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Evaluation of Global Geo potential Models Made Possible Through the Application of Precise DGPS and Level ling Observations Along the Mediterranean,

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Abstract Along the Mediterranean Western Coastal Line in Egypt, from El- Salloum to El- Alameen, the ability of Global Geo potential Models (GGMs) to compute Geoid undulation has been studied. The evaluation took place from El- Salloum to El- Alameen. The area that was chosen offers opportunities in both tourism and geodetic research. The accuracy of the geoid undulation, denoted by "N," will undoubtedly have an impact on the final orthometric height, which will be derived from the Differential Global Positioning System (DGPS). In this investigation, the EGM96 and EGM08 were put through their paces, along with Bi-Linear Interpolation, Bi-Quadratic Interpolation, Triangulation, and Nearest Neighbor.

The NGGMs value was derived using the "AllTrans v.3.002" EGM08 geoid calculator and the free website of "ICGEM," while the Nobs value was derived from the equation N= h-H. As a measure of how accurate the data is, the calculated standard deviation () of differences in (Nobs – NGGMs) is applied over a total of 52 DGPS/Precise Levelling Stations. It has been determined that the standard deviation, also known as the root-mean-square error (RMSE), of the undulation discrepancies ranges from 24 cm for EGM08-Bi-Linear Interpolation to 45 cm for EGM08-Nearest Neighbour and 1.393 m for EGM96. When comparing (EGM08-Nearest Neighbour) to (EGM08-Bi-Linear Interpolation), there is a 54% reduction in the total RMSE, which is a significant improvement. According to the findings of this research, the EGM08-Bi-Linear Interpolation model is a substantial improvement over previous models for predicting the behavior of objects like the Northern-coastal line. A procedure like this provides a good option, from the point of view of economics, to replace the costly conventional levelling approach, in particular for linear topographic projects with intermediate accurate survey..

Keywords Precise leveling, Global Geopotential Models (GGMs), Differential Global Positioning Systems (DGPS), and Undulation

1. Introduction

Because it verifies the existence of locations in a worldwide reference system based on objects that have been gathered and constructed, the Global Navigation Satellite System (GNSS) has emerged as an essential piece of technological infrastructure (Bernabe et al., 2012). When GPS data are first used for the monitoring of vertical ground movement, the height differences between the monitoring sites—obtained by using both GPS and leveling measurements—are typically compared to realize the accuracy of height achieved by GPS. This is done so that the monitoring of vertical ground movement can be performed more effectively (Parks and Dial, 1997; Ollikainen, 1998). These days, GNSS/leveling might be regarded an alternative to the traditional method of practically determining height (Featherstone, et al., 1998; Erol, 2011).

EGM96 and EGM08 have been subjected to analysis by a number of writers in various localities across the globe (e.g. Huang and Vernneau, 2009; Claessens et al., 2009; Hirt et al., 2010; Pavlis et al., 2012; Featherstone and Olliver, 2013; Odera and Fukuda, 2013; Abeho et al., 2014). The majority of the studies that have been conducted to compare the two versions demonstrate that EGM08 is a considerable improvement over EGM96. On the other hand, comparable research has not been conducted in Egypt, particularly along the country's northern shore line.
In this study, an initial evaluation of EGM96 and EGM08 is carried out using four distinct methodologies (namely, bi-linear interpolation, bi-quadratic interpolation, triangulation, and nearest neighbor analysis).

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More assumptions and mathematical explanations on the used interpolation techniques may be found by visiting the following website: http://docs.geotools.org/latest/javadocs/org/opengis/coverage/InterpolationMethod.html. These models have been evaluated in comparison with accurate DGPS/precise leveling determined undulations across 52 stations along the Northern-Coastal line of the Mediterranean Sea in Egypt.

The estimation of the geoid via the use of various interpolation techniques has been the subject of a great deal of study and debate (ARANA et al., 2017; Chymyrov and Busics 2014; Janssen and Watson 2010; Lambrou 2018; Soycan 2014).

