Novelty Journals

ISSN 2394-7357

International Journal of Novel Research in Civil Structural and Earth Sciences
Vol. 11, Issue 2, pp: (1-6), Month: May - August 2024, Available at: www.noveltyjournals.com

Determination of the geodetic coordinates of the selected points within the Awka North and South using GNSS for Sustainable Urban Development and Growth

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DOI: https://doi.org/10.5281/zenodo.12514739

Published Date: 24-June-2024

Abstract: **This study presents the results of geodetic coordinates determination of selected points within the Awka North and South regions utilizing Global Navigation Satellite Systems (GNSS) technology. The study aims to establish accurate positioning data essential for various engineering, surveying, and geospatial applications in the study areas. The study involved conducting a comprehensive field survey using state-of-the-art GNSS equipment to collect satellite data of strategically selected points across the study area. Subsequently, rigorous data processing techniques, including data reduction, adjustment, and quality control, are applied to ensure the reliability and accuracy of the derived geodetic coordinates. The findings revealed the geodetic coordinates of the selected points, providing valuable information for spatial referencing, infrastructure development, land management, and environmental monitoring in Awka North and South regions. The achieved accuracies met the requirements of modern surveying and mapping standards, facilitating seamless integration with existing geospatial databases and frameworks. The methodology employed in this study serves as a guideline for similar projects aiming to establish precise positioning data using GNSS technology in diverse geographical contexts**

***Keywords*:** **Geodetic coordinates, GNSS (Global Navigation Satellite Systems), Geospatial applications, Database.**

1. INTRODUCTION

The rapid pace of urbanization and development in regions like Awka North and South, Nigeria, underscores the critical need for accurate geodetic coordinates. As these areas undergo dynamic transformations, precise spatial referencing data becomes essential for effective planning, infrastructural development, and resource management. However, the existing geospatial information often lacks the required level of accuracy and currency to meet the demands of modern applications.

Accurate positioning data is fundamental in a wide range of applications, from infrastructure development and land management to environmental monitoring and disaster response (Ali and Imran, 2021). In regions like Awka North and South, Nigeria, where urbanization and development are rapidly progressing, the need for precise geodetic coordinates is paramount. Global Navigation Satellite Systems (GNSS) have emerged as one of the tools for obtaining such data due to their capability to provide accurate and reliable positioning information.

Global Navigation Satellite Systems (GNSS), is the beacon of hope in the quest for accurate geodetic information. With their ability to provide reliable positioning data (Arief and Gatti, 2020), GNSS systems have become indispensable tools in the arsenal of urban planners and developers. They offer a lifeline amidst the tumultuous waves of progress, anchoring development initiatives with precision and foresight.

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Geodesy as the science of the Earth's shape and size, Torge (1980) states that Geodesy is the science concerned with the exact positioning of points on the surface of the Earth. It also involves the study of variations in the earth's gravity, the application of these variations to exact measurements on the earth and the study of exact size and shape of the earth.

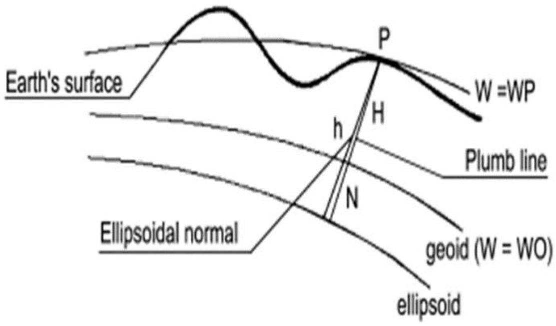
Central to geodesy is the concept of the geoid, a theoretical surface that mirrors Earth's shape sea-surface topographic and oceanic features. The geoid's significance reverberates across various fields, from oceanography to navigation, serving as a cornerstone for accurate mapping endeavors (Smith and Sandwell, 1997). Meanwhile, the geoid height acts as a compass, guiding us through the deviations of Earth's surface from a perfect ellipsoid (Flechtner et al., 2017). It ensures that satellite measurements align seamlessly with reality, offering a clear lens through which to view our ever-changing world.

As Awka North and South burgeon with urban development, the importance of precise geodetic data cannot be overstated. It is the compass guiding planners, developers, and policymakers through the maze of progress, ensuring that every step forward is grounded in accuracy and foresight. With GNSS systems illuminating the path and geodesy unraveling the mysteries of Earth's shape, these regions are poised to navigate the challenges of urbanization with confidence and clarity.

