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(Research Article)

Dual-frequency static GNSS solution over fixing time using Trimble RTX-PP free online service: GPS Vs. GPS + GLONASS

Mustafa M. Amami *

Department of Civil Engineering, Benghazi University, Benghazi, Libya.

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Abstract

This study assessed the performance of dual-frequency static solutions as a function of fixing time using the Trimble RTX-PP free online service under two scenarios: GPS-only and GPS+GLONASS. The results confirm that both approaches achieve centimeter-level accuracy even after 1 hour of observation. GPS-only yields accuracies of 0.5 cm, 0.7 cm, and 1.8 cm in the E, N, and H components, corresponding to 0.9 cm and 2 cm in 2D and 3D, respectively. In contrast, GPS+GLONASS provides 0.5 cm, 0.5 cm, and 1.2 cm in E, N, and H, with 2D and 3D accuracies of 0.7 cm and 1.4 cm, respectively. Millimeter-level accuracy is achieved faster with GPS+GLONASS, reaching the 1 mm level after 10 hours, 2 hours, and 12 hours in E, N, and H, respectively, compared to 17 hours, 3 hours, and 12 hours for GPS-only. This demonstrates a clear improvement in convergence time, particularly in the east component. While both solutions converge to comparable accuracy over longer observation periods, the inclusion of GLONASS consistently enhances solution stability and reliability. The improvement remains within a few millimeters overall but is more evident during shorter observation durations, especially within the first hour, where increased observation redundancy and improved satellite geometry play a critical role. In conclusion, Trimble RTX-PP provides precise and reliable dual-frequency static differential-GNSS solutions suitable for most engineering applications. Although GPS-only delivers high accuracy, the integration of GLONASS offers faster convergence and improved stability, particularly for short fixing times, with measurable gains at the millimeter level.

Keywords: GPS; GLONASS; DGNSS; Trimble RTX; Static Positioning; Fixing Time

1. Introduction

The Global Navigation Satellite Systems (GNSS), including the Global Positioning System (GPS) and Russia's Global Navigation Satellite System (GLONASS), are space-based positioning and navigation infrastructures that enable the determination of instantaneous position and velocity using passive range measurements [1]. These systems operate continuously under all weather conditions and provide high-accuracy, real-time global positioning and timing information [2]. GNSS satellites broadcast signals on two primary frequencies, each modulated with Coarse/Acquisition (C/A) and Precise (P) codes [3]. These signals support the derivation of pseudo-range and carrier-phase observations, which form the backbone of contemporary geodetic, surveying, and navigation applications [4].

The accuracy of GNSS positioning is influenced by several factors, including satellite geometry, atmospheric conditions, receiver performance, and signal environment [5,6]. Code-based positioning typically achieves meter-level accuracy, which is sufficient for low-precision applications such as vehicular navigation [7,8], drone operations [9,10], or the generation of low-accuracy ortho-mosaics and digital elevation models [11]. In contrast, high-precision applications, such as geodetic network establishment, structural deformation monitoring, and precision engineering, require centimeter-level accuracy [12]. Such performance can be achieved through advanced techniques like Differential Carrier-Phase GNSS (DGNSS) and Precise Point Positioning (PPP) [13].

* Corresponding author: Mustafa M. Amami

PPP emerges as a globally applicable alternative that provides high accuracy without requiring a local reference station. It employs precise satellite orbit and clock products, typically supplied by the International GNSS Service (IGS), along with sophisticated atmospheric and relativistic error models [14]. PPP can deliver centimeter-level accuracy in both static and kinematic modes, although it typically involves longer convergence times compared to DGNSS [15]. DGNSS enhances positioning accuracy by employing simultaneous observations from a known reference station and an unknown rover receiver [16]. Forming single, double, or triple differences between observations effectively mitigates many common GNSS error sources, including satellite clock offsets and ionospheric delays [17]. Dual-frequency DGNSS systems can achieve millimeter-level precision, whereas single-frequency variants generally reach decimeter-level accuracy at a considerably lower cost [18]. Despite its strengths, DGNSS is constrained by the requirement for proximity to a reference station, limiting its usability on a global scale [19].

