# Assessment of Positioning with IGS02 and IGS03 Real Time Service Data Compared to Long Convergence Static-PPP in Gwagwalada, Abuja, Nigeria.

**Atoki, Lucas Olu; Ono, Matthew N.; Ibraheem, Sikiru Temitope**

**Department of Geoinformatics and Surveying, Nnamdi Azikiwe University, Akwa, Anambra State, Nigeria.**

**DOI:** https://doi.org/10.51584/IJRIAS.2024.909028

**Received: 01 September 2024; Accepted: 11 September 2024; Published: 08 October 2024**

## ABSTRACT

The persistent challenges being faced daily on the downtimes and completely data outages of Continuously Operating Reference Stations (CORS) is becoming worrisome and also the unavailability of GNSS control points around local regions where access to CORS is also difficult or unavailable in developing countries, such as Nigeria, has become a major challenge to accurate positioning by differential GNSS method. Also, acquisition of two units of dual frequency GNSS receivers is as well becoming too costly and unaffordable for users due to economic downturn. With the advent of International GNSS Service (IGS) - real-time service (IGS-RTS) which provides corrections that can be applied in real time, precise point positioning (PPP) with just a receiver unit has recently given a relief. The purpose of this study was to assess the positioning with IGS02 and IGS03 Real Time Service data stream compared to long convergence Static-PPP in Gwagwalada, Abuja, Nigeria. The study determined the GNSS Static observations (minimum of three hours per session) on the chosen stations as reference, determination of the IGS-RTS data observations using RTKLIB software; and also observations were done with IGS-RTS data stream of IGS02 and IGS03 and statistical tests were performed. The GNSS Static coordinates and IGS-RTS coordinates were compared and analyzed. The results show the Root Mean Square (RMS) discrepancy of IGS02 and IGS03 observations, as was compared to the Static-PPP, the results fell within 0.065(m) and 0.028(m) respectively. This result indicates that IGS03 yields better performances in term of accuracy.

**Key Words:** IGS-RTS Data, PPP, GNSS Static positioning, Assessment

## INTRODUCTION

Precise Point Positioning (PPP) has been affirmed as a valuable method for single point positioning which can be used all over the world. PPP has also become a viable technique that can give an accurate positioning with just a single receiver. Also where the installation of a reference station for RTK could be difficult or simply too expensive, PPP is usually used in such environment. However, a clear-horizon environment is recommended as it is very sensitive to cycle slip. It consists in using precise orbits and clock products, as it is freely available on the IGS website or using private companies such as satellite link with Navcom Technology, which are considered as fundamental corrections for systematic satellite orbit and clock errors that cannot be modeled. Katrin *et al*., **(**2010); Ju *et al*., (2022).

One serious problem for real-time PPP applications such as natural hazard early warning systems and surveying is when a sudden communication break takes place resulting in a discontinuity in receiving these orbit and clock corrections for a period that may extend from a few minutes to hours as opined by El-Mowafy, Deo, and Kubo (2019); El-Mowafy (2011).

The principal challenge in the use of the DGPS technique in some developing countries such as Nigeria, is the non-availability of GPS control points, to some sufficient geographic spread and density, for use as “Master” control. Also, the deficiency of CORS is an added worry and challenge because they are not sometimes at proximity, like more than 500km away from remote areas and may not stream data for quite numbers of days.

Happily, the arrival of precise point positioning (PPP) technique has been developed in recent times and requires only one dual frequency receiver unit (instead of a pair). The PPP technique is well described in (Kouba and Heroux, 2001). Meanwhile, in 2010, the International GNSS Service (IGS) launched its real-time service (IGS-RTS) for GNSS orbit and clock correction service that enables real-time precise point positioning worldwide. The data are also expected to be suitable for time synchronization and disaster monitoring in all parts of the world (www.rts.igs.org). These attributes make IGS-RTS potentially very essential to developing countries like Nigeria.

However, the PPP-based positioning solution using real-time IGS-RTS service is still under assessment by many researchers to ratify its accuracy and solution performance in static and kinematic modes (Elsobeiey and Al-Harbi, 2015; and El-Diasty and Elsobeiey, 2015). Even though the IGS opines that RTS provides orbit and clock parameters at an accuracy of 5cm and 0.5nanoseconds (ns) (~15cm) respectively in Table 1.1, studies kept showing it is not always so. For example, (Hadas and Bosy, 2015) shows that GPS orbit and clock outliers can be as high as 30cm and 20cm respectively in different parts of the world, the corresponding GLONASS orbit and clock outliers can be as high as 50cm and 75cm respectively. (El-Diasty and Elsobeiey, 2015) in their study of the suitability of IGS-RTS for maritime application achieved mean and maximum errors of 0.07m and 0.22m respectively. They achieved also, 2-dimensional horizontal accuracy (RMS) of 0.08m at 39% confidence limit and 0.19m at 95% limit. However, there is need for the Surveyors to ratify the exact achievable positioning accuracy within his locality in order to determine to what extent he can rely on RTS data. This study is inclined on the need to verify the level of accuracy achievable by RTS data using IGS02 and IGS03 in Gwagwalada, Abuja, Nigeria. We have however, restricted our study to position determination alone.

In this study, we determined the positions of six ground control points (GCPs) within the Gwagwalada Area Council, Abuja, by both IGS-RTS data and differential static GPS methods and results were compared and analyzed.

