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(Research Article)

CSRS-PPP and Trimble RTX-PP Static GNSS Solutions under GPS-Only and GPS+GLONASS Configurations

Mustafa M. Amami *

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

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Abstract

This study presents a comparative evaluation of two widely used free online GNSS post-processing services, namely the Canadian Spatial Reference System Precise Point Positioning (CSRS-PPP) service and Trimble RTX Post-Processing (RTX-PP), using dual-frequency static observations collected under true open-sky desert conditions. The analysis investigates the influence of fixing time and satellite constellation configuration on positioning accuracy, convergence behavior, and solution stability. Two processing scenarios were examined for both services: GPS-only and combined GPS+GLONASS. Ten spatially well-distributed datasets collected across Libya were processed using fixing intervals beginning at 1 hour and incrementally increasing to 24 hours. The 24-hour solution was treated as the reference benchmark for evaluating all shorter observation intervals. The results demonstrate substantial differences between the two processing strategies in terms of convergence behavior and achievable positioning accuracy.

The Trimble RTX-PP service achieved centimeter-level accuracy after only one hour of observation under both processing configurations. GPS-only produced accuracies of 0.5 cm, 0.7 cm, and 1.8 cm in the Easting, Northing, and Height components, corresponding to 0.9 cm and 2 cm in 2D and 3D positioning, respectively. The integration of GLONASS improved the solution to 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. Furthermore, GPS+GLONASS reduced convergence time and enabled millimeter-level positioning to be achieved faster than GPS-only. In contrast, CSRS-PPP demonstrated larger positioning errors during the initial convergence period but showed significant improvement when GLONASS observations were incorporated. During the first observation hour, the absolute errors in the Northing, Height, 2D, and 3D components were reduced by approximately 2.2 cm, 3 cm, 1.8 cm, and 2.22 cm, respectively, when GPS+GLONASS was used instead of GPS-only. Although the average positional improvement became marginal after longer observation periods, the inclusion of GLONASS significantly improved solution robustness and reduced residual dispersion.

The comparative analysis confirms that both services benefit substantially from multi-constellation integration, particularly during short observation durations where satellite geometry and convergence behavior dominate solution quality. However, Trimble RTX-PP consistently demonstrated faster convergence and higher short-term accuracy than CSRS-PPP under identical observing conditions. Meanwhile, CSRS-PPP exhibited strong long-term stability and robustness, especially after convergence was achieved. The results demonstrate that integrating GLONASS with GPS improves convergence speed, solution reliability, and positioning stability for both PPP- and DGNSS-based services, even under optimal open-sky conditions with negligible multipath effects. The findings also highlight the importance of selecting an appropriate online processing strategy according to the required observation duration and target positioning accuracy.

Keywords: GPS; GLONASS; CSRS-PPP; Trimble RTX-PP; PPP; DGNSS; Static Positioning; Fixing Time; Convergence Time

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[*] Corresponding author: Mustafa M. Amami

1. Introduction

Global Navigation Satellite Systems (GNSS), including the Global Positioning System (GPS) and Russia's Global Navigation Satellite System (GLONASS), provide continuous and highly accurate positioning and navigation information worldwide [1]. These systems rely on satellite-based ranging observations and have become fundamental tools in geodesy, surveying, engineering, navigation, and remote sensing applications [2]. GNSS positioning accuracy is strongly affected by satellite geometry [3], atmospheric effects [4], receiver quality [5], observation strategy [6], antenna quality [7], and signal environment [8]. Standard code-based positioning techniques generally provide meter-level accuracy suitable for low-precision navigation applications [9-11]. However, high-precision engineering and geodetic applications require centimeter- or millimeter-level positioning accuracy [10], which can be achieved using advanced carrier-phase techniques such as Differential Global Navigation Satellite Systems (DGNSS) [12], and Precise Point Positioning (PPP) [13].

PPP is a globally applicable technique that utilizes precise satellite orbit and clock corrections [14], typically provided by the International GNSS Service (IGS), together with advanced atmospheric and relativistic modeling [15] to achieve centimeter-level positioning without requiring a nearby reference station [16]. One of the most widely used free PPP processing services is the Canadian Spatial Reference System Precise Point Positioning (CSRS-PPP) service developed by Natural Resources Canada (NRCan) [16,17]. DGNSS, on the other hand, improves positioning accuracy by differencing observations between a reference station and a rover receiver to eliminate or reduce common error sources [18]. Although DGNSS can provide faster convergence and very high accuracy, its performance depends on the availability of suitable reference infrastructure [19]. Trimble RTX Post-Processing (RTX-PP) provides a high-accuracy online GNSS processing service capable of delivering centimeter-level positioning using static observations [20].