2. LITERATURE REVIEW

2.1 The Geodetic Surfaces

All activities in Surveying are done on three basic surfaces referred to as "geodetic surfaces" namely: the topographic (earth) surface, the geoid and the ellipsoid and presented in Figure 2.1



(Source: DMA 1996)

Fig. 2.1. Geoid as a relation between orthometric and ellipsoidal heights.

In figure 2.1, $N = h - H$. Where h is the ellipsoidal height, i.e. the height concerning the reference ellipsoid; and H is the orthometric height, i.e. the height concerning the MSL or the geoid, depending on the vertical datum definition.

2.2 The Ellipsoid

An ellipsoid of revolution is a solid figure generated by rotating an ellipse about its minor axis. In its simplest format, an ellipsoid is a smooth elliptical model of the earth's surface. The earth is flattened slightly at the poles and bulges out at the equator. Due to this fact, the geometrical figure used in geodesy to most nearly approximate the shape of the earth is an ellipsoid of revolution.

Historically, different ellipsoids have been chosen by different countries of the world in order to simplify surveying and mapping in their region and as such these ellipsoids are not necessarily geocentric. In Nigeria, the regional (local) coordinate system is the Minna Datum based on Clarke 1880 ellipsoid, Ono (2009).

The ellipsoid is mathematically and analytically represented to be the closest to the shape of the earth and it is the computation surface used in geodesy, in which horizontal control networks are referenced to, Fajemirokun (2006). According to Andrew (1998) spheroid (also referred to as an ellipsoid) provides a better option. A spheroid is the figure generated by rotating an ellipse about its minor (shorter) axis. It has the advantages of accommodating the bulge at the equator while remaining relatively simple mathematically. For these reasons, a spheroid is the figure usually chosen to represent the shape of the Earth.

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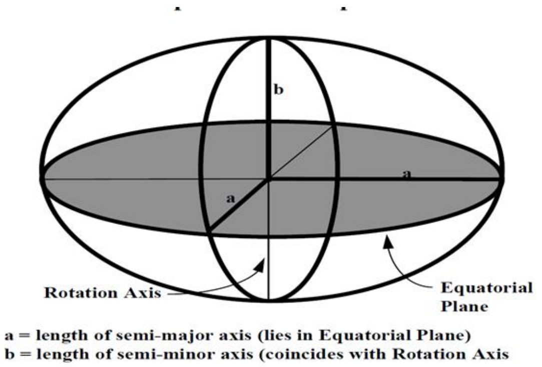

Source: Andrew (1998)

Figure 2.2: The spheroid or Ellipsoid

The ellipsoid may also be defined as a surface whose plane sections are all ellipses. It is a figure formed when an ellipse is rotated about its minor axis. Ellipse can also be defined as the locus of points such that the sum of the distances from two fixed points (foci) to any point on the ellipse is constant. One particular ellipsoid of revolution, also called the "Normal Earth", is the one having the same angular velocity and the same mass as the actual Earth, the potential (U0) 15 on the ellipsoidal surface equal to the potential (W0) on the geoid, and the centre coincident with the center of mass of the Earth (Xiong, 2001). The ellipsoid defines a mathematical surface approximating the physical reality of the Earth, while simplifying the geometry. "Ellipsoid is a good approximation to the shape of the Earth but not an exact representation" (Gen, 2003).

It is the only regular surface among the three geodetic surfaces; hence, it has a regular shape which makes it possible to be represented mathematically, and therefore enable computations to be done on it. (Rapp, 1981; Vanicek and Krakiwsky, 1986; Petrovskaya and Pishchukhina, 1989; Vanicek, 2001; Gen, 2003; Kaplan and Hegarty, 2006; Moka and Agajelu, 2006; Jokeli, 2006).

The ellipsoid serves as a basis for the 3D coordinates of satellite systems such as the Global Navigation Satellite System (GNSS). World Geodetic System 1984 (WGS 84) is the reference ellipsoid of the GNSS.

2.3 Geoid

The Geoid is the equipotential surface (where potential is constant and gravity is perpendicular at all points) that best represents, in a least-squares sense, the global mean-sea-level (reference surface for heights). The practical way to express the geoid is through geoid heights. The geoid height is the distance (or separation) between the geoid and the ellipsoid. Geoid heights (N) allow the transformation of ellipsoidal heights (h) from GPS to orthometric heights (H). Ezeigbo (2007) concurred that the geoid is an equipotential surface of the earth gravity field, whose surface coincides with the undisturbed mean sea level, with its extension into the land under undisturbed and free State equilibrium.