## Study Area

The research work was carried out within Gwagwalada Area Council, Abuja, FCT, Nigeria. Gwagwalada is one of the six Area Councils in the administration of the FCT, Abuja, Nigeria. The area is geographically located at the north central part of Nigeria. It falls between latitude 8.05515211N, 9.0113411N and longitude 6.05113611E, 7.01113511E (fig.1.1). Gwagwalada has a landmass of approximately 1,043 km$^2$.

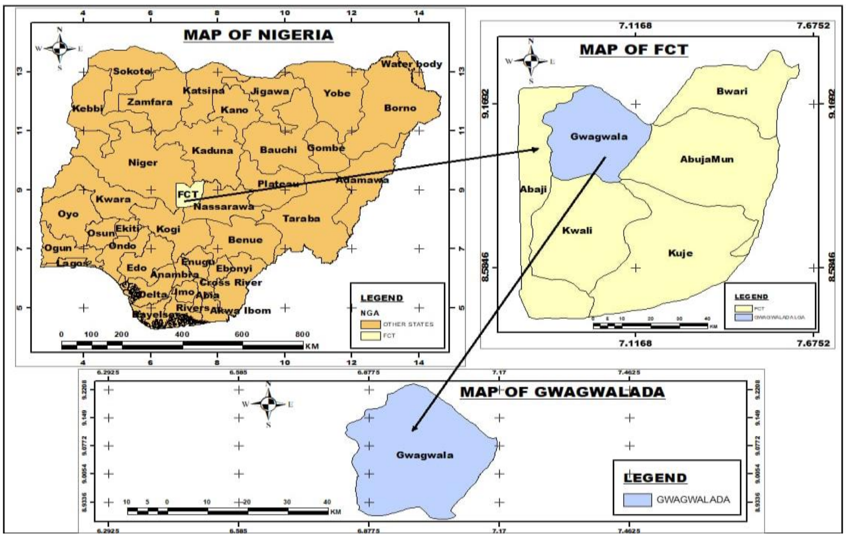

Fig. 1.1: Study area in Gwagwalada, Nigeria.

## IGS-Real Time Service

The International GNSS Service (IGS) real-time service (IGS-RTS) is operated as a public service in which users are offered free access to products through subscription. Its services are located at (www.rts.igs.org) and are based on the IGS global infrastructure of network stations, data centres and analysis centres that provide world standard high-precision GNSS data products. 160 station operators, multiple data centres, and 10 analysis centres around the world participate in the Service.

RTS is currently offered as a GPS-only operational service. IGS partners with Natural Resources, Canada (NRCan), the German Federal Agency for Cartography and Geodesy (BKG), and the European Space Agency's Space Operations Centre in Darmstadt, Germany (ESA/ESOC). It uses the format of the RTCM standard for State Space Representation (RTCM-SSR) to stream RTS corrections via the NTRIP protocol. SSR corrections include satellite ephemeris, clock, and ionospheric corrections. Some of the product streams (IGS01, IGC01, IGS02, and IGS03) and their corresponding message numbers are shown in Table 2.1. Users can choose to download any data stream of their choice (either "IGS combined data" or "Analysis Centre (AC) data"). Positions are given in the International Terrestrial Reference Frame 2008 (ITRF08). More details are given at the IGS-RTS home page (www.rts.igs.org); Kim and Kim 2015; Hadas and Bosy 2015; etc.

**IGS Data Stream** (IGS02 and IGS03)

The International GNSS Service (IGS) data stream such as IGS02 and IGS03 are both global geodetic reference frames that can be used to convert between coordinates in different systems. They are both maintained by the IGS, and they are widely used in geodesy, surveying, and other applications. IGS02 and IGS03 are both based on the International Terrestrial Reference Frame (ITRF) which is a global geodetic reference frame. They are both consistent with ITRF, but they differ in the way they handle coordinate inconsistencies, Agrotis, Caissy, Weber, Hernandez-Pajares and Hugentobler, (2012). IGS02 uses a grid-based adjustment method, while IGS03 uses a Kalman filter-based adjustment method. Abdelazeem, Celik, and El-Rabbany, (2015).

Another important difference is the way that the two systems handle the effects of the Earth's rotation. IGS02 uses a classical geocentric model of the Earth's rotation, while IGS03 uses a dynamic model that takes into account the effects of the Earth's core and oceans. This difference is important for applications that require high-precision positioning.

In practice, IGS02 is commonly used for applications like single-epoch coordinate transformations and surveying. IGS03 is more commonly used for time-series analysis and coordinate transformation over a period of time. They are both maintained by the IGS and used for geodetic applications. But they have different strengths and weaknesses depending on the specific needs of the user. Wenju, Jin, Lei and Ruizhi (2022).

The IGS02 and IGS03 frames are not specific sets of coordinates, they are just frameworks for the GPS tracking stations. So, the IGS frames do not have their own coordinates, they are defined by the coordinates of the GPS tracking stations. So, one can think of the IGS02 and IGS03 frames as coordinate systems, but not actual coordinates. The ITRF frames define the IGS frames. The IGS frames are coordinate systems, but not specific coordinates. The GPS tracking stations have specific coordinates that define the IGS frames as detailed in IGS (2022).

