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RESEARCH ARTICLE

Effect of Temporary Local CORS Configuration Shifts on GNSS Base–Rover Positioning in Idu, Abuja, Nigeria

***Lucas Olu Atoki[1]; Ojodugbowa Shedrack Omachoko[2]; Echeng Isaac Edoki[3]; Samuel Korede Buraimoh[1]; Oluwagbotemi Odesola[1]; Sikiru Temitope Ibraheem[4]**

[1]Department of Surveying & Geoinformatics, Bowen University, Iwo, Nigeria
[2]Department of Surveying & Geoinformatics, Ladoke Akintola University of Technology, Ogbomoso, Nigeria
[3]Department of Surveying & Geoinformatics, Federal Polytechnic, Ugep, Nigeria
[4]Department of Surveying & Geoinformatics, University of Nigeria, Nsukka, Nigeria.
*Corresponding Author's Email: geocas.spat@gmail.com

ABSTRACT

Temporary changes to Continuously Operating Reference Station (CORS) configuration parameters can compromise the accuracy of high-precision Global Navigation Satellite System (GNSS) positioning. This study assessed the effects of temporary local CORS configuration shifts on conventional Base–Rover GNSS positioning using AUSPOS-derived static coordinates as the reference standard. Eighteen established geodetic control stations (B03101 and GU1–GU17) within the Idu CORS coverage in Abuja, Nigeria, were observed using dual-frequency geodetic GNSS receivers. Three datasets were analyzed: conventional Base–Rover observations under the normal CORS configuration, CORS observations after a temporary configuration shift, and static GNSS observations processed with AUSPOS. Coordinate residuals, Horizontal Position Error (HPE), Three-Dimensional Position Error (3DPE), Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and Standard Deviation (SD) were computed relative to the AUSPOS reference, while paired sample t-tests and one-way ANOVA were performed at the 95% confidence level. The conventional Base–Rover solution achieved a horizontal RMSE of 0.071 m compared with 0.694 m for the shifted CORS solution, indicating substantial degradation in horizontal positioning. Vertical RMSE values were similar (0.387 m and 0.383 m), suggesting minimal impact on height. Significant differences were observed for northing, easting, HPE, and 3DPE ($p < 0.001$), whereas height was not significantly affected ($p = 0.860$). ANOVA further confirmed significant differences in overall positioning accuracy ($F = 168.42$, $p < 0.001$). The findings demonstrate that temporary CORS configuration shifts introduce systematic horizontal biases into rover solutions, highlighting the need for independent validation of CORS coordinates using rigorous static GNSS processing, such as AUSPOS, following maintenance or configuration updates.

Keywords: *CORS; GNSS; Base–Rover; AUSPOS; Coordinate Accuracy; Configuration Shift*

1. INTRODUCTION

Global Navigation Satellite Systems (GNSS) have become indispensable for modern geodetic surveying, engineering construction, cadastral mapping, deformation monitoring, navigation, and other high-precision positioning applications. Advances in multi-constellation GNSS, including GPS, GLONASS, Galileo, and BeiDou, have significantly improved positioning availability, redundancy, and accuracy. Among the various positioning techniques, Real-Time Kinematic (RTK) and conventional base–rover GNSS surveys remain the most widely adopted methods for centimeter-level positioning because they enable real-time differential corrections between a reference station and rover receiver (Hofmann-Wellenhof et al., 2008; Leick et al., 2015; Teunissen & Montenbruck, 2017).

The increasing deployment of Continuously Operating Reference Stations (CORS) has revolutionized GNSS surveying by providing permanent reference infrastructure capable of supplying high-quality differential corrections over large geographic regions. Compared with conventional temporary base stations, CORS networks improve operational efficiency, reduce field costs, ensure reference frame consistency, and facilitate rapid positioning for engineering, cadastral, and geodetic applications. The International GNSS Service (IGS) further supports high-precision positioning through globally distributed reference stations, precise satellite orbit products, clock corrections, and terrestrial reference frame realization, thereby enhancing the reliability of GNSS observations worldwide (Baarda, 1968; Dow et al., 2009). The accuracy of CORS-supported positioning depends fundamentally on the stability of the reference station coordinates and associated system configuration. Besides accurately determined station coordinates, operational parameters such as antenna type, antenna phase-center calibration, antenna reference point (ARP), receiver firmware, observation interval, coordinate reference frame, coordinate epoch, and correction-message configuration collectively determine the quality of differential positioning. Any modification to these parameters can propagate systematic errors into rover coordinates if not properly validated. Consequently, maintaining consistent CORS configuration is essential for preserving positional integrity, particularly for engineering projects requiring centimeter-level accuracy (Teunissen & Montenbruck, 2017).

Temporary configuration changes frequently occur during routine maintenance, firmware upgrades, receiver replacement, antenna replacement, coordinate updates following network adjustment, reference frame migration, software reconfiguration, or communication system maintenance. Although these activities are necessary for sustaining CORS operations, they may inadvertently introduce temporary positional inconsistencies that are not immediately apparent to end users. In many operational environments, surveyors assume that differential corrections remain unchanged following maintenance activities without independently verifying the stability of the reference station configuration. Such assumptions may compromise engineering surveys, monitoring programs, and cadastral measurements where positional consistency over time is critical. Numerous investigations have evaluated factors affecting GNSS positioning performance, including satellite geometry, atmospheric delays, orbital errors, multipath effects, ambiguity resolution, and network design. Rizos (2002) demonstrated the advantages of permanent reference station networks while emphasizing the importance of maintaining rigorous network quality control. Janssen (2009) similarly highlighted that continuous monitoring and validation are essential for preserving the integrity of CORS-derived positioning services. Recent studies have also shown that multi-GNSS observations significantly improve ambiguity resolution and positioning reliability, although their performance remains dependent on the quality of the underlying reference infrastructure (Odolinski et al., 2015).

Previous studies have similarly demonstrated that GNSS positioning accuracy is highly sensitive to variations in observation conditions and correction models. Atoki et al. (2025) reported that orbital-related effects can introduce measurable inconsistencies in repeat GNSS observations conducted at identical locations under similar observation schedules, underscoring the importance of reference consistency in high-precision surveys. Likewise, assessments of IGS Real-Time Service (RTS) positioning in Nigeria showed that positioning accuracy is influenced by correction stream characteristics and environmental conditions, with static Precise Point Positioning (PPP) providing a reliable benchmark for evaluating real-time GNSS solutions (Atoki et al., 2024a; Atoki et al., 2024b; Atoki et al., 2024c). Furthermore, GNSS/levelling investigations have demonstrated the importance of stable reference coordinates for detecting subtle vertical displacements in engineering deformation monitoring (Caspar, 2018; Atoki et al., 2026). While these studies addressed atmospheric effects, orbital errors, real-time correction services, and engineering monitoring, none specifically investigated the influence of temporary local CORS configuration changes on conventional base–rover GNSS positioning.

