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Integrating Multi-Networks Of GNSS And Precise Leveling For The Estimation Of Optometric Heights In The Owerri Region And Its Surroundings, Imo State, Nigeria.

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Abstract:

Optometric heights obtained from GNSS require geoid models to convert precise ellipsoidal heights (h) into optometric heights (H), crucial for various applications such as cadastral, surveying, mapping, engineering, and environmental work. While GNSS typically uses global geoid models like EGM96/EGM2008 for height conversion, these models may prove inadequate for local applications, particularly in the absence of a national geoid model. This research aims to model orthometric heights in the Owerri region of Imo State, Nigeria, using multi-networks of GNSS and precise leveling data. The research utilizes a dual-base reference station approach and static 2-hour DGPS data capture. Polynomial models, including a multi-quadratic model and a bi-cubic model, are used to represent the Owerri region's surface. The least squares method is employed to determine model coefficient parameters, which are used to develop a geometric geoid model program in Microsoft Excel 2010. The standard deviations of the geoid model-determined orthometric heights are 11 cm for the multi-quadratic model and 14 cm for the bi-cubic model. Statistical tests, including t-tests, confirm the accuracy and reliability of the multi-quadratic model for modeling orthometric heights. The model's high coefficient of correlation (R) and coefficient of determination (R^2) values indicate its strong predictive ability. Diagnostic tests further support the adequacy of the multi-quadratic model for geoid modeling. The developed model provides a reliable alternative for obtaining orthometric heights with centimeter-level accuracy, suitable for topographic maps and large-scale engineering plans. Kriging interpolation is used to generate contour maps, geoidal maps, and digital elevation models. This research recommends adopting the multi-quadratic model for everyday geospatial data needs in cadastral, mapping, engineering, and environmental applications.

Keywords: Orthometric heights; Geoid modeling; GNSS; Ellipsoidal height; Geoidal maps

Introduction:

The Nigerian geodetic network serves as a crucial infrastructure for precisely determining geographic coordinates, encompassing various parameters related to the Earth's size, shape, orientation, and position concerning the actual Earth's surface [1]. The roots of this network extend back to Nigeria's colonial era when it was initially established to support activities such as resource exploitation and efficient transportation within the country [2]. This network's development began with the creation of a leveling network in 1891, and it was subsequently expanded to include a triangulation network in 1912. These triangulations were computed using the Clarke 1880 reference ellipsoid [2], providing provisional coordinates essential for mapping purposes [3].

Heights were determined through vertical angle observations and, wherever feasible, levelling data was employed. The network was adjusted geometrically, with the coordinates at L40 serving as the reference point, and the mean datum was computed based on values obtained through triangulation, located at the northern terminus of the Minna base.
However, the Minna datum, established in 1928, has inherent limitations due to its arbitrary selection and the absence of triangulation data to the south and west of Minna [2]. Furthermore, the network's shortcomings are compounded by distortions inherent in the observational data [3], rendering it unsuitable for meeting the demands of modern positioning and geodetic projects. In addition, the geodetic reference system used in Nigeria is founded on the Clarke 1880 reference ellipsoid, with the origin not coinciding with the Earth's center of mass, but rather situated at one of the stations within the triangulation network [3]. These combined factors contribute to significant distortions within the Nigerian geodetic network, underscoring the urgent need for its improvement and transformation into a more robust geocentric datum.
To address these challenges, it is imperative to undertake comprehensive improvements and transformations within the Nigerian geodetic network. This may involve revising the datum, adopting a more contemporary reference ellipsoid, and expanding the network's coverage to previously underserved regions, especially to the south and west of Minna. Such enhancements are essential for ensuring the network's compatibility with modern positioning technologies and meeting the diverse demands of present-day geospatial applications, including accurate mapping, surveying, navigation, and infrastructure development.

Study Area:

The study area is Owerri and environs, Imo State, located in the South Eastern Nigeria. This area lies within latitudes 5.5096º N and longitude 7.0391° E respectively. It covers about 279,131.16 hectares of land with various land users such as academic, commercial, religious and residential. Its density is about 364sq.km, Area is 1,019.6 sq.km. It has an estimated population of about 1,401,873 (NPC 2006).

