International Journal of Scientific & Engineering Research Volume 10, Issue 12, December-2019
ISSN 2229-5518

Assessment of the Fit of Different Versions of Global Geopotential Models Over a Micro-environment Using GPS/Leveling Data

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Abstract

This work focuses on the assessment of the fit of different versions of Global Geopotential Models over a Micro-Environment based on comparisons of geoid undulations that are computed from the global geopotential models (GGMs) and the GPS/leveling data using kriging interpolation for the evaluations with a decay distance of 50km to restrict which block is included in the neighborhood analysis results to avoid excessive extrapolation away from the data. Root Mean Square Error statistical tool was employed to test the reliability of the results obtained in this study. In this application framework, differences between geoid undulations obtained by GGMs and GNSS/leveling were computed. Three Global Models were assessed Viz; the Preliminary Earth Gravitational Model PGM 2000a, (supplied by Gravity Recovery And Climate Experiment {GRACE} data), EGM2008 (a combination of GRACE, MARINE AND LAND GRAVITY DATA), and EIGEN-CG01C (the combined Challenging Mini-satellite Payload {CHAMP} and GRACE model). The Greater Port Harcourt City Agency control diversification Project as a strip area project was chosen as the study area. The project cut across the upland areas in Rivers State and consists of 61 benchmarks that belong to the GPHA Triangulation Network. Available data for this study only falls in eight (8) out of the twenty-three (23) Local Government Areas of Rivers State, covering a total of 4,268km^2 out of 11,077km^2 of Rivers State. Less than 40% of Rivers State land mass. Evaluation of the different geopotential models was done within spherical harmonic coefficients limits of order 2190 and degree 90, Latitude $2.5° \leq \theta \leq 4.5°$ and Longitude $4° \leq \lambda \leq 14°$ and a grid step of 0.05 degrees at zero tide influence and reference system WGS 84 via the calculation service of the International Centre for Global Earth Models (ICGEM). The study shows that new released combined model (EGM2008) is relatively superior to other tested models in the region. According to our numerical results, the new EGM2008 model fits better the observed values used in this investigation. Its standard deviations after fitting with GPS/leveling data is 7cm using three-parameters transformation model. We strongly recommend the use of this new model for the computation of the geoid for a reliable height datum for vertical and astronomical observations in Rivers State.

Key Words: Geoid, Spherical Harmonics, Geoid Undulation, Global Geopotential Model, and

Microenvironment.

I. INTRODUCTION

The choice of best global geopotential model (GGM) for the reduction of geodetic data is of serious concern especially when the use of geoid modeling is required [2], [3]. In order to determine the optimum global geopotential model for an area's gravity field, geoid heights derived from the GPS/Leveling method is compared to the geoid heights generated by global geopotential models (GGMs) [1]. The evaluations are carried out with reference to a geocentric reference datum World Geodetic System 1984 (WGS84). This work shows a summary of the evaluation results for three gravity models using mainly Geoidal Heights from Global models and Mean Sea Level Heights from GPS/Leveling data (assumed to be orthometric heights) considering that the orthometric correction is small, especially in areas of low elevations such as the study area. So its effect on the results can be neglected, especially as it poses no threat on engineering and geodetic applications within the study area.

Statistical comparison of geoidal undulation deduced from GPS/Leveling observations in Rivers State and those from the global geopotential models were made in order to find the version of GGM that best fits the local gravity field features over the study area.

Statement of the Problem

Ellipsoidal heights obtained with GPS have little or no direct practical meaning in engineering constructions and geodetic applications [1]. There is, therefore the need to transform these ellipsoidal heights to highly needed orthometric heights. This process (geometric) is quite tedious and expensive as gravity corrections is to be carried at least at the first and last points of observation to obtain an interpolated average orthometric heights [8].

Global geopotential models make it relatively easy to collect gravity information such as geoidal undulations over the entire Earth. Hence, Orthometric height is the difference between the ellipsoidal height and the geoidal undulation; $H = h - N$

This research thus, assessed different versions of global geopotential models GGMs to ascertain which GGM has the best fit geoidal undulations to the observed undulation values of the study area. Once the best fit global model is known, orthometric heights can be computed directly with minimal cost implications.

