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Comparative Study of Reduced Orthometric Heights from EGM_{2008} AND EGM_{1996}

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ABSTRACT
High resolution geoid models in different scales currently play a fundamental role in a wide range of the most challenging applications in geodesy and geosciences in general. The considerable development of these geoid models in recent years is mainly due to the advanced availability of satellite, airborne and terrestrial datasets. The aim of this paper is to provide an explanation for the comparison of Orthometric heights obtained from the observations of GNSS, EGM2008 and EGM1996 models. In this study, a large part of Federal Polytechnic Ado-Ekiti campus was selected. A total of twenty five (25) Ground Control Points (GCPs) were occupied for GNSS observations and Alltrans software 3.002was used for the computation of geoidal undulation of selected points. Dual frequency GPS Hi-Target was used in acquiring GPS data, which were processed using Hi-Target GNSS processor software for deriving Ellipsoidal heights while Alltrans software 3.002 was used to calculate the geoidal heights. The RMSE index and Standard Deviation was applied to compute the accuracy of the geoid modelling. The computed results show that the Orthometric heights can be obtained in the study area using the two methods with accuracy of RMSE± 0.4271961m. With respect to the standard deviation, EGM2008 modelsσ±2.76628 performed relatively better than the EGM96σ±2.76638. Hence, the EGM2008 can be applied for Orthometric height determination in the study area.

Keyword: Geoidal height, GPS, Orthometric height

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I. INTRODUCTION

One of the basic goals of geodesy is the determination of the geoid which is the equipotential surface of the earth gravity field and which coincides on the average with the mean sea level (Vanicerk, 1986). According to Gauss, geoid is the "mathematical figure of the earth" and the gravity field (Kiamehr, 2006).

Furthermore, the geoid surface is considerably smoother than the physical surface of the earth but more irregular than the ellipsoid of revolution. Therefore, geoid as an equipotential surface of the earth's gravity field has its conceptual importance in geodetic applications, because it is the datum upon which most height systems [orthometric height] are based. Also all terrestrial measuring techniques are actually oriented relative to the geoid. The advent of satellite based positioning techniques, especially Global Positioning System (GPS), which is presently used in a wide range of geodetic and surveying applications, has brought tremendous changes in the processes of precise geodetic control establishment; data acquisition techniques have become more efficient, accuracies greatly improved with new areas of applications opened up, orthometric heights can thus, be acquired indirectly through geodetic heights from GPS if the geoid over the area is known (Moka and Agajelu, 2006).

Since the ellipsoidal heights from GPS are basically geometric in nature and therefore, do not reflect the direction of flow under the influence of gravity, heights from GPS are of little or no direct meaning in engineering construction and geodetic applications. Therefore, to utilize the opportunities provided by this technique, the need for the transformation between ellipsoidal heights and orthometric heights become more important. This is because, using GPS technique, the positions are determined as related to geocentric WGS84(World Geodetic System 1984) reference ellipsoid of which surface is assumed to be the datum of points heights which are derived from GPS measurements, while orthometric heights are determined with reference to the geoid.

Therefore, there is need for accurate geoid model for transforming the geometrical (ellipsoidal) heights from GPS to the highly needed orthometric heights. Unfortunately, the geoid for Nigeria has not been accurately determined, also because of uneven distribution as well as insufficient availability of gravity data in Nigeria, gravimetric geoid for Nigeria will be weak in some part of the country than the other. Consequently, the national/regional geoid model may not satisfy the accuracy, which is necessary for most of the routine geodetic applications (Opaluwa, 2008)

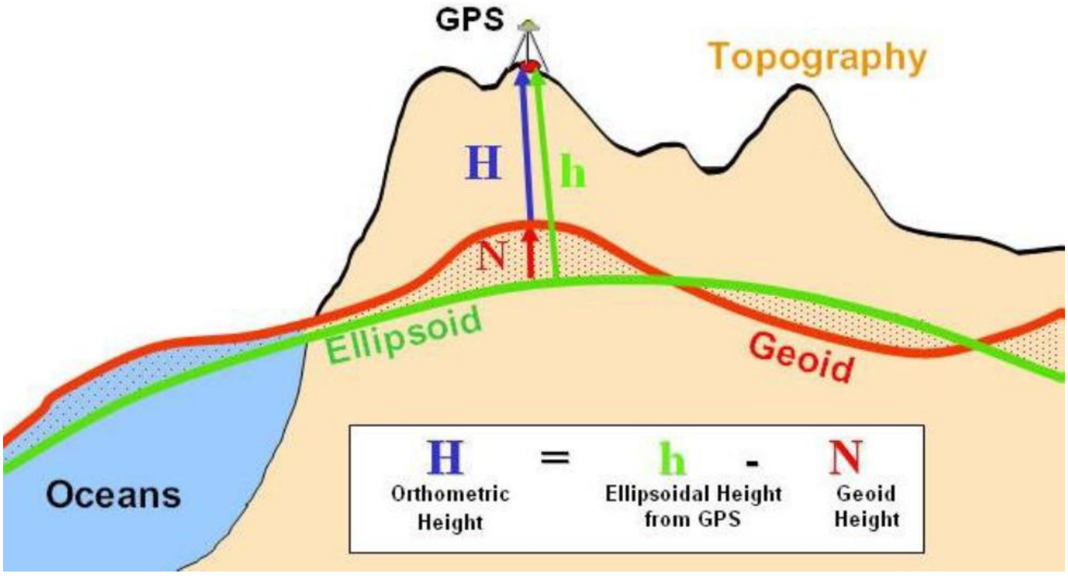

Fig. 1.0: Relationship between orthometric, geoid and ellipsoidal heights Source: (Badejo,et al, 2016)

The optimal combination of geometric heights obtained from Global Positioning System (GPS) measurements with geoidal undulations derived from a gravimetric geoid model, to determine orthometric heights relative to a vertical geodetic datum, is well suited for many practical applications as given in (Fig. 1) and equations (1). This process, referred to as GPS/levelling geoid is based on a simple geometrical relationship that exists between the geodetic surfaces given by Heiskanen and Moritz,(1967).

