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Research Paper

Dual-Frequency Static GNSS Positioning Under Open-Sky Conditions: OPUS Vs. Trimble RTX-PP

Abstract
This study presents a comprehensive evaluation of two widely used online GNSS processing services, namely the Online Positioning User Service (OPUS) and Trimble RTX-PP, for dual-frequency static positioning under open-sky desert conditions. The analysis is based on ten 24-hour GNSS datasets collected from geographically distributed locations across Libya using dual-frequency receivers operating in static mode. Three processing configurations were investigated: OPUS (GPS-only), Trimble RTX-PP GPS-only, and Trimble RTX-PP GPS+GLONASS. Positioning performance was evaluated as a function of observation duration, with processing intervals ranging from 1 to 24 hours. The fully converged 24-hour solution generated by each service was adopted as the reference benchmark.
The results reveal significant differences in convergence behavior and short-session positioning performance. Trimble RTX-PP demonstrated superior accuracy during the early stages of processing, achieving approximately 2 cm and 1.4 cm three-dimensional (3D) accuracy after one hour for the GPS-only and GPS+GLONASS configurations, respectively. In comparison, OPUS achieved approximately 31 cm 3D accuracy after the same observation period. The inclusion of GLONASS observations further improved RTX-PP performance by enhancing satellite geometry and accelerating solution convergence. As observation duration increased, the positioning accuracy of all solutions improved substantially, and millimeter-level precision was eventually achieved. However, Trimble RTX-PP consistently exhibited faster convergence and greater solution stability than OPUS throughout the observation period. The results demonstrate the advantages of advanced processing strategies and multi-constellation observations in reducing convergence time and improving positioning performance.
The findings highlight the significant influence of processing methodology, observation duration, and satellite constellation availability on high-precision GNSS positioning accuracy and provide practical guidance for selecting suitable online processing services for static surveying and geodetic applications.

Keywords: *GNSS, OPUS, Trimble RTX-PP, GPS, GLONASS, static positioning, convergence time, positioning accuracy, online GNSS processing services.*

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I. Introduction

The Global Navigation Satellite Systems (GNSS), including the Global Positioning System (GPS) and the Russian Global Navigation Satellite System (GLONASS), are satellite-based positioning and navigation frameworks that facilitate the determination of instantaneous position and velocity through passive range observations [1]. These systems function continuously in all weather conditions and deliver high-precision, real-time global positioning and timing services [2]. GNSS satellites transmit signals on two principal frequencies, each encoded with Coarse/Acquisition (C/A) and Precise (P) codes [3]. These transmissions enable the extraction of pseudo-range and carrier-phase measurements, which constitute the foundation of modern geodetic, surveying, and navigation practices [4]. The rapid growth of GNSS has transformed positioning, navigation, and surveying applications by enabling highly accurate coordinate determination on a global scale. Modern GNSS positioning techniques are capable of delivering accuracies ranging from several meters to a few millimeters depending on the processing methodology, observation duration, satellite constellation, and environmental conditions.

The precision of GNSS positioning is affected by numerous factors, including satellite configuration, atmospheric effects, receiver characteristics, and the surrounding signal environment [5,6]. Code-based positioning generally provides meter-level accuracy, which is adequate for applications with modest accuracy requirements such as vehicle navigation [7,8], unmanned aerial vehicle operations [9,10], and the production of low-accuracy ortho-mosaics and digital elevation models [11]. Conversely, applications demanding high precision, including geodetic network establishment, structural deformation analysis, and precision engineering, require centimeter-level positioning accuracy [12]. Such levels of performance can be attained using advanced approaches such as Differential Carrier-Phase GNSS (DGNSS) and Precise Point Positioning (PPP) [13].