The integration of multiple satellite constellations, particularly GPS and GLONASS, has become increasingly important for improving positioning performance [21]. Increasing the number of available satellites improves observation redundancy, enhances satellite geometry, reduces dilution of precision (DOP), and strengthens parameter estimation [22]. These benefits are especially important during short observation durations when convergence behavior dominates solution quality [23,24].

Although many previous studies investigated PPP and DGNSS performance individually, relatively few studies have directly compared free online PPP and DGNSS processing services under identical observing conditions while also evaluating the impact of fixing time and constellation integration. Moreover, most existing investigations focus on the final converged solution rather than analyzing solution progression over incremental observation intervals. Therefore, this study presents a comparative evaluation of CSRS-PPP and Trimble RTX-PP under GPS-only and GPS+GLONASS configurations using dual-frequency static observations collected under multipath-free desert conditions across Libya. The investigation focuses on assessing positioning accuracy as a function of fixing time, evaluating convergence behavior for both services, investigating the impact of integrating GLONASS observations, comparing the robustness and stability of PPP- and DGNSS-based online services, and determining the suitability of each service for short- and long-duration static observations.

The dataset used in this study was obtained through the Engineering Consultancy Office at the University of Benghazi from multiple engineering and surveying projects distributed across Libya. Ten dual-frequency GNSS datasets were collected under unobstructed open-sky desert conditions with negligible multipath effects. Each observation session lasted continuously for 24 hours. The use of geographically distributed stations enabled assessment of the influence of satellite visibility and geometry over different regions while minimizing environmental effects such as signal obstruction and multipath. All datasets were processed using: GPS-only configuration and GPS+GLONASS configuration for both CSRS-PPP and Trimble RTX-PP services. Fixing intervals began at 1 hour and increased incrementally to 24 hours. The 24-hour solution was considered the reference benchmark for evaluating all shorter observation periods.

The processing workflow consisted of submitting identical dual-frequency static GNSS datasets to both CSRS-PPP and Trimble RTX-PP online processing services. The datasets were processed incrementally from 1-hour observation durations up to 24 hours. For each fixing interval, the obtained coordinates were compared against the corresponding 24-hour reference solution to compute absolute positioning errors in: Easting (E), Northing (N), Height (H), Two-dimensional position (2D), and Three-dimensional position (3D). The resulting coordinate residuals from all stations were statistically analyzed to derive average positioning accuracies and assess convergence behavior. The investigation focused on: accuracy progression with fixing time, convergence characteristics, impact of GLONASS integration, solution stability and robustness, residual dispersion and outlier behavior.

This study forms part of ongoing efforts at the University of Benghazi to evaluate widely used free PPP and DGNSS online services in both static and kinematic modes, including Qinertia Cloud [14,15]. CSRS-PPP [16,17], PPP-WIZARD [18,19], APPS [21,22], magic-GNSS [25], Trimble RTX-PP [20], and Future work will extend this research to multipath-rich environments, as well as to the integration of PPP with MEMS-based inertial navigation systems and vision-based navigation techniques. Additional efforts will also focus on improving PPP and fast static 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 [26-30].

2. Results and Discussion

The average quality of CSRS-PPP in N, H, 2D and 3D absolute differences in GPS-alone and GPS + GLONASS are shown in figures (1), (2), (3), and (4), respectively and the average quality of Trimble in E, N, H, 2D and 3D absolute differences in GPS-alone and GPS + GLONASS are shown in figures (5), (6), (7), (8), and (9), respectively.