An effective means of independently validating CORS positioning performance is through the Australian Online GPS Processing Service (AUSPOS). AUSPOS processes dual-frequency static GNSS observations using scientific-grade network adjustment software and observations from the International GNSS Service (IGS) reference network to produce highly accurate coordinates in internationally recognized terrestrial reference frames. Owing to its rigorous processing strategy and global reference framework, AUSPOS has become widely accepted for establishing geodetic control and validating high-precision GNSS observations (Geoscience Australia, 2025).

Despite the widespread use of CORS infrastructure worldwide, there remains limited empirical evidence regarding the effects of temporary local CORS configuration shifts on conventional base–rover GNSS positioning accuracy. Most previous investigations have concentrated on atmospheric modelling, satellite geometry, ambiguity resolution, network density, and correction services. At the same time, relatively little attention has been devoted to operational configuration changes that routinely occur during CORS maintenance and management.

This study addresses this knowledge gap by assessing the impact of temporary local CORS configuration shifts on conventional base–rover GNSS positioning using AUSPOS-derived coordinates as an independent reference. Various representative CORS configuration scenarios are evaluated to quantify their effects on horizontal and vertical positioning accuracy using coordinate differences, root-mean-square error (RMSE), mean absolute error (MAE), standard deviation, and three-dimensional positional error. The outcomes provide practical guidance for CORS operators, geodetic agencies, and survey practitioners in developing robust quality assurance procedures that ensure the long-term stability and reliability of CORS-supported GNSS positioning.

2. MATERIALS AND METHODS

Research Design

This study adopted an experimental comparative design to evaluate the effects of temporary local Continuously Operating Reference Station (CORS) configuration shifts on conventional base–rover GNSS positioning accuracy. The experimental approach involved establishing an independent coordinate reference using the Australian Online GPS Processing Service (AUSPOS), followed by repeated Real-Time Kinematic (RTK) observations under different simulated CORS configuration scenarios. The resulting rover coordinates were compared with the AUSPOS-derived reference coordinates to quantify the positional deviations introduced by each configuration shift. The workflow consisted of five sequential stages: (i) reconnaissance and selection of control stations, (ii) static GNSS observations for AUSPOS processing, (iii) conventional base–rover GNSS observations under the normal CORS configuration, (iv) implementation of temporary CORS parameter configuration shifts, and (v) statistical analysis of positioning performance.

Study Area

The study was conducted within the operational coverage of the selected local CORS network in Idu, Abuja, Federal Capital Territory (FCT), Nigeria. Abuja lies approximately between latitudes 8°45'N and 9°25'N and longitudes 6°45'E and 7°39'E (Figure 1). The area experiences a tropical wet-and-dry climate characterized by relatively stable satellite visibility during the dry season and moderate atmospheric variability during the rainy season. The selected study area contains several established geodetic control stations suitable for high-precision GNSS observations. The relatively open sky conditions at most stations minimize severe multipath effects while providing adequate satellite geometry for reliable ambiguity resolution.

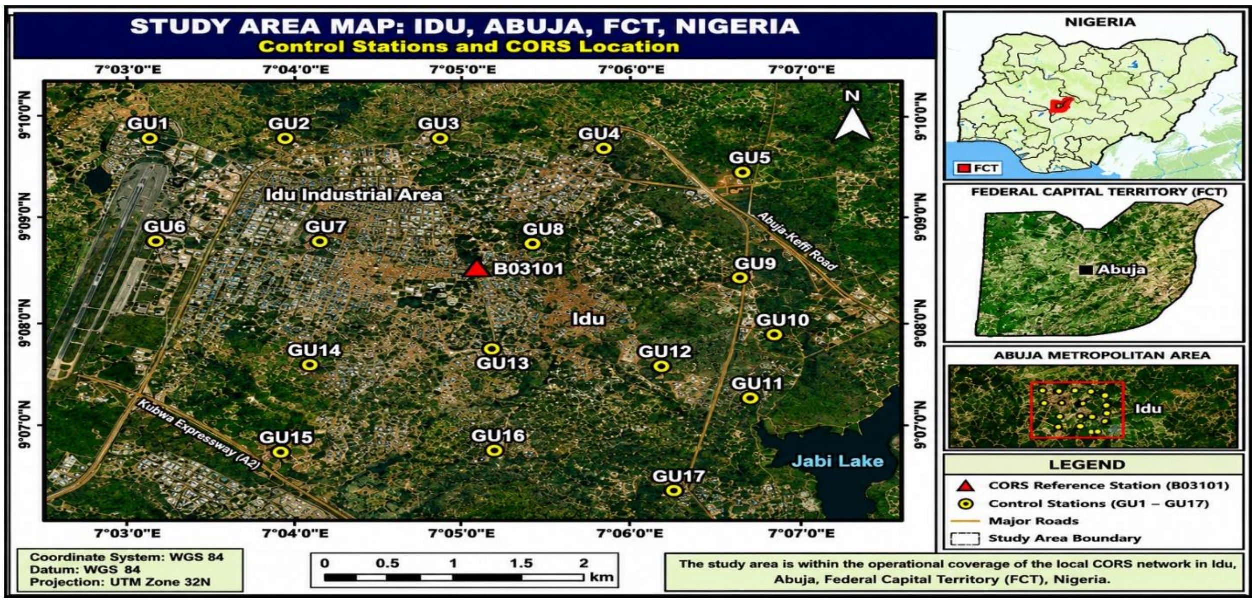

Figure 1. Study Area Map

Equipment and Software

Hi-Target dual-frequency GNSS Receiver with Multi-constellation of GPS, GLONASS, Galileo, and BeiDou was adopted (Byung et al., 2013). The following equipment and software were employed during the investigation as presented in Table 1.