Models of the Gravitational Field on a Global Scale (GGMs)

The Global Gravitational Models, often known as GGMs, are geopotential models of the Earth that are issued by the Office of Geomatics of the National Geospatial-Intelligence Agency. These models consist of spherical harmonic coefficients (NGA). When calculating the geoid undulation of a region, three different EGM models are used. The first implementation uses EGM84 with n=m=180. EGM96 is the second version, and it has n=m=360. The third version is called EGM08 and has the value n=m=2160. Where n and m are the degree and order of the harmonic coefficients, respectively. A high level of accuracy may be achieved as a result of the increased number of parameters made available to the models by the higher degrees and orders of harmonic coefficients. Additionally, extensions through n=2190 are included in EGM08.

The model may either be obtained in the form of a raster picture that records the geoid height at each position at a specific resolution or in the form of a format that gives the numerical parameters – the coefficients – that define the model. Both forms are provided by the NGA.

The Earth Global Model (EGM96) is the product of a joint effort on the part of the National Imagery and Mapping Agency (NIMA), the NASA Goddard Space Flight Center (GSFC), and Ohio State University. It made use of fresh surface gravity data from a wide variety of places all around the world, including data that had just been made available from the NIMA archives. Since 1990, some of the most important terrestrial gravity acquisitions made by NIMA have been aircraft gravity surveys carried out over Greenland as well as areas of both the Arctic and the Antarctic. These data gathering initiatives have enhanced the data holdings throughout a significant portion of the geographical regions of the globe, including sections of South America and Africa, Southeast Asia, Eastern Europe, and the region that once included the Soviet Union. In addition, there have been significant efforts made to update NIMA's current 30' mean anomaly database via contributions made across a variety of nations in Asia. These contributions have been made. EGM96 also contained altimeter-derived anomalies that were produced from ERS-1 by Kort & Matrikelstyrelsen (KMS), (National Survey and Cadastre, Denmark), across areas of both the Arctic and the Antarctic. These anomalies were included in both regions. The resolution of the raster that was generated from EGM96 is 15' x 15'.

The new Earth Gravitational Model EGM08 has been created by the National Geospatial-Intelligence Agency (NGA), and its development has been finished to degree 2160. This model uses an updated version of the 5' x 5' global gravity anomaly database, as well as an improved ocean-wide collection of altimetry-derived gravity anomalies, and it has benefitted from the most recent GRACE-based satellite-only solutions (Pavlis et al., 2012). EGM08 offers a resolution and precision that has never been seen before, revealing even the tiniest of faults that occur due to incompatibility. In 2008, the official Earth Gravitational Model, often known as EGM08, was made available to the public as the Zero Tide model. This model includes extra coefficients, which go all the way up to degree 2190 and order 2159. On the website, full access may be gained to the coefficients of the model in addition to other descriptive files that include extra information on EGM2008. As far as permanent tide is concerned, every piece of synthesis software, every coefficient, and every accessible pre-computed geoid grid assumes a tide-free system.

2. A Place to Study

The research area consists of the towns of El Salloum and El Alameen, both of which can be found in northern Egypt and are located along a line that is perpendicular to the northern coast of the Mediterranean (see "Figure 1"). Its latitude ranges from 30 degrees 57 minutes 10 seconds north to 31 degrees 37 minutes 07 seconds north, while its longitude ranges from 25 degrees 09 minutes 45 seconds east to 28 degrees 49 minutes 37 seconds east. As can be seen in "Figure 1," the research was carried out with the help of fifty-two GPS/Leveling data points. The Survey Research Institute in Egypt carried out a research investigation, which resulted in the generation of this data collection as part of that study (SRI). The precise leveling observations were performed as closed loops, run between known high precision benchmarks established by the Egyptian Survey Authority (ESA) based on the national vertical datum of Egypt, whose origin is based on Mean Sea Level (MSL) at the Alexandria tide gauge 1906. The Egyptian Survey Authority (ESA) is responsible for establishing vertical datums in Egypt. The Egyptian Survey Authority, abbreviated as ESA, was the organization in charge of determining the vertical datum. In addition to this, GPS measurements were obtained relative to the national geodetic reference system that is managed by the ESA..