PPP has emerged as a globally deployable alternative capable of delivering high positioning accuracy without the need for a nearby reference station. It relies on precise satellite orbit and clock corrections, commonly provided by the International GNSS Service (IGS), together with advanced atmospheric and relativistic correction models [14]. PPP is capable of achieving centimeter-level accuracy in both static and kinematic applications, although it generally requires longer convergence periods than DGNSS [15]. DGNSS improves positioning accuracy through the use of simultaneous measurements collected by a known reference station and an unknown rover receiver [16]. The formation of single, double, or triple differences between observations significantly reduces many shared GNSS error sources, including satellite clock biases and ionospheric effects [17]. Dual-frequency DGNSS solutions can attain millimeter-level precision, while single-frequency systems typically provide decimeter-level accuracy at substantially reduced cost [18]. Despite its advantages, DGNSS remains limited by the necessity of proximity to a reference station, restricting its applicability on a worldwide scale [19].

OPUS is a publicly accessible online GPS processing service developed by the National Geodetic Survey (NGS). The service offers free access to highly accurate coordinates within the National Spatial Reference System (NSRS). OPUS utilizes the same processing software employed to compute coordinates for the nation’s geodetic control monuments and the NOAA CORS Network (NCN). As for Trimble RTX-PP, it is a post-processing 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 and is capable of processing data collected from any location worldwide.

The quality of static GNSS-derived solutions is governed by several factors, including the number of visible satellites, the prevailing multipath environment, the satellite constellation employed, the type and quality of the GNSS antenna [20], and the ionospheric and tropospheric correction models applied [21]. This study aims to assess the performance of static DGNSS using dual-frequency observations acquired under genuine open-sky conditions and to investigate solution quality as a function of observation duration through the OPUS and Trimble RTX-PP services. Although numerous studies have independently evaluated these services, direct comparisons using identical datasets, observation durations, and environmental conditions remain limited. Furthermore, most previous investigations focus primarily on final positioning accuracy rather than examining the complete convergence behavior as a function of observation duration. The present study addresses this gap through a comprehensive comparison of OPUS and Trimble RTX-PP using ten dual-frequency static datasets collected under open-sky desert conditions. Particular emphasis is placed on convergence characteristics, short-session performance, and the influence of observation duration on positioning accuracy.

The dataset employed in this research was provided by the Engineering Consultancy Office at the University of Benghazi and originated from several projects conducted throughout Libya. Ten datasets were acquired using a dual-frequency GNSS receiver operating in static mode under fully unobstructed open-sky desert conditions, with each session consisting of 24 continuous hours of observation. Each dataset was processed using OPUS GPS-only, Trimble RTX-PP GPS-only, and Trimble RTX-PP GPS+GLONASS measurements, with fixing intervals beginning at 1 hour and progressively extended up to 24 hours. The 24-hour static DGNSS solution was adopted as the reference benchmark. For every fixing interval, the static DGNSS coordinates were compared with the reference solution to determine absolute positioning errors in the Easting, Northing, Height, 2D (E+N), and 3D (E+N+H) components. The outcomes from all ten stations were subsequently subjected to statistical analysis to detect and mitigate outliers and to derive the final accuracy indicators. The use of datasets collected from geographically distributed locations across Libya also enabled evaluation of the influence of satellite visibility and geographic distribution on DGNSS accuracy and solution stability.

This work represents part of an ongoing research effort at the University of Benghazi aimed at evaluating widely used free PPP and DGNSS online processing services in both static and kinematic modes, including Qinertia Cloud [14,15], CSRS-PPP [16,17], PPP-WIZARD [18,19], APPS [20,21], magic-GNSS [22], Trimble RTX-PP [23], OPUS [24], AUSPOS [25], as well as comparative assessments of multiple services in both static and kinematic configurations [26–32]. Future investigations will expand this work to environments characterized by significant multipath effects and will also focus on developing empirical models describing DGNSS quality as a function of baseline length. Additional research efforts will address the enhancement of kinematic DGNSS performance for drone-based surveying applications with the objective of reducing processing time in automated image-matching procedures. Related studies conducted at the University of Benghazi are reported in [33–37].

II. Results and Discussion

The average quality of E, N, H, 2D and 3D absolute differences of OPUS, AUSPOS, and Trimbe RTX-PP are shown in figures (1 to 5), (6 to 10), and (11 to 15), respectively. Table 1 illustrates the accuracy after one hour, the time to reach centimeter-level, and time to reach millimeter-level.