Table2.1: Precise GPS satellite orbits and clock corrections provided by the IGS.

| Stream Name | Description | Ref. Point | RTCM Messages | Provider/ Solution ID | Bandwidth (kbits) | Software |
|---|---|---|---|---|---|---|
| IGS01 | Orbit/Clock Correction, Single-Epoch Combination | APC | 1059(5),1060(5) | 258/1 | 1.8/sec | ESA/ESOC |
| IGC01 | Orbit/Clock Correction, Single-Epoch Combination | CoM | 1059(5),1060(5) | 258/9 | 1.8/sec | ESA/ESOC |
| IGS02 | Orbit/Clock Correction, Kalman Filter Combination | APC | 1057(60),<br>1058(10), 1059(10) | 258/2 | 0.6/sec | BKG |

| | | | | | | |
|---|---|---|---|---|---|---|
| IGS03 | Orbit/Clock Correction, Kalman Filter Combination | APC | 1057(60),<br>1058(10),<br>1059(10), 1063(60) | 258/3 | 0.8/sec | BKG |

### GPS Satellite Ephemerides / Type of Orbit and Clocks

El-Diasty and Elsobeiey (2015) pointed out the viable efforts of the International GNSS Service (IGS) at ensuring the precise GPS satellite orbit and clock corrections which are available in real-time service. These products are known as the IGS-Real Time Service (IGS-RTS) and the precision and accuracy of IGS orbits as was explained by Griffiths and Ray (2009).

Also, Ahmed, Manoj and Nobuaki (2017); Mervart and Weber (2011), ascertained the maintenance of real-time precise point positioning during outages of orbit and its clock corrections as represented in the table 2.2.

Table 2.2: Precise GPS satellite orbits and clock corrections as provided by the IGS (Hadas *et al* 2015).

| Product | Parameter | Accuracy | Latency |
|---|---|---|---|
| Real-time service (IGS-RTS) (estimated) | Orbit | 5cm | 25s |
| | Clock | 0.5ns | |
| Ultra rapid (predicted) | Orbit | 10cm | Real-time |
| | Clock | 5ns | |
| Ultra rapid (estimated) | Orbit | 3cm | 3hrs |
| | Clock | 0.2ns | |
| Rapid (estimated) | Orbit | 2.5cm | 7hrs |
| | Clock | 0.10ns | |
| Final (estimated) | Orbit | 2cm | 14days |
| | Clock | < 0.10ns | |

### Mathematical Expression for IGS RTS Corrections

A broadcast orbit using the RTS satellite position ($\delta\vec{X}$) correction can be corrected as given by Kim and Kim (2015);

$$\vec{X}_{\text{Orbit}} = \vec{X}_{\text{broadcast}} - \delta\vec{X} \qquad (2.1)$$

Where $\delta\vec{X}$ is the RTS satellite position correction expressed in earth-centered earth-fixed (ECEF) coordinates, $\vec{X}_{\text{orbit}}$ is the satellite position vector corrected by the RTS correction, and $\vec{X}_{\text{broadcast}}$ is the satellite position vector computed from GNSS broadcast ephemeris. The raw RTS correction data is expressed in radial, along-track, and cross-track (RAC) coordinates, also the broadcast orbit is expressed in ECEF coordinates. These differences demand a transformation of the correction from RAC to ECEF coordinate. Unit vectors $\vec{r}$ representing the RAC components can be computed from the broadcast position and velocity vectors $\dot{\vec{r}}$ as

$$\vec{e}_{\text{Along}} = \frac{\dot{\vec{r}}}{[\boldsymbol{\vec{r}}]},\ \vec{e}_{\text{cross}} = \frac{\vec{r}\,\text{x}\,\dot{\vec{r}}}{[\boldsymbol{\vec{r}}\,\text{x}\,\dot{\vec{r}}]},$$
$$\vec{e}_{\text{radial}} = \vec{e}_{\text{along}} \times \vec{e}_{\text{cross}} \qquad (2.2)$$

$$\delta\vec{X}\ (t) = [\vec{e}_{\text{radial}},\ \vec{e}_{\text{along}},\ \vec{e}_{\text{cross}}]\ \delta\vec{O}\ (t), \qquad (2.2a)$$

where $\vec{e}_{\text{radial}}$, $\vec{e}_{\text{along}}$, and $\vec{e}_{\text{cross}}$ are the unit vectors for radial, along-track, and cross-track coordinates, respectively $\delta\vec{O}\ (t)$ is the orbit correction represented in RAC coordinates. All the correction components consist of transmitted orbit correction, $\delta O_i$, and its rate of change, $\delta\dot{O}_{\text{i}}$, as

$\delta O_i(t) = \delta\ (t_0) + \delta\dot{O}_{\text{i}}\ (t - t_0)$ (2.3)

Where $_i$ = radial, along-track, and cross-track, also $t$ is the current time to compute the correction, and $t_0$ is the time of applicability that is included in the RTS message, Hadas *et al* (2015); El-Mowafy, Deo and Kubo (2019).