$H = h – N$……………………………………………………(1)

Global Geopotential Models (GGM) has become an essential tool in geodesy as wellas in other Earth Sciences and engineering field applications. For instance, for surveying,mapping, and engineering projects GGM can be combined with precise Global Navigation Satellite System (GNSS) positioning to efficiently yield orthometric heights to benchmarks over the Earth's surface, avoiding the costly and time demanding spirit leveling. Several GGMs have been produced during the last decades. At present there are more than 170 GGMs available at the International Center for Global Gravity Field Models (ICGEM) (Potsdam Germany), in the form of fully normalized spherical harmonic coefficients that can be used to compute geodetic and Earth's gravity field quantities (http://icgem.gfzpotsdam.de).The EGM96 and EGM08 are some of the models used to calculate the geoid undulation of an area to determine the orthometric height from GPS measurements (Do, 2011). The original technique that was used to compute the geoid undulation was the Stokes' integral (Heiskanen and Moritz, 1967).

Global Geopotential Models offer long wavelength information of the earth's gravity field and contribute to the regional geoid model through the Remove-Compute-Restore (RCR) technique. The recent improvements of GGMs have been based on satellite-only solutions or solutions that conglomerate satellite and terrestrial measurements; and, they have been shaped in the form of spherical harmonic expansions (Torge, 2001). As one of the combination models, Earth Geopotential Model 1996 (EGM96) is an extension of spherical harmonics up to degree and order 360 (Lemoine et al., 1998). Recent satellite missions such as CHAllengingMinisatellite Payload (CHAMP), Gravity Recovery and Climate Experiment (GRACE), and Gravity field and steady-state Ocean Circulation Explorer (GOCE), designed specifically to measure the global gravitational field of the earth, have contributed to improve the long wavelength accuracies of GGMs (Reigber et al., 2002; Tapley et al., 2004; Pail et al., 2010; Mayer-Guerr et al., 2012). The newly published Earth Geopotential Model 2008 (EGM08) up to degree 2190 has included the harmonics from the GRACE mission for its lower degrees (Pavlis et al., 2012). In addition, recently published satellite-only GGMs such as GOCO03S (Mayer-Guerr et al., 2012) and GO_CONS_GCF_2_DIR (Pail et al., 2011) are based on the GOCE mission launched by ESA in 2009. In this chapter, GGMs are introduced and analyzed with respect to actual measurements for Federal Polytechnic Ado-Ekiti.

EGM96 from 1996 is the result of a collaboration between the National Imagery and Mapping Agency(NIMA), the NASA Goddard Space Flight Center (GSFC). It took advantage of new surface gravity data from many different regions of the globe, including data newly released from the NIMA archives. Major terrestrial gravity acquisitions by NIMA since 1990 include airborne gravity surveys over Greenland and parts of the Arctic and the Antarctic, surveyed by the Naval Research Lab (NRL) and cooperative gravity collection projects.

The aim of this research is to determine orthometric height of points for FPA Campus using online EGM calculator and GPS observations.

II. PROJECT SITE

The Federal Polytechnic, Ado-Ekiti is a government owned institution located along Ado/Ikare road, Ado-Ekiti, Ekiti State, Nigeria. The institution lies between latitude 7˚32'0"N and 7˚37'0"N, and longitude 5˚17'0"E and 5˚20'0"E. Ekiti is one of the 36 states of Nigeria and is located in Southwestern part of the country.The project site is located in the South-western part of Federal Polytechnic Ado-Ekiti, Ekiti State. The project site covers AfeBabalola Hall (New Administrative building), AtikuAbubakar Hall, Banks and the security office of Federal Polytechnic Ado-Ekiti.