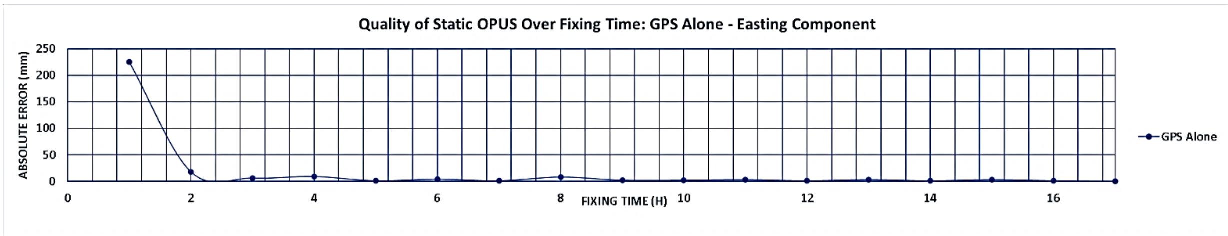

Figure 1: OPUS: GPS-alone - Easting component

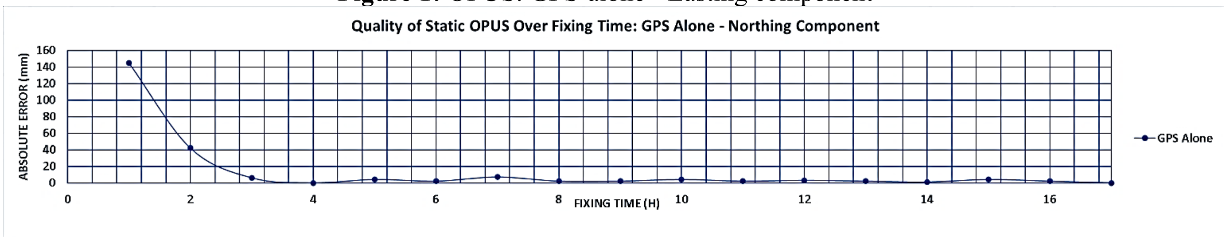

Figure 2: OPUS: GPS-alone - Northing component

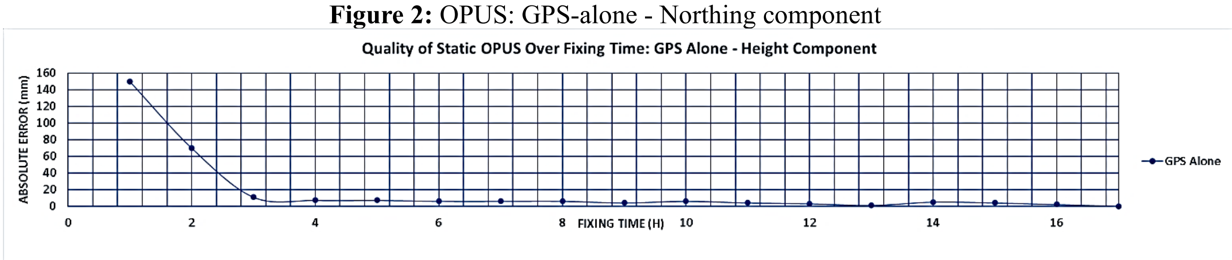

Figure 3: OPUS: GPS-alone - Height component

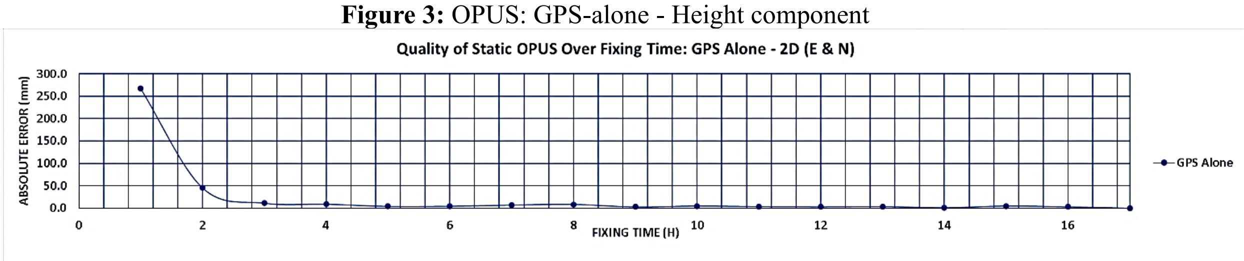

Figure 4: OPUS: GPS-alone – 2D component

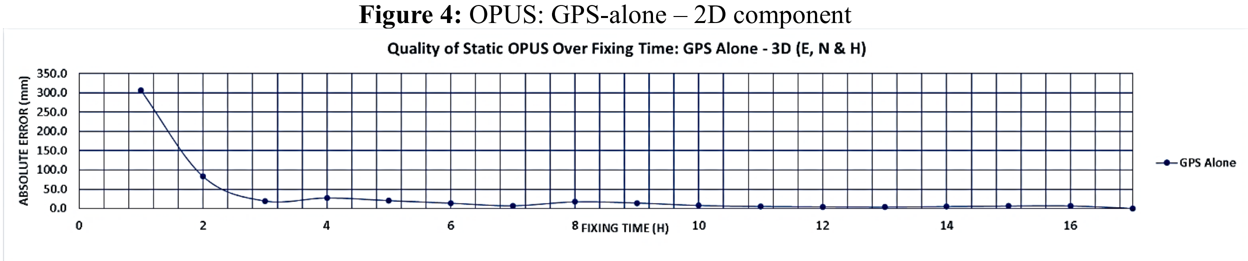

Figure 5: OPUS: GPS-alone - 3D component

