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(Research Article)

Dual-Frequency Static GNSS Positioning Under Open-Sky Conditions: OPUS Vs. AUSPOS

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Abstract

This study presents a comprehensive evaluation of two widely used free online Global Navigation Satellite System (GNSS) processing services, namely the Online Positioning User Service (OPUS) and the Australian Positioning Open Service (AUSPOS), for dual-frequency static positioning under open-sky desert conditions. The analysis was conducted using ten 24-hour GNSS datasets collected from geographically distributed stations across Libya using dual-frequency receivers operating in static mode. Two processing configurations were investigated: OPUS (GPS-only) and AUSPOS (GPS-only). Positioning performance was evaluated as a function of observation duration, with data segments ranging from 1 to 24 hours. The fully converged 24-hour solution generated by each service was adopted as the reference benchmark for accuracy assessment.

The results indicate noticeable differences in convergence behavior and short-session positioning performance between the two services. OPUS demonstrated superior accuracy during the early observation periods, achieving approximately 31 cm three-dimensional (3D) accuracy after one hour of observation, whereas AUSPOS achieved approximately 83 cm under the same conditions. As the observation duration increased, the positioning accuracy of both services improved substantially, with both solutions converging toward millimeter-level precision. Overall, OPUS exhibited faster convergence and more stable positioning performance than AUSPOS, particularly for short observation sessions. The findings highlight the significant influence of processing strategy and observation duration on high-precision GNSS positioning performance and provide valuable guidance for selecting appropriate online processing services for static surveying and geodetic applications.

Keywords: GNSS; OPUS; AUSPOS, static positioning; Online processing services; GPS; Convergence time; Positioning accuracy

1. 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.

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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). Also, AUSPOS is an openly available online GPS data processing service provided by Geoscience Australia and relies on a network-based, double-difference relative positioning strategy. It takes advantage of both the International GNSS Service (IGS) Stations Network and the IGS product range, as well as the Asia-Pacific Reference Frame Network (APREF) station data and coordinate solutions. AUSPOS works with data collected anywhere on Earth.

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 compare the performance of dual-frequency double-differencing static positioning using OPUS and AUSPOS - which use GPS-only observations - and under genuine open-sky conditions. The study investigates solution quality as a function of observation duration through the OPUS and AUSPOS 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 AUSPOS 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 and AUSPOS GPS-only 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], and, OPUS [24], AUSPOS [25], as well as comparative assessments of multiple services in both static and kinematic configurations [26–30].

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 [31–35].