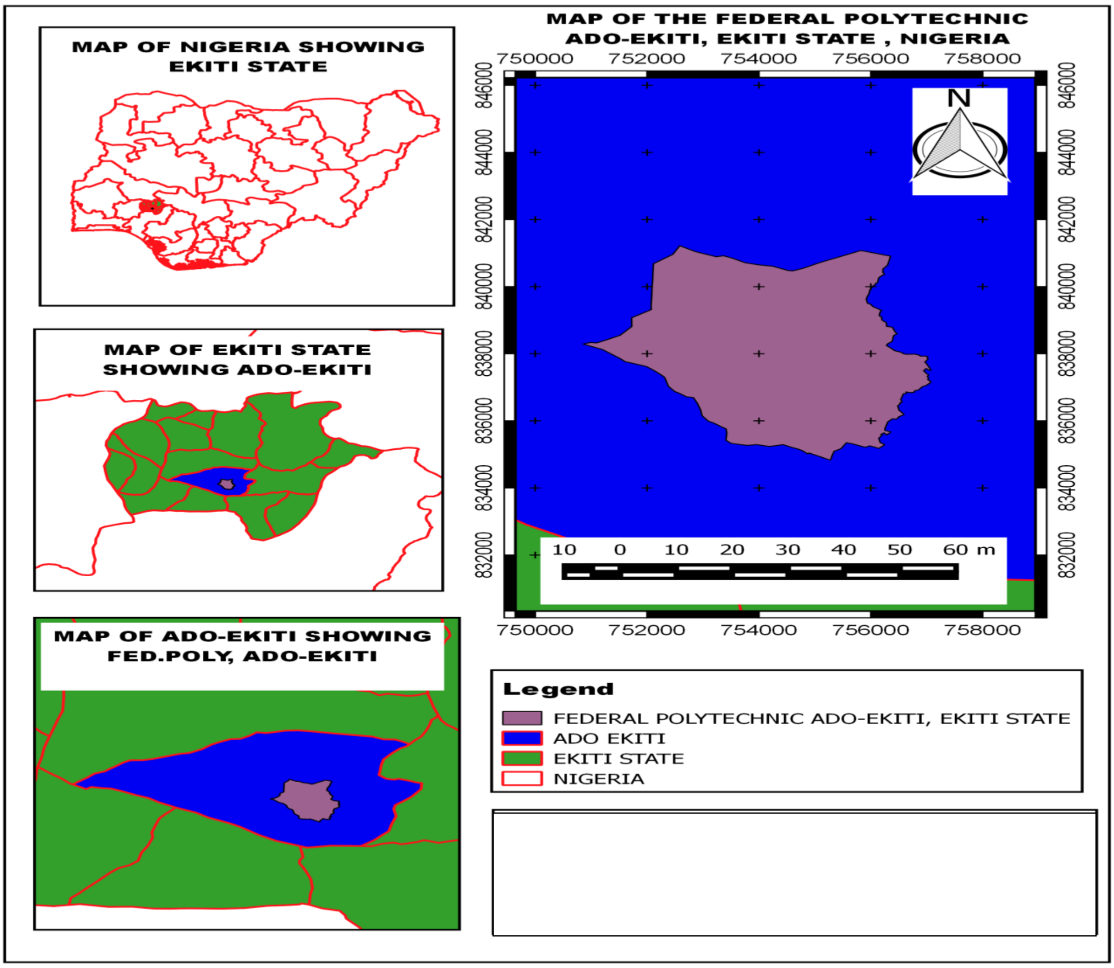

Figure 2: Study Area

III. METHODOLOGY

In this study, the framework involves planning,followed by acquisition of geodalundulation values using All Trans 3.002 EGM 2008, 96,84 and Geodetic coordinates by dual frequency GPS Hi-Target for the primary data; and Earth Gravitational Models were downloaded as the secondary data. The observed data were calculated to determine the geoidal undulation of the selected points. The geoidal undulation obtained from All trans 3.002 (N) was deducted from ellipsoidal heights obtained from GPS observation to give the corresponding Orthometric heights of the study area (H = h – N)

3.1EQUIPMENT& SOFTWARE

3.1.1 HARDWARE:

1. Dual frequency GPS Hi-Target and its accessories

3.1.2 SOFTWARE:

1. Dual frequency GPS Hi-Target processor
2. All Trans 3.002 EGM 2008,96,84
3. Surfer 10
4. Microsoft package

3.2. GNSS Observation

The geodetic coordinates (φ, λ, h) of a total of 25 points were acquired in static mode with Dual frequency GPS Hi-Target. The base receiver was set on the control beacon (FPA01S), and the rover receiver was placed on the selected points for a minimum of 30minutes each. The necessary settings of the parameters needed for the observation were set (base or rover) such as the station ID, antenna height, epoch rate, etc. The mode of observation was post-processing with the base receiver at station FPA01S (control inside FPA) and the rover receiver taking round from pillar-to-pillar after carrying out all the necessary settings. The PDOP value was less than 4.0 throughout the period of observation.

3.3. Data Sets

The datasets required for this study include: Ellipsoidal height (h) from static DGPS measurements by relative technique; EGM geoid calculator for geoid undulation (N) computation.

3.3.1. Orthometric Height (H)

This is the height required for survey, mapping, engineering/environmental applications as well as geo-scientific studies. These heights are referred to the geoid surface which is a surface that is at all places on the surface at right angles to the gravity vector direction. The orthometric heights of these points will be deduced from the ellipsoidal heights by using the global geoid model, the EGM 2008 and EGM 96 respectively.

Fig 3.1: Image showing the secondary data

IV. RESULTS AND DISCUSSION

4.1. PRESENTATION OF RESULTS

There are some differences in the results between EGM models and GPS observations because each of the dataset acquired depend on different datum. GPS provide ellipsoid heights, while EGM provide geoidal undulation/geoidal heights based on a level surface called the geoid (M.S.L).The results in Table 4.1 to 4.3 represent a part of Ground Control Points (GCPs) which are observed by using EGM and GPS. The total number of these points was twenty-five distributed in the site. Table: 4.1showthe observation of geoidal undulation and ellipsoidal heights and deduced orthometric height(H = h - N).