Aim

The aim of this study is to determine which version of global geopotential model has a geoidal undulation value that best fits the observed geoidal undulation of the study area.

II. STUDY AREA

The study area covers about eight local government areas viz; Ikwerre, Etche, Obio/Akpor, Eleme, Degema, Emohua, Ahoda West and Port Harcourt Local Government Areas of Rivers State, which falls within the Greater Port Harcourt City Development Authority, South-South of Nigeria. It covers an area of 4,268km^2. The study area lies between 04 15 N to 04 25 N in latitude and 05 20 E and 07 15 E in Longitude.

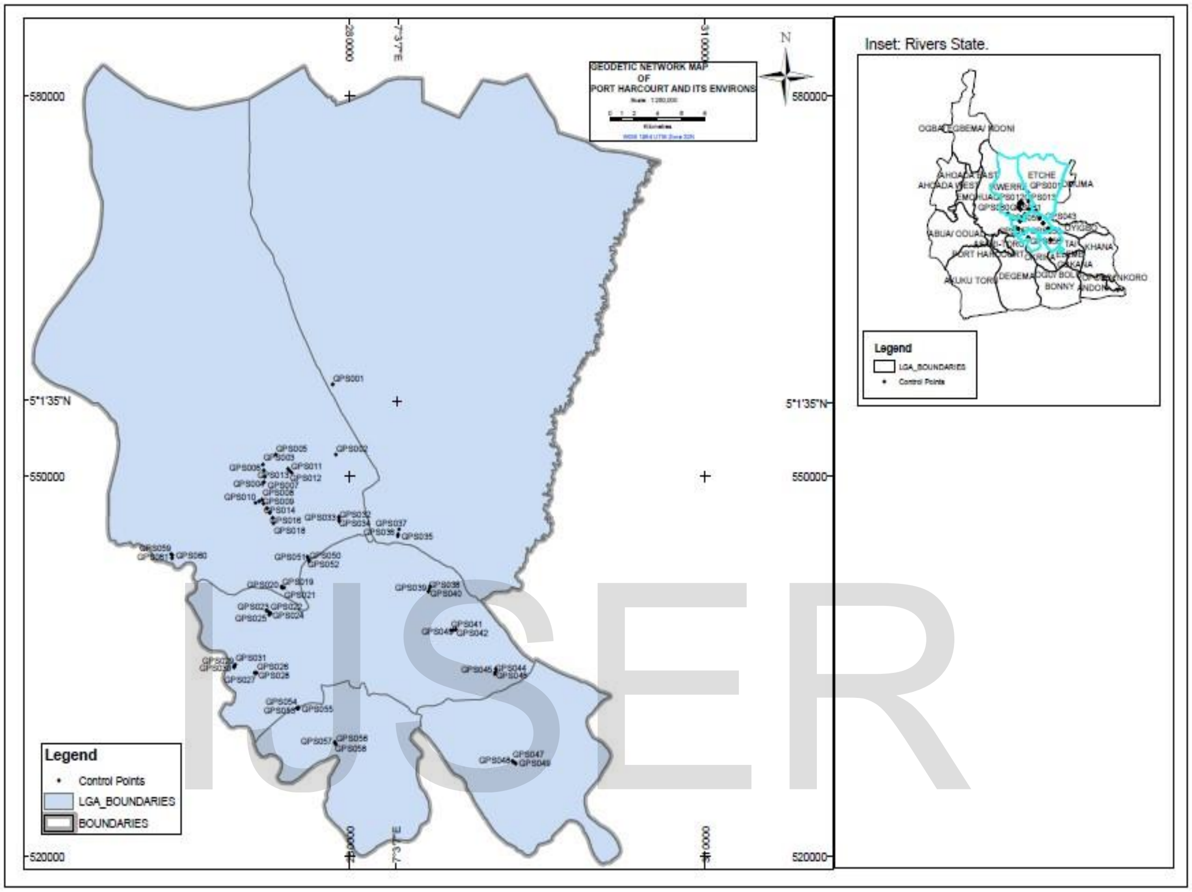

Fig.1.0 Map of Rivers State showing the distribution of points (Source: GPHA)

III. METHODOLOGY

Data Collection

The study obtained GPS/Leveling data from real time survey observations by Greater Port Harcourt City Agency (GPHA) under the supervision of Prof. J. B Olaleye (Table 1.0). Global Geopotential Model data are generated by the calculation service of the International Centre for Global Earth Models (ICGEM) via the web site http://icgem.gfz-potsdam.de/ICGEM/. kriging interpolation data from a program designed by a researcher on geoid modeling and some lay down literature principles to support the general data for this investigation.

GPS/Leveling Data

There are several GPS/Leveling stations distributed over Rivers State by Greater Port Harcourt City Agency (GPH). This distribution is good but the number of GPS stations (61) is too small in relations to the entire Rivers State. For this investigation a total of 61 precise GPS/Leveling points have been used of which 47 are bench marks of first order leveling network and the others are second order leveling network. The GPS observations were performed using LEICA GPS 1230 dual frequency receivers with observation periods between 2 and 3 hours and were processed with the LEICA Geosystem software version 4.2. The computed ellipsoidal heights were referenced to World Geodetic System 1984 (WGS 84) and their standard deviations did not exceed 3cm. All GPS stations have been connected by traditional leveling network tied to the sounding vertical Datum of the Nigerian Port Authority Port Harcourt (NPA Port Harcourt).
The reduced data were gotten from Greater Port Harcourt city Agency (GPHA) for the purpose of this study.
After plotting the GPS points onto the Rivers State shape file, the whole sixty-one (61) points fall in eight different Local Government Areas of the State viz; Ikwerre, Etche, Obio/Akpor, Eleme, Degema, Emohua, Ahoda West, and Port Harcourt Local Government Areas.
Below is the GPS/Leveling reduced data used for this study.

Table 1.0: Showing Stations, Latitude in Decimal, Longitude in Decimal, Ellipsoid Height in Meters, M.S.L Height in Meters (Source: GPHA)

STN	LAT (DEC)	LONG (DEC)	GPS Ellipsoidal Height (m)	M.S.L. Ht (m)
GPS 01	5.038475911	7.002731106	47.654	29.5125
GPS 02	4.988341858	7.005441514	42.542	24.2936
GPS 03	4.981133603	6.966507189	40.065	21.9104
GPS 04	4.972244803	6.951180808	38.771	20.62994
GPS 05	4.988165797	6.959676808	41.357	23.09642
GPS 06	4.976870211	6.950525386	39.485	21.28941
GPS 07	4.968417417	6.950765697	38.351	20.21777
GPS 08	4.956065461	6.949389547	36.427	18.23191
GPS 09	4.95495015	6.947081147	34.627	16.47622
GPS 10	4.953781161	6.944284003	36.819	18.64814
GPS 11	4.978015694	6.968921853	38.155	20.16492
GPS 12	4.976619567	6.970370336	39.661	21.44542

GPS 13	4.975173192	6.971955836	40.589	22.34242
GPS 14	4.953134586	6.950453306	35.359	17.18118
GPS 15	4.949708683	6.952838769	34.766	16.58004
GPS 16	4.946587319	6.955108775	34.756	16.56791
GPS 17	4.943006336	6.957377311	34.79	16.59155
GPS 18	4.939244417	6.957961819	34.784	16.56934
GPS 19	4.893158592	6.964717458	29.266	10.98616
GPS 20	4.89404995	6.964342617	29.87	11.58037
GPS 21	4.893297169	6.966278353	30.338	12.02362
GPS 22	4.875097889	6.955985178	32.335	14.0169
GPS 23	4.875640256	6.954831264	33.256	14.93279
GPS 24	4.873833222	6.955013361	33.065	14.74194
GPS 25	4.876598708	6.952834056	33.532	15.44379
GPS 26	4.832460906	6.945637275	20.18	1.92008
GPS 27	4.832444461	6.9448869	19.557	1.2753
GPS 28	4.832327742	6.944121753	20.699	2.4258
GPS 29	4.836480189	6.928271461	20.239	1.96999
GPS 30	4.837388344	6.928477733	20.984	2.73048
GPS 31	4.838183467	6.929087211	23.319	5.05886
GPS 32	4.940823194	7.007985167	37.527	19.23387
GPS 33	4.942280164	7.008015719	38.369	20.09062
GPS 34	4.943984306	7.007760989	39.567	21.27872
GPS 35	4.930137067	7.052698958	40.67	22.31141
GPS 36	4.931735783	7.052849775	40.87	22.52091
GPS 37	4.935097586	7.053556919	38.757	20.39331
GPS 38	4.890883953	7.076113975	34.478	16.08226

GPS 39	4.892411842	7.076911742	36.043	17.65456
GPS 40	4.8946095	7.07747475	37.128	18.74006
GPS 41	4.862920831	7.093361511	37.962	19.54203
GPS 42	4.863447247	7.095125922	38.177	19.7546
GPS 43	4.863901311	7.09699115	36.294	17.87197
GPS 44	4.832048442	7.126734136	34.411	15.90601
GPS 45	4.833776561	7.127300578	33.432	14.97657
GPS 46	4.835730717	7.127621192	31.881	13.64999
GPS 47	4.769962542	7.140300147	32.793	14.2907
GPS 48	4.769413628	7.141166558	33.017	14.51478
GPS 49	4.7683703	7.14278445	33.822	15.31026
GPS 50	4.911981411	6.985296881	35.117	16.83407
GPS 51	4.913761719	6.984875258	35.499	17.22736
GPS 52	4.91531205	6.983788856	35.254	16.96535
GPS 53	4.807930044	6.977191642	29.078	10.75411
GPS 54	4.807218517	6.976286997	29.336	10.9946
GPS 55	4.806990144	6.977222258	29.173	10.798
GPS 56	4.781655028	7.006075439	28.033	9.5584
GPS 57	4.782321533	7.005458108	27.536	9.0616
GPS 58	4.783296731	7.005240433	27.441	8.8238
GPS 59	4.916896858	6.880102978	20.494	2.33017
GPS 60	4.91610835	6.881154569	20.982	2.81912
GPS 61	4.913981969	6.880881275	20.672	2.4882

International Journal of Scientific & Engineering Research Volume 10, Issue 12, December-2019 1617
ISSN 2229-5518

Data Analysis

Statistical Comparison of Geoid Undulation from Geopotential Models and GPS/Leveling Derived Geoid Undulations

Ellipsoidal height (h) is equal to Orthometric height (H) + geoid Undulation (N)

But for this study, the Reduced Mean Sea Level (M.S.L.) height is assumed to be the Orthometric Height.

$$h = H + N \quad \ldots \quad (4.1)$$

Where h is the ellipsoidal height

H is the orthometric height

N is the geoidal Undulation

Therefore $N = h - H$ . . . (4.2)

$$N^{GPS} = h^{GPS} - H^{EARTH} \quad \ldots \quad (4.3)$$

In comparing (fitting) the geoidal undulation, the GGM geoidal undulation is subtracted from the GPS/Leveling geoidal undulation and the difference between them is squared. This is divided by one less than the total number of observations and the summation of this gives the Standard error. This is the method from which the Root Mean Square for each comparison is made.

Table 5.0: Showing comparison (fitting) of PGM 2000a geoid undulation and geoid undulation from GPS/Leveling data

ID	LAT Dec.	LONG Dec.	GPS Ellipsoid Height, h (m)	Mean Sea Level Height, H (m)	N^{GPS}(m) = h – H	$N^{PGM2000a}$(m)	Diff in N	Diff squared
1	5.0385	7.0027	47.654	29.5125	18.1415	18.394	-0.2525	0.06375625
2	4.9883	7.0054	42.542	24.2936	18.2484	18.409	-0.1606	0.02579236
3	4.9811	6.9665	40.065	21.9104	18.1546	18.364	-0.2094	0.04384836
4	4.9722	6.9512	38.771	20.62994	18.14106	18.351	-0.20994	0.044074804
5	4.9882	6.9597	41.357	23.09642	18.26058	18.354	-0.09342	0.008727296
6	4.9769	6.9505	39.485	21.28941	18.19559	18.348	-0.15241	0.023228808
7	4.9684	6.9508	38.351	20.21777	18.13323	18.352	-0.21877	0.047860313
8	4.9561	6.9494	36.427	18.23191	18.19509	18.357	-0.16191	0.026214848
9	4.9550	6.9471	34.627	16.47622	18.15078	18.355	-0.20422	0.041705808
10	4.9538	6.9443	36.819	18.64814	18.17086	18.352	-0.18114	0.0328117
11	4.9780	6.9689	38.155	20.16492	17.99008	18.368	-0.37792	0.142823526
12	4.9766	6.9704	39.661	21.44542	18.21558	18.371	-0.15542	0.024155376