2. Data Sets

The datasets that were collected for this investigation from station L1 to L52, as shown in "Figures 1,2," include the following information: station name;

projected coordinates (ETM); geographic coordinates; orthometric height (H) from precise levelling; ellipsoidal height (h) from static DGPS measurements by relative technique.

The "AllTrans v.3.002" EGM08 geoid calculator program, which was created by Hans-Gerd Duenck-Kerst, has been used to compute geoid undulations for the EGM08 model using four distinct approaches. In addition, the ICGEM website has been used to generate geoid undulations for the EGM96 model.

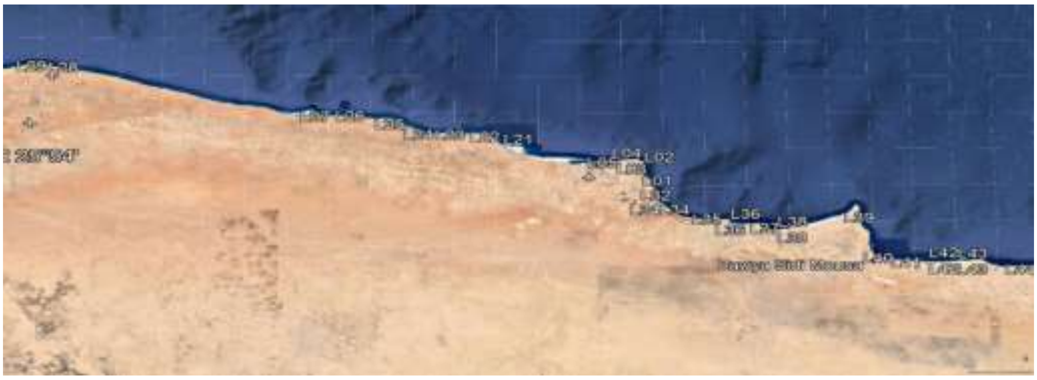
1.1. Accurate Leveling (Orthometric Height, or H)

The orthometric heights are necessary for a variety of applications, including mapping, surveying, and engineering and environmental work. These heights are measured relative to the geoid surface, which is a surface that is always and everywhere on the planet oriented in a direction that is perpendicular to the direction of the gravity vector (Awka, et. Al. 2018).

The first-order levelling loops at each station were connected to Egypt's national vertical datum, which is determined by the mean sea level measured at the Alexandria tidal gauge in 1906. This allowed for the stations' orthometric heights to be calculated and acquired.

1.1. DGPS measurements (Ellipsoidal Height (h))

The dual frequency Trimble 5700 GPS receivers were used in static mode for an average session length of two hours, with a a minimum of fifteen degrees of elevation angle, geometric a precision that is diluted by a factor of two to four, and an epoch period that is set at fifteen seconds. Figure 3 provides a visual representation of the total number of satellites that were seen during the fieldwork at the location. During the whole of the time spent gathering fieldwork, the base receiver at the main control base reference station was continually recording data in relative technique mode. This was carried out at the same



time as the fieldwork that was being done on the station. Following that, the processing will be done online.

Figure 1. DGPS/Precise levelling observed stations

Figure 2. Station L1

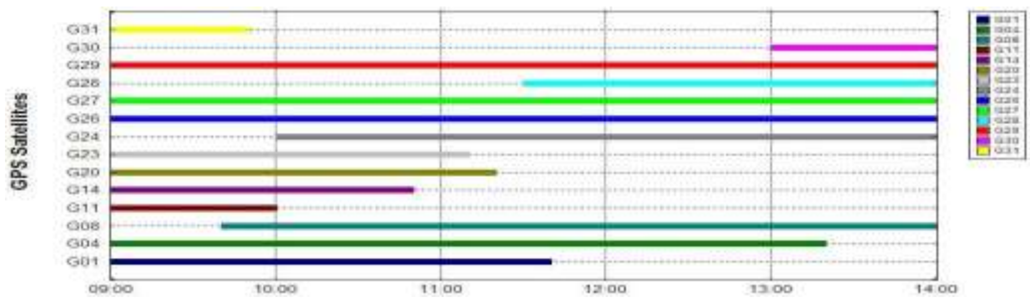


Figure 3. Number of satellite covