World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Static GPS-alone solution over fixing time using AUSPOS free online service

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World Journal of Advanced Research and Reviews, 2026, 30(03), 329-335

Publication history: Received on 25 April 2026; revised on 02 June 2026; accepted on 04 June 2026

Article DOI: https://doi.org/10.30574/wjarr.2026.30.3.1581

Abstract

This study evaluates the performance of dual-frequency static solution as a function of observation duration using the AUSPOS free online service under a GPS-only processing strategy. 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 analysis is based on ten GNSS datasets collected from different locations across Libya using dual-frequency receivers operating in static mode under open-sky desert conditions. Each dataset consists of continuous 24-hour observations, with processing performed at fixing intervals ranging from 1 to 24 hours. The fully converged 24-hour solution was adopted as the reference benchmark for accuracy assessment in Easting, Northing, Height, 2D, and 3D components. The results show that static double-difference relative positioning performance is strongly dependent on observation time. After one hour, relatively large positioning errors are observed, reaching approximately 32 cm, 19 cm, and 75 cm in the East, North, and Height components, respectively, corresponding to 38 cm and 83 cm in 2D and 3D accuracy. However, a significant improvement is observed with increasing observation duration, where centimeter-level accuracy (~2 cm) is achieved across all components after two hours of data processing. Further extension of the observation time leads to gradual refinement of the solution, reaching millimeter-level accuracy after approximately 11 hours in Easting, 15 hours in Northing, and 16 hours in Height, after which the solution stabilizes. These results confirm that GPS-only static solution using AUSPOS is capable of delivering high-precision positioning under open-sky conditions, but its convergence is relatively slow and highly dependent on observation duration. The use of geographically distributed datasets further highlights the influence of satellite visibility and geometry on positioning stability and accuracy. Overall, the findings emphasize that sufficient observation time is essential to achieve reliable centimeter to millimeter level accuracy in GPS-only static double-differencing relative processing.

Keywords: GPS; DGNSS; AUSPOS; 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].

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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].

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].

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. You can submit dual-frequency geodetic quality GPS RINEX data observed in a 'static' mode to AUSPOS, and an AUSPOS report will be emailed to the user with the Geocentric Datum of Australia 2020 (GDA2020), Geocentric Datum of Australia 1994 (GDA94) and International Terrestrial Reference Frame (ITRF) coordinates.

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 performance of GPS-alone 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 AUSPOS 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 observations 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 GPS-only observations, 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 DGNSS 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], magic-GNSS [24], Trimble RTX-PP [25], and Qinertia Cloud [14,15], as well as comparative assessments of multiple services in both static and kinematic configurations [26–28]. 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 [29-33].

2. Results and Discussion

The average quality of E, N, H, 2D and 3D absolute differences of static GPS-alone using AUSPOS free online service is shown in figures (1), (2), (3), (4), and (5), respectively.

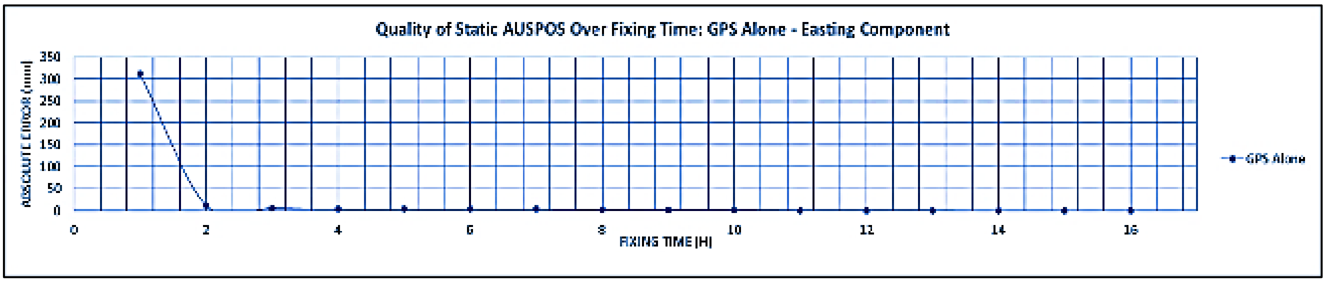

Figure 1 Quality of static GPS-alone over fixing time using AUSPOS - Easting component

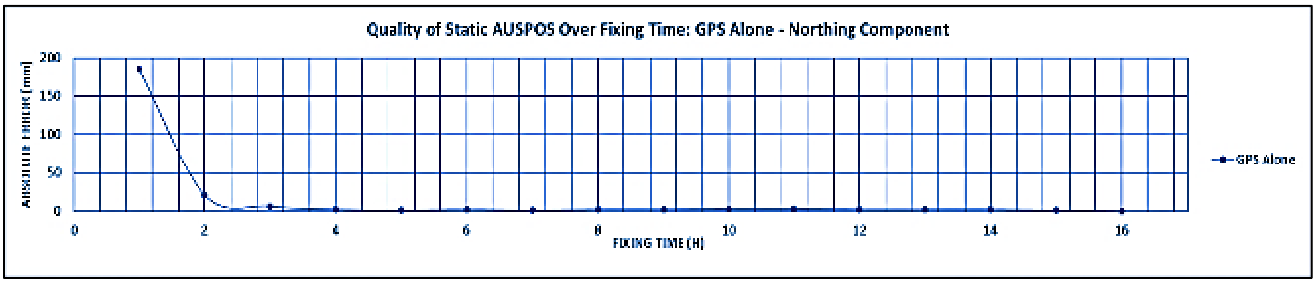

Figure 2 Quality of static GPS-alone over fixing time using AUSPOS - Northing component