13	4.9752	6.9720	40.589	22.34242	18.24658	18.374	-0.12742	0.016235856
56	4.7817	7.0061	28.033	9.5584	18.4746	18.491	-0.0164	0.00026896
57	4.7823	7.0055	27.536	9.0616	18.4744	18.491	-0.0166	0.00027556
58	4.7833	7.0052	27.441	8.8238	18.6172	18.49	0.1272	0.01617984
59	4.9169	6.8801	20.494	2.33017	18.16383	18.32	-0.15617	0.024389069
60	4.9161	6.8812	20.982	2.81912	18.16288	18.322	-0.15912	0.025319174
61	4.9140	6.8809	20.672	2.4882	18.1838	18.323	-0.1392	0.01937664
							Σ Diff squared	1.500510304
							R.M.S ERROR	0.156839184

The table above shows the fitting statistics of PGM 2000a geoidal height and geoidal height from the observed value of the study area.

Table 6.0: Showing Comparison (fitting) of geoid undulation from EIGEN CG01C model and GPS/Leveling data

ID	LAT Dec.	LONG Dec.	GPS Ellipsoidal Height h(m)	Mean Sea Level Height H(m)	N^{GPS}(m) = h – H	$N^{SAT\ EIGEN-CG01C}$ (m)	Diff in N	Diff squared
1	5.0385	7.0027	47.654	29.5125	18.142	18.341	-0.1995	0.0398002
2	4.9883	7.0054	42.542	24.2936	18.248	18.376	-0.1276	0.0162818
3	4.9811	6.9665	40.065	21.9104	18.155	18.319	-0.1644	0.0270274
4	4.9722	6.9512	38.771	20.62994	18.141	18.303	-0.16194	0.0262246
5	4.9882	6.9597	41.357	23.09642	18.261	18.305	-0.04442	0.0019731
6	4.9769	6.9505	39.485	21.28941	18.196	18.299	-0.10341	0.0106936
7	4.9684	6.9508	38.351	20.21777	18.133	18.305	-0.17177	0.0295049
8	4.9561	6.9494	36.427	18.23191	18.195	18.311	-0.11591	0.0134351
9	4.9550	6.9471	34.627	16.47622	18.151	18.309	-0.15822	0.0250336
10	4.9538	6.9443	36.819	18.64814	18.171	18.306	-0.13514	0.0182628
11	4.9780	6.9689	38.155	20.16492	17.990	18.325	-0.33492	0.1121714
12	4.9766	6.9704	39.661	21.44542	18.216	18.329	-0.11342	0.0128641
13	4.9752	6.9720	40.589	22.34242	18.247	18.333	-0.08642	0.0074684
14	4.9531	6.9505	35.359	17.18118	18.178	18.315	-0.13718	0.0188184
15	4.9497	6.9528	34.766	16.58004	18.186	18.321	-0.13504	0.0182358
16	4.9466	6.9551	34.756	16.56791	18.188	18.326	-0.13791	0.0190192
17	4.9430	6.9574	34.79	16.59155	18.198	18.332	-0.13355	0.0178356
18	4.9392	6.9580	34.784	16.56934	18.215	18.336	-0.12134	0.0147234
19	4.8932	6.9647	29.266	10.98616	18.280	18.376	-0.09616	0.0092467
20	4.8940	6.9643	29.87	11.58037	18.290	18.374	-0.08437	0.0071183
21	4.8933	6.9663	30.338	12.02362	18.314	18.377	-0.06262	0.0039213
22	4.8751	6.9560	32.335	14.0169	18.318	18.378	-0.0599	0.0035880

