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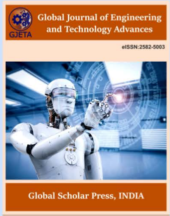

(Research Article)

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Assessment of Static PPP Accuracy Over Observation Time Using Qinertia Cloud: GPS vs. GPS+GLONASS Integration

Mustafa M. Amami *

Professor of Engineering Surveying and Space Geodesy, Department of Civil Engineering, Benghazi University, Benghazi, Libya.

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Abstract

The Global Navigation Satellite Systems (GNSS) provides continuous, high-precision positioning and timing capabilities on a global scale through satellite-based observations. However, exclusive reliance on a single GNSS constellation imposes inherent limitations associated with satellite visibility and geometric strength, which may degrade positioning reliability, particularly under conditions of poor satellite geometry or partial signal obstruction. In this study, the performance of static Precise Point Positioning (PPP) is rigorously evaluated as a function of fixing time using the Qinertia Cloud free online processing service. Two processing strategies are examined: GPS-only and combined GPS+GLONASS. The analysis is conducted under ideal open-sky conditions to effectively eliminate multipath effects and isolate the influence of constellation configuration. Dual-frequency GNSS observations were acquired from ten spatially distributed stations across Libya, each consisting of continuous 24-hour datasets. Static PPP solutions were computed for fixing intervals ranging from 1 hour to 24 hours, with the fully converged 24-hour solution adopted as the reference benchmark for accuracy and stability assessment.

The results demonstrate that both configurations yield highly precise and reliable positioning solutions. Nevertheless, the integration of GLONASS observations with GPS systematically enhances solution robustness and positional stability across all fixing intervals. The improvement is particularly pronounced during short observation durations, especially within the first hour, where absolute errors in the East, North, Height, 2D, and 3D components are reduced by approximately 4, 2, 2, 4, and 4 cm, respectively, when adopting the GPS+GLONASS configuration. The superiority of the multi-constellation approach is most evident during the initial convergence phase, when PPP solutions are highly sensitive to satellite geometry and stochastic modeling. Although the improvement in mean absolute positioning accuracy diminishes for longer observation durations, the inclusion of GLONASS significantly mitigates the occurrence of outliers and reduces the dispersion of coordinate residuals. These findings confirm that even under near-ideal open-sky conditions, where multipath effects are negligible, multi-constellation integration contributes substantially to enhancing the robustness and reliability of static PPP solutions. In agreement with existing literature, the Qinertia Cloud platform demonstrates high-quality performance in static mode for both GPS-only and GPS+GLONASS configurations, with results comparable to those obtained from advanced PPP services such as CSRS-PPP. Overall, while long-term accuracy gains from GLONASS integration remain marginal, its contribution during early convergence stages is substantial, with one-hour dual-frequency PPP solutions (GPS+GLONASS) achieving accuracy levels comparable to 2–3 hours of GPS-only observations.

Keywords: GPS; GLONASS; Precise Point Positioning (PPP); Qinertia Cloud; Static Positioning; Fixing Time

* Corresponding author: Mustafa M. Amami.

1. Introduction

Global Navigation Satellite Systems (GNSS), including GPS and GLONASS, constitute space-based positioning infrastructures that enable precise determination of position and velocity through passive range measurements [1]. These systems provide continuous, all-weather, real-time positioning and timing services on a global scale [2]. GNSS satellites transmit dual-frequency signals modulated with Coarse/Acquisition (C/A) and Precise (P) codes [3], enabling the derivation of pseudo-range and carrier-phase observables that underpin modern geodetic, surveying, and navigation applications [4]. Positioning accuracy is influenced by several factors, including satellite geometry [5], atmospheric propagation effects, receiver quality, and environmental conditions [6]. Conventional code-based positioning techniques typically achieve meter-level accuracy [7], which is sufficient for low-precision applications such as ground vehicle navigation [8], UAV operations [9,10], and low-resolution mapping products [11]. In contrast, high-precision applications, such as geodetic network realization, deformation monitoring, and precision engineering, require centimeter-level accuracy [12], achievable through advanced techniques such as Differential GNSS (DGNSS) and Precise Point Positioning (PPP) [13].