Trimble RTX Post-Processing (RTX-PP) is a high-accuracy GNSS service that provides centimeter-level positions without needing a local base station, supporting only static datasets. It is provided as an alternative to local DGNSS services and is especially useful in remote areas. The user only needs to provide raw GNSS files from single- or dual-frequency receivers directly to the Trimble RTX Post-Processing website, select the suitable coordinate system and tectonic plate.

The performance of static GNSS-based solution is influenced by several parameters, including the number of available satellites, the surrounding multipath environment, the constellation used, the type and quality of the GNSS antenna [20], the ionospheric and tropospheric delay models [21]. This study seeks to evaluate the benefits of augmenting GPS with GLONASS in Static DGNSS using dual-frequency observations collected under true open-sky conditions, and to analyze solution quality as a function of fixing time using the Trimble RTX-PP service. This aspect warrants further investigation because most previous studies evaluated DGNSS performance at the final convergence epoch rather than examining accuracy progression at incremental hourly intervals. Furthermore, acquiring data in multipath-free desert environments provides clearer insight into the intrinsic value of GPS+GLONASS integration without the confounding influence of multipath and poor satellite geometry.

The dataset used in this study was obtained through the Engineering Consultancy Office at Benghazi University from various projects conducted across Libya. Ten datasets were collected using a dual-frequency GNSS receiver operating in static mode under unobstructed open-sky desert conditions, with each observation session lasting 24 continuous hours. Each dataset was processed using two configurations: (1) GPS-only and (2) GPS + GLONASS, with fixing intervals initiated at 1 hour and increased incrementally up to 24 hours. The 24-hour static DGNSS solution was treated as the reference benchmark. For each fixing period, the static PPP coordinates were compared with the reference solution to compute the absolute positioning errors in Easting, Northing, Height, 2D (E+N), and 3D (E+N+H) components. The results from all ten stations were then statistically analyzed to identify and mitigate outliers and to derive the final accuracy metrics. Using datasets collected from geographically distributed locations across Libya enabled assessment of how satellite visibility and geographic distribution influence PPP accuracy and solution stability.

This study forms part of ongoing efforts at the University of Benghazi to evaluate widely used free PPP & DGNSS online services in both static and kinematic modes, including CSRS-PPP [16,17], PPP-WIZARD [18,19], APPS [20,21], and Qinertia Cloud [14,15], and comparison of multi services in kinematic and static [22,23]. Future work will extend this research to multipath-rich environments, as well as to the derivation of empirical equations of the quality of DGNSS as a function of base-line length. Additional efforts will also focus on improving kinematic DGNSS performance for drone-based surveying to reduce processing time in automated image-matching workflows. Related studies conducted at the University of Benghazi are presented in [24-28].

2. 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.