Table 4.1: showing the relationship of ellipsoidal, geoidal undulation and orthometric heights (EGM_{08})

Site ID	Eastings(m)	Northings(m)	ELL.HT(m)	EGM 2008(m)	ORTH.(H)m
FPA1678	753318.036	839825.162	377.405	25.404	352.001
GPS 18/001	753306.468	839827.941	376.124	25.404	350.72
GPS 18/002	753304.038	839828.765	375.523	25.404	350.119
GPS 18/003	753290.718	839836.41	376.119	25.4043	350.7147
GPS 18/004	753314.198	839914.983	379.867	25.405	354.462
FPAT182B	753353.215	840110.769	379.169	25.407	353.762
GPS 18/005	753328.785	839946.418	382.082	25.4052	356.6768
GPS 18/006	753325.957	839954.447	379.088	25.4053	353.6827
SUG07/A2	753309.384	839960.433	380.483	25.4056	355.0774
GPS18/007	753372.762	840114.905	381.218	25.4068	355.8112
FPA004T	753366.043	840135.101	378.792	25.4071	353.3849
FPA1655	753249.245	840187.304	377.261	25.4093	351.8517
FPA169S	753188.487	840206.424	380.53	25.4103	355.1197
GPS 18/008	753744.441	839860.388	376.244	25.3989	350.8451
GPS 18/009	753746.634	839844.592	376.018	25.3987	350.6193
FPA2381	753766.482	839856.953	375.065	25.3986	349.6664
GPS 18/010	754121.96	839713.361	382.698	25.3926	357.3054
SUG110066	754077.854	839678.319	373.741	25.3927	348.3483
FPA1635	754079.981	839697.911	373.048	25.3929	347.6551
FPA1645	753778.43	840006.082	375.523	25.4003	350.1227

FPA001T	753777.127	840012.426	374.726	25.4004	349.3256
GPS 18/011	753716.416	840028.608	375.463	25.4014	350.0616
FPA003T	753488.199	840096.515	375.411	25.4051	350.0059
FPA 229T	753498.225	839732.381	373.111	25.4003	347.7107
CONTROL 9531 OBS	753459.146	839903.693	375.912	25.403	350.509

Table 4.2: shows the relationship of ellipsoidal, geoidal undulation and orthometric heights. (EGM_{96}).

Site ID	Eastings(m)	Northings(m)	ELL.HT	EGM 96	ORTH.(H)m
FPA1678	753318.036	839825.162	377.405	24.9763	352.4287
GPS 18/001	753306.468	839827.941	376.124	24.9764	351.1476
GPS 18/002	753304.038	839828.765	375.523	24.9765	350.5465
GPS 18/003	753290.718	839836.41	376.119	24.9767	351.1423
GPS 18/004	753314.198	839914.983	379.867	24.9775	354.8895
FPAT182B	753353.215	840110.769	379.169	24.9797	354.1893
GPS 18/005	753328.785	839946.418	382.082	24.9778	357.1042
GPS 18/006	753325.957	839954.447	379.088	24.9779	354.1101
SUG07/A2	753309.384	839960.433	380.483	24.9782	355.5048
GPS18/007	753372.762	840114.905	381.218	24.9796	356.2384
FPA004T	753366.043	840135.101	378.792	24.9799	353.8121
FPA1655	753249.245	840187.304	377.261	24.9819	352.2791
FPA169S	753188.487	840206.424	380.53	24.9828	355.5472
GPS 18/008	753744.441	839860.388	376.244	24.972	351.272
GPS 18/009	753746.634	839844.592	376.018	24.9718	351.0462
FPA2381	753766.482	839856.953	375.065	24.9717	350.0933
GPS 18/010	754121.96	839713.361	382.698	24.9657	357.7323
SUG110066	754077.854	839678.319	373.741	24.9658	348.7752
FPA1635	754079.981	839697.911	373.048	24.966	348.082
FPA1645	753778.43	840006.082	375.523	24.9736	350.5494
FPA001T	753777.127	840012.426	374.726	24.9737	349.7523
GPS 18/011	753716.416	840028.608	375.463	24.9746	350.4884
FPA003T	753488.199	840096.515	375.411	24.978	350.433
FPA 229T	753498.225	839732.381	373.111	24.973	348.138
CONTROL 9531 OBS	753459.146	839903.693	375.912	24.9758	350.9362

Table 4.3: Shows the Orthometric heights obtained from $EGM_{2008(H1m)}$ and $EGM_{1996(H2m)}$

Site ID	Eastings(m)	Northings(m)	ORTH.(H)m(EGM 2008)	ORTH.(H)m(EGM 1996)
FPA1678	753318.036	839825.162	352.001	352.4287
GPS 18/001	753306.468	839827.941	350.72	351.1476
GPS 18/002	753304.038	839828.765	350.119	350.5465
GPS 18/003	753290.718	839836.41	350.7147	351.1423
GPS 18/004	753314.198	839914.983	354.462	354.8895
FPAT182B	753353.215	840110.769	353.762	354.1893
GPS 18/005	753328.785	839946.418	356.6768	357.1042

GPS 18/006	753325.957	839954.447	353.6827	354.1101
SUG07/A2	753309.384	839960.433	355.0774	355.5048
GPS18/007	753372.762	840114.905	355.8112	356.2384
FPA004T	753366.043	840135.101	353.3849	353.8121
FPA1655	753249.245	840187.304	351.8517	352.2791
FPA169S	753188.487	840206.424	355.1197	355.5472
GPS 18/008	753744.441	839860.388	350.8451	351.272
GPS 18/009	753746.634	839844.592	350.6193	351.0462
FPA2381	753766.482	839856.953	349.6664	350.0933
GPS 18/010	754121.96	839713.361	357.3054	357.7323
SUG110066	754077.854	839678.319	348.3483	348.7752
FPA1635	754079.981	839697.911	347.6551	348.082
FPA1645	753778.43	840006.082	350.1227	350.5494
FPA001T	753777.127	840012.426	349.3256	349.7523
GPS 18/011	753716.416	840028.608	350.0616	350.4884
FPA003T	753488.199	840096.515	350.0059	350.433
FPA 229T	753498.225	839732.381	347.7107	348.138
CONTROL 9531 OBS	753459.146	839903.693	350.509	350.9362
		MEAN	351.822328	352.249524
		ST.DEV	2.766280101	2.766388422

