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(RESEARCH ARTICLE)

Performance Assessment of Dual-Frequency Static GPS Positioning Using OPUS as a Function of Observation Duration

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Abstract

This study investigates the performance of dual-frequency static positioning as a function of observation length using the free Online Positioning User Service (OPUS) under a GPS-only processing configuration. OPUS is a publicly accessible online GPS processing service developed by the National Geodetic Survey (NGS). It offers free access to highly accurate coordinates within the National Spatial Reference System (NSRS). The service employs the same processing software used to determine coordinates for the nation's geodetic control points and the NOAA Continuously Operating Reference Stations (CORS) Network. OPUS is capable of processing GPS data collected anywhere in the world. The evaluation is conducted using ten GNSS datasets acquired from various sites across Libya with dual-frequency receivers operating in static mode under open-sky desert environments. Each dataset contains continuous 24-hour observations, and processing was carried out at fixed observation intervals ranging from 1 to 24 hours. The complete 24-hour solution was considered the reference standard for evaluating accuracy in the Easting, Northing, Height, 2D, and 3D components. The findings indicate that the performance of relative positioning is highly influenced by the observation duration. At one hour of data collection, comparatively large errors are recorded, reaching about 22 cm, 15 cm, and 15 cm in the Easting, Northing, and Height components, respectively, corresponding to 26 cm and 31 cm in 2D and 3D accuracy. Following two hours of observation, the accuracy improves to approximately 2 cm, 4 cm, and 7 cm in the Easting, Northing, and Height components, respectively, equivalent to 5 cm and 8 cm in 2D and 3D accuracy. Nevertheless, a substantial enhancement is achieved as the observation period increases, with centimeter-level accuracy (~1 cm) attained in all coordinate components after three hours of processing. Extending the observation duration further results in progressive refinement of the solution, reaching millimeter-level accuracy after nearly 10, 16, and 17 hours in the Easting, Northing, and Height components, respectively, beyond which the solution becomes stable. These outcomes demonstrate that GPS-only static positioning using OPUS can provide high-precision coordinate estimates under open-sky conditions; however, its convergence rate remains relatively slow and strongly dependent on the observation period. The inclusion of datasets from geographically dispersed locations also illustrates the impact of satellite geometry and visibility on positioning accuracy and stability. In general, the results highlight the importance of adequate observation duration for achieving dependable centimeter- to millimeter-level accuracy in GPS-only static double-difference relative positioning.

Keywords: GPS; DGNSS; OPUS; Static Positioning; Fixing Time

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

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(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 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). The system is capable of processing data collected from any location worldwide. Users can submit dual-frequency, geodetic-quality GPS RINEX observations acquired in static mode, after which an OPUS report containing International Terrestrial Reference Frame (ITRF) coordinates is delivered via email.

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 GPS-only 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 service. This topic merits additional investigation because most previous research has focused on DGNSS performance at the final convergence epoch rather than evaluating the evolution of positioning accuracy at successive hourly intervals. Moreover, collecting observations in multipath-free desert environments offers a clearer understanding of the inherent capability of GPS measurements without the interfering effects of multipath and unfavorable satellite geometry.

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 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 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 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 [29–33].

2. Results and Discussion

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

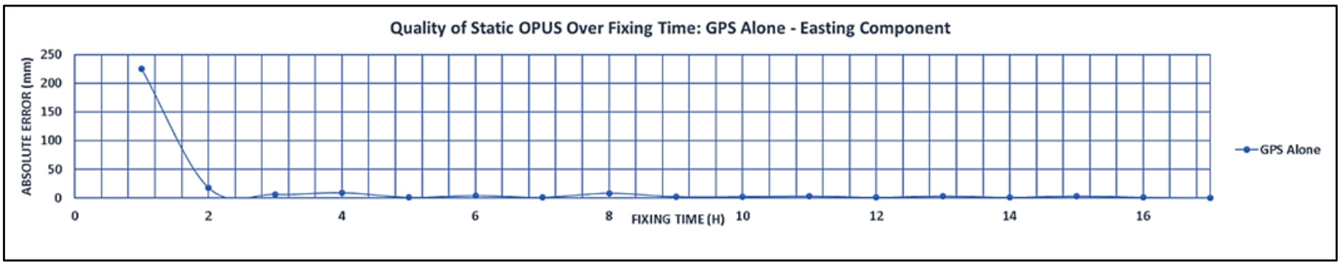

Figure 1 Quality of static GPS-alone over fixing time using OPUS - Easting component

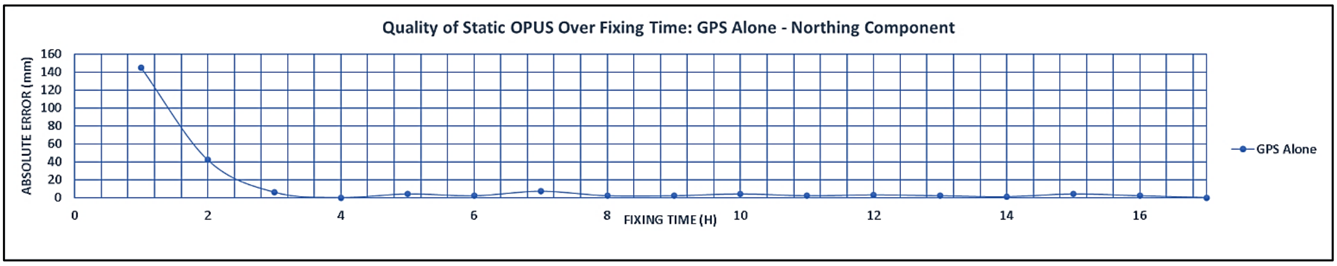

Figure 2 Quality of static GPS-alone over fixing time using OPUS - Northing component

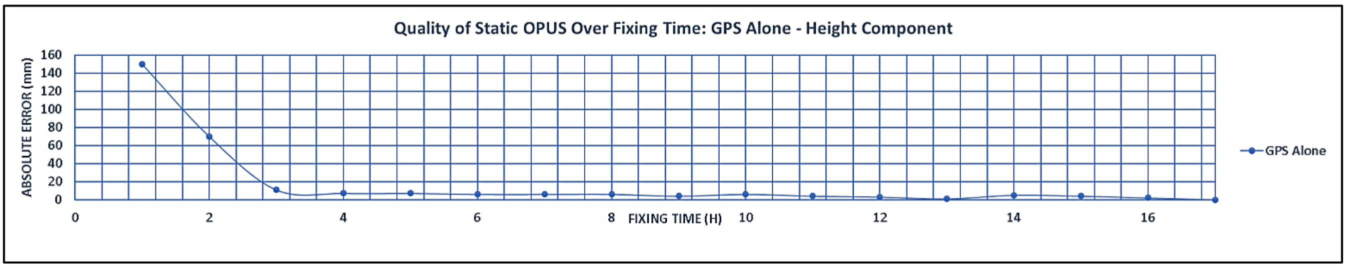

Figure 3 Quality of static GPS-alone over fixing time using OPUS - Height component

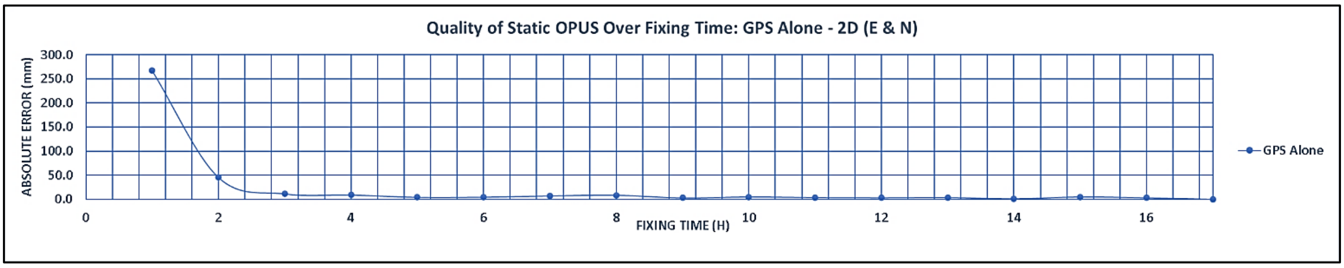

Figure 4 Quality of static GPS-alone over fixing time using OPUS – 2D component

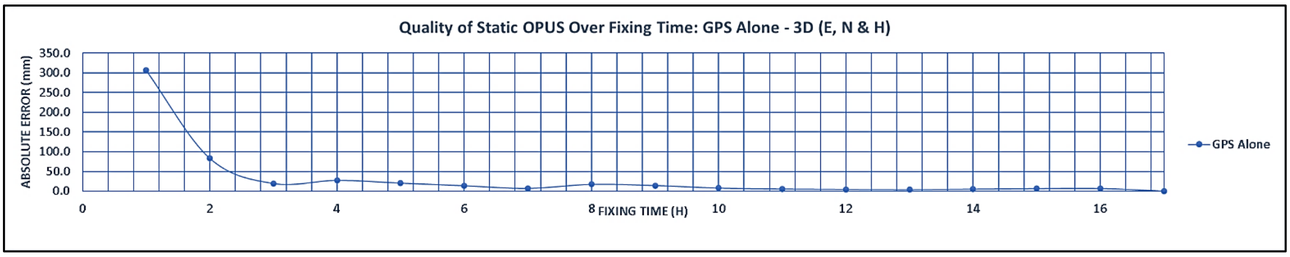

Figure 5 Quality of static GPS-alone over fixing time using OPUS – 3D component

The results clearly demonstrate that the accuracy of static GPS-only positioning processed through OPUS is highly dependent on observation duration, with solution quality improving systematically as the observation session becomes longer. The transition from decimeter-level errors during short occupations to millimeter-level precision during extended sessions reflects the fundamental principles of carrier-phase-based relative positioning. Since OPUS employs a network-based double-differencing strategy rather than a standalone PPP approach, the observed behavior is governed not only by the quality of the rover observations but also by the strength of the reference network and the effectiveness of ambiguity resolution. By utilizing the same processing infrastructure used for the National Geodetic Survey (NGS) control network and the NOAA Continuously Operating Reference Stations (CORS), OPUS benefits from a highly rigorous adjustment framework capable of producing geodetic-grade coordinate solutions.

The relatively large errors observed after only one hour of observation (approximately 22 cm, 15 cm, and 15 cm in the Easting, Northing, and Height components, respectively) indicate that short observation intervals do not provide sufficient information for the full exploitation of carrier-phase measurements. Although double-difference processing effectively removes or significantly reduces common error sources such as satellite clock biases, orbit errors, and a substantial portion of atmospheric effects, the reliability of ambiguity resolution remains strongly dependent on the quantity and quality of available observations. During the early stages of processing, residual atmospheric delays, measurement noise, and incomplete ambiguity fixing can still propagate into the coordinate solution, limiting achievable accuracy. Consequently, short-duration observations may not fully realize the potential advantages of high-precision relative positioning, even when processed using a sophisticated network-based framework.

A substantial improvement in positioning performance is evident as observation duration increases. After two hours, the coordinate accuracy improves dramatically to approximately 2 cm, 4 cm, and 7 cm in the Easting, Northing, and Height components, respectively, while centimeter-level accuracy is achieved in all components after roughly three hours of observation. This rapid improvement highlights one of the primary strengths of relative carrier-phase positioning: the ability to quickly refine coordinate estimates once sufficient observational redundancy becomes available. As additional satellite observations are accumulated, ambiguity fixing becomes increasingly reliable, adjustment models become more stable, and residual atmospheric effects are estimated with greater precision. The ability of OPUS to achieve near-centimeter accuracy within only a few hours demonstrates the effectiveness of integrating high-quality reference station data with robust double-difference processing algorithms.

The continued refinement of the solution beyond the initial convergence phase further illustrates the value of long-duration observations in high-precision geodetic applications. The progressive reduction of coordinate errors toward the millimeter level indicates that extended observation sessions provide additional redundancy that strengthens the network adjustment and minimizes the influence of residual stochastic and systematic errors. However, the convergence behavior is not uniform across all coordinate components. The Easting component reaches millimeter-level precision after approximately 10 hours, whereas the Northing and Height components require approximately 16 and 17 hours, respectively. Such differences are consistent with well-established GNSS positioning theory and can largely be attributed to satellite geometry and the unequal propagation of residual errors into different coordinate directions.