2. Results and Discussion

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

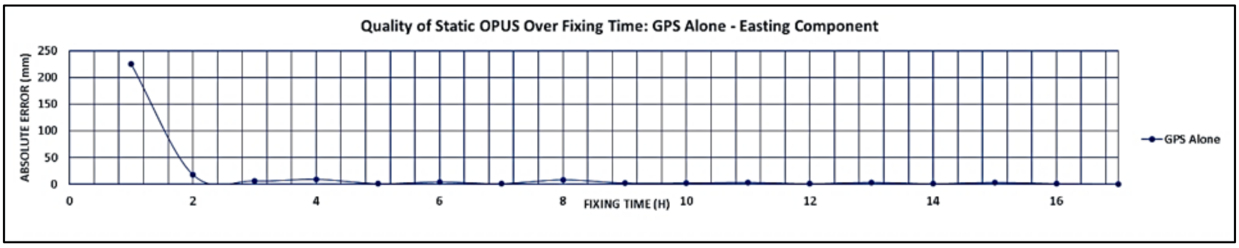

Figure 1 OPUS: GPS-alone - Easting component

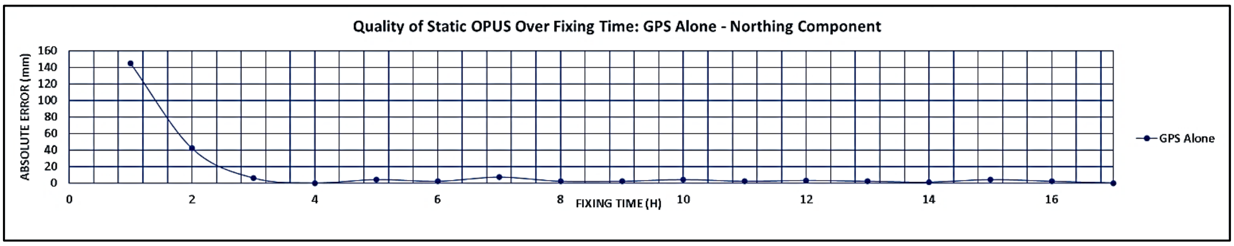

Figure 2 OPUS: GPS-alone - Northing component

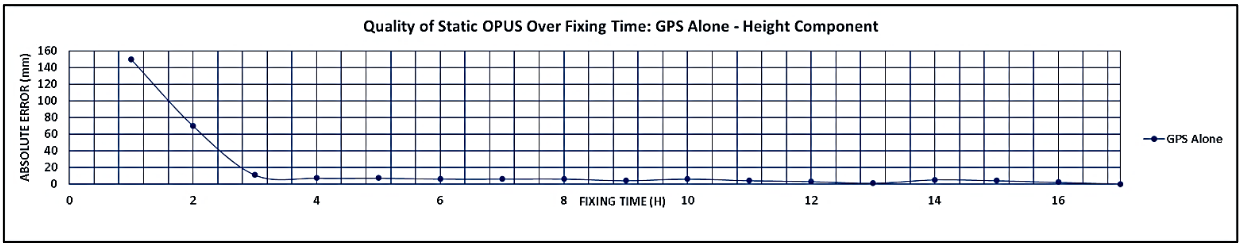

Figure 3 OPUS: GPS-alone - Height component

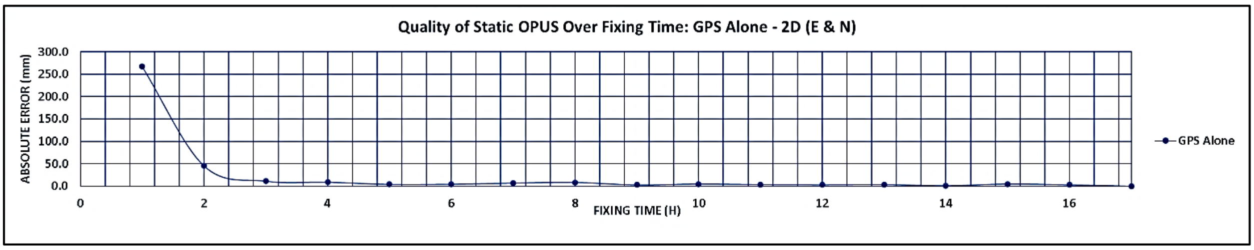

Figure 4 OPUS: GPS-alone – 2D component

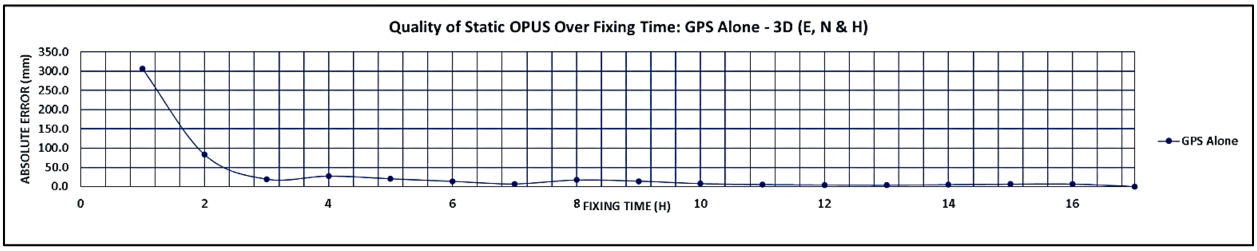

Figure 5 OPUS: GPS-alone - 3D component

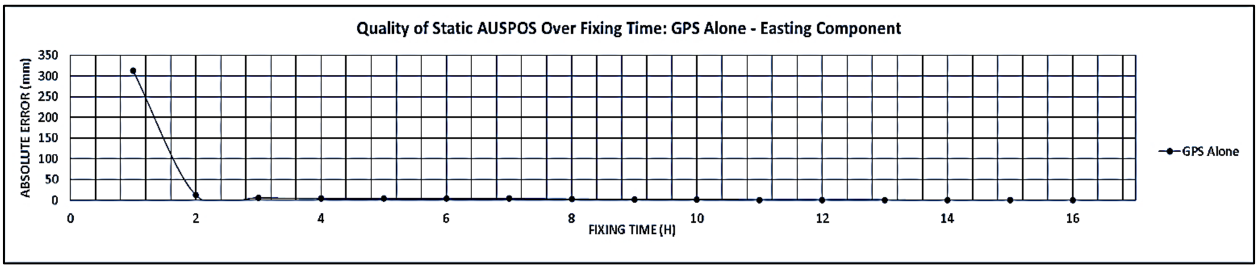

Figure 6 AUSPOS: GPS-alone - Easting component

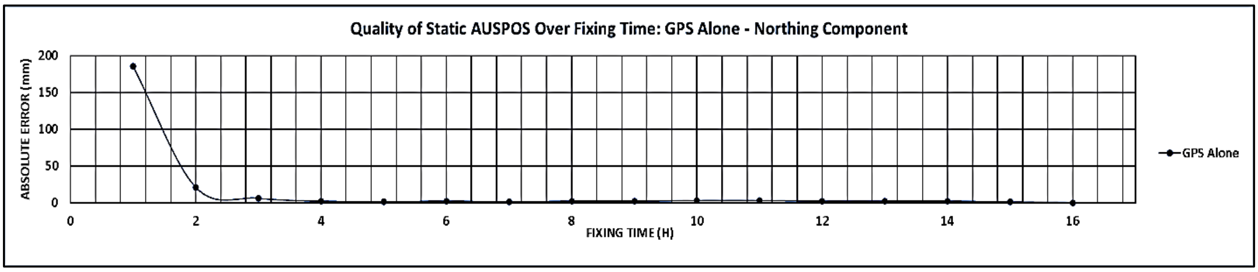

Figure 7 AUSPOS: GPS-alone - Northing component

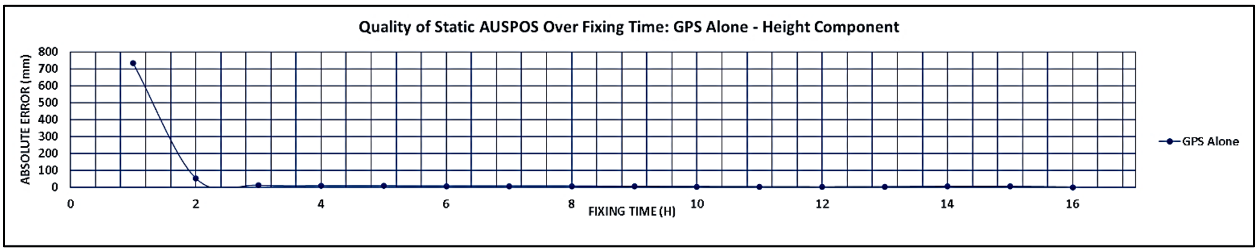

Figure 8 AUSPOS: GPS-alone - Height component

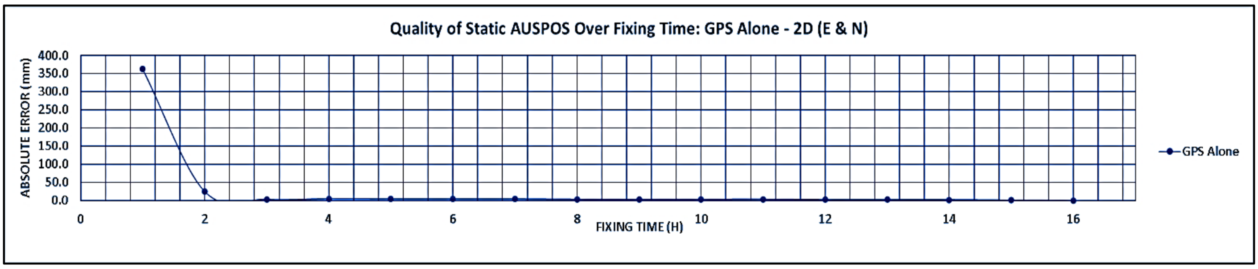

Figure 9 AUSPOS: GPS-alone - 2D component

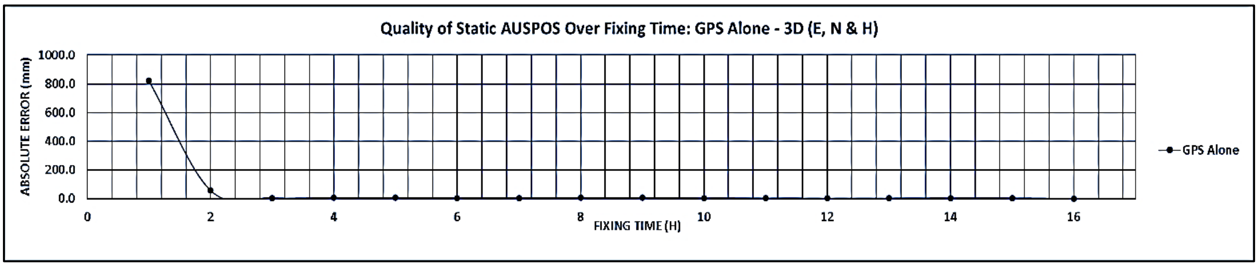

Figure 10 AUSPOS: GPS-alone - 3D component

Table 1 Quality of Static GPS-alone using OPUS & AUSPOS

Service	Accuracy After One Hour		Time to Reach Centimeter-Level Accuracy	Time to Reach Millimeter-Level Accuracy		
	2D	3D		East	North	Height
OPUS	26 cm	31 cm	≈2 h	10 h	16 h	17 h
AUSPOS	38 cm	83 cm	≈3 h	11 h	15 h	16 h

The results reveal significant differences in convergence behavior between the two evaluated services. The most notable finding is the superior short-session performance achieved by OPUS. After only one hour of observations, OPUS produced approximately 31 cm 3D accuracy, whereas AUSPOS achieved approximately 83 cm 3D accuracy. This indicates that OPUS provides more reliable positioning solutions during short observation periods and converges more rapidly toward its final solution.

The largest discrepancies between the two services were observed in the vertical component, suggesting differences in atmospheric modeling strategies, reference station selection, network geometry, and processing algorithms. Since height determination is generally more sensitive to residual atmospheric and satellite-related errors than horizontal positioning, these differences become particularly evident during the early stages of processing.