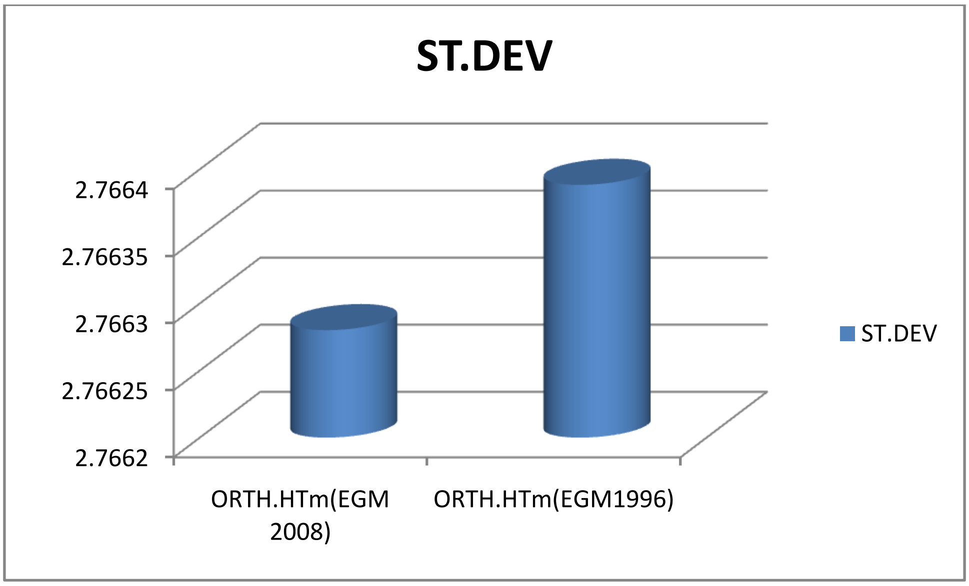

Figure 4.1: Image showing the Standard Deviation of Orthometric heights obtained from EGM_{2008}(H1) and EGM_{1996}(H2)

Table 4.4: Showing the difference between the orthometric heights obtain from EGM $_{2008}$(H1m), EGM_{1996} (H2m) and the RMSE.

	Site ID	ORTH.(H1)m(EGM 2008)	ORTH.(H2)(EGM 1996)	$(H1-H2)^2$
1	FPA1678	352.001	352.4287	0.18292729
2	GPS 18/001	350.72	351.1476	0.18284176
3	GPS 18/002	350.119	350.5465	0.18275625

4	GPS 18/003	350.7147	351.1423	0.18284176
5	GPS 18/004	354.462	354.8895	0.18275625
6	FPAT182B	353.762	354.1893	0.18258529
7	GPS 18/005	356.6768	357.1042	0.18267076
8	GPS 18/006	353.6827	354.1101	0.18267076
9	SUG07/A2	355.0774	355.5048	0.18267076
10	GPS18/007	355.8112	356.2384	0.18249984
11	FPA004T	353.3849	353.8121	0.18249984
12	FPA1655	351.8517	352.2791	0.18267076
13	FPA169S	355.1197	355.5472	0.18275625
14	GPS 18/008	350.8451	351.272	0.18224361
15	GPS 18/009	350.6193	351.0462	0.18224361
16	FPA2381	349.6664	350.0933	0.18224361
17	GPS 18/010	357.3054	357.7323	0.18224361
18	SUG110066	348.3483	348.7752	0.18224361
19	FPA1635	347.6551	348.082	0.18224361
20	FPA1645	350.1227	350.5494	0.18207289
21	FPA001T	349.3256	349.7523	0.18207289
22	GPS 18/011	350.0616	350.4884	0.18215824
23	FPA003T	350.0059	350.433	0.18241441
24	FPA 229T	347.7107	348.138	0.18258529
25	CONTROL 9531 OBS	350.509	350.9362	0.18249984
			RMSE	0.4271961