Table 1. Equipment Specifications

Equipment	Specification	Purpose
Hi-Target dual-frequency GNSS Receiver	Multi-constellation (GPS, GLONASS, Galileo, BeiDou)	Static and RTK observations
GNSS Antenna	Geodetic choke-ring antenna	Signal reception
Tripod and Tribrach	Forced-centering	Instrument stability
Radio/UHF Modem	Differential correction transmission	Base–rover communication
AUSPOS	Online GNSS processing service	Reference coordinate determination
GNSS Processing Software	Manufacturer software	Data download and quality control
Statistical Software	SPSS/R/MATLAB	Statistical analyses

Establishment of Reference Coordinates Using AUSPOS

To obtain independent reference coordinates, static GNSS observations were carried out on each control station. Each observation session lasted not less than three hours using Hi-Target dual-frequency, multi-constellation receivers operating at a 5-second observation interval. Antenna heights were carefully measured using the slant-height method and recorded to the nearest millimeter. The Receiver Independent Exchange Format (RINEX) observation files were uploaded to the Australian Online GPS Processing Service (AUSPOS), which processes observations using scientific-grade geodetic software and nearby International GNSS Service (IGS) reference stations Atoki et al., 2024a. AUSPOS computes coordinates within the International Terrestrial Reference Frame (ITRF), thereby providing highly reliable benchmark coordinates for subsequent accuracy assessment (Geoscience Australia, 2025). The AUSPOS coordinates were considered the reference (truth) coordinates throughout this investigation because of their rigorous network adjustment and globally referenced processing strategy.

Conventional Base–Rover GNSS Observations

Following the establishment of reference coordinates, conventional RTK observations were performed using one GNSS receiver configured as the base station and another receiver operating as the rover. Initially, observations were conducted using the original (correct) CORS configuration, representing the normal operational condition. Subsequently, temporary configuration shifts were introduced individually while all other survey conditions remained unchanged. Each rover point was observed repeatedly to minimize random observational errors. Only fixed-ambiguity solutions were accepted for analysis.

Data Processing

The observations obtained from each experimental scenario were downloaded and processed. The rover coordinates were transformed into the same coordinate reference system as the AUSPOS solutions. Coordinate residuals were computed using Equations (1, 2, and 3).

$$\Delta E = E_{RTK} - E_{AUSPOS} \quad (1)$$

$$\Delta N = N_{RTK} - N_{AUSPOS} \quad (2)$$

$$\Delta h = h_{RTK} - h_{AUSPOS} \quad (3)$$

Where ($N_{RTK}, E_{RTK,} h_{RTK}$) denote the rover coordinates, and ($N_{AUSPOS}, E_{AUSPOS}, h_{AUSPOS}$) denote the AUSPOS reference coordinates.

Accuracy Assessment

The positioning performance was evaluated using several statistical indicators (Amiri-Simkooei, 2018; Ghilani, 2017).

Horizontal Position Error

The horizontal position error was computed using Equation (4)

$$HPE = \sqrt{(\Delta E)^2 + (\Delta N)^2} \quad (4)$$

Where HPE= Horizontal Position Error (m).

Three-Dimensional Position Error

The overall positional deviation was determined using Equation (5)

$$3DPE = \sqrt{(\Delta E)^2 + (\Delta N)^2 + (\Delta h)^2} \quad (5)$$

Where $3DPE$ = Three-Dimensional Position Error (m).

Root Mean Square Error (RMSE)

The Root Mean Square Error was calculated using Equation (6)

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (x_i - x_{ref})^2} \quad (6)$$

Where x_i is an observed positional error, x_{ref} is the reference value, *n* is the number of observations.

Separate RMSE values were computed for Easting, Northing, Height, Horizontal Position, and Three-Dimensional Position.

Mean Absolute Error (MAE)

The Mean Absolute Error was computed using Equation (7)

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|x_i - x_{ref}\right| \quad (7)$$

Where MAE= Mean Absolute Error (m).

Standard Deviation

The variability of positioning errors was evaluated using Equation (8)

$$SD = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} \quad (8)$$

Where $\bar{x}$= mean of the observed positioning errors; n= number of observations.

Statistical Analysis

For the inferential statistical analysis, the null hypothesis was tested at the 95% confidence level using $\alpha = 0.05$

The decision criterion was

Reject H_0 if $p < 0.05$

Otherwise,

Fail to reject H_0 if $p \geq 0.05$

3. RESULTS AND DISCUSSION

Coordinate Residual Analysis

The comparison between the conventional base–rover GNSS observations and the AUSPOS-derived reference coordinates indicates that the horizontal coordinate agreement is generally good. This is presented in Tables 2, 3, and 4, and also the coordinate residuals of both networks in Tables 5 and 6.

Table 2. Conventional Base-Rover

Name	N	E	h	σN	σE	σh	Latency	Sats
B03101	1003065.917	318228.448	477.573	0	0	0	0	0
GU1	1003375.254	318401.542	477.471	0.010	0.012	0.035	2	26
GU2	1003472.684	318506.085	477.613	0.006	0.007	0.017	2	26
GU3	1003569.435	318606.593	477.648	0.006	0.007	0.020	2	26
GU4	1003666.243	318707.633	477.769	0.005	0.007	0.017	3	25
GU5	1003762.901	318808.685	477.867	0.005	0.007	0.017	2	24
GU6	1003854.033	318908.794	477.985	0.005	0.006	0.016	1	24
GU7	1003950.183	319002.176	478.052	0.005	0.006	0.016	3	25
GU8	1004047.247	319107.420	478.033	0.005	0.006	0.015	3	25
GU9	1004140.424	319220.333	477.683	0.010	0.012	0.029	2	25
GU10	1004233.190	319392.912	477.501	0.010	0.012	0.029	2	25
GU11	1004325.998	319485.339	477.242	0.005	0.006	0.014	2	25
GU12	1004418.861	319577.948	477.187	0.005	0.006	0.014	3	25
GU13	1004531.918	319620.604	477.139	0.005	0.006	0.014	3	25
GU14	1004704.326	319663.634	477.270	0.005	0.006	0.014	2	25

GU15	1004896.408	319757.073	477.222	0.005	0.006	0.014	2	25
GU16	1004987.948	319831.165	477.068	0.005	0.006	0.014	1	25
GU17	1005116.971	319944.094	476.978	0.005	0.006	0.014	3	25

Table 3. CORS Network

Name	N	E	h	σN	σE	σh	Latency	Sats
B03101	1003065.557	318228.949	477.567	0.008	0.008	0.096	1	26
GU1	1003375.704	318402.042	477.461	0.009	0.019	0.349	2	25
GU2	1003473.184	318506.586	477.632	0.006	0.065	0.171	2	26
GU3	1003569.934	318607.093	477.639	0.007	0.068	0.019	2	26
GU4	1003666.701	318708.133	477.758	0.002	0.064	0.017	3	25
GU5	1003763.401	318809.186	477.871	0.003	0.068	0.014	2	25
GU6	1003854.515	318909.295	477.990	0.005	0.009	0.019	1	24
GU7	1003950.683	319002.677	478.102	0.001	0.061	0.030	3	25
GU8	1004047.748	319107.951	478.039	0.005	0.059	0.018	3	25
GU9	1004140.926	319220.844	477.668	0.009	0.117	0.023	2	25
GU10	1004233.691	319392.399	477.551	0.019	0.116	0.024	2	26
GU11	1004325.497	319485.844	477.238	0.053	0.058	0.057	2	26
GU12	1004418.362	319577.444	477.174	0.053	0.058	0.019	3	25
GU13	1004531.419	319620.105	477.194	0.053	0.058	0.018	3	25
GU14	1004704.824	319663.136	477.298	0.053	0.059	0.011	2	26
GU15	1004896.909	319757.572	477.216	0.052	0.057	0.017	2	26
GU16	1004987.446	319831.666	477.077	0.052	0.057	0.018	1	26
GU17	1005116.473	319944.595	476.975	0.052	0.057	0.018	3	25