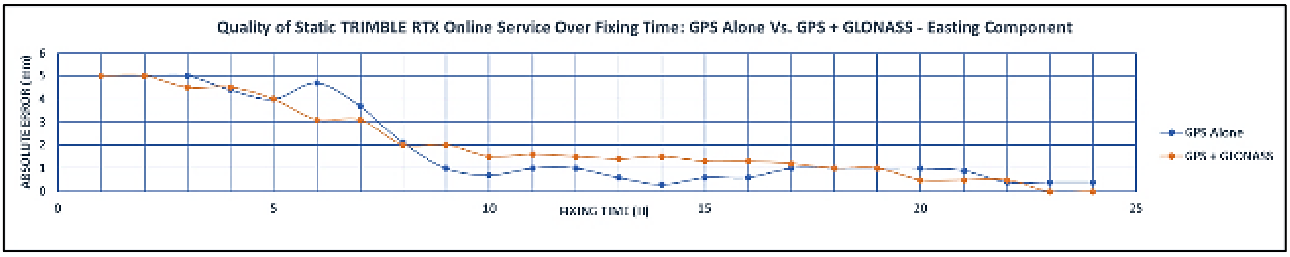

Figure 1 Easting Quality: GPS-alone Vs. GPS+GLONASS

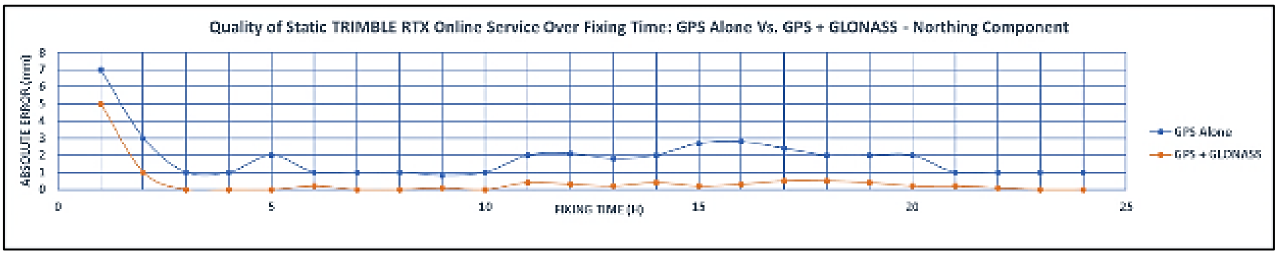

Figure 2 Northing Quality: GPS-alone Vs. GPS+GLONASS

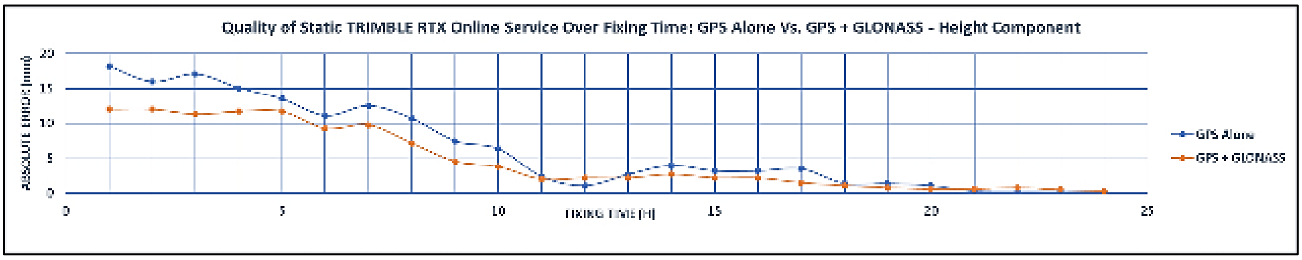

Figure 3 Height Quality: GPS-alone Vs. GPS+GLONASS

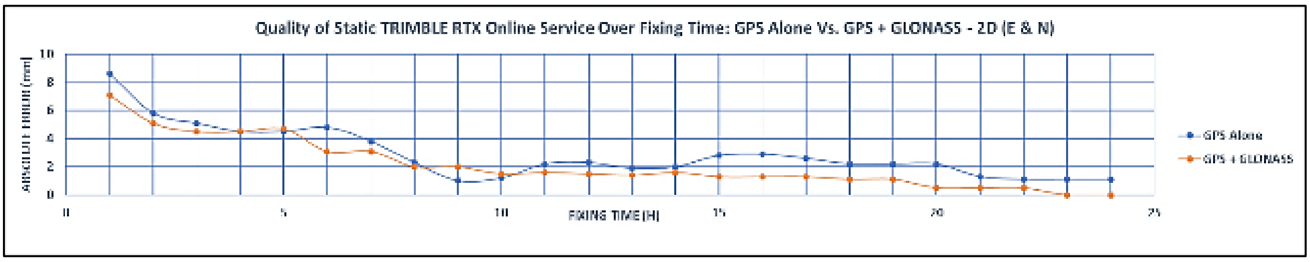

Figure 4 2D (E and N) Quality: GPS-alone Vs. GPS+GLONASS

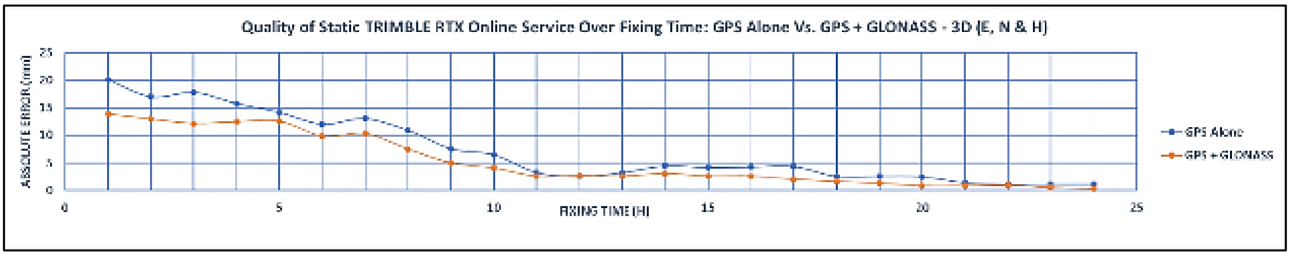

Figure 5 3D (E, N and H) Quality: GPS-alone Vs. GPS+GLONASS

The results demonstrate that both configurations achieve centimeter-level accuracy even after 1 hour of observation, where GPS-only yields 0.5 cm, 0.7 cm, and 1.8 cm in the E, N, and H components, corresponding to 0.9 cm and 2 cm in 2D and 3D, respectively, while GPS+GLONASS provides 0.5 cm, 0.5 cm, and 1.2 cm in E, N, and H, with 0.7 cm and 1.4 cm in 2D and 3D, respectively. Moreover, millimeter-level accuracy is achieved more rapidly with GPS+GLONASS, reaching the 1 mm level after 10 hours, 2 hours, and 12 hours in E, N, and H, respectively, compared to 17 hours, 3 hours, and 12 hours for GPS-only, indicating a clear improvement in convergence behavior, particularly in the east component.

Although both solutions converge to comparable accuracy levels over extended observation periods, the integration of GLONASS consistently enhances solution stability and reduces convergence time, with overall improvements remaining within the few-millimeter level. From a geometrical perspective, the inclusion of GLONASS increases the number of visible satellites and improves their spatial distribution, leading to stronger observation geometry and lower dilution of precision (DOP). This improvement is particularly impactful during shorter observation intervals, especially within the first hour, where solution convergence is more sensitive to satellite availability and geometry.

From a stochastic and estimation standpoint, the increased number of observations enhances redundancy, which strengthens the adjustment model and improves the reliability of parameter estimation. This allows for more effective detection and exclusion of outliers and high-residual measurements without degrading solution quality. In addition, improved satellite geometry contributes to better decorrelation between estimated parameters, particularly for atmospheric delays and receiver clock errors, leading to more stable and faster-converging solutions. Even under open-sky conditions, where multipath effects are minimal, these factors collectively contribute to a measurable improvement in robustness. Furthermore, the integration of GLONASS reduces reliance on low-elevation satellites, which are generally more susceptible to atmospheric errors due to longer signal paths and increased noise levels. By prioritizing higher-quality observations, the combined solution achieves better overall precision and stability.