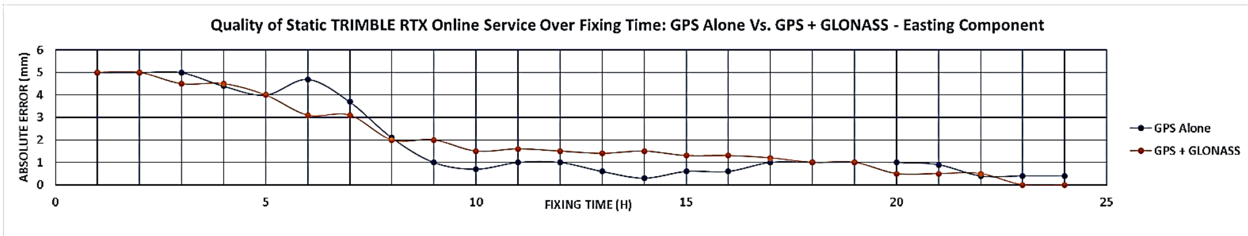

Figure 6: Trimble RTX-PP: GPS-alone Vs. GPS+GLONASS - Easting component

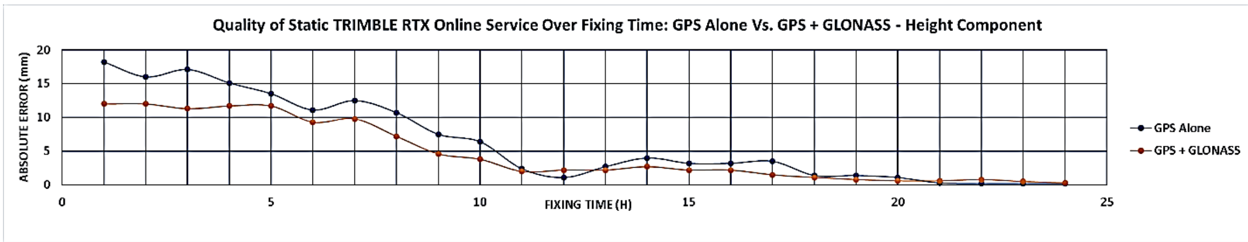

Figure 7: Trimble RTX-PP: GPS-alone Vs. GPS+GLONASS - Northing component

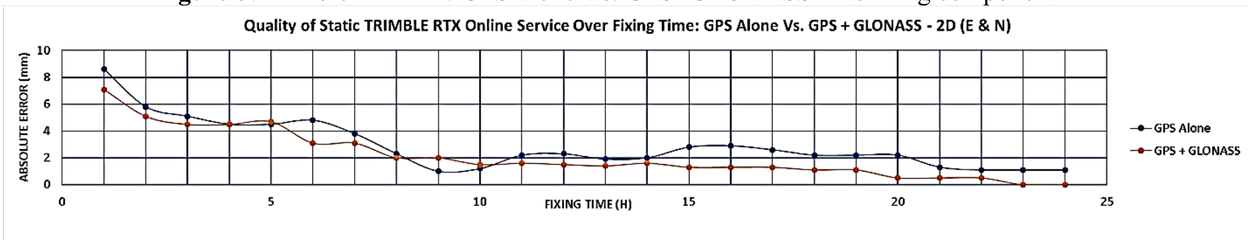

Figure 8: Trimble RTX-PP: GPS-alone Vs. GPS+GLONASS - Height component

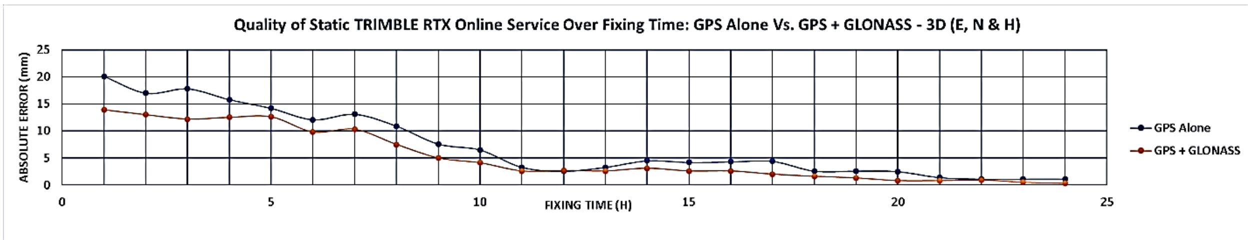

Figure 9: Trimble RTX-PP: GPS-alone Vs. GPS+GLONASS – 2D component