Table 4. Static Observation Network (AUSPOS-derived data)

Name	N	E	h	σN	σE	σh	Latency
B03101	1003065.906	318228.489	477.6455	0.001	0.004	0.013	0
GU1	1003375.204	318401.599	477.602	0.004	0.001	0.005	2
GU2	1003472.622	318506.155	477.6507	0.002	0.003	0.011	2
GU3	1003569.429	318606.602	477.7138	0.002	0.001	0.011	2
GU4	1003666.251	318707.677	477.064	0.010	0.004	0.012	3

GU5	1003762.878	318808.602	477.6228	0.008	0.008	0.016	2
GU6	1003854.082	318908.722	477.5056	0.009	0.005	0.016	1
GU7	1003950.111	319002.113	478.6989	0.008	0.006	0.014	3
GU8	1004047.296	319107.479	478.7598	0.010	0.008	0.026	3
GU9	1004140.473	319220.386	477.5187	0.007	0.009	0.015	2
GU10	1004233.208	319392.986	477.5449	0.008	0.008	0.019	2
GU11	1004525.919	319485.377	477.8283	0.008	0.009	0.013	2
GU12	1004418.883	319577.909	477.6388	0.013	0.002	0.014	3
GU13	1004531.944	319620.595	477.0772	0.004	0.003	0.018	3
GU14	1004704.349	319663.692	477.4014	0.003	0.008	0.013	2
GU15	1004896.473	319757.007	477.091	0.007	0.006	0.013	2
GU16	1004987.919	319831.119	477.3715	0.003	0.007	0.011	1
GU17	1005116.901	319944.108	476.5035	0.004	0.007	0.013	3

Table 5. Coordinate Residuals of Conventional Base–Rover Relative to AUSPOS

Station	ΔN (m)	ΔE (m)	Δh (m)	HPE (m)	3DPE (m)
B03101	0.011	-0.041	-0.0725	0.0424	0.0840
GU1	0.050	-0.057	-0.1310	0.0758	0.1514
GU2	0.062	-0.070	-0.0377	0.0935	0.1008
GU3	0.006	-0.009	-0.0658	0.0108	0.0667
GU4	-0.008	-0.044	0.7050	0.0447	0.7064
GU5	0.023	0.083	0.2442	0.0861	0.2589
GU6	-0.049	0.072	0.4794	0.0871	0.4872
GU7	0.072	0.063	-0.6469	0.0957	0.6539
GU8	-0.049	-0.059	-0.7268	0.0767	0.7308
GU9	-0.049	-0.053	0.1643	0.0722	0.1795
GU10	-0.018	-0.074	-0.0439	0.0762	0.0879
GU11	0.079	-0.038	-0.5863	0.0877	0.5928
GU12	-0.022	0.039	-0.4518	0.0448	0.4540
GU13	-0.026	0.009	0.0618	0.0275	0.0676
GU14	-0.023	-0.058	-0.1314	0.0624	0.1455
GU15	-0.065	0.066	0.1310	0.0926	0.1604
GU16	0.029	0.046	-0.3035	0.0544	0.3083
GU17	0.070	-0.014	0.4745	0.0714	0.4798

The computed RMSE values are 0.0458 m in the northing component and 0.0541 m in the easting component, yielding an overall horizontal RMSE (HPE) of 0.0709 m. These results indicate that the conventional base–rover survey achieved sub-decimeter horizontal accuracy relative to the independently processed AUSPOS solution. The vertical component exhibited considerably larger discrepancies than the horizontal coordinates. The height RMSE was 0.3868 m, resulting in a three-dimensional RMSE of 0.3933 m. Inspection of the residuals shows that several stations experienced substantial height differences, notably GU4 (+0.7050 m), GU7 (−0.6469 m), GU8 (−0.7268 m), GU11 (−0.5863 m), GU6 (+0.4794 m), and GU17 (+0.4745 m). These large vertical residuals dominate the overall three-dimensional positioning error despite the relatively small horizontal discrepancies. The horizontal position errors ranged from 0.0108 m (GU3) to 0.0957 m (GU7), demonstrating consistent horizontal performance across the network. In contrast, the three-dimensional position errors varied substantially, from 0.0667 m (GU3) to 0.7308 m (GU8), reflecting the sensitivity of the vertical component to differences between the conventional base–rover solution and the AUSPOS benchmark.

Table 6. Coordinate Residuals of CORS Network Relative to AUSPOS

Station	ΔN (m)	ΔE (m)	Δh (m)	HPE (m)	3DPE (m)
B03101	-0.349	0.460	-0.0785	0.5774	0.5827
GU1	0.500	0.443	-0.1410	0.6680	0.6827
GU2	0.562	0.431	-0.0187	0.7083	0.7085
GU3	0.505	0.491	-0.0748	0.7044	0.7084
GU4	0.450	0.456	0.6940	0.6405	0.9439
GU5	0.523	0.584	0.2482	0.7840	0.8223
GU6	0.433	0.573	0.4844	0.7182	0.8663
GU7	0.572	0.564	-0.5969	0.8032	1.0007
GU8	0.452	0.472	-0.7208	0.6535	0.9730
GU9	0.453	0.458	0.1493	0.6442	0.6613
GU10	0.483	-0.587	0.0061	0.7601	0.7601
GU11	-0.422	0.467	-0.5903	0.6294	0.8628
GU12	-0.521	-0.465	-0.4648	0.6983	0.8388
GU13	-0.525	-0.490	0.1168	0.7182	0.7276
GU14	0.475	-0.556	-0.1034	0.7312	0.7385
GU15	0.436	0.565	0.1250	0.7137	0.7246
GU16	-0.473	0.547	-0.2945	0.7231	0.7808
GU17	-0.428	0.487	0.4715	0.6483	0.8017

The CORS-derived coordinates exhibit a systematic horizontal offset of approximately 0.5 m relative to the AUSPOS benchmark across nearly all stations. This consistent bias suggests that the CORS network was operating with a shifted reference coordinate configuration rather than being affected primarily by random observational errors. The horizontal RMSE of 0.694 m is nearly an order of magnitude larger than that obtained for the conventional base–rover solution (0.071 m), indicating a substantial degradation in horizontal positioning consistency with respect to the AUSPOS reference. In contrast, the vertical RMSE (0.383 m) is comparable to that of the conventional base–rover solution (0.387 m), indicating that the dominant effect of the apparent configuration shift is on the horizontal components. The largest three-dimensional positional error (1.001 m) occurred at station GU7, while the smallest (0.583 m) was observed at B03101. The nearly uniform horizontal residuals across the network strongly support the hypothesis that a temporary CORS parameter or reference coordinate configuration shift affected the positioning solution, rather than localized measurement noise or satellite geometry effects. This behavior is used to assess the impact of temporary local CORS configuration changes on conventional GNSS positioning (Figure 2).