DGNSS enhances positioning accuracy by utilizing simultaneous observations from a reference station with known coordinates and a rover receiver [14]. Through differencing techniques (single, double, or triple differences), common error sources, including satellite clock biases and ionospheric delays, are significantly reduced or eliminated [15]. Dual-frequency DGNSS can achieve millimeter-level precision, whereas single-frequency implementations typically provide decimeter-level accuracy at reduced cost [16-18]. However, its dependence on nearby reference stations limits its applicability over large or remote regions [19]. PPP offers a globally applicable alternative that eliminates the need for local reference infrastructure [20]. It relies on precise satellite orbit and clock products, typically provided by the International GNSS Service (IGS), in combination with rigorous modeling of atmospheric, relativistic, and geophysical effects. PPP is capable of delivering centimeter-level accuracy in both static and kinematic modes, albeit with longer convergence times compared to DGNSS [21]. The Qinertia Cloud platform represents a widely adopted online PPP service that supports both static and kinematic processing, producing solutions in the ITRF2020 reference frame. The platform accepts RINEX data from single- and dual-frequency receivers and automatically applies precise ephemerides, clock corrections, and atmospheric models to generate high-quality solutions. The performance of static PPP is influenced by multiple factors, including satellite availability, multipath conditions, constellation configuration, antenna characteristics [11], atmospheric modeling strategies, and the quality of orbit products employed (ultra-rapid, rapid, or final) [3].

The primary objective of this study is to quantify the impact of integrating GLONASS with GPS in static PPP using dual-frequency observations acquired under genuine open-sky conditions, and to evaluate solution accuracy as a function of fixing time using Qinertia Cloud with final precise products. Unlike most previous investigations, which predominantly focus on fully converged PPP solutions, this study emphasizes the temporal evolution of positioning accuracy at incremental hourly intervals. The utilization of multipath-free desert environments, combined with high-quality final ephemerides, enables an unbiased assessment of the intrinsic benefits of multi-constellation integration, independent of environmental interference or degraded satellite products. Future work will extend this framework to include multipath analysis, integration with MEMS-based inertial navigation systems and vision-based navigation, and applications in UAV photogrammetry for improved estimation of exterior orientation parameters and enhanced image matching efficiency. For more information about the efforts carried out at Benghazi University regarding integration systems, automatic image matching, and vision navigation, the reader is referred to [22–26].

2. Objectives and Methodology

The dataset employed in this study was obtained from the Engineering Consultancy Office at the University of Benghazi and comprises GNSS observations collected from multiple projects across Libya. Ten independent datasets were acquired using dual-frequency GNSS receivers operating in static mode under unobstructed desert open-sky conditions, with each observation session spanning 24 continuous hours. Each dataset was processed under two configurations: (i) GPS-only and (ii) combined GPS+GLONASS. Static PPP solutions were generated for fixing intervals ranging from 1 hour to 24 hours. The fully converged 24-hour solution was adopted as the reference for accuracy assessment. For each fixing interval, absolute positioning errors were computed in the Easting, Northing, and Height components, as well as in the derived two-dimensional (2D) and three-dimensional (3D) metrics. A comprehensive statistical analysis was then conducted across all stations to identify and mitigate outliers and to derive robust accuracy indicators. The spatial distribution of stations across Libya enabled an assessment of the influence of satellite visibility and geometric variability on PPP solution quality and stability.

3. Results and Discussion

The average quality of E, N, H, 2D and 3D absolute differences in GPS-alone and GPS + GLONASS are shown in figures (1), (2), (3), (4), and (5), respectively.