The geoid is the figure that actually corresponds to the actual shape of the earth but it is not used as a computation surface because it cannot be represented mathematically. Owing to the local anomalous gravitational attraction, the geoid is not a regular surface capable of practical mathematical definition, thus the shape of the geoid surface is estimated globally as a function of horizontal coordinates referenced to a common geometric position.

At every point, the geoid surface is perpendicular to the local plumb line, thus it is a natural reference surface for heights measured along the plumb line (that is the reference datum for orthometric height) and is also the most graphical representation of the earth gravity field, Ezeigbo (2007).

Aside, the three computational surfaces mentioned above, there are other unpopular reference surfaces in surveying. They are Telluriod and Quasigeoid

a. **The Telluriod:** A Telluriod is defined as a surface, whose height above a geocentric reference ellipsoid is the same as the height of the terrain above the geoid, Hirvonen (1960).

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b. **The Quasigeoid:** The quasigeoid can be described as a close relative to the geoid and it was introduced and developed as a solution to the practical problems encountered in geoid computations, Molodensky (1960).

The quasigeoid is a surface that does not have any physical meaning. It is purely a mathematical creation and it is not an equipotential surface of the earth's gravity field. It coincides with the geoid on open sea, where the geoid height (N) equals to the height anomaly, but in the inland, these two surfaces departs by as much as a few meters, Heiskanen and Moritz(1967). Heights referred to the quasigeoid, are now being used in Russia and in most Eastern European countries for various applications.

2.4 The Relationship Between the Geodetic Surface

Orthometric Heights and ellipsoidal heights are measured with reference to the geoid and the ellipsoid respectively. The relationship between them is Geoidal Undulation. They are also related angularly by the deflection of vertical (ε) also called Vertical deflection (VD). It is defined as the angle between the true zenith (plumb line or the direction of gravity) and the normal (that is the line perpendicular to the surface of the ellipsoid chosen to approximate the Earth's sea-level surface).

Merry and Vanicek (1974) defined gravimetric deflection as the angle between the actual plumb line and the normal to the geocentric reference ellipsoid, measured at the geoid (Figure 2.3). VDs are caused by mountain and underground geological irregularities. The deflection of vertical has two components. These are the components along the prime vertical (NorthSouth component ξ) and along the meridian (East-West component η) (Fajemirokun, 1980; 1981 and 1988; Vanicek and Krakiwsky, 1986; Uzodinma and Ezenwere, 1993; Agajelu, 1997 and Vanicek et al., 2000).

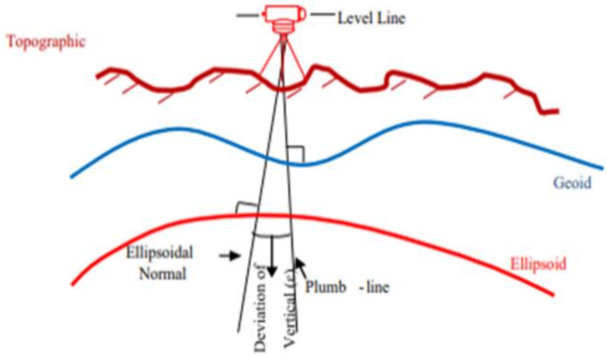

Figure 2.3: Relationship Between the Geodetic Reference Surface and Deflection of the Vertical

Deflections of Verticals are usually determined by astronomical observation. VD can be determined by observing the true zenith astronomically with respect to the stars, and the ellipsoidal normal (theoretical vertical or ellipsoidal zenith) by geodetic network computation which always takes place on a reference ellipsoid. Veining Meinesz originally developed the theory of computing the local variations of the VD from gravimetric survey data and Digital Terrain Modelling (DTM). This deflection of vertical (Figure 2.3) has also been used in the Astrogravimetric and astro-geodetic determination of geoid. In practice, "the deflections areobserved at special points with spacings of 20 to 50 kilometres. The densification is done by a combination of DTM models and a real gravimetry model. Precise VD observations have accuracies of ± 0.2" (on high mountains ± 0.5"), calculated values of about 1–2" (Bomford, 1980 and Torge, 1989).

In physical geodesy, deflection of vertical is defined as the difference in direction between the natural gravity with reference to the geoid and the normal gravity vector with reference to the ellipsoid, while the magnitude is called the gravity anomaly (δ). Therefore, deflections of verticals are functions of the gravity gradient and it's in homogeneities because they are always connected with the local and regional undulations of the geoid and also related with gravity anomalies.