The RTS clock correction, $\delta C$ (t), is given as a correction to the broadcast clock offset. And for the orbit correction, the clock correction consists of the transmitted correction and its rate of change:

$\delta C\ (t) = C_0 + C_1\ (t - t_0) + C_2\ (t - t_0)^2$ (2.4)

Where $C_0$, $C_1$, and $C_2$ represent the transmitted clock corrections. (t) is expressed as a correction-equivalent range unit, and where $\delta t\ (t)$ is expressed as the clock offset, which can be obtained by dividing it by the speed of light c:

$\delta t\ (t) = (\delta \mathrm{C}\ (\mathrm{t})\mathrm{c}\ )/c$ (2.5)

Types of IGS orbit and clock products available to user are more detailed in (Kim *et al* 2015); (El-Diasty and Elsobeiey, 2015) and (Hadas *et al* 2015).

**RTKLIB: The IGS-RTS Software**

RTKLIB is an open source program package for standard and precise positioning with GNSS, Manandhar (2018). RTKLIB consists of a portable program library and several APs (application programs) utilizing the library. Recently, RTKLIB has two function types capable of handling real-time service, which are RTKNAVI and RTKGPS+.

RTKNAVI is the file designed as one of the suite files incorporated in RTKLIB to handle the differential mode of operation in real-time service on a computer system.

The Google Smartphone Decimeter Challenge (GSDC) was a recent competition that was held in 2021, whereby data from various instruments that are useful for determining a phone's position (signals from GPS satellites, accelerometer readings, gyroscope readings, etc.) using Android Smartphone was provided to be processed and assessed in regard to the most accurate determination of the longitude and latitude of user positions. One of the tools that can be utilized to process the GNSS measurements is RTKLIB as opined by Everett, Taylor, Lee and Akos (2022).

Table 2.3: The GUI and CUI applications

| | **Function** | **GUI AP** | **CUI AP** | **Note** |
|---|---|---|---|---|
| (a) | AP Launcher | RTKLAUNCH | - | |
| (b) | Real-Time Positioning | RTKNAVI | RTKRCV | |
| (c) | Communication Server | STRSVR | STR2STR | |
| (d) | Post-Processing Analysis | RTKPOST | RNX2RTKP | |
| (e) | RINEX Converter | RTKCONV | CONVBIN | |
| (f) | Plot Solutions and Observation Data | RTKPLOT | - | |

## METHODOLOGY

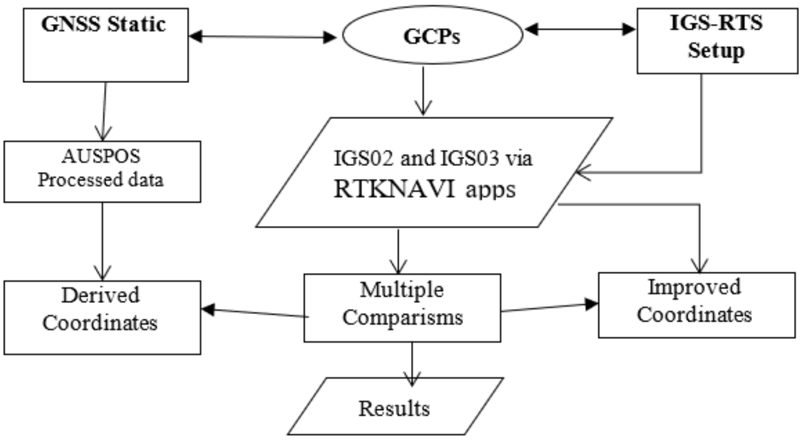

Figure 3.1:  A flowchart of the design.

### GNSS Static Method

GNSS observations were carried out on six [6] stations monumented, having widely spaced, as described by Olushola, Dahir, Chukwuma, Olagoke and Tosin **(**2021). The antenna height placed at a height of more than one meter as recommended by Ibrahim, Dodo and Ojigi (2018).

The details of the instrument's technical specifications can be found in Table 3.1. data were captured on each Ground Control Point (GCP) for a minimum of three hours between July 18-19, 2023 (DOY 199-200). During this time, the receiver was set to record data at a 15-second capture rate with a mask angle of 15 degrees for each setup. The collected data was converted into RINEX format and submitted for online processing on August 13, 2023 (DOY 225), using the AUSPOS online GPS processing service (version 2.4) in Australia. This service utilizes various IGS products (including final, rapid, and ultra-rapid, depending on availability) to calculate precise coordinates in the International Terrestrial Reference Frame (ITRF). AUSPOS uses the Bernese (scientific) GNSS Software Version 5.2 for GNSS data processing (for more information on AUSPOS, visit its homepage at (http://www.ga.gov.au/geodesy/sgc/wwwgps/). All the data were optimally processed and positions given in the International Terrestrial Reference Frame 2014 (ITRF14). El-Mowafy (2011) found that AUSPOS and CSRS-PPP online services deliver precise results for static data from dual-frequency receivers, with AUSPOS achieving mm-cm accuracy and CSRS-PPP achieving decimeter precision.