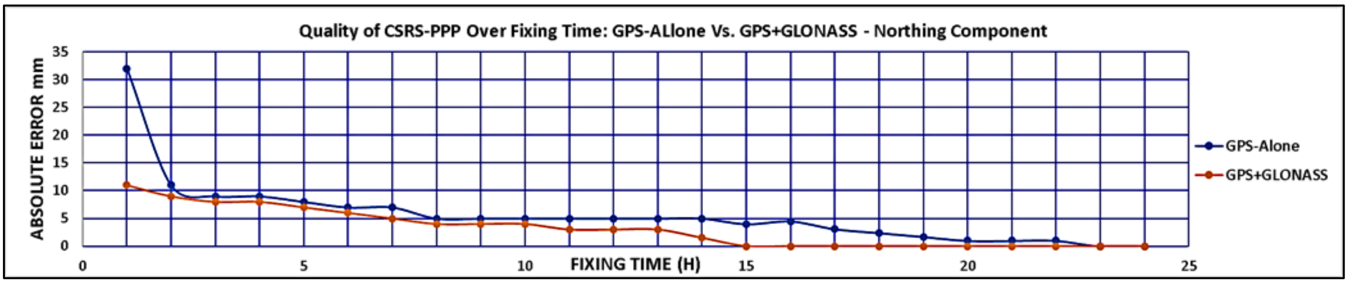

Figure 1 CSRS-PPP: Northing Quality: GPS-alone Vs. GPS+GLONASS

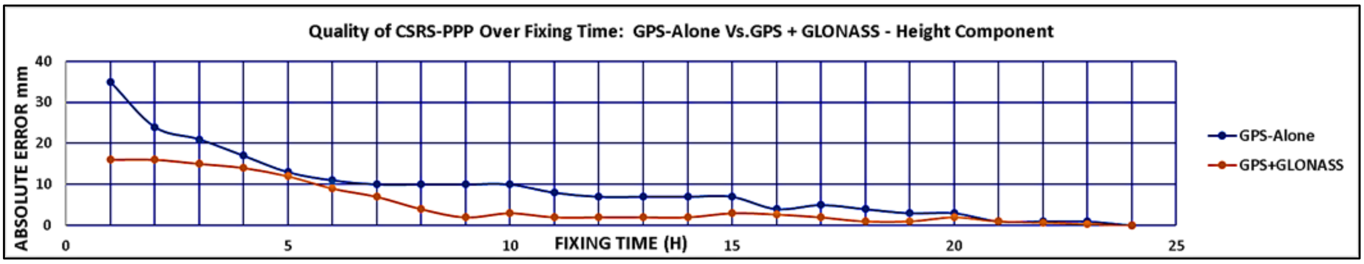

Figure 2 CSRS-PPP: Height Quality: GPS-alone Vs. GPS+GLONASS

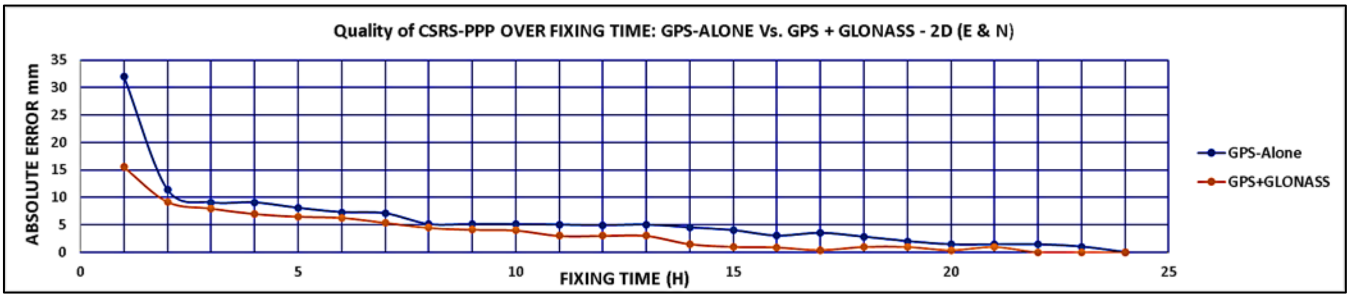

Figure 3 CSRS-PPP: 2D (E and N) Quality: GPS-alone Vs. GPS+GLONASS

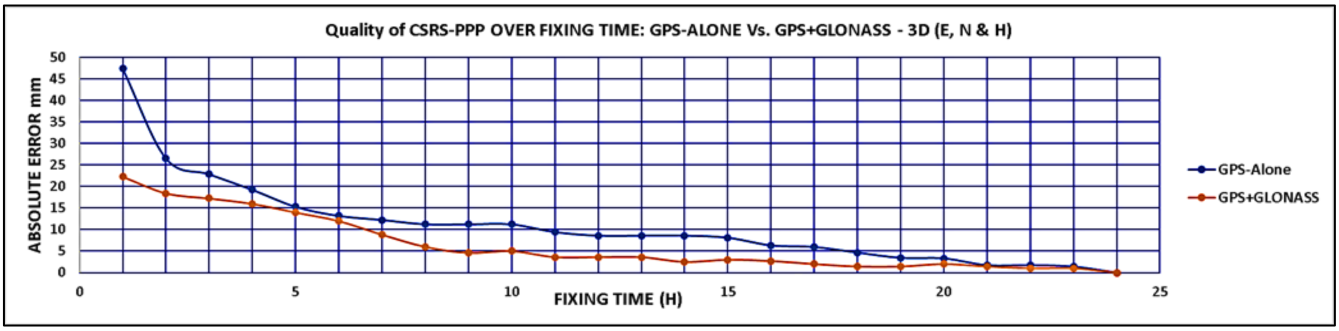

Figure 4 CSRS-PPP: 3D (E, N and H) Quality: GPS-alone Vs. GPS+GLONASS

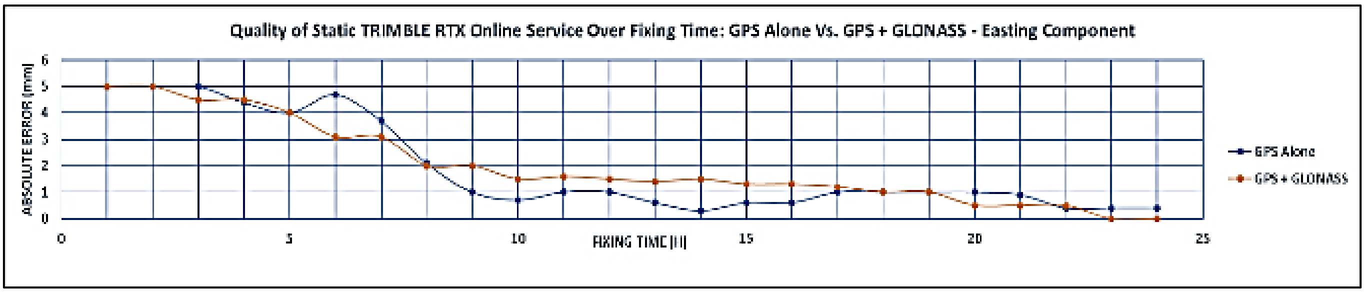

Figure 5 Trimble RTX: Easting Quality: GPS-alone Vs. GPS+GLONASS

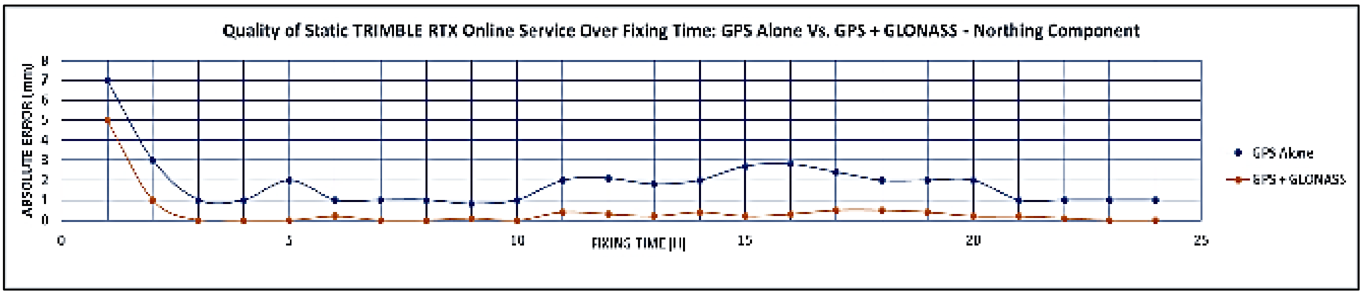

Figure 6 Trimble RTX: Northing Quality: GPS-alone Vs. GPS+GLONASS

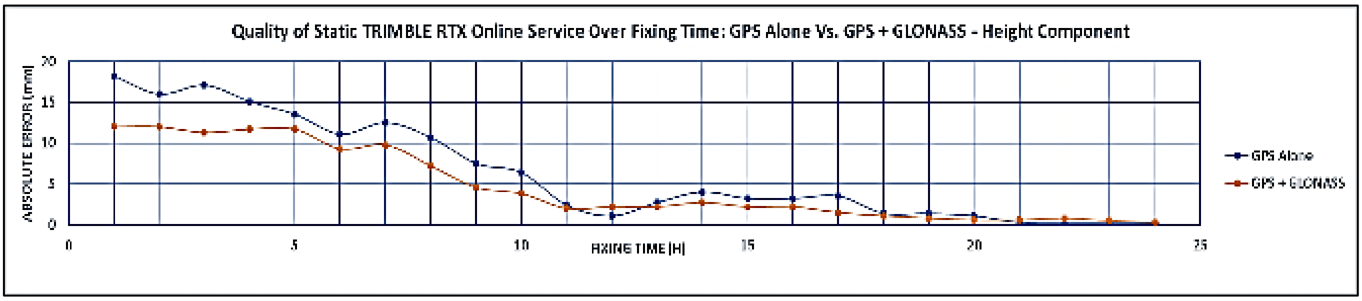

Figure 7 Trimble RTX: Height Quality: GPS-alone Vs. GPS+GLONASS

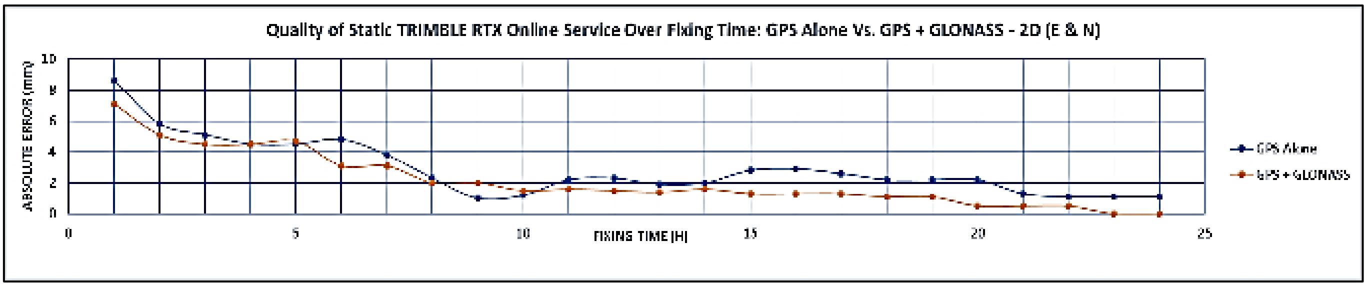

Figure 8 Trimble RTX: 2D (E and N) Quality: GPS-alone Vs. GPS+GLONASS

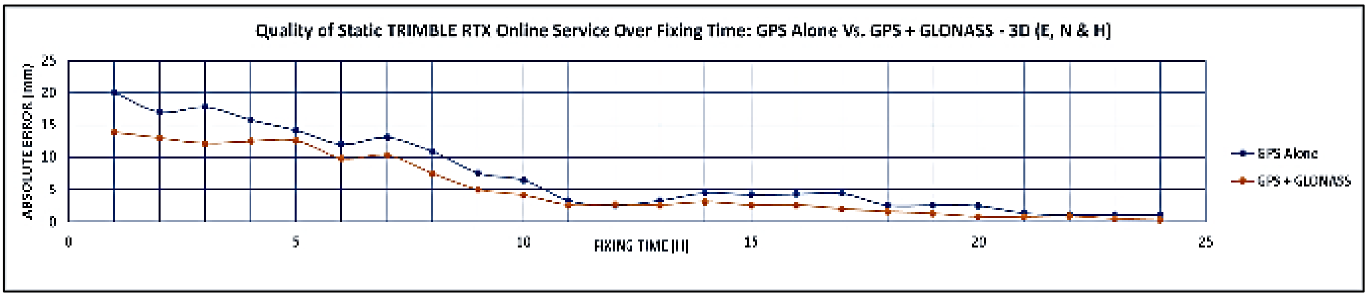

Figure 9 Trimble RTX: 3D (E, N and H) Quality: GPS-alone Vs. GPS+GLONASS

The results demonstrate that Trimble RTX-PP provides extremely high positioning accuracy even for short observation durations. Both GPS-only and GPS+GLONASS configurations achieved centimeter-level accuracy after only one hour of observation. GPS-only produced accuracies of approximately: 0.5 cm in Easting, 0.7 cm in Northing, 1.8 cm in Height, 0.9 cm in 2D, and 2.0 cm in 3D. The integration of GLONASS further improved the solution to:0.5 cm in Easting, 0.5 cm in Northing, 1.2 cm in Height, 0.7 cm in 2D, and 1.4 cm in 3D. Millimeter-level convergence was also achieved faster when GLONASS observations were incorporated. GPS+GLONASS reached the 1 mm level