ellipsoidal height (m)
10 min.	1.317	2.051	2.847
20 min.	0.935	1.465	1.984
30 min.	0.769	1.199	1.639
45 min.	0.634	0.986	1.391
1 hour	0.547	0.842	1.235
1.5 hour	0.433	0.613	1.025
2.0 hours	0.368	0.463	0.912
2.5 hours	0.325	0.367	0.830
3.0 hours	0.296	0.310	0.761
4 .0 hours	0.264	0.263	0.650
6.0 hours	0.221	0.223	0.560
8.0 hours	0.189	0.191	0.475
10.0 hours	0.170	0.164	0.403
12.0 hours	0.151	0.148	0.372
14.0 hours	0.139	0.138	0.350
16.0 hours	0.130	0.127	0.325

Table 4: Static-PPP accuracy variation with observation duration from mixed single frequency GPS/GLONASS observations.

Duration of observations	Static-PPP accuracy variation		
	Sigma (95%) Latitude (m)	Sigma (95%) Longitude (m)	Sigma (95%) Ellipsoidal height (m)
10 min.	1.113	1.581	2.710
20 min.	0.786	1.106	1.888
30 min.	0.642	0.890	1.553
45 min.	0.525	0.717	1.307
1 hour	0.455	0.613	1.158
1.5 hour	0.371	0.476	0.971
2.0 hours	0.323	0.386	0.859
2.5 hours	0.289	0.322	0.778
3.0 hours	0.265	0.279	0.708
4 .0 hours	0.235	0.240	0.596
6.0 hours	0.197	0.204	0.508
8.0 hours	0.168	0.175	0.431
10.0 hours	0.152	0.151	0.372
12.0 hours	0.136	0.137	0.343
14.0 hours	0.126	0.127	0.323
16.0 hours	0.118	0.117	0.299

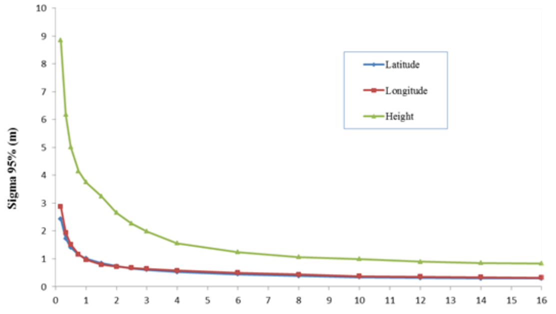

Fig. 7: PPP Positioning Precision as a function of observation duration for single frequency GLONASS static observations.

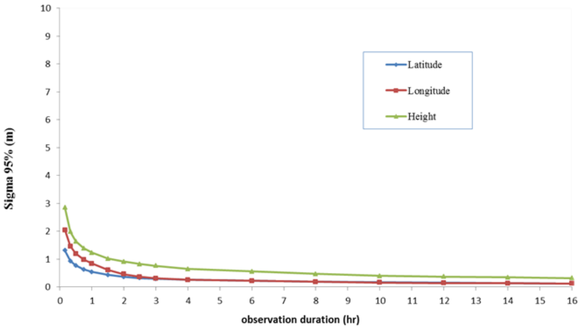

Fig. 8: PPP Positioning Precision as a function of observation duration for single frequency GPS static observations.

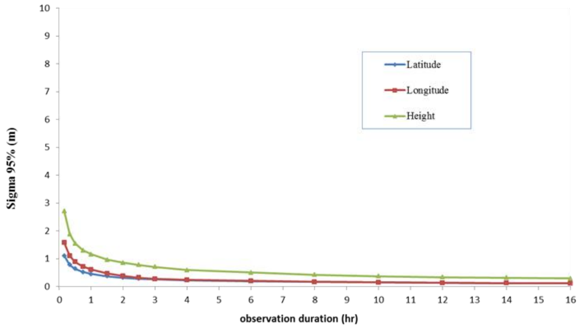

Fig. 9: PPP Positioning Precision as a function of observation duration for single frequency mixed GPS/GLONASS static observations.

It can be concluded that GLONASS constellation offers less number of visible satellites (average no. of 6 satellites) where GPS constellation offers more visible satellites (average number of 8 satellites). GPS constellation offers better DOP values (HDOP, VDOP and PDOP) than GLONASS constellation (25% to 33 % improvement). The improvement of no. of visible satellites and DOP values for GPS over GLONASS reflected in static-PPP accuracy based on single frequency observations. Combined GPS/GLONASS constellation offers an average of 16 visible satellites with an improved DOP values (average 50% improvement over GLONASS constellation behaviour). It worth mentioning that GPS constellation had 31 working satellite while GLONASS offers 24 working satellites only on date of observation collection (17/1/2017).

By examining static-PPP accuracy using single frequency observations from GLONASS constellation (Table 2 & Fig.7), it can be concluded that one hour of observations yield an average of 1 m accuracy for horizontal coordinates and 3.7m accuracy in height coordinate. Four hours of single frequency GLONASS observations give an average accuracy of 0.50m for hz. coordinates and 1.5m accuracy for height coordinate. Sixteen hours of observations give an accuracy of 0.30 m for hz. coordinates and 0.80 m accuracy for height coordinate.

Static-PPP accuracy using single frequency observations from GPS constellation (Table 3 & Fig.8), it can be concluded that one hour of observations yield an average of 0.5 m accuracy for latitude coordinate, 0.80 m accuracy for longitude coordinate and 1.23m accuracy in height coordinate. Four hours of single frequency GPS observations give an average accuracy of 0.26m for hz. coordinates and 0.6m accuracy for height coordinate. Sixteen hours of observations give an accuracy of 0.13 m for hz. coordinates and 0.32 m accuracy for height coordinate.

Static-PPP accuracy using single frequency observations from combined GPS/GLONASS constellation (Table 4 & Fig. 9), it can be concluded that one hour of observations yield an average of 0.46

m accuracy for latitude coordinate, 0.61 m accuracy for longitude coordinate and 1.16m accuracy in height coordinate. Four hours of single frequency combined observations give an average accuracy of 0.24m for hz. coordinates and 0.6m accuracy for height coordinate. Sixteen hours of observations give an accuracy of 0.12 m for hz. coordinates and 0.30 m accuracy for height coordinate.

IV CONCLUSIONS

This research presented a study for static-PPP behavior in Aswan city, Egypt using single frequency observations from GLONASS, GPS and combined constellation respectively. During the study date (17/1/2017) GPS constellation offers 31 working satellites where GLONASS offers 24 working satellites only. GPS offers more number of visible satellites and better DOP values for the tested station (Aswan, Egypt). GLONASS offers 1m accuracy of static-PPP for hz coordinates using one hour of single frequency observations. This accuracy improves by 50 % using 4 hours of observations. GLONASS offers an accuracy of 0.3 m in hz. coordinates and 0.8m for height coordinate using 16 hours of observations. GPS offers improvement in static-PPP accuracy with 50% using the same duration of single frequency observations. Using single frequency observations from combined constellations improves slightly the accuracy from GPS constellation alone (to a few centimeters).

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