Table 3.1: Technical Specifications of GPS Receivers

| **ITEM** | **HI-TARGET V90+ GPS RECEIVER** |
|---|---|
| Type | Dual frequency |
| Channels | 220 Channels (GPS, GLONASS, SBAS, GALILEO, BDS, QZSS) |
| Ports | 1 mini USB, 1 5-pin serial for NMEA output, external devices, power, etc |
| Bluetooth | Dual mode BT4.0 |
| Kinematic Accuracies | Horizontal: 10mm + 1ppm RMS<br>Vertical: 2.5mm + 1ppm RMS<br>**RTK:** Hor.: 8mm+1ppm; Vert.: 15mm+1ppm |
| Static Accuracies | Horizontal: 2.5mm + 1ppm RMS<br>Vertical: 5mm + 1ppm RMS |

| | |
|---|---|
| Transmission/ Reception Formats | CMR, CMR+, sCMRx<br>RTCM: 2.1, 2.3, 3.0, 3.1, 3.2 |
| DGPS | NMEA 0183GSV, AVR, RMC, HDT, VGK, VHD, ROT, GGK, GGA, GSA, ZDA, VTG, GST, PJT, PJK, etc |
| Communication (Data Links) | Radio modem, Internal 3G, compatible with GPRS, GSM, and Network RTK |

### IGS-RTS Methods

The Hi-Target V90+ dual-frequency GPS receiver was chosen for the IGS-RTS PPP method because it came fully equipped with all the necessary components required for this precise technique. (The technical specifications of the instrument are given in Table 3.1). A laptop PC was set up with the RTKLIB/RTKNAVI software, and the Hi-Target V90+ dual-frequency GPS receiver was linked to the PC via a serial port connection (with Bluetooth as an alternative option). The RTKNAVI real-time navigation software was then initiated, and the instrument was configured to receive correction data from IGS servers, enabling precise positioning as shown in Fig. 3.2.

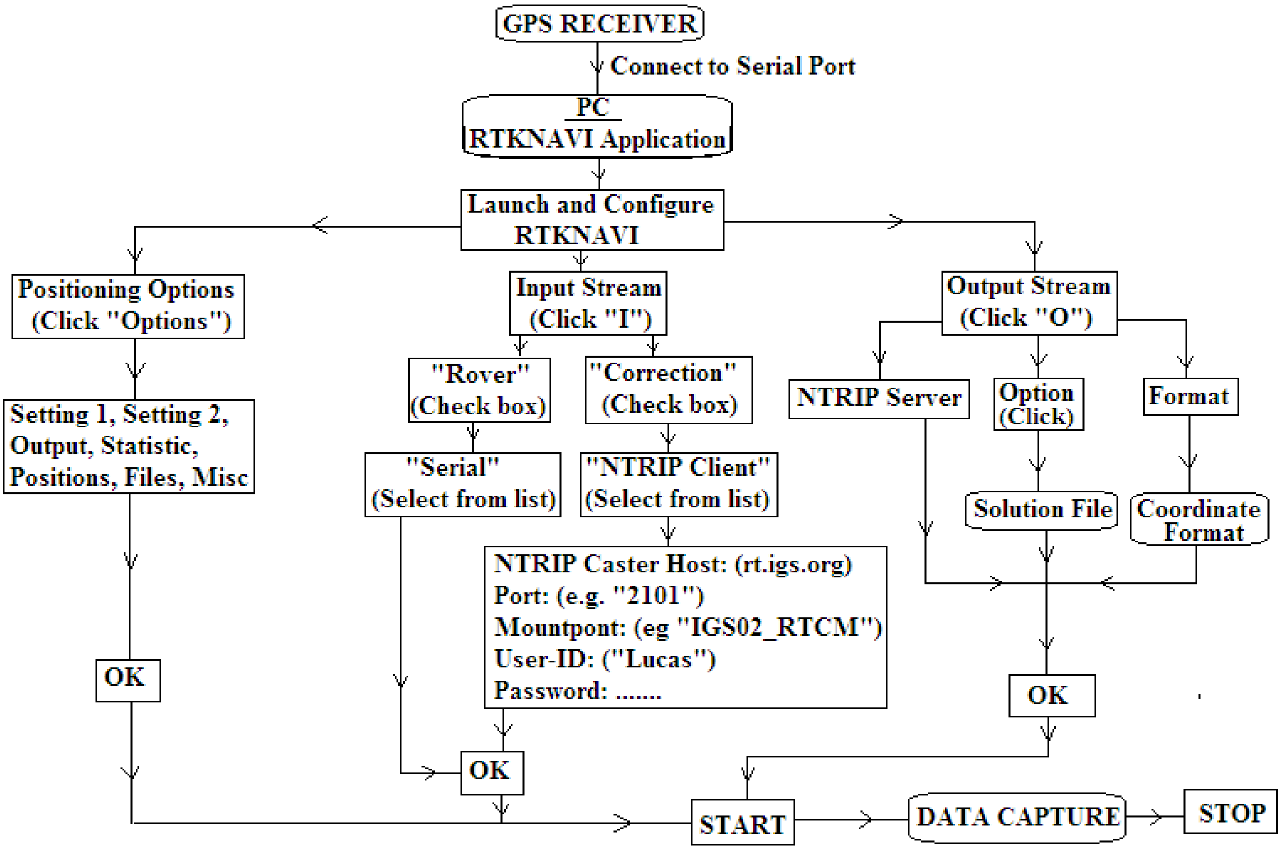

Fig 3.2: Configuration of RTKNAVI

## RESULTS AND DISCUSSIONS

### Results from Differential GNSS Static Positioning

Table 4.1 presents the results of the differential GNSS static positioning exercise, which utilized the Hi-Target V90 GNSS dual-frequency receiver and was processed online via AUSPOS using Bernese software version 5.2. The six ground control points (ZIK1 to ZIK6) had their positions defined in both Cartesian coordinates (X, Y, Z) and geodetic coordinates (latitude, longitude, and ellipsoidal height) within the ITRF 2014 reference frame. Data collection took place over a two-day period, from July 18 to July 19, 2023 (DOY 199-200).