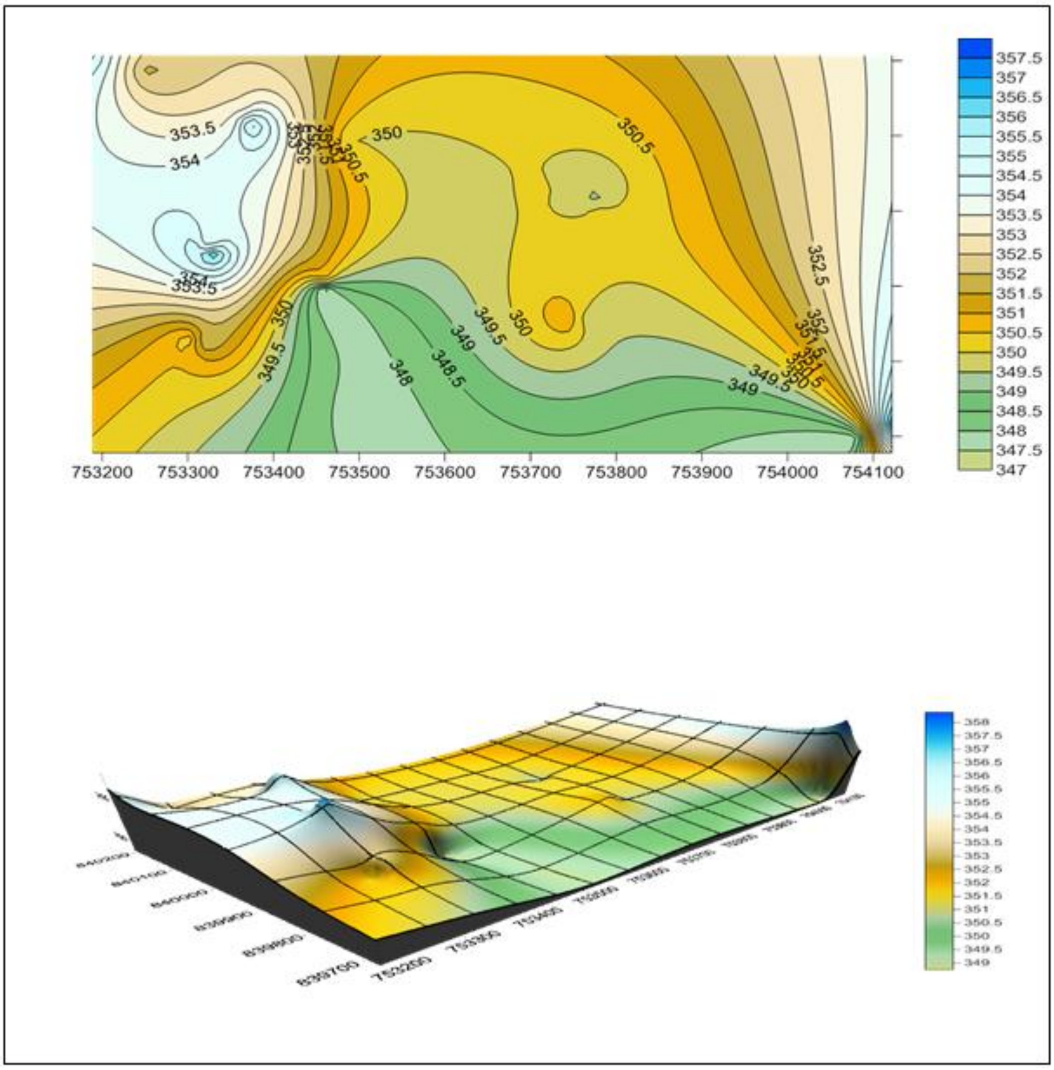

Figure 4.2: Contour and 3D Surface Plots of Orthometric Height via EGM_{2008}

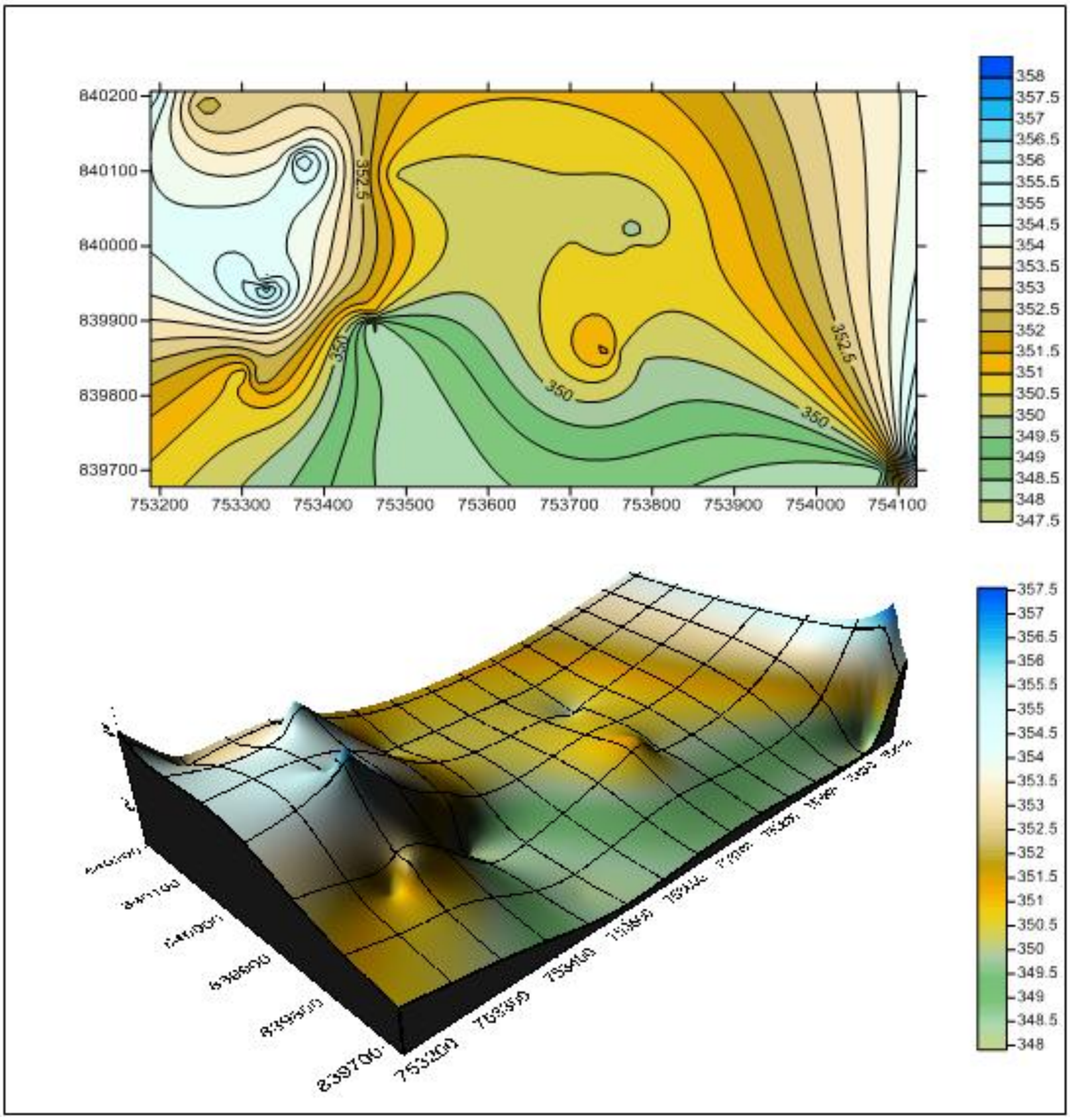

Figure 4.3: Contour and 3D Surface Plots of Orthometric Height via EGM_{1996}

4.2 DISCUSSION OF RESULTS

The results obtained from this study are the coordinates of twenty-five (25) selected control points determined using GNSS observation and Geoidalundulations (N_{EGM}) each selected points was obtained by Alltrans 3.002 software downloaded online. The difference between the ellipsoidal heights(h) obtained from GNSS and the geoidal undulation obtained from Alltrans 3.002 software were used to produce the ortometric heights of the study area (H = h - N), which shows in tables 4.1-4.3. The difference between the Orthometric heights obtained from EGM_{2008} and EGM_{1996} have been calculated this shows in table 4.4 above. The statistical validity of results can be assessed by considering the Standard Deviation and the Root Mean Square Error(RMSE) which was shown in figure 4.1 and table 4.4 respectively.

H1is the orthometric height of stations of EGM 2008

H2 is the orthometric height of stations of EGM 1996

4.3 Root Mean Square Error:

The Root Mean Square Error (RMSE), also called the Root Mean Square Deviation, is a frequently used measure of the difference between values observed from different sets of measurement. These individual differences are also called residuals, and the RMSE serves to aggregate them into a single measure of predictive power. Therefore the RMSE of the processed coordinates (obtained by GNSS softwares) with respect to the geoidal undulation obtained from Alltrans software 3.002 observed is defined as the square root of the mean squared error.

In this study, n (i = 1 - 25) control points were observed with All trans software 3.002 and dual frequency GPS.

The Root Mean Square Error (RMSE) of the Orthometric height differences of Geoidal undulation from EGM 2008 and EGM 1996 were computed by squaring the difference in heights using equation (2)

$$RMSE=\sqrt{\frac{1}{n}\sum_{k=1}^{n}(H1-H2)^2} \quad \text{...(2)}$$

In equation (2), n is the number of the points used for the accuracy confirmation and k is the residual sequence

4.4 HYPOTHESIS TESTING

A hypothesis is a statement about a parameter of distribution. A test of a hypothesis is a rule that, based on the sample values, leads to a decision to accept or reject the null hypothesis. Normally, a test statistic is computed form the sample values (observations) and from the specification of the null hypothesis. If the test statistic falls within a critical region, the null hypothesis is rejected otherwise it is accepted.

Hypothesis testing was carried out to test the result of orthometric height obtained through EGM_{2008} and EGM_{1996}. This is to show if there is a significant difference in the mean of the result obtained from the comparative methods.

Table:4.5T-test of difference in the influence exerted byorthometric heights of point obtained from EGM_{2008} and EGM_{1996}

t-Test: Two-Sample Assuming Equal Variances		
	ORTH.(H)m(EGM 2008)	*ORTH.(H)m(EGM 1996)*
Mean	351.822328	352.249524
Variance	7.652305598	7.652904904
Observations	25	25
Pooled Variance	7.652605251	
Hypothesized Mean Difference	0	
df	48	
t Stat	-0.545980998	
P(T<=t) one-tail	0.293803873	
t Critical one-tail	1.677224196	
P(T<=t) two-tail	0.587607746	
t Critical two-tail	2.010634758	

Hypotheses: $\mathbf{H_O}$**:** $\mu_{EGM2008} = \mu_{EGM1996} \leq 0$

$\mathbf{H_1}$: $\mu_{EGM2008} = \mu_{EGM1996} > 0$

Rejection Region: Where: α = Level of Significance = 0.05

Reject $\mathbf{H_O}$ if $t > 1.677$

Test Statistic:

t = -0.546

Decision/Conclusion:

Revealed that there was a significant difference in the mean influence exerted by orthometric heights of point obtain from EGM_{2008} and $EGM_{1996.}$ There was a significant difference. Also show mean differences that EGM2008 has mean value of 351.8223and EGM_{1996} with mean value of 352.2495. Null hypothesis was rejected, Lastly the contour and the 3D surface plots of Orthometric heights obtained from the EGMs are shown in figures 4.2 and 4.3 above. The highest points within the study area as shown in the two figures were found in the western part. Even at that, the figures shows the variations between the Orthometric heights obtained from the two models used i.e. EGM $_{2008}$ and EGM $_{1996}$.

V. CONCLUSION

An analysis was made for the accuracy improvement of geoid Modelling values from a comparison of geoid undulation (N_{EGM}) values, as produced by the geoid models EGM2008, and EGM96 with respect to the corresponding values of Ellipsoidal heights (h) obtained from GNSSobservations.The study has shown the potentials on the use of ellipsoidal heights andgeoidal heights data for reduceOrthometric heights determination. The results obtained from this study, as well as the two approaches, show that there is a difference between the two methods as indicated by the Standard Deviation results. The RMSE computation results also show that

Orthometric heights can be obtained in the study area using any of the two approaches with an accuracy ofRMSE ± 0.4271961m.Thus, in the two methods the EGM2008can be applied in the study area for Orthometric heights determination.

REFERENCES

[1]. Badejo, O.T., Aleem, K. F. and Olaleye, J. B. (2016). Replacing Orthometric Heights with Ellipsoidal Heights in Engineering Surveys. Nigerian Journal of Technology. (35) 4

[2]. Do, N. D. (2011), "Fitting Research about EGM2008 High Anomaly Bases on GPS/LevellingDatas in local Vietnam, Published Thesis, HA NOI University of Mining and Geology, Vietnam, 26 pp.

[3]. Hasan Bilani* and Ismat Elhassan (2020)'' Geoid Modelling for Surveying Works Using Satellite Geo-Spatial Data '' Civil Engineering Department, College of Engineering, King Saud University Saudi Arabia. Civil Engineering Research Journal ISSN:2575-8950

[4]. Heiskanen, W. A. and H. Moritz., 1967 Heiskanen and Moritz (1967) , Moka and Agajelu(2006): Physical Geodesy. Institute of Physical Geodesy, Technical University of Graz, Austria, W.H. Freeman.

[5]. http://icgem.gfzpotsdam.de.

[6]. Kiamehr R., 2006: Precise Gravimetric Geoid Model for Iran Based on GRACE and SRTM data and the Least-Square Modification of Stokes' Formula with Some Geodynamic Interpretations. PhD Dissertation in Geodesy, Royal Institute of Technology (KTH), Stockholm, Sweden.

[7]. Lemoine F., Kenyon S., Factor J., et al. (1998) The Development of the Joint NASA GSFC and the National Imagery and Mapping Agency(NIMA). Greenbelt, Maryland 20771

[8]. Mayer-Guerr T., Rieser D., Höck E., BrockmannJ..M., Schuh W.-D., Krasbutter I., Kusche J., Maier A., Krauss S., Hausleitner W., Baur O., Jäggi A., Meyer U., Prange L., Pail R., Fecher T., Gruber T. (2012): The new combined satellite only model GOCO03s. Abstract submitted to GGHS2012, Venice (Poster).

[9]. Moka, E.C. and Agajelu, S. I., 2006: On the Problem of Computing Orthometric Heights from GPS data. Proceedings of the first international workshop on Geodesy and Geodynamics, pp 85-91; November.

[10]. Norberto Alcantar-Elizondo *, Ramon Victorino Garcia-Lopez , Xochitl Guadalupe Torres-Carillo and Guadalupe Esteban Vazquez-Becerra (2021)'' Combining Global Geopotential Models, Digital Elevation Models, and GNSS/Leveling for Precise Local Geoid Determination in Some Mexico Urban Areas: Case Study'' Faculty of Earth and Space Sciences, Autonomous University of Sinaloa, Culiacán Rosales 80040, Mexico; rvgarcia@uas.edu.mx (R.V.G.-L.); xochitl.torres@uas.edu.mx (X.G.T.-C.); gvazquez@uas.edu.mx (G.E.V.-B.)

[11]. Opaluwa, Y. D., 2008: Determination of Optimum Geometrical Interpolation Technique For Modelling Local Geoid And Evaluation Of GPS Derived Orthometric Height. M. Sc. Dissertation, Department of Surveying &Geoinformatics, University of Lagos, Akoka, Nigeria.

[12]. Pail R, Bruinsma S, Migliaccio F, et al. (2011) First GOCE gravity field models derived by three different approaches. Journal of Geodesy 85:819–843. doi: 10.1007/s00190-011-0467-x.

[13]. Pail R, Goiginger H, Schuh W-D, et al. (2010) Combined satellite gravity field model GOCO01S derived from GOCE and GRACE. Geophysical Research Letters 37:n/a– n/a. doi: 10.1029/2010GL044906

[14]. Pavlis NK, Holmes S a., Kenyon SC, Factor JK (2012) The development and evaluation of the Earth Gravitational Model 2008 (EGM2008). Journal of Geophysical Research.doi: 10.1029/2011JB008916. Proceedings of the 2nd regional Geodesy and Geophysics.

[15]. Reigber C, Balmino G, Schwintzer P, et al. (2002) A high-quality global gravity field model from CHAMP GPS tracking data and accelerometry(EIGEN-1S). Geophysical Research Letters 29:94–97.(accessed on line 17th May, 2022)

[16]. Tapley BD (2004) The gravity recovery and climate experiment: Mission overview and early results. Geophysical Research Letters 31:L09607. doi: 10.1029/2004GL019920

[17]. Vaníček P., Krakiwsky E.J., 1986: Geodesy: the Concepts, pp.714, Elsevier.

KehindeOlusegun ISHOLA, et. al. "Comparative Study of Reduced Orthometric Heights from EGM_{2008} AND EGM_{1996}." *IOSR Journal of Humanities and Social Science (IOSR-JHSS)*, 27(08), 2022, pp. 15-26.