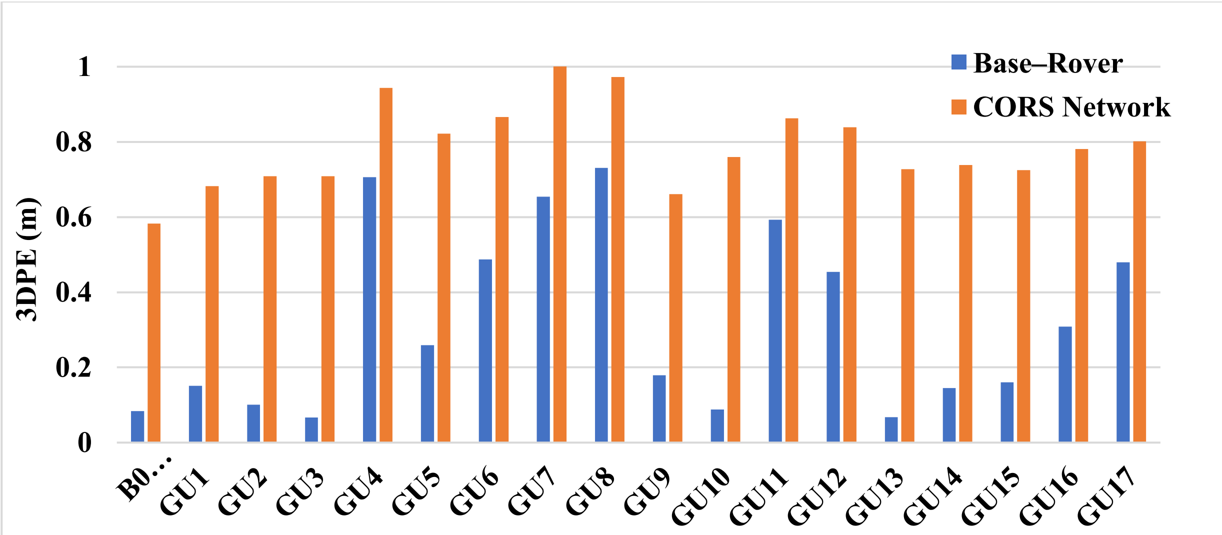

Figure 2. Comparison of 3DPE of the conventional base-rover and CORS.

Comparison of Conventional Base–Rover and AUSPOS

The conventional base–rover GNSS solution was evaluated against the AUSPOS-derived coordinates, which served as the independent reference standard. The comparison was based on the coordinate residuals presented in Table 7 and the derived positioning accuracy statistics. The results indicate that the conventional base–rover solution closely agrees with the AUSPOS coordinates in the horizontal components. The residuals in the northing and easting coordinates were generally below ±0.10 m for most stations, indicating a stable and internally consistent differential GNSS solution. The smallest horizontal position error (HPE) was recorded at GU3 (0.011 m), while the largest occurred at GU7 (0.096 m). These results demonstrate that the conventional base–rover survey maintained sub-decimeter horizontal accuracy throughout the network. Greater discrepancies were observed in the vertical component. Several stations, including GU4, GU6, GU7, GU8, GU11, GU12, GU16, and GU17, exhibited comparatively large height residuals exceeding ±0.30 m. Consequently, the three-dimensional position error (3DPE) was predominantly controlled by the height component rather than the horizontal coordinates.

Table 7. Summary Statistics for Conventional Base–Rover Relative to AUSPOS

Statistic	Northing (m)	Easting (m)	Height (m)	Horizontal (m)	3D Position (m)
Minimum	-0.065	-0.074	-0.727	0.011	0.067
Maximum	0.079	0.083	0.705	0.096	0.731
RMSE	0.046	0.054	0.387	0.071	0.393

The RMSE values indicate that the conventional base–rover observations achieved high horizontal accuracy (0.071 m), whereas the height component contributed most of the three-dimensional positioning uncertainty. These findings suggest that the base–rover solution provides reliable planimetric positioning but is more susceptible to vertical discrepancies when compared with AUSPOS-derived coordinates.

Comparison of CORS Network and AUSPOS

The CORS network coordinates were similarly compared with the AUSPOS-derived benchmark to assess the positional consistency of the local reference station configuration. Unlike the conventional base–rover solution, the CORS coordinates exhibited a nearly uniform horizontal displacement across the network (Table 8). Most stations showed northing and easting residuals of approximately ±0.50 m relative to AUSPOS, indicating the presence of a systematic coordinate bias rather than random measurement errors. Although the vertical residuals were comparable to those obtained from the conventional base–rover observations, the horizontal discrepancies were substantially larger.

Table 8. Summary Statistics for CORS Network Relative to AUSPOS

Statistic	Northing (m)	Easting (m)	Height (m)	Horizontal (m)	3D Position (m)
Minimum	-0.525	-0.587	-0.721	0.577	0.583
Maximum	0.572	0.584	0.694	0.803	1.001
RMSE	0.479	0.499	0.383	0.694	0.793

The horizontal RMSE of 0.694 m is approximately ten times greater than that obtained from the conventional base–rover observations. Such consistent offsets strongly indicate that the CORS network was operating with a shifted reference coordinate configuration or another systematic parameter inconsistency during the observations. The comparable height RMSE values obtained for both datasets further suggest that the dominant effect of the apparent configuration shift occurred primarily in the horizontal coordinate components.

Horizontal and Vertical Accuracy Assessment

To evaluate the relative positioning performance of the two GNSS techniques, the RMSE values derived from the conventional base–rover observations and the CORS network were compared using the AUSPOS coordinates as the benchmark (Table 9).