after approximately:10 hours in Easting, 2 hours in Northing, and 12 hours in Height, compared to GPS-only, which required:17 hours in Easting, 3 hours in Northing, and 12 hours in Height. These findings indicate that GLONASS integration significantly improves convergence speed and positioning stability, particularly during short observation intervals.

The CSRS-PPP results indicate that PPP convergence behavior is more sensitive to short observation durations than Trimble RTX-PP. Nevertheless, the integration of GLONASS observations produced clear improvements in positioning quality and robustness. During the first observation hour, GPS+GLONASS reduced the absolute positioning errors in: Northing by approximately 2.2 cm, Height by approximately 3 cm, 2D positioning by approximately 1.8 cm, and 3D positioning by approximately 2.22 cm compared with GPS-only processing. The Easting component showed very small errors for both configurations due to the relatively symmetrical east-west satellite distribution. The larger improvement observed in the Northing component can be attributed to the higher orbital inclination of GLONASS satellites, which improves north-south satellite geometry and reduces the satellite visibility gap toward the north. Although the improvement in average positional accuracy became relatively small after long observation periods, the inclusion of GLONASS significantly reduced residual dispersion and minimized outlier occurrence.

The comparative analysis reveals clear differences between the two processing strategies. Trimble RTX-PP consistently demonstrated: faster convergence, higher short-term accuracy, better millimeter-level performance, stronger short-duration stability. In contrast, CSRS-PPP exhibited: longer convergence behavior, greater sensitivity during early observation periods, strong long-term robustness after convergence, significant improvement when GLONASS was integrated. The superior short-term performance of Trimble RTX-PP may be attributed to its differential processing strategy and advanced correction modeling. Meanwhile, PPP solutions inherently require longer convergence periods due to ambiguity convergence and atmospheric parameter estimation. For both services, integrating GLONASS observations increased observation redundancy and improved satellite geometry, leading to: lower dilution of precision (DOP), improved parameter decorrelation, better atmospheric delay estimation, enhanced outlier detection capability, reduced dependence on low-elevation satellites. The benefits were particularly significant during the first few observation hours when convergence behavior dominates positioning quality. Overall, the results confirm that multi-constellation integration substantially enhances the performance of both PPP- and DGNSS-based online GNSS services.

3. Conclusion

This study presented a comparative evaluation of CSRS-PPP and Trimble RTX-PP free online GNSS processing services using dual-frequency static observations collected under open-sky desert conditions. The investigation assessed the influence of fixing time and satellite constellation configuration under GPS-only and GPS+GLONASS processing scenarios. The results demonstrate that Trimble RTX-PP achieves superior short-term positioning performance and faster convergence compared with CSRS-PPP. Centimeter-level accuracy was achieved by Trimble RTX-PP after only one hour of observation under both processing configurations, while the integration of GLONASS further improved convergence speed and positioning stability.

CSRS-PPP exhibited longer convergence behavior during short observation durations; however, the integration of GLONASS significantly improved solution reliability, reduced residual dispersion, and enhanced positioning stability. The improvements were particularly evident during the first observation hour, where notable reductions in Northing, Height, 2D, and 3D positioning errors were observed. For both services, integrating GLONASS observations increased the number of available satellites and improved satellite geometry, resulting in stronger observation redundancy, improved atmospheric parameter estimation, reduced dilution of precision, and enhanced robustness against noisy observations and outliers.

The findings indicate that Trimble RTX-PP is particularly suitable for applications requiring rapid convergence and high short-term positioning accuracy, while CSRS-PPP provides reliable and robust long-duration PPP solutions with significant benefits from multi-constellation integration. Overall, the study confirms that combining GPS and GLONASS observations significantly improves the performance of both PPP- and DGNSS-based online processing services, especially during short fixing intervals where convergence behavior and satellite geometry are critical factors controlling positioning quality.

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