50	4.9120	6.9853	35.117	16.83407	18.283	18.388	-0.10507	0.0110397
51	4.9138	6.9849	35.499	17.22736	18.272	18.387	-0.11536	0.0133079
52	4.9153	6.9838	35.254	16.96535	18.289	18.384	-0.09535	0.0090916
53	4.8079	6.9772	29.078	10.75411	18.324	18.447	-0.12311	0.0151561
54	4.8072	6.9763	29.336	10.9946	18.341	18.447	-0.1056	0.0111514
55	4.8070	6.9772	29.173	10.798	18.375	18.448	-0.073	0.0053290
56	4.7817	7.0061	28.033	9.5584	18.475	18.491	-0.0164	0.0002690
57	4.7823	7.0055	27.536	9.0616	18.474	18.49	-0.0156	0.0002434
58	4.7833	7.0052	27.441	8.8238	18.617	18.489	0.1282	0.0164352
59	4.9169	6.8801	20.494	2.33017	18.164	18.262	-0.09817	0.0096373
60	4.9161	6.8812	20.982	2.81912	18.163	18.264	-0.10112	0.0102253
61	4.9140	6.8809	20.672	2.4882	18.184	18.266	-0.0822	0.0067568
							Σ Diff squared	1.1163149
							R.M.S ERROR	0.1364

The table above shows the fitting statistics of EIGEN CG01C geoidal height and geoidal height from the observed value of the study area.

Table 7.0: Showing Comparison (Fitting) Of Geoid Undulation from EGM 2008 And GPS/Leveling Data

ID	LAT Dec.	LONG Dec.	GPS Ellipsoidal Height h(m)	Mean Sea Level Height H(m)	N^{GPS}(m) = h – H	$N^{SAT\ EGM}$ 2008 (m)	Diff in N	Diff Squared
1	5.0385	7.0027	47.654	29.5125	18.1415	18.227	-0.0855	0.00731025
2	4.9883	7.0054	42.542	24.2936	18.2484	18.265	-0.0166	0.00027556
3	4.9811	6.9665	40.065	21.9104	18.1546	18.205	-0.0504	0.00254016
4	4.9722	6.9512	38.771	20.62994	18.14106	18.187	-0.04594	0.002110484
5	4.9882	6.9597	41.357	23.09642	18.26058	18.19	0.07058	0.004981536
6	4.9769	6.9505	39.485	21.28941	18.19559	18.183	0.01259	0.000158508
7	4.9684	6.9508	38.351	20.21777	18.13323	18.189	-0.05577	0.003110293
8	4.9561	6.9494	36.427	18.23191	18.19509	18.196	-0.00091	8.281E-07
9	4.9550	6.9471	34.627	16.47622	18.15078	18.194	-0.04322	0.001867968
10	4.9538	6.9443	36.819	18.64814	18.17086	18.191	-0.02014	0.00040562
11	4.9780	6.9689	38.155	20.16492	17.99008	18.211	-0.22092	0.048805646
12	4.9766	6.9704	39.661	21.44542	18.21558	18.216	-0.00042	1.764E-07
13	4.9752	6.9720	40.589	22.34242	18.24658	18.219	0.02758	0.000760656
14	4.9531	6.9505	35.359	17.18118	18.17782	18.201	-0.02318	0.000537312
57	4.7823	7.0055	27.536	9.0616	18.4744	18.415	0.0594	0.00352836

58	4.7833	7.0052	27.441	8.8238	18.6172	18.414	0.2032	0.04129024
59	4.9169	6.8801	20.494	2.33017	18.16383	18.144	0.01983	0.000393229
60	4.9161	6.8812	20.982	2.81912	18.16288	18.146	0.01688	0.000284934
61	4.9140	6.8809	20.672	2.4882	18.1838	18.148	0.0358	0.00128164
							Σ Diff squared	0.305963524
							R.M.S ERROR	0.071410028

The table above shows the fitting statistics of EGM 2008 geoidal height and geoidal height from the observed value of the study area.

IV. DISCUSSION OF RESULTS

From Table 5.0, the minimum maximum geoidal height difference after fitting is -0.0164 and -0.37792 respectively and RMSE of 0.156839.

In Table 6.0, the minimum and maximum geoidal difference after fitting is -0.0156 and 0.36099 respectively and RMSE of 0.1364.

Table 7.0, shows the minimum and maximum geoidal height difference after fitting to be -0.00007 and -0.0305 respectively and RMMSE of 0.07141.