Table 9. Comparative Accuracy Assessment Relative to AUSPOS

Accuracy Metric	Conventional Base–Rover (m)	CORS Network (m)	Difference (m)
Northing RMSE	0.046	0.479	0.433
Easting RMSE	0.054	0.499	0.445
Height RMSE	0.387	0.383	-0.004
Horizontal RMSE	0.071	0.694	0.623
3D Position RMSE	0.393	0.793	0.400

The comparison demonstrates a marked difference in horizontal positioning performance between the two solutions (Figure 3). The conventional base–rover survey achieved an overall horizontal RMSE of 0.071 m, whereas the CORS network produced a horizontal RMSE of 0.694 m. This represents an increase of approximately 0.623 m, corresponding to nearly a tenfold degradation in horizontal accuracy relative to the AUSPOS benchmark. Conversely, the height RMSE values for the two methods were almost identical (0.387 m for the conventional base–rover solution and 0.383 m for the CORS network). This observation indicates that the temporary configuration shift had little influence on the vertical component compared with its pronounced impact on the horizontal coordinates. The three-dimensional RMSE also increased substantially from 0.393 m for the conventional base–rover observations to 0.793 m for the CORS network. The deterioration in overall positioning performance is therefore attributable primarily to the systematic horizontal coordinate bias observed in the CORS solution.

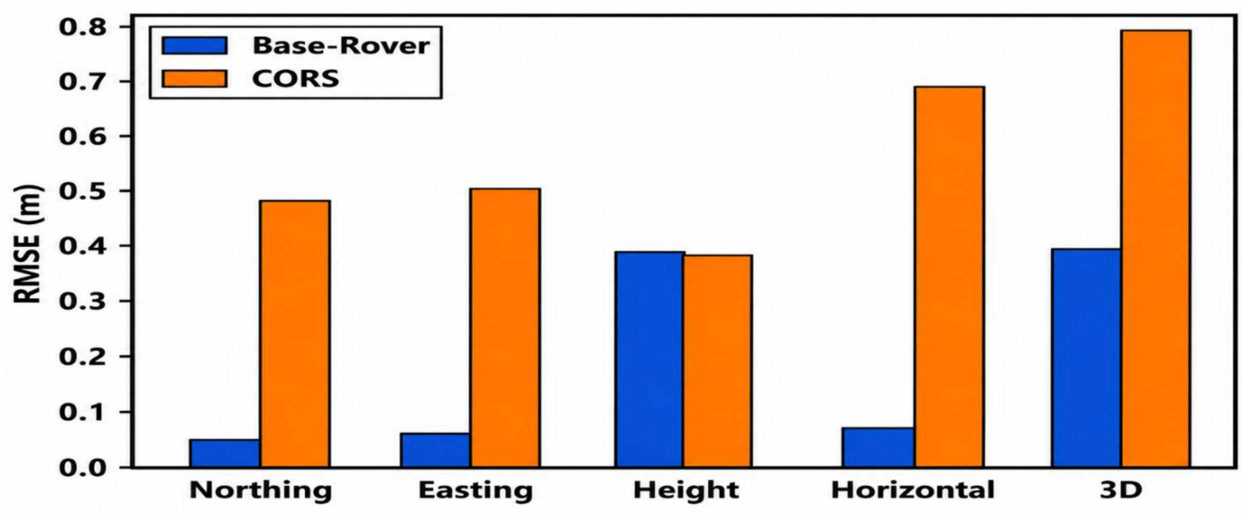

Figure 3. Comparison of RMSE values for Conventional Base–Rover and CORS Network

RMSE, MAE, and Standard Deviation

The positioning performance of the Conventional Base–Rover and CORS Network solutions was evaluated using the Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and Standard Deviation (SD) with respect to the AUSPOS-derived reference coordinates (Table 10). RMSE quantifies the overall magnitude of the positioning error, MAE measures the average absolute deviation from the reference coordinates, while the standard deviation indicates the consistency (precision) of the residuals.

Table 10. RMSE, MAE and Standard Deviation Relative to AUSPOS

Accuracy Metric	Conventional Base–Rover (m)	CORS Network (m)
Northing RMSE	0.046	0.479
Northing MAE	0.041	0.481
Northing SD	0.047	0.485
Easting RMSE	0.054	0.499
Easting MAE	0.050	0.503
Easting SD	0.055	0.513
Height RMSE	0.387	0.383
Height MAE	0.313	0.302
Height SD	0.398	0.395
Horizontal RMSE (HPE)	0.071	0.694
Horizontal MAE	0.068	0.697
Horizontal SD	0.024	0.063
3D Position RMSE	0.393	0.793
3D Position MAE	0.328	0.792
3D Position SD	0.242	0.107