Therefore, gravity is a vector quantity. It has both magnitude and direction. The direction is the gravity vector along the plumb line and its corresponding normal gravity along the ellipsoidal normal differed by gravity disturbance. This is the difference between the Normal (perpendicular to the ellipsoid) and the plumb line i.e., direction of gravity (perpendicular to the geoid).

3. MATERIALS AND METHODS

This study employed an experimental research design method. The data used in this research include: Satellite Altimetry Data, Latitude, Longitude and Ellipsoidal Height. The primary data were obtained through field visits to the selected Towns peculiar to the study area. These include the 17 (A001-A017) selected stations within the Towns covered by Awka and Environ (Isiagu, Nibo, Umuawulu, Nise, Amawbia, Amaenyi, Aguawka, Umuokpu, Amansea, Ifite-Awka, Okpuno, Isuaniocha, Mgbakwu, Urum, Amanuke, Achalla, and Ebenebe.) their positions in terms of Latitude, Longitude and Ellipsoidal Height were successfully obtained using Ground Measurements from GNSS observations.

The entire data processing workflow was executed within the Broadview Radar Altimetry Toolbox (BRAT) GUI, a comprehensive tool adept at handling various radar altimetry data sources. Notably, it can seamlessly process data from missions such as ERS-1 & 2 (ESA), To determine the orthometric heights (H) of Awka and Environs, the formula below was used

$H = h_{ellipsoid} – N$,

Where H = Orthometric Height

h = Ellipsoidial Height

N = Geoidial Height

In the course of this research the computed mean Geoidal height of 20.75m which functions as a pivotal reference point for Anambra State and determined by Satellite Altimetry is a Constant and is used for Awka and Environs. As shown in Table 1

4. RESULT / EXPERIMENTAL

Table 1. Orthometric height of Awka and Environs determined by Satellite Altimetry

STATION	TOWN IN AWKA AND ENVIRONS	LATITUDE in meters	LONGITUDE in meters	Ellipsoidal height (h) in meters	Average Geoid height (N) for Anambra State determined by Satellite Altimetry in meters	orthometric height (H) determined by Satellite Altimetry H = h - N
A001	ISIAGU	6.212244	7.144081	46.310	20.750	25.560
A002	NIBO	6.171969	7.067929	125.510	20.750	104.760
A003	UMUAWULU	6.156109	7.094173	110.250	20.750	89.500
A004	NISE	6.160191	7.050656	137.530	20.750	116.780
A005	AMAWBIA	6.204175	7.047398	109.780	20.750	89.030
A006	UMUOKPU	6.194001	7.035739	112.015	20.750	91.265
A007	AMAENYI	6.220856	7.084409	144.953	20.750	124.203
A008	AGUAWKA	6.233602	7.115673	47.430	20.750	26.680
A009	AMEANSEA	6.254245	7.141445	42.174	20.750	21.424
A010	IFITE	6.259819	7.110129	45.404	20.750	24.654
A011	OKPUNO	6.241804	7.059458	95.820	20.750	75.070
A012	ISUANIOCHA	6.254539	7.051851	88.972	20.750	68.222
A013	MGBAKWU	6.265865	7.053681	85.071	20.750	64.321
A014	URUM	6.290813	7.042870	93.579	20.750	72.829
A015	AMANUKE	6.306298	7.037403	111.771	20.750	91.021
A016	ACHALLA	6.340419	6.982209	69.005	20.750	48.255
A017	EBENEBE	6.330287	7.128961	75.571	20.750	54.821

5. CONCLUSIONS

This study has yielded invaluable insights into the geodetic characteristics of Awka and Environs in Anambra State through the meticulous determination of the Orthometric heights of the areas. The utilization of satellite altimetry has enabled the determination of a confined range of Geoidal heights of Anambra State and also extended it to the determination of Orthometric height of Awka and Environs.

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In conclusion, the rapid urbanization and development unfolding in Awka North and South, Nigeria, highlight the critical importance of accurate geodetic data. As these regions undergo dynamic transformations, precise geodetic coordinates and ellipsoidal heights emerge as indispensable tools for effective planning, infrastructure development, and resource management. While challenges abound, the integration of Global Navigation Satellite Systems (GNSS) and the principles of geodesy offer a beacon of hope, guiding stakeholders through the complexities of urban growth with clarity and precision. By harnessing the power of accurate positioning data and understanding Earth's shape and size, Awka North and South are poised to chart a course toward sustainable development and prosperous futures for their communities.

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