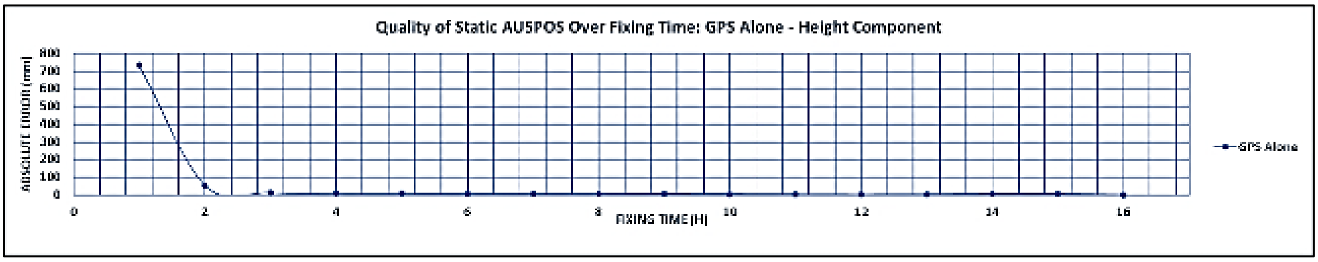

Figure 3 Quality of static GPS-alone over fixing time using AUSPOS - Height component

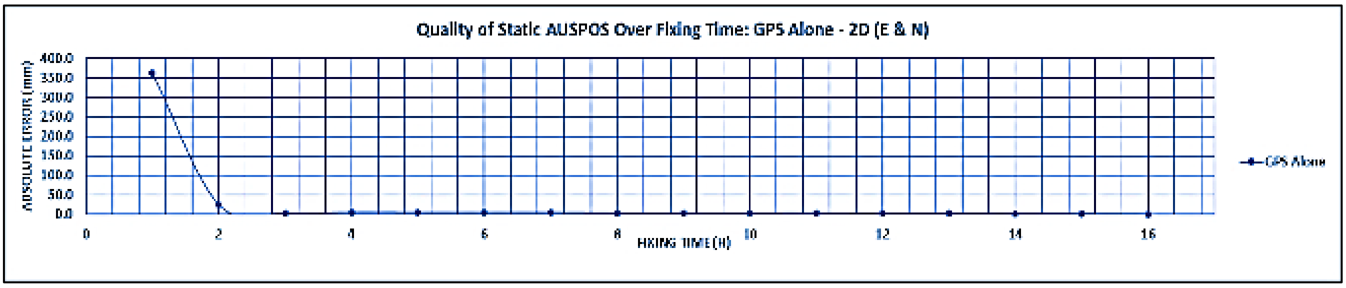

Figure 4 Quality of static GPS-alone over fixing time using AUSPOS – 2D component

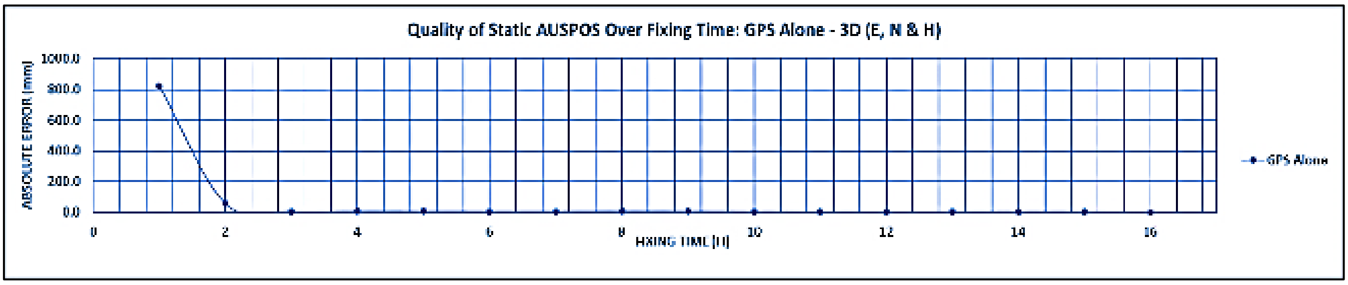

Figure 5 Quality of static GPS-alone over fixing time using AUSPOS – 3D component

The results demonstrate that the performance of static positioning using AUSPOS is strongly dependent on observation duration, exhibiting a clear progression from decimeter-level accuracy during short observation periods to millimeter-level precision as the session length increases. This behavior reflects the characteristics of high-precision network-based GNSS processing, where solution quality improves with increased observational redundancy and stronger geometric constraints. Unlike Precise Point Positioning (PPP), AUSPOS employs a network-based relative positioning approach based on double-difference observations, utilizing data from surrounding IGS and APREF reference stations to estimate positions within a well-defined global reference frame.