Table 4.1: ITRF2014 Coordinates from GNSS Static method processed by AUSPOS

| Station | ITRF 2014 COORDINATES | | | | | | Ambiguity Resolution (%) |
|---|---|---|---|---|---|---|---|
| | CARTESIAN (m) | | | GEODETIC (±2σ) | | | |
| | X (m) | Y (m) | Z (m) | ϕ (DMS±m) | λ (DMS±m) | h (m) | |
| ZIK1 | 6252855.930 | 778709.086 | 986131.768 | 8 57 13.035 ± 0.022 | 7 05 55.930 ± 0.008 | 233.059 ±0.036 | 64.5 |
| ZIK2 | 6252867.417 | 778887.666 | 985906.152 | 8 57 05.612 ± 0.028 | 7 06 01.685 ± 0.016 | 231.012± 0.078 | 59.6 |
| ZIK3 | 6252883.279 | 778999.713 | 985709.505 | 8 56 59.139 ± 0.058 | 7 06 05.260 ± 0.013 | 229.648 ±0.061 | 58.7 |
| ZIK4 | 6252830.968 | 779255.827 | 985836.155 | 8 57 03.314 ± 0.027 | 7 06 13.791 ± 0.016 | 229.356 ±0.089 | 46.6 |
| ZIK5 | 6252749.708 | 779693.680 | 985930.578 | 8 57 06.484 ± 0.022 | 7 06 28.343 ± 0.010 | 217.899 ±0.050 | 59.0 |
| ZIK6 | 6252939.956 | 778711.973 | 985560.103 | 8 56 54.231 ± 0.030 | 7 05 55.684 ± 0.012 | 226.832±0.057 | 61.5 |

$$\text{rms vertical error} = \sqrt{\frac{\sum_{i=1}^{n}(\Delta \mathrm{U}^2)i}{\mathrm{n}}} \qquad (4.1)$$

$$2 - \mathrm{D}\ \text{rms horizontal error} = \sqrt{\frac{\sum_{i=1}^{n}(\Delta \mathrm{E}i^2 + \Delta \mathrm{N}i^2)}{\mathrm{n}}} \qquad (4.2)$$

The ambiguity resolution (A.M.) success rate, expressed as a percentage (%), reflects the processing's effectiveness. According to the AUSPOS Report (2023), a baseline with an ambiguity resolution of 50% or higher is considered a reliable solution. The AUSPOS processing report reveals that the geodetic positional uncertainties for the GCPs were calculated at a 95% confidence level. The average uncertainties for horizontal and vertical positions were found to be ±0.036m and ±0.064m, respectively, with maximum uncertainties of ±0.058m and ±0.089m, respectively.

**Results from IGS-RTS Positioning using IGS02 Data Stream**

The NTRIP caster host (rt.igs.org) was used to facilitate our RTK positioning, with RTS corrections streamed through NTRIP caster version 2.0.21/2.0. The coordinates were provided in the WGS84 reference system, as specified by the RTKNAVI software version 2.4.3 b3 used in the operation.

On August 30, 2023 (DOY: 242). data was streamed using IGS02, with stream messages formatted as 1057(60), 1059(5), and 1060(5). As part of this process, the geodetic positional uncertainties of the GCPs were calculated.

Table4.2: The Coordinates of points streamed by IGS-RTS with IGS02

| Station | WGS84 COORDINATES | | | | | |
|---|---|---|---|---|---|---|
| | CARTESIAN (m) | | | GEODETIC (±2σ) | | |
| | X (m) | Y (m) | Z (m) | ϕ (DMS±m) | λ (DMS±m) | h (m) |
| ZIK1 | 6252856.023 | 778709.188 | 986131.761 | 8 57 13.035± 0.098 | 7 05 55.933± 0.157 | 233.161±0.144 |
| ZIK2 | 6252867.662 | 778887.667 | 985906.211 | 8 57 05.613 ± | 7 06 01.684 ± | 231.262±0.347 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | 0.080 | 0.041 | |
| ZIK3 | 6252883.192 | 778999.718 | 985709.468 | 8 56 59.139 ± 0.055 | 7 06 05.260 ± 0.159 | 229.558±0.184 |
| ZIK4 | 6252830.985 | 779255.831 | 985836.137 | 8 57 03.313± 0.036 | 7 06 13.791 ± 0.027 | 229.371±0.104 |
| ZIK5 | 6252749.758 | 779693.753 | 985930.618 | 8 57 06.485 ± 0.044 | 7 06 28.345 ± 0.119 | 217.963±0.151 |
| ZIK6 | 6252939.952 | 778711.926 | 985560.082 | 8 56 54.231 ± 0.032 | 7 05 55.682 ± 0.073 | 226.820±0.117 |

From the Table 4.2, the mean uncertainties for horizontal and vertical positions at the IGS02 were computed as ±0.126m and ±0.192m respectively; while the maximum were ±0.159m and ±0.347m respectively.