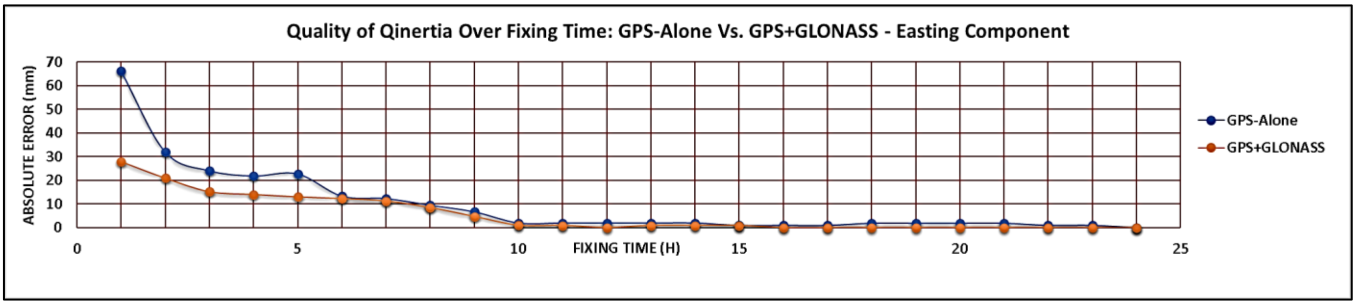

Figure 1 Easting Quality: GPS-alone Vs. GPS+GLONASS

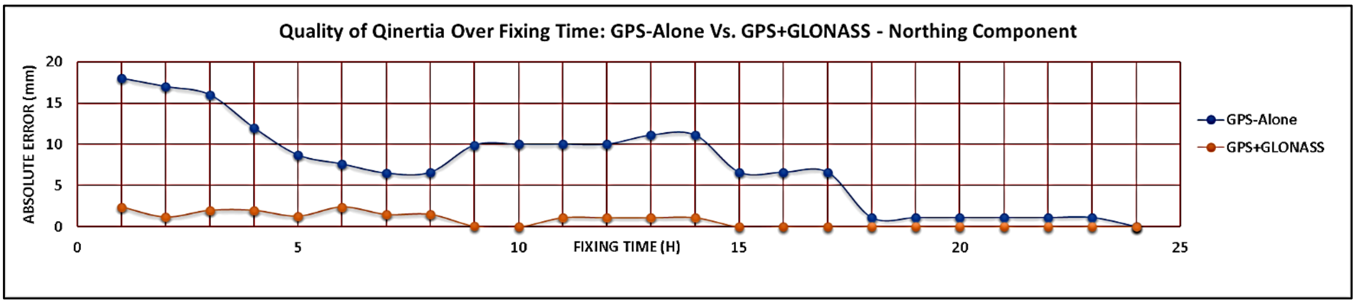

Figure 2 Northing Quality: GPS-alone Vs. GPS+GLONASS

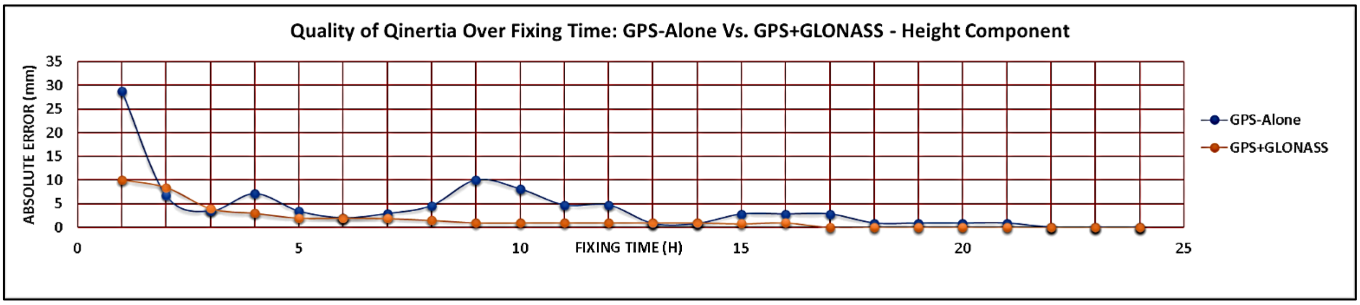

Figure 3 Height Quality: GPS-alone Vs. GPS+GLONAS

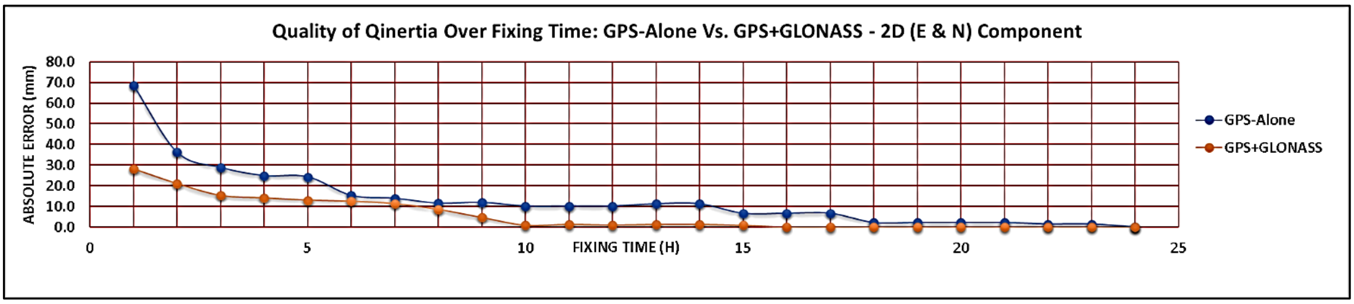

Figure 4 2D (E and N) Quality: GPS-alone Vs. GPS+GLONASS

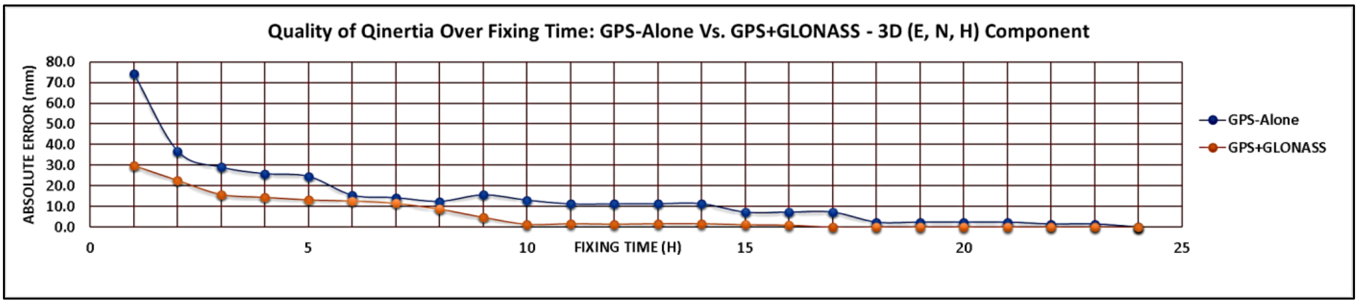

Figure 5 3D (E, N and H) Quality: GPS-alone Vs. GPS+GLONASS

The results confirm that both GPS-only and GPS+GLONASS configurations achieve high levels of positioning accuracy and reliability. However, the integration of GLONASS observations leads to consistent improvements in solution robustness, geometric strength, and overall stability across all fixing intervals. These improvements are primarily attributed to enhanced satellite geometry, increased observational redundancy, and reduced sensitivity to periods of limited GPS satellite availability. The most significant gains are observed during short observation intervals, particularly within the first hour. In this case, absolute positioning errors in the E, N, H, 2D, and 3D components decrease from (6.8, 1.5, 2.8, 7, and 7.4 cm) for the GPS-Alone solution to (2.8, 0.25, 1, 2.8, and 3 cm) for the combined GPS+GLONASS solution.

An atypical observation is that Easting errors exceed those in the Northing and Height components. This behavior can be attributed to the geometric distribution of GNSS satellites, which is generally more symmetric in the East–West direction than in the North–South direction due to orbital inclination constraints. GLONASS satellites, characterized by higher orbital inclination angles relative to GPS, improve North–South coverage and reduce this geometric imbalance, thereby enhancing Northing accuracy.

The benefits of multi-constellation integration are particularly evident during the early convergence phase, when PPP solutions are highly sensitive to satellite geometry and stochastic parameter estimation. Furthermore, Qinertia Cloud demonstrates strong performance in the vertical component, achieving errors below 3 cm for GPS-Alone and approximately 1 cm for GPS+GLONASS within the first hour. This performance is partly attributed to the exclusion of low-elevation observations, which reduces noise and multipath effects, albeit with potential implications for Geometric Dilation of Precision (GDOP). While improvements in mean