Overall, the Trimble RTX-PP service provides precise and reliable dual-frequency static GNSS solutions suitable for a wide range of engineering applications. While GPS-only processing already delivers high accuracy, the inclusion of GLONASS offers a clear advantage in terms of convergence speed, robustness, and solution stability, particularly for short observation durations, with consistent improvements observed at the millimeter level.

3. Conclusion

This study evaluated the performance of dual-frequency static DGNSS solutions as a function of fixing time using the Trimble RTX-PP free online service under GPS-only and GPS+GLONASS processing scenarios. The results demonstrate that both approaches achieve centimeter-level accuracy after only 1 hour of observation, where GPS-only provides 0.5 cm, 0.7 cm, and 1.8 cm in the E, N, and H components, corresponding to 0.9 cm and 2 cm in 2D and 3D, respectively, while GPS+GLONASS achieves 0.5 cm, 0.5 cm, and 1.2 cm in E, N, and H, with 0.7 cm and 1.4 cm in 2D and 3D, respectively. The integration of GLONASS observations reduces convergence time, reaching the 1 mm level after 10 hours, 2 hours, and 12 hours in E, N, and H, respectively, compared to 17 hours, 3 hours, and 12 hours for GPS-only, with the most notable improvement observed in the east component. Although both solutions converge to comparable accuracy over longer observation periods, GPS+GLONASS consistently provides enhanced stability and reliability, with improvements remaining within a few millimeters. These gains are primarily attributed to improved satellite geometry, increased observation redundancy, and stronger parameter estimation, which enable more effective mitigation of atmospheric effects and measurement noise, even under open-sky conditions. In conclusion, Trimble RTX-PP delivers precise and reliable static DGNSS solutions suitable for most engineering applications. While GPS-only processing achieves high accuracy, the inclusion of GLONASS offers faster convergence and improved robustness, making it the preferred choice, particularly for short observation durations and time-sensitive applications.

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