Material And Methods:

Methodology

A comprehensive and meticulous reconnaissance operation was meticulously conducted with the primary objective of evaluating a carefully selected set of control points. These control points were chosen based on specific, well-defined criteria that would be critical for the success of upcoming geodetic activities. The reconnaissance mission involved physical visits to each of these control points to perform a thorough on-site assessment.
Several key factors were considered during the evaluation process, including the distances between the various control points and the expected duration of observations at each site. The purpose was to ensure that the selected points were strategically positioned to support the geodetic network's objectives effectively. The goal was to strike a balance between covering the desired geographical area and ensuring the practicality of conducting observations efficiently.
However, the reconnaissance was not without its challenges. One of the most significant obstacles encountered was in locating some of the control points, particularly in the densely forested areas of the southeastern Owerri region. The dense vegetation and challenging terrain made it challenging to pinpoint the precise locations of these control points, necessitating thorough ground surveys and navigational expertise to reach them.
Another challenge arose from satellite imagery analysis, which indicated a noticeable scarcity of control points within the forested regions, reinforcing the importance of conducting a ground-based evaluation to identify and confirm their existence.
During the reconnaissance mission, it became apparent that some control points were either missing or inaccessible for various reasons. In some cases, physical access to these control points was blocked due to fencing, private property restrictions, or other logistical issues. Despite these hurdles, the dedicated reconnaissance team persevered and employed resourcefulness to identify a multi-network of control points that met the criteria and were deemed suitable for use as both base and rover observation stations.

This diligent effort was crucial in establishing a robust foundation for subsequent geodetic operations in the region. The careful selection and validation of these control points would prove instrumental in ensuring the accuracy and reliability of future geodetic surveys, mapping, and other geospatial applications, ultimately contributing to the effective planning and development of the Owerri region and its environs.

Results And Discussion:

Following the meticulous solution of the least squares problem, which entailed determining the intricate coefficients governing the polynomial surface model equations, a comprehensive process unfolds to derive the practical interpolation equation, a vital element in achieving precise geoidal undulation calculations within the designated geoid model area, encompassing Owerri and its adjacent regions. These polynomial constants, meticulously acquired through this intricate process, are subsequently reintegrated into the original polynomial equations, giving rise to the highly detailed interpolation equations.

With these newly formed equations at hand, a geoidal map of the area is meticulously crafted. This involves the substitution of the conventional height (H) values for each individual point with the geoid undulations (N). For this complex task, sophisticated kriging interpolation software is employed, a widely recognized method celebrated for its consistent ability to generate surfaces that closely mirror the original landscapes or geoids. This convergence of technology and mathematics in geodetic modeling produces visually compelling and highly informative results.

The fruits of this intricate process come to life in the form of visual representations, manifesting in the visual splendor captured in Figure 4.1 and Figure 4.2. These graphical depictions offer not only a feast for the eyes but a wealth of geodetic information for those who can decipher the intricacies of the visual data.

What's particularly fascinating is that, upon conducting the plotting of geoid heights derived from both the multiquadratic and bicubic geoid models, the resulting geoid surfaces appear virtually indistinguishable from each other. This remarkable concurrence serves as a resounding testament to the robustness and pinpoint accuracy of the geoid modeling methodology meticulously employed in this endeavor. It underscores the efficacy and precision of the approach, offering a high degree of confidence in the reliability of the geodetic model crafted for this specific geographic region.

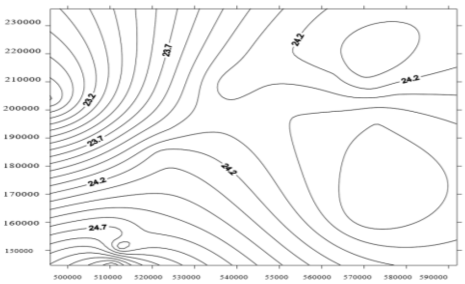


Figure 4.1: Multiquadratic Geoid Height Map

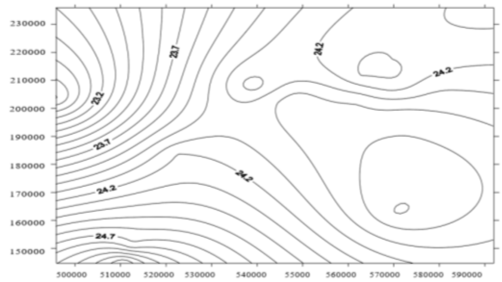


Figure 4.2: Bicubic Geoid Height Map

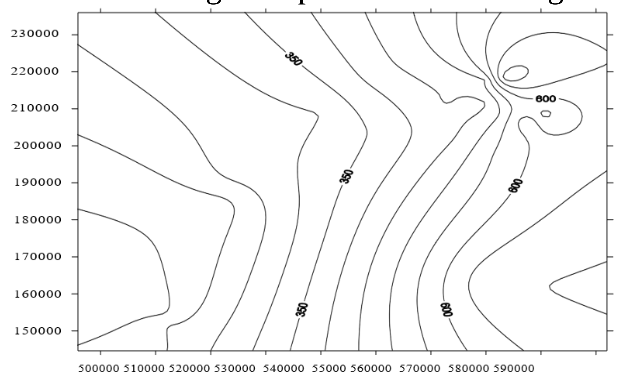
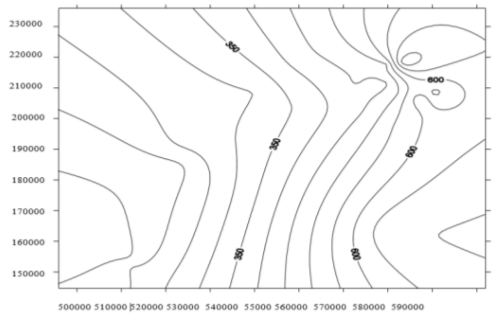