### Results for IGS-RTS Positioning with IGS03 as Data Stream

IGS03 was also used as data stream, the Coordinates are also given based on the World Geodetic System 1984 (WGS84), it used 1057(60),1058(10), 1059(10), 1063(60), 1064(10), 1065(10) as its stream messages format. Geodetic positional uncertainties of the GCPs were determined. The observations were carried out on 31st August, 2023 (DOY: 243).

Table4.3: The Coordinates of points streamed by IGS-RTS with IGS03

| Station | WGS84 COORDINATES | | | | | |
|---|---|---|---|---|---|---|
| | CARTESIAN (m) | | | GEODETIC (±2σ) | | |
| | X (m) | Y (m) | Z (m) | $\phi$ (DMS±m) | $\lambda$ (DMS±m) | h (m) |
| ZIK1 | 6252855.925 | 778709.081 | 986131.778 | 8 57 13.036± 0.049 | 7 05 55.930± 0.052 | 233.055±0.022 |
| ZIK2 | 6252867.454 | 778887.670 | 985906.163 | 8 57 05.612 ± 0.036 | 7 06 01.685 ± 0.108 | 231.051±0.138 |
| ZIK3 | 6252883.295 | 778999.643 | 985709.493 | 8 56 59.139 ± 0.020 | 7 06 05.258 ± 0.019 | 229.653±0.060 |
| ZIK4 | 6252830.970 | 779255.871 | 985836.166 | 8 57 03.314 ± 0.078 | 7 06 13.792 ± 0.029 | 229.366±0.095 |
| ZIK5 | 6252749.717 | 779693.668 | 985930.568 | 8 57 06.484 ± 0.022 | 7 06 28.342 ± 0.068 | 217.905±0.039 |
| ZIK6 | 6252940.054 | 778711.938 | 985560.098 | 8 56 54.231 ± 0.032 | 7 05 55.682 ± 0.073 | 226.923±0.117 |

From the Table 4.4, the mean uncertainties for horizontal and vertical positions were computed as ±0.079m and ±0.089m respectively; while the maximum are ±0.108m and ±0.138m respectively.

### Comparison of IGS-RTS and GNSS Static Results

Tables 4.1-4.3 display positions obtained from GNSS Static and IGS-RTS in ITRF 2014 and WGS84 reference frames, respectively. To facilitate a precise comparison, it's necessary to convert the results to a single coordinate system. Fortunately, WGS84 and ITRF are highly compatible, with an agreement level of approximately 10 centimeters. As a result, no official transformation parameters are required, allowing for the assumption that ITRF coordinates are equivalent to WGS84 at a 10-centimeter accuracy level. According to

Dave (2022), ITRF2014 and WGS84 are likely to align at the centimeter level, making conventional transformation parameters unnecessary.

$$\text{RMS} = \sqrt{\frac{\sum_{i=1}^{n}(\Delta x)2}{\mathbf{n}}} \qquad (4.3)$$

Table 4.4: The difference in coordinates of GNSS Static compared to IGS02 and IGS03

| Station | IGS-RTS REFERENCE FRAME | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | IGS02 (m) | | | | IGS03 (m) | | | |
| | ΔX | ΔY | ΔZ | 3-D Error | ΔX | ΔY | ΔZ | 3-D Error |
| ZIK1 | -0.093 | -0.102 | 0.007 | 0.138 | 0.005 | 0.005 | -0.010 | 0.012 |
| ZIK2 | -0.245 | -0.001 | -0.059 | 0.252 | -0.037 | -0.004 | -0.011 | 0.039 |
| ZIK3 | 0.087 | -0.005 | 0.037 | 0.095 | -0.016 | 0.070 | 0.012 | 0.073 |
| ZIK4 | -0.017 | -0.004 | 0.018 | 0.025 | -0.002 | -0.044 | -0.011 | 0.045 |
| ZIK5 | -0.050 | -0.073 | -0.040 | 0.097 | -0.009 | 0.012 | 0.010 | 0.018 |
| ZIK6 | 0.004 | 0.047 | 0.021 | 0.052 | -0.098 | 0.035 | 0.005 | 0.104 |
| | RMS $_{\text{Discrepancy}}$ = 0.065 | | | | RMS $_{\text{Discrepancy}}$ = 0.028 | | | |