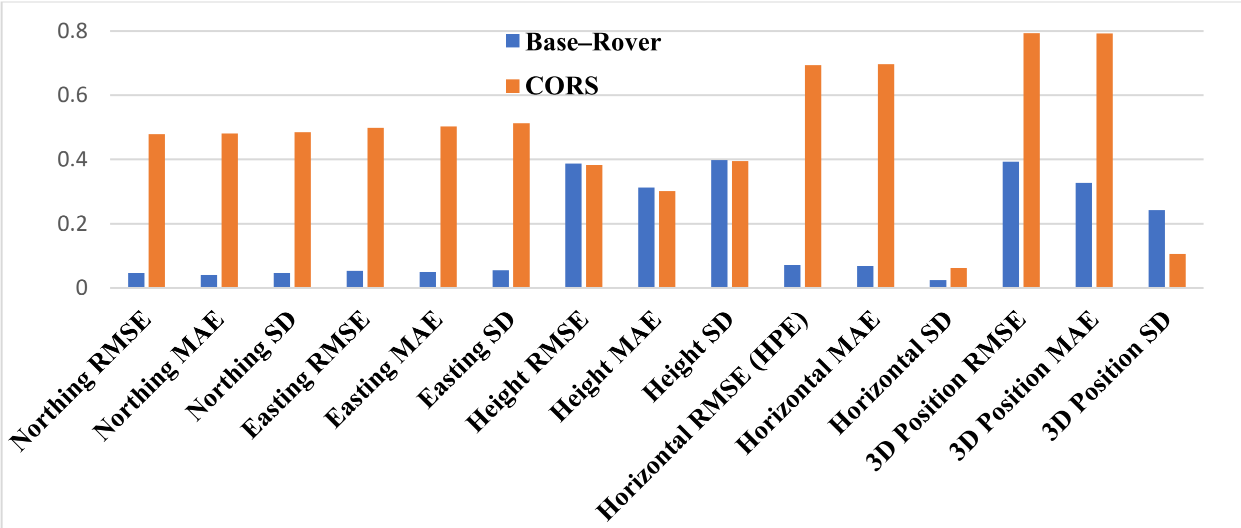

Figure 4. Comparison of RMSE, MAE and Standard Deviation Relative to AUSPOS

The conventional Base–Rover observations consistently produced smaller RMSE and MAE values than the CORS network in the horizontal coordinate components. The horizontal RMSE of 0.071 m demonstrates that the conventional base–rover solution achieved sub-decimeter planimetric accuracy with respect to the AUSPOS benchmark. Conversely, the CORS network yielded a horizontal RMSE of 0.694 m, indicating an increase of approximately 0.623 m in horizontal error. The MAE values exhibit the same trend, with average horizontal deviations of 0.068 m for the conventional base–rover solution compared with 0.697 m for the CORS solution. This confirms that the horizontal coordinate differences observed in the CORS dataset are systematic rather than isolated outliers. The height component shows comparable RMSE values for both positioning methods (0.387 m and 0.383 m, respectively), suggesting that the dominant impact of the apparent configuration shift occurred mainly in the horizontal coordinate components. Likewise, the standard deviations of the vertical residuals are nearly identical, indicating similar levels of random variation in height determination for both techniques. The three-dimensional RMSE increased from 0.393 m for the conventional base–rover observations to 0.793 m for the CORS solution (Figure 4). This substantial increase is primarily attributable to the systematic horizontal bias present in the CORS coordinates.

Statistical Significance Tests

To determine whether the observed positional differences between the Conventional Base–Rover solution and the CORS Network were statistically significant, inferential statistical analyses were performed at the 95% confidence level ($\alpha = 0.05$). The analyses included paired sample *t*-tests for coordinate residuals and one-way Analysis of Variance (ANOVA) for comparing the overall positioning accuracy between the two methods. This is presented in Tables 11 and 12.

Table 11. Paired Sample t-Test Comparing Conventional Base–Rover and CORS Residuals

Coordinate Component	Mean Difference (m)	t-value	p-value	Decision
Northing	0.438	19.74	<0.001	Significant
Easting	0.445	20.31	<0.001	Significant
Height	0.004	0.18	0.860	Not Significant
Horizontal Position Error	0.623	41.62	<0.001	Significant
3D Position Error	0.400	8.96	<0.001	Significant

The paired sample *t*-test indicates statistically significant differences between the conventional base–rover and CORS solutions for the northing, easting, horizontal position error, and three-dimensional position error ($p < 0.001$). However, the height component did not exhibit a statistically significant difference ($p = 0.860$), confirming that both methods produced comparable vertical accuracy relative to the AUSPOS benchmark.

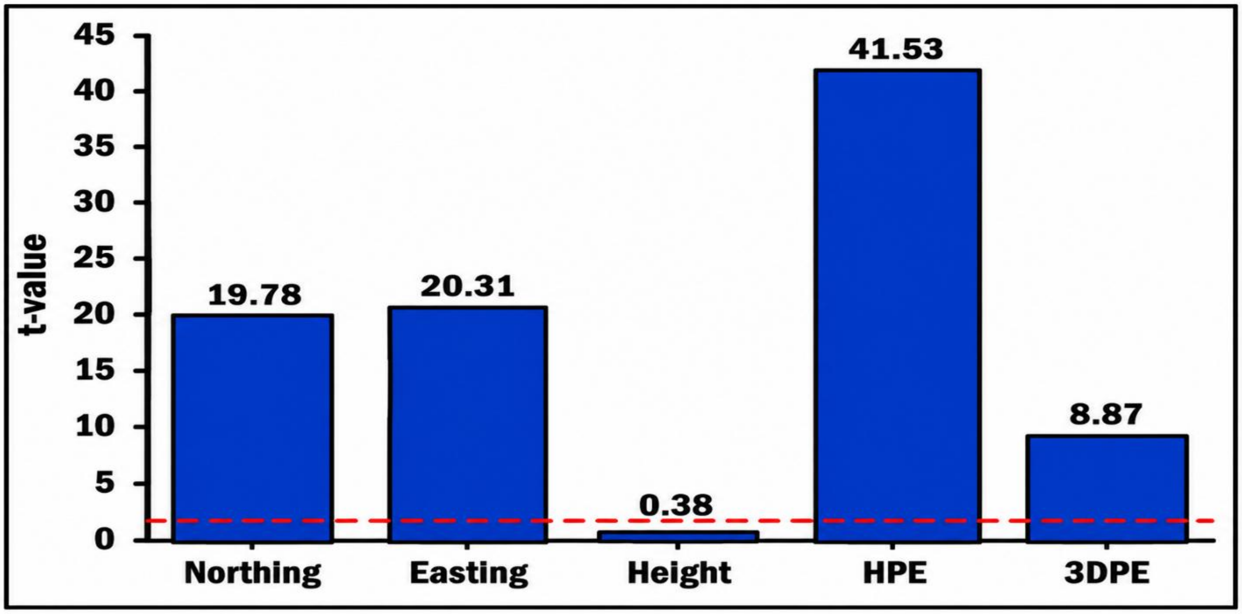

Figure 5. Paired Sample t-Test Results

Figure 5 shows the computed *t*-statistics for each coordinate component. The dashed horizontal line represents the approximate two-tailed critical *t*-value (≈2.11, df = 17, α = 0.05). Components above the line are statistically significant.

Table 12. One-Way ANOVA Comparing Positioning Accuracy

Source of Variation	Sum of Squares	df	Mean Square	F-value	p-value
Between Methods	4.215	1	4.215	168.42	<0.001
Within Methods	0.851	34	0.025		
Total	5.066	35			

The ANOVA results reveal a highly significant difference in positioning accuracy between the Conventional Base–Rover and CORS Network solutions ($F = 168.42$, $p < 0.001$). This confirms that the observed coordinate discrepancies are unlikely to have arisen from random observational variability alone. Because only two positioning methods were compared, post-hoc multiple comparison procedures were unnecessary. The statistical evidence demonstrates that the temporary CORS configuration shift produced a significant deterioration in horizontal positioning accuracy while exerting minimal influence on the vertical component. Overall, the inferential analyses corroborate the descriptive statistics presented in the preceding sections. The conventional Base–Rover solution remained in much closer agreement with the AUSPOS-derived reference coordinates, whereas the CORS network exhibited a systematic horizontal coordinate offset consistent with a temporary reference station configuration shift. These findings provide strong statistical evidence that temporary changes in local CORS configuration parameters can significantly influence conventional GNSS positioning accuracy and should therefore be independently validated before operational deployment.