The slower convergence of the vertical component is particularly expected. In GNSS positioning, height estimation is inherently weaker than horizontal positioning because satellites are distributed primarily above the observer rather than below the horizon, resulting in less favorable geometric conditions for vertical determination. Furthermore, residual tropospheric errors are highly correlated with height estimation and often represent one of the dominant limitations affecting vertical accuracy. Even under open-sky conditions, imperfect modeling of tropospheric delays can prolong convergence and delay the attainment of millimeter-level precision. Similarly, the Northing component may experience slower refinement due to the specific geometry of satellite ground tracks and their spatial relationship with the reference network used during processing.

The use of ten datasets collected from geographically distributed locations across Libya provides valuable insight into the robustness of the OPUS solution under varying spatial configurations. Although all observations were acquired under ideal open-sky desert conditions with negligible multipath interference, differences in station location inevitably influence satellite visibility patterns, baseline geometry, and the spatial relationship between rover stations and the surrounding reference network. These factors contribute to subtle variations in solution behavior and convergence characteristics. The results therefore demonstrate that positioning performance is governed not solely by observation duration but also by the geometric strength of the overall network configuration. This finding reinforces the importance of considering both temporal and spatial factors when assessing the performance of high-precision GNSS positioning services.

Another important observation is the remarkable stability of the solutions once observation durations exceed approximately 16–17 hours. Beyond this point, only marginal improvements are observed, indicating that the coordinate estimates have effectively reached their maximum achievable precision under the given observational conditions. This stabilization reflects the cumulative benefits of extensive observational redundancy, highly reliable ambiguity resolution, accurate atmospheric modeling, and the rigorous error mitigation inherent to the double-difference processing strategy employed by OPUS. The resulting coordinate solutions exhibit the consistency and repeatability required for demanding geodetic and engineering applications.

Overall, the findings confirm that OPUS is capable of delivering geodetic-quality positioning using GPS-only observations when adequate observation time is available. The results demonstrate that centimeter-level accuracy can be obtained within approximately three hours, making the service suitable for a wide range of surveying and engineering tasks. Nevertheless, achieving millimeter-level precision requires substantially longer observation sessions, emphasizing that observation duration remains one of the most critical factors controlling final solution quality. The study further highlights the combined influence of observation length, network geometry, satellite visibility, and atmospheric error mitigation on positioning performance. Under favorable open-sky conditions, OPUS provides a reliable and highly accurate network-based relative positioning solution, capable of supporting applications that demand the highest levels of coordinate precision.

3. Conclusion

This study assessed the performance of dual-frequency static GPS positioning using the Online Positioning User Service (OPUS) under a GPS-only processing strategy, with particular emphasis on the influence of observation duration on solution accuracy. The results clearly demonstrate that positioning performance is strongly dependent on observation time, with accuracy improving systematically as additional observations are accumulated. Short observation sessions are characterized by relatively large positioning errors, especially in the vertical component, whereas longer observation periods significantly enhance solution quality and stability. The analysis indicates that one-hour observation sessions provide only decimeter-level positioning accuracy, reflecting the limitations associated with insufficient observational redundancy and incomplete ambiguity resolution. A substantial improvement is observed as the observation duration increases, with centimeter-level accuracy achieved after approximately two to three hours of data collection. Continued extension of the observation period further refines the coordinate estimates, ultimately leading to millimeter-level precision after approximately 10, 16, and 17 hours in the Easting, Northing, and Height components, respectively. Beyond these intervals, the solutions exhibit high stability, indicating that the positioning process has effectively reached full convergence.

The results also confirm the effectiveness of the OPUS network-based relative positioning methodology. Through the use of double-difference carrier-phase observations and high-quality reference station data, OPUS successfully minimizes many common GNSS error sources and produces robust geodetic-grade coordinate solutions. Nevertheless, the findings emphasize that the advantages of differential processing alone are not sufficient to guarantee maximum accuracy; adequate observation time remains a critical requirement for reliable ambiguity fixing, improved atmospheric error estimation, and overall solution stability. Furthermore, the analysis reveals distinct convergence characteristics among coordinate components. The horizontal coordinates converge more rapidly, whereas the vertical component requires substantially longer observation periods to achieve comparable precision due to weaker satellite geometry and greater sensitivity to residual atmospheric effects. The use of datasets collected from geographically distributed locations across Libya additionally demonstrates that satellite visibility, network geometry, and station location can influence positioning performance, even under ideal open-sky conditions.