absolute accuracy become less pronounced for longer observation durations, the integration of GLONASS reduces the occurrence of outliers and decreases the dispersion of coordinate residuals across all components. Even under ideal open-sky conditions, these findings highlight the intrinsic value of multi-constellation processing in strengthening PPP solutions. The increased number of tracked satellites improves GDOP, enhances atmospheric parameter estimation, and provides greater flexibility for excluding low-quality observations without compromising overall solution integrity. Notably, during the first hour, the positioning accuracy achieved using GPS+GLONASS is comparable to that obtained after 2–3 hours of GPS-only observations.

3. Conclusion

This study systematically evaluated the impact of GLONASS integration on static PPP performance as a function of fixing time using the Qinertia Cloud platform with final precise products under ideal open-sky conditions. Dual-frequency observations from ten spatially distributed stations across Libya were processed under GPS-only and GPS+GLONASS configurations over 24-hour sessions. The fully converged 24-hour solution served as the reference for assessing shorter-duration results. The findings confirm that both configurations provide precise and reliable positioning solutions. However, the integration of GLONASS consistently enhances solution robustness and positional stability, particularly during short observation intervals. Within the first hour, absolute errors in the E, N, H, 2D, and 3D components are reduced by approximately (4, 2, 2, 4, 4 cm), respectively. Although improvements in mean absolute accuracy become marginal for longer sessions, the multi-constellation approach significantly reduces outliers and residual dispersion. These results further demonstrate that, even under near-ideal conditions with negligible multipath effects, the inclusion of GLONASS contributes meaningfully to improving PPP reliability. Consistent with prior studies, the Qinertia Cloud service delivers high-quality static PPP solutions comparable to established platforms such as CSRS-PPP. In conclusion, while long-term accuracy gains from GLONASS integration remain limited, its contribution during early convergence stages is substantial, with one-hour GPS+GLONASS solutions achieving accuracy levels comparable to 2–3 hours of GPS-only observations.

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