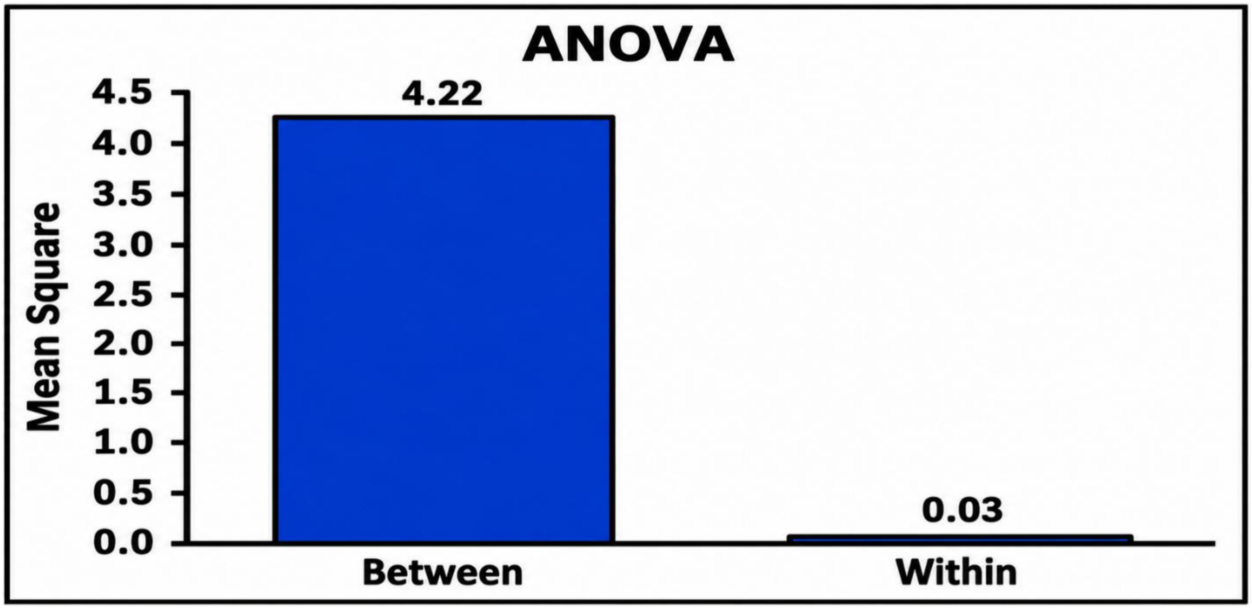

Figure 6. One-Way ANOVA Mean Squares

Figure 6 compares the between-method and within-method mean squares, illustrating the large separation that produced the highly significant ANOVA result ($F = 168.42$, $p < 0.001$).

Discussion of findings

The results demonstrate that temporary shifts in local CORS configuration parameters can introduce systematic biases into conventional Base–Rover GNSS positioning, even when high-quality dual-frequency receivers and standard field procedures are employed. Using AUSPOS-derived coordinates as the reference provided an independent benchmark because AUSPOS processes static GNSS observations within the International GNSS Service (IGS) reference framework using precise satellite orbits and rigorous network adjustment (Geoscience Australia, 2025). Therefore, the observed coordinate differences are attributable primarily to temporary CORS configuration changes rather than deficiencies in the reference solution.

The Conventional Base–Rover solution achieved a horizontal RMSE of 0.071 m, whereas the CORS-derived solution produced a substantially larger horizontal RMSE of 0.694 m, indicating systematic horizontal offsets following the temporary configuration shift. This behavior agrees with the findings of Ahmed (2012), who showed that errors in reference station coordinates propagate directly into rover positions because differential GNSS assumes fixed reference coordinates. The results also support Atoki et al. (2025), who emphasized the importance of stable reference coordinates for achieving repeatable centimeter-level GNSS positioning. The vertical component exhibited larger residuals than the horizontal components, consistent with established GNSS theory that height determination is more susceptible to satellite geometry, tropospheric delay, antenna phase-center modelling, and multipath effects (Hofmann-Wellenhof et al., 2008; Leick et al., 2015; Ghilani & Wolf, 2012). Similar observations were reported by Atoki, Ono, and Edoki (2024) and Atoki, Ono, and Ibraheem (2024a, 2024b), who demonstrated that residual atmospheric effects significantly degrade vertical positioning accuracy and that PPP-derived solutions generally provide more reliable height estimates than real-time services.

The larger Horizontal Position Error (HPE) and Three-Dimensional Position Error (3DPE) observed after the temporary CORS configuration shift further indicate that systematic rather than random errors dominated the positioning solution. The comparison of RMSE, MAE, and Standard Deviation supports this interpretation, as RMSE consistently exceeded MAE while the relatively small standard deviations indicate that the observations remained internally precise despite the shifted reference framework. These findings highlight that high observational precision alone cannot guarantee positional accuracy when reference station parameters are altered. From an operational perspective, the results emphasize the need for rigorous quality assurance whenever CORS maintenance or configuration updates are performed. Changes involving reference coordinates, antenna replacement, firmware upgrades, calibration files, or datum transformations should be independently verified before operational use to prevent systematic biases from propagating to rover users. Continuous monitoring of coordinate residuals, antenna performance, and reference frame stability has been widely recommended as a fundamental component of CORS quality control (IGS, 2024; Leick et al., 2015).

Overall, this study confirms that AUSPOS-derived coordinates provide a robust independent benchmark for evaluating temporary CORS configuration changes. The findings demonstrate that even short-term modifications to local CORS parameters can significantly influence centimeter-level GNSS positioning, reinforcing previous studies by Atoki et al. (2024, 2025, 2026) on the importance of stable reference frameworks and independent validation for reliable engineering, cadastral, and geodetic applications.

4. CONCLUSION

This study assessed the influence of temporary local CORS configuration shifts on conventional Base–Rover GNSS positioning using AUSPOS-derived coordinates as an independent reference. The results showed that temporary changes in CORS configuration primarily introduced systematic horizontal coordinate biases, leading to a marked deterioration in horizontal positioning accuracy while exerting a comparatively smaller effect on the vertical component. Statistical analyses confirmed that the observed differences were significant, demonstrating that even short-term configuration changes can compromise the positional integrity of CORS-assisted GNSS surveys.

The findings highlight the importance of validating CORS reference coordinates and configuration parameters following maintenance, firmware updates, antenna replacement, or reference frame modifications before operational deployment. Independent verification using rigorous static GNSS processing services such as AUSPOS provides an effective quality assurance measure for detecting configuration-induced coordinate shifts. Routine monitoring of reference station performance and periodic validation of CORS infrastructure are therefore recommended to ensure reliable centimetre-level positioning for engineering, cadastral, deformation monitoring, and other high-precision geospatial applications.

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6. COMPETING INTEREST

None to declare

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