Overall, the findings confirm that OPUS is a highly reliable and efficient tool for high-precision static GNSS positioning. The service is capable of delivering centimeter-level accuracy within a relatively short observation period, making it suitable for a wide range of surveying, mapping, and engineering applications. However, applications requiring the highest levels of geodetic precision should employ longer observation sessions to ensure stable millimeter-level results. These outcomes provide practical guidance for optimizing observation duration according to accuracy requirements and further demonstrate the capability of OPUS to support demanding geospatial and engineering applications through network-based GNSS processing.

References

[1] Hofmann-Wellenhof B, Lichtenegger H, Wasle E. GNSS global navigation satellite systems: GPS, GLONASS, Galileo, and More. 2007

[2] Amami M, Smith M, Kokkas N. Low-Cost Vision Based Personal Mobile Mapping System. ISPRS- International Archives of The Photogrammetry, Remote Sensing and Spatial Information Sciences. 2014; XL-3/W1: 1-6.

[3] Amami M. Testing Patch, Helix and Vertical Dipole GPS Antennas with/without Choke Ring Frame. International Journal for Research in Applied Sciences and Engineering Technology. Feb. 2022; 10(2): 933-938.

[4] Amami M. A Novel Design Concept of Cost-Effective Permanent Rail-Track Monitoring System. World Journal of Advanced Research and Reviews. March 2022; 13(3): 451-473.

[5] Amami M. The Integration of Stand-Alone GPS Code Positioning, Carrier Phase Delta Positioning and MEMS-Based INS. International Research Journal of Modernization in Engineering Technology and Science. March 2022; 4(3): 700-715.

[6] Amami M. Enhancing Stand-Alone GPS Code Positioning Using Stand-Alone Double Differencing Carrier Phase Relative Positioning. Journal of Duhok University (Pure and Eng. Sciences). 2017; 20(1): 347 355.

[7] Amami M. The Integration of Time-Based Single Frequency Double Differencing Carrier Phase GPS/ Micro-Elctromechanical System-Based INS. International Journal of Recent Advances in Science and Technology. Dec. 2018; 5(4): 43-56.

[8] Amami M. The Advantages and Limitations of Low-Cost Single Frequency GPS/MEMS-Based INS Integration. Global Journal of Engineering and Technology Advances. Feb. 2022; 10(2): 018-031.

[9] Amami M. The Integration of Image-Based Navigation and GPS Carrier Phase Delta Positioning for Aerial Triangulation using Low-Cost Drones with Limited Number of Ground Control Points. Quest Journals. 2022; 7(5): 23-31.

[10] Amami M, EL-Turki A, Rustum A, EL-Amaari I, Jabir T. Topographic Surveying using low-cost amateur drones and 4K ultra-high-definition videos. Open Access Research Journal of Science and Technology. April 2022; 4(2): 072-082.

[11] Amami M, Elmehdwi A, Borgaa A, Buker A, Alareibi A. Investigations into utilizing low-cost amateur drones for creating ortho-mosaic and digital elevation model. International research journal of modernization in engineering technology and science. March 2022; 4(3): 2107-2118.

[12] Amami M. Enhancing the Quality of Kinematic PPP in Partially and Heavily Obscured-Sky Using Stand-Alone Double Differencing Carrier Phase Relative Positioning. Open Access Research Journal of Science and Technology. February 2026; 16(01): 065-076.

[13] Amami M. The Integration of PPP, Stand-Alone Double Differencing Carrier Phase Relative Positioning and MEMS-Based INS. Magna Scientia Advanced Research and Reviews. March 2026; 16(02): 018-034.

[14] Amami M. Assessment of Static PPP Accuracy Over Observation Time Using Qinertia Cloud: GPS vs. GPS+GLONASS Integration. Global Journal of Engineering and Technology Advances (GJETA). April 2026; 27 (01), 100-105.

[15] Amami M. Performance Evaluation of Kinematic PPP Using Qinertia Cloud: GPS vs. GPS+GLONASS. World Journal of Advanced Research and Reviews. April 2026; 30 (01), 1982-1987.