The minimum and maximum values from the different global geopotential models indicate that EGM 2008 has closest gravity features with the study area.

The mean of the fitting results of the different models also indicates that EGM 2008 is best compatible with the gravity features of the study area in Rivers State.

Statistics of Reduced Data Between Geopotential Geoid Undulation and GPS/Leveling Data Geoid Undulation

Models	Min. Diff (m)	Max. Diff (m)	Mean of Diff (m)	Standard error (σ) (m)
PGM 2000a	**-0.0164**	**-0.37792**	**-0.139337**	**0.156839**
EIGEN CG01C	**-0.0156**	**0.36099**	**-0.1182390**	**0.1364**
EGM 2008	**-0.00007**	**-0.0305**	**-0.021698**	**0.07141**

Mean = sum of variables divided by number of variables.

Standard error = $\sqrt{\sum\left(\frac{x-\bar{x}}{n-1}\right)^2}$ . . . (4.6)

Where Σ = summation, x = variable $\bar{x}$ = mean of variables, n = number of variables.

From the statistical analyses and comparison of geoid undulation from GPS/Leveling data and geoid undulation from the global geopotential models, we can see that EGM 2008 has the least standard error of about 7cm compared to 15cm and 13cm from the PGM 2000a and EIGEN CG01C respectively.

Below is graphical illustration of how the geoid undulations of different GGM fit the undulation features of the study area.