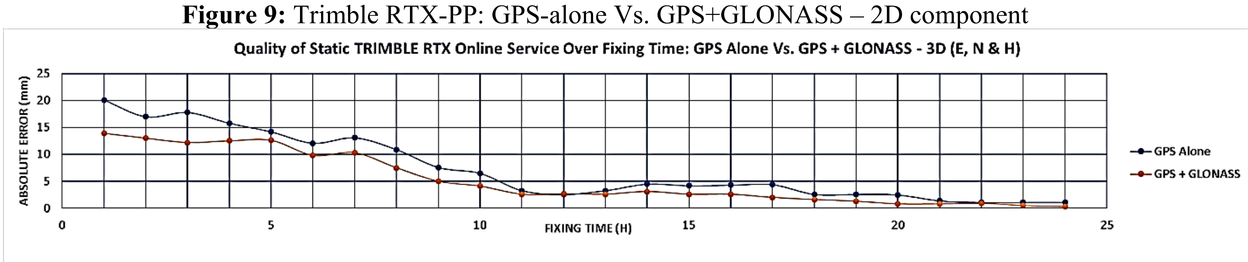

Figure 10: Trimble RTX-PP: GPS-alone Vs. GPS+GLONASS – 3D component

Table (1): Quality of Trimble RTX-PP & OPUS

Service	Accuracy After One Hour		Time to Reach Centimeter-Level Accuracy	Time to Reach Millimeter-Level Accuracy		
	2D	3D		East	North	Height
RTX GPS+GLONASS	0.7 cm	1.4 cm	<1 h	10 h	2 h	12 h
RTX GPS	0.9 cm	2 cm	<1 h	10 h	3 h	12 h
OPUS	26 cm	31 cm	≈2 h	10 h	16 h	17 h