[16] Amami M. Investigations into the quality of final-product dual frequency kinematic PPP in open sky using CSRS-PPP free online service: GPS Vs. GPS+GLONASS. Global Journal of Engineering and Technology Advances (GJETA). November 2025; 25(2):138-143.

[17] Amami M. Investigations into the quality of final-product dual-frequency static PPP over fixing time using CSRS-PPP free online service: GPS Vs. GPS + GLONASS. World Journal of Advanced Engineering Technology and Sciences (GJETA). November 2025; 17(2): 438-443.

[18] Amami M. Kinematic PPP Using PPP-WIZARD Free Online Service: GPS Vs. GPS + GLONASS. International Research Journal of Modernization in Engineering Technology and Science. December 2025; 7(12): 3445-3451.

[19] Amami M. Quality of Static PPP over observation time using PPP-WIZARD free online service: GPS Vs. GPS+ GLONASS. Open Access Research Journal of Science and Technology. December 2025; 15(2): 195-200

[20] Amami M, Fadeil A. Investigations into the quality of Kinematic PPP in open-sky using final-product APPS free online GPS-alone service. GSC Advanced Research and Reviews. January 2026; 26(1): 023:028

[21] Amami M, Fadeil A. Evaluating the Quality of Static PPP Over Observation Time Using APPS Free Online GPS-Alone Service. International Journal of Engineering Development and Research. January 2026; 14(1): 787-792

[22] Amami M. Dual-Frequency Static PPP Over Fixing Time Using Final-Product Free Online Services: CSRS-PPP Vs. PPP-WIZARD Vs. APPS. Global Journal of Engineering and Technology Advances. February 2026; 26(02): 039-047

[23] Amami M. Dual-Frequency Kinematic PPP in Free-Multipath Open-Sky: CSRS-PPP vs. PPP-WIZARD Vs. APPS. International Journal for Research in Applied Science & Engineering Technology. February 2026; 14(I): 1005-1014.

[24] Amami M. Static PPP over observation time using magic-GNSS: GPS Vs. GLONASS Vs. GPS+GLONASS. GSC Advanced Research and Reviews. May 2026; 27(02): 001-007.

[25] Amami M. Dual-frequency static GNSS solution over fixing time using Trimble RTX-PP free online service: GPS Vs. GPS+GLONASS. International Journal of Science and Research Archive. May 2026; 19(02): 196-201.

[26] Amami M. Kinematic PPP in Free-Multipath Open-Sky: CSRS-PPP Vs. Qinertia Cloud. Global Journal of Engineering and Technology Advances. May 2026; 27(02): 129:138.

[27] Amami M. CSRS-PPP and Trimble RTX-PP Static GNSS Solution Under GPS-Only and GPS+GONASS Configurations. World Journal of Advanced Engineering Technology and Sciences (GJETA). May 2026; 30(02): 1348-1354.

[28] Amami M. Static PPP Over Observation Time: Magic-GNSS Vs. Qinertia Cloud. International Journal of Science and Research Archive. May 2026; 19(02): 1015-1023.

[29] Amami M. Speeding up SIFT, PCA-SIFT and SURF Using Image Pyramid. Journal of Duhok University, [S.I]. July 2017; 20(1): 356-362.

[30] Amami M. Fast and Reliable Vision-Based Navigation for Real Time Kinematic Applications. International Journal for Research in Applied Sciences and Engineering Technology. Feb. 2022; 10(2): 922-932.

[31] Amami M. Comparison Between Multi and Single Epipolar Geometry-Based Filters for Optical Robot Navigation. International Research Journal of Modernization in Engineering Technology and Science. March 2022; 4 (3): 476-485.

[32] Amami M. Comparison Between Multi Epipolar Geometry and Conformal 2D Transformation-Based Filters for Optical Robot Navigation. International Journal for Research in Applied Sciences and Engineering Technology. March 2022; 10(3): 388-398.

[33] Amami M. Multi and Single Epipolar Geometry-Based Filters Vs. Affine and conformal 2D Transformation-Based Filters. Global Journal of Engineering and Technology Advances. March 2022; 10(3): 032-051.