As observation duration increased, the positioning accuracy of both services improved steadily. OPUS reached centimeter-level accuracy after approximately two hours of observations, while AUSPOS required approximately three hours. This result demonstrates the importance of observation duration in static GNSS positioning and highlights the faster convergence characteristics of OPUS under the tested conditions.

Longer observation sessions enabled both services to achieve millimeter-level precision. However, differences in convergence rates remained evident. OPUS achieved millimeter-level accuracy after approximately 10 hours, 16 hours, and 17 hours in the Easting, Northing, and Height components, respectively. AUSPOS required approximately 11 hours, 15 hours, and 16 hours to reach similar precision levels. Although both services ultimately converged to highly precise solutions, OPUS generally provided more accurate results during shorter observation sessions and demonstrated slightly better overall convergence performance.

The findings also confirm that observation duration remains one of the most influential factors affecting high-precision GNSS positioning. Increased observation time enhances satellite geometry, strengthens redundancy, improves ambiguity resolution, and allows more effective estimation of atmospheric parameters, resulting in progressively improved coordinate stability and accuracy.

Furthermore, the geographically distributed nature of the datasets highlights the influence of station location and satellite visibility on solution quality. Even under ideal open-sky desert conditions, variations in geographic location can affect satellite geometry and reference network configuration, thereby influencing convergence behavior and final positioning accuracy. Overall, both OPUS and AUSPOS proved capable of delivering high-accuracy static GNSS solutions, although OPUS demonstrated superior performance for short observation sessions and faster convergence toward high-precision positioning results.

3. Conclusions

This study evaluated the performance of two widely used free online GNSS processing services, OPUS and AUSPOS, using ten dual-frequency static GNSS datasets collected under open-sky desert conditions at geographically distributed locations across Libya. The analysis examined positioning accuracy as a function of observation duration, with observation intervals ranging from 1 to 24 hours. The results demonstrated that both services are capable of producing highly accurate static positioning solutions when sufficient observation time is available. However, notable differences were observed in their convergence behavior and short-session performance. OPUS consistently outperformed AUSPOS during the initial stages of processing, achieving approximately 31 cm 3D accuracy after one hour of observation compared with approximately 83 cm for AUSPOS. Furthermore, OPUS reached centimeter-level accuracy after approximately two hours, whereas AUSPOS required approximately three hours. As observation duration increased, the accuracy of both services improved significantly. Millimeter-level precision was achieved by both OPUS and AUSPOS after extended observation periods, confirming their suitability for high-precision geodetic and surveying applications. Nevertheless, the results indicate that observation duration remains a critical factor influencing solution quality, particularly during the convergence phase.

Overall, OPUS demonstrated faster convergence and relatively superior performance for short observation sessions, while both services provided comparable high-precision results for long-duration observations. These findings provide practical guidance for surveyors and geospatial professionals when selecting an appropriate online processing service based on required accuracy and available observation time. Future research should investigate the performance of these services under challenging environments characterized by significant multipath effects, partial sky obstruction, and varying baseline lengths to further assess their operational capabilities under real-world surveying conditions.

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