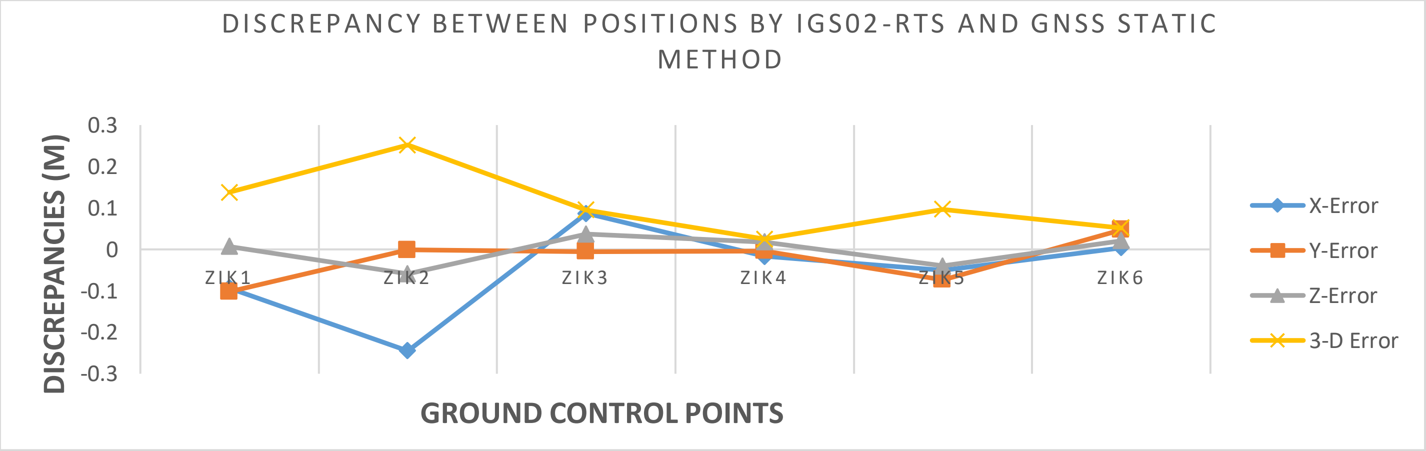

Fig. 4.1: Discrepancies between positions from IGS02-RTS and GNSS Static methods

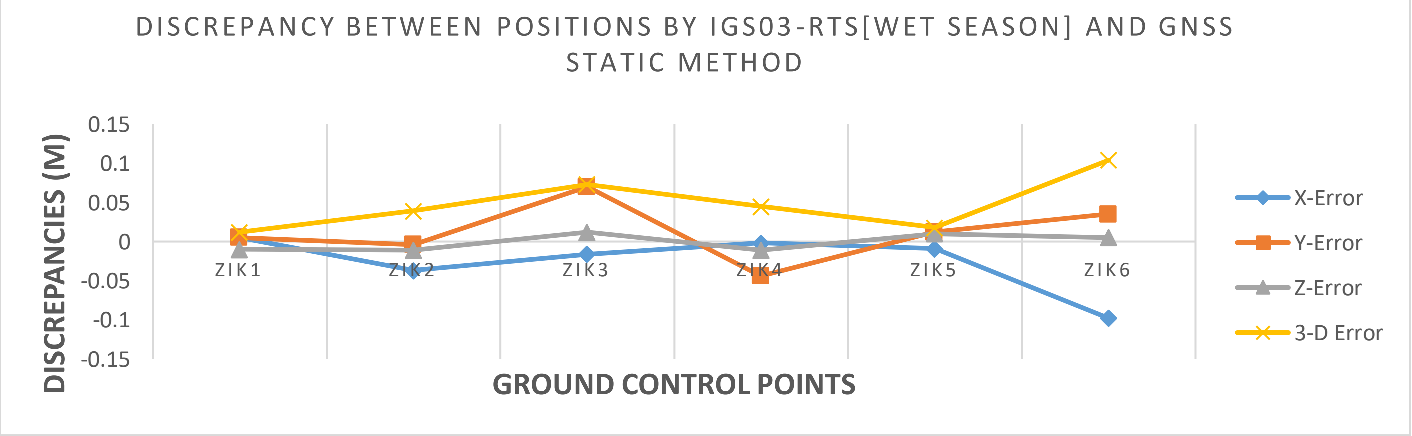

Fig. 4.2: Discrepancies between positions from IGS03-RTS and GNSS Static methods

The RMSE values reveal that the IGS03 approach (0.028m) outperforms the IGS02 approach (0.065m) in terms of accuracy. This improvement is due to IGS03's enhanced message format, which incorporates GLONASS corrections in addition to GPS corrections, and employs a Kalman filter approach to combine clock data from both systems. As described by Mervart and Weber (2011), IGS03 also obtains orbits from incoming correction streams and conducts rigorous error screening. The expanded message format of IGS03, including six components, contributes to its superior accuracy compared to the more limited IGS02 format.

**Field Speed:** The field observations for the Static GNSS method were conducted for a minimum of two hours at each ground control point, whereas the IGS-RTS method required less than 15 minutes per point for both approaches. Notably, the IGS-RTS method achieved an agreement of less than 7cm with the Static method, leading us to conclude that IGS-RTS offers a significantly faster processing time without compromising accuracy.

**Availability:** Our observation period of over four hours, we experienced uninterrupted access to streamed data, achieving 100% availability. While this may not be a sufficient basis for drawing definitive conclusions about data availability, it nonetheless represents an improvement over the current state of affairs in certain regions, such as Nigeria, where data outages and downtimes from CORS can persist for several weeks.

## CONCLUSION AND RECOMMENDATIONS

This study has evaluated the suitability of IGS03 and IGS02 for the operation, and found both to be well-suited. Our findings indicate that both IGS-RTS methods are compatible with the GNSS static method in terms of 2D horizontal accuracy (RMS), with IGS03 demonstrating superior accuracy at 0.028m compared to IGS02 at 0.065m. The results clearly demonstrate that IGS03 offers better performance than IGS02 in terms of accuracy.

## ACKNOWLEDGEMENT

We are deeply grateful to the IGS for granting us access to the IGS-RTS data, which played a crucial role in our research. We also wish to acknowledge the AUSPOS online processing service for their generous assistance in processing our observations with their advanced Bernese scientific software v.5.2, which was provided free of charge.

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