This processing strategy plays a critical role in shaping the observed accuracy trends. The relatively large errors obtained after one hour (≈32 cm, 19 cm, and 75 cm in East, North, and Height, respectively) indicate that, despite the use of differential techniques, short observation durations are still insufficient to fully stabilize the solution. This is primarily due to the limited number of observations available for resolving carrier-phase ambiguities and accurately estimating residual atmospheric effects, particularly the troposphere. In double-difference processing, although many systematic errors such as satellite clock and orbit biases are effectively reduced or eliminated, the reliability of ambiguity resolution and baseline estimation remains strongly dependent on observation time and data redundancy.

The significant improvement in accuracy after the first few hours highlights the effectiveness of extended observation sessions in strengthening the adjustment model. As more data are accumulated, the redundancy of the system increases, allowing for more reliable ambiguity fixing and improved estimation of atmospheric delays. The achievement of centimeter-level accuracy within approximately two hours reflects the strength of network-based positioning, which benefits from short-to-medium baseline constraints and high-quality reference station data. This is a key advantage over standalone techniques, as the inclusion of multiple reference stations enhances solution stability and accelerates the transition to high-accuracy positioning.

The gradual refinement toward millimeter-level accuracy with longer observation durations further demonstrates the impact of prolonged data collection on solution quality. However, differences in convergence rates among coordinate components are evident. The East component reaches millimeter-level accuracy faster (≈11 hours) than the North (≈15 hours) and Height (≈16 hours). This variation can be attributed to satellite geometry and the differential sensitivity of each component to residual errors. The vertical component, in particular, is more susceptible to tropospheric mismodeling and generally exhibits weaker geometric strength, resulting in slower convergence. The North component may also be influenced by the spatial distribution of satellite tracks and baseline orientations relative to the reference network.

The use of datasets from geographically distributed locations across Libya provides additional insight into the influence of spatial geometry and satellite visibility. Even under open-sky desert conditions, variations in station location affect the configuration of baselines with respect to reference stations, which in turn impacts the strength and stability of the solution. This confirms that positioning accuracy is influenced not only by observation duration but also by network geometry and the spatial relationship between rover and reference stations. At longer observation durations, the solution stabilizes and achieves millimeter-level accuracy across all components. This reflects the combined benefits of precise reference station data, effective error cancellation through double differencing, and increased observational redundancy. The AUSPOS processing strategy ensures a robust and reliable solution by anchoring user observations to a global network, thereby minimizing systematic errors and enhancing overall positioning consistency.

In summary, the findings confirm that AUSPOS, as a network-based relative positioning service, is capable of delivering high-precision results under GPS-only processing. While centimeter-level accuracy can be achieved within a few hours, the results highlight that extended observation time is still essential for reaching millimeter-level precision and ensuring solution stability. These outcomes emphasize the importance of observation duration, network geometry, and data quality in achieving optimal performance in high-precision GNSS applications.

3. Conclusion

This study investigated the performance of dual-frequency static double-differenced relative positioning using the AUSPOS online service as a function of observation duration under a GPS-only processing strategy. The results confirm that positioning accuracy is strongly time-dependent, with relatively large errors observed during short observation periods, followed by rapid improvement and eventual stabilization at high precision levels. The findings show that decimeter-level accuracy characterizes the initial stage of processing, where one-hour solutions exhibit significant errors, particularly in the vertical component. However, the solution improves substantially with increasing observation time, achieving centimeter-level accuracy within approximately two hours. Continued data accumulation leads to further refinement, reaching millimeter-level precision after extended observation periods of approximately 11 to 16 hours, depending on the coordinate component. As AUSPOS operates using a network-based relative positioning approach based on double-difference observations, this strategy enables effective mitigation of satellite-related errors through differencing and benefits from strong geometric constraints provided by IGS and APREF reference station networks. As a result, the method delivers robust and reliable positioning solutions. Nevertheless, despite these advantages, the results demonstrate that sufficient observation time remains essential for reliable ambiguity resolution, accurate atmospheric modeling, and overall solution stability. The analysis also highlights differences in convergence behavior among coordinate components, with the vertical component exhibiting the slowest improvement due to its higher sensitivity to residual atmospheric errors and weaker geometric strength. Additionally, the use of geographically distributed datasets emphasizes the influence of satellite geometry and network configuration on positioning performance, even under ideal open-sky conditions.

Overall, AUSPOS proves to be a reliable and effective tool for high-precision static GNSS positioning. While centimeter-level accuracy can be achieved within relatively short observation durations, obtaining consistent millimeter-level results requires longer sessions. These findings underline the importance of balancing observation time with required accuracy in practical applications and provide valuable guidance for surveyors and engineers relying on network-based GNSS processing solutions.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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