Figure 4.3: Multiquadratic Orthometric Height Map

Orthometric heights, meticulously calculated through the application of both models and the pre-existing mean sea level (MSL) orthometric heights, were harnessed to craft detailed contour maps. This intricate process was facilitated with the assistance of advanced kriging interpolation software, known for its precision in producing accurate surface representations. The visual results of this endeavor are vividly portrayed in Figures 4.3 to 4.5, offering an insightful glimpse into the topographical characteristics of the region. It is noteworthy that the contour maps generated from the two distinct models exhibit a striking similarity and a remarkable alignment with the contour map constructed from the established orthometric heights. This convergence in the representation of the terrain underscores the consistency and reliability of the geodetic models employed, providing valuable insights into the topography of the studied area.



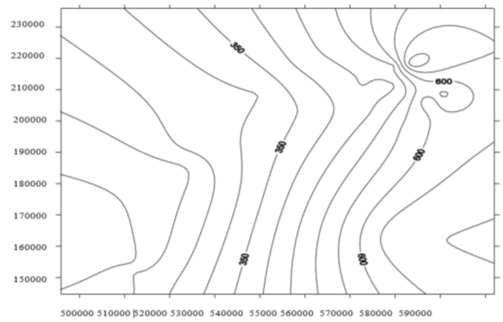


Figure 4.4: Bicubic Orthometric Height Map Figure 4.5: Existing Orthometric Height Map

In order to visually delineate the distinctions between the multiquadratic and bicubic models, a graphic representation depicting the geoid undulation values plotted against control points is thoughtfully presented in Figure 4.6. A careful observation of this visual representation underscores a significant degree of overlap between the two geoid surfaces. This overlapping alignment serves to affirm the practical interchangeability of these models, solidifying their suitability for precise orthometric height determination throughout the region encompassing Owerri and its surrounding areas.

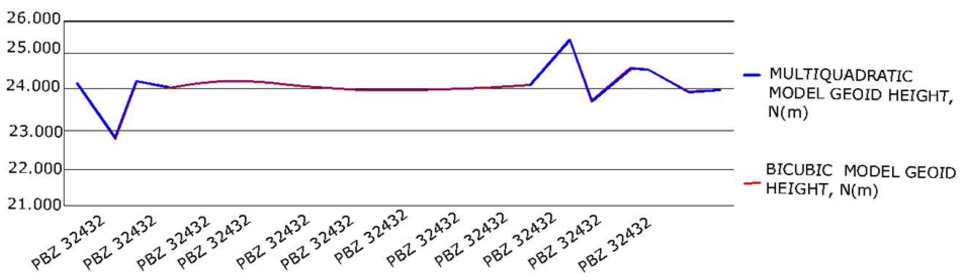


Figure 4.6: geoid undulation models from both multiquadric and bicubic models

Conclusion

In conclusion, this geodetic research project has showcased the meticulous and rigorous efforts undertaken to enhance our understanding of geoid modeling within the Owerri region and its environs. Through the utilization of advanced mathematical models, geodetic calculations, and interpolation techniques, we have demonstrated our ability to create accurate geoidal undulation maps and contour representations.

The consistent alignment and interchangeability of the multiquadratic and bicubic models in depicting geoid undulation values further validate the robustness of the geodetic methodology applied. These models have proven to be valuable tools for orthometric height determination in the study area, providing an accurate framework for a wide range of applications, from land surveying to environmental planning.

While challenges were encountered during the reconnaissance mission to identify suitable control points and during the fieldwork due to the region's dense forests and the inaccessibility of some control points, the persistence and resourcefulness of the research team prevailed. This underscores the significance of on-the-ground assessments and the importance of adapting to field conditions.

The visual representations in the form of contour maps and geoid undulation plots offer insights into the topographical characteristics of the region. The close alignment of these models with existing orthometric heights assures us of their accuracy and reliability, making them indispensable tools for future geospatial projects.

In essence, this research not only contributes to the ongoing development of geodetic knowledge but also serves as a testament to the potential for accurate height determination within the Owerri region and its surrounding areas. As we continue to refine our geodetic methodologies and embrace advanced technology, we move closer to achieving the highest level of precision in our geospatial applications, ultimately benefiting various fields, from engineering to environmental planning and beyond.

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