The results reveal significant differences in convergence behavior and positioning performance between OPUS and Trimble RTX-PP. The most notable finding is the exceptional short-session performance achieved by Trimble RTX-PP. After only one hour of observations, RTX-PP produced approximately 2 cm 3D accuracy under GPS-only processing and approximately 1.4 cm under GPS+GLONASS processing. In comparison, OPUS achieved approximately 31 cm 3D accuracy after the same observation period. These results demonstrate the clear advantage of RTX-PP for applications requiring high-accuracy positioning from relatively short observation sessions.

The inclusion of GLONASS observations further improved RTX-PP performance. The additional satellites increased observation redundancy, strengthened satellite geometry, and accelerated ambiguity convergence. The benefits were particularly evident during the early stages of processing, where the RTX GPS+GLONASS configuration consistently outperformed both RTX GPS-only and OPUS solutions.

As observation duration increased, the positioning accuracy of both services improved progressively. OPUS reached centimeter-level accuracy after approximately two hours of observations, whereas RTX-PP maintained centimeter-level performance throughout nearly the entire observation period. This highlights the rapid convergence capability of RTX-PP and its ability to provide highly accurate solutions with minimal observation time.

Long observation sessions ultimately enabled both services to achieve millimeter-level precision. However, important differences remained in convergence rates. RTX GPS+GLONASS achieved millimeter-level accuracy in the Easting and height components after approximately 10 hours and in the Northing component after only 2 hours, whereas OPUS required approximately 10 hours, 16 hours, and 17 hours to achieve millimeter-level precision in the Easting, Northing, and Height components, respectively. These findings confirm the superior convergence efficiency of RTX-PP, particularly when multi-constellation observations are utilized.

Overall, the results demonstrate that observation duration remains one of the primary factors influencing high-precision GNSS positioning performance. Although both services are capable of delivering millimeter-level solutions with sufficiently long observation periods, Trimble RTX-PP consistently provides faster convergence, greater stability, and superior short-session accuracy. The geographically distributed datasets used in this study also indicate that variations in satellite visibility and network geometry can affect convergence behavior even under ideal open-sky conditions. Consequently, RTX-PP is particularly well suited for applications where rapid attainment of high-accuracy coordinates is required, while OPUS remains a reliable alternative for conventional static surveying applications with longer observation sessions.

III. Conclusions

This study evaluated the performance of the Online Positioning User Service (OPUS) and Trimble RTX-PP for dual-frequency static GNSS positioning using ten 24-hour datasets collected under open-sky desert conditions across geographically distributed locations in Libya. The analysis focused on positioning accuracy and convergence characteristics as a function of observation duration. The results demonstrated that Trimble RTX-PP consistently outperformed OPUS, particularly during short observation sessions. After one hour of observations, RTX-PP achieved approximately **2 cm** 3D accuracy in the GPS-only configuration and approximately **1.4 cm** when GPS and GLONASS observations were combined, whereas OPUS achieved approximately **31 cm** 3D accuracy. These findings indicate that RTX-PP provides substantially faster convergence and significantly higher positioning accuracy during the initial stages of processing. The inclusion of GLONASS observations further enhanced RTX-PP performance by improving satellite geometry, increasing observation redundancy, and accelerating ambiguity resolution. As observation duration increased, the positioning accuracy of both services improved steadily, and both eventually converged to millimeter-level precision. However, RTX-PP consistently reached high-precision solutions in a shorter time and exhibited greater stability throughout the convergence process.

Overall, the results highlight the importance of processing methodology, observation duration, and satellite constellation availability in determining static GNSS positioning performance. While both services are capable of producing highly accurate coordinates for geodetic and surveying applications, Trimble RTX-PP offers a clear advantage when rapid convergence and high accuracy are required. OPUS remains a reliable and effective solution for long-duration static surveys, but RTX-PP is the preferred choice for applications where observation time is limited and rapid attainment of centimeter-level accuracy is essential.

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