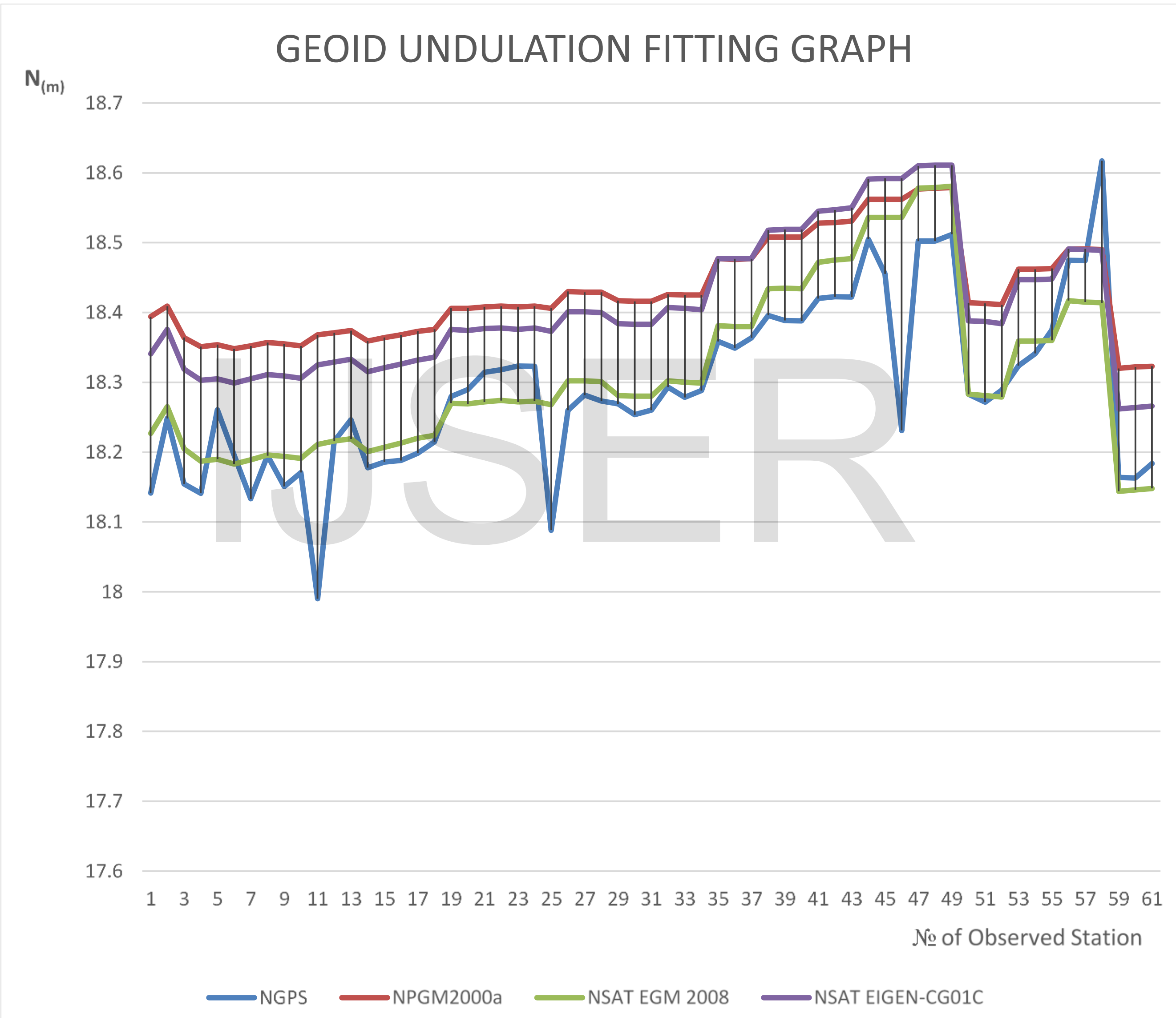

Fig 4.0: Geoidal Undulation Fitting Graph for the three GGM over the Study Area.

From the graph shown above, Blue colour stands for geoid undulation (N^{GPS}) from the observed values of the study area, while the Green, Violet and Red colours shows the geoidal undulations of EGM 2008, PGM 2000a and EIGEN CGO1C gravity models respectively.
Earth Gravity Model 2008 fits closely with the computed geoid undulation over the study area than the other two global models.
Hence, the deduction that EGM 2008 will give a better reference frame for geoid modelling in Rivers State of Nigeria.

V. CONCLUSION & RECOMMENDATIONS

The ability to statistically reach a conclusion that there is need to first of all evaluate the compatibility of global geopotential models which (long wavelength component) serve as the reference frame for geoid computation to avoid inherent inconsistencies in the height data obtained in the results is what the statistical tool ‘’standard error’’ can provide.
Numerical analyses in this project have shown that the latest Earth Gravity Model 2008 is an improvement of other Global Geopotential Models and that Earth Gravity Model 2008 (EGM 2008) is the best-fit model for geoid computation in Rivers State.

We make the following recommendations in view of the assessment of the best-fit global geopotential model over a microenvironment where gravimetric geoid model is to be computed:

1. That a further research on this topic using free air gravity anomalies instead be carried out to confirm the results of this research.
2. That a more rigorous statistical tool employed to scrutinize the validation of the results of this study.
3. That wider range of field data covering the entire State be sort for and use to validate the claims in this study.

References

[1] Banerjee, P., Foulger, G., Satyaprakash, Dabral, C.P. (1999) ‘Geoid undulation modelling and interpretation at Ladak, NW Himalaya using GPS and Levelling data’ Journals of Geodesy 73;79-86.

[2] Bjelotomic, O. (2015). High Resolution Geoid Modelling of Croatia (PhD thesis) Faculty of Geodesy, University of Zagreb.

[3] Daho, B. S.A. (2014). Assessment of Different versions of Global Geopotential Models Over Algeria Using the free air Gravity Anomalies supplied by BGI and GPS/Leveling data. A bulletin of the BGI and of the International Geoid service – ISSN 1810-8547: pp 52 – 59.

[4] Fubara, D.M.J., Fajemirokun, F.A., and Ezeigbo, C.U. (2017). ‘’Fundamentals Of Geodesy’’ Concept Publications Limited.

[5] Heiskanen, W. A. and Moritz, H. (1967). Physical Geodesy, W. H. Freeman and company, London. 617–639.

[6] Molodensky, M. S., Eremeer, V.F., Yurkina, M.I. (1962). Methods for Study of the External Gravitation

ISSN 2229-5518

Field and Figure of the Earth.

[7] Uzodinma, N.V., Ezenwere,O.C. (1993). Map Projections, Practical Computations on the Traverse Mercator Projection. El'Demak company, first Edition.

[8] Younis, G. (2018). The Integration of GNSS/Leveling Data with Global Geopotential Models to Define the Height Reference System of Palestine. Arabian Journal for Science and Engineering, Volume 43, Issue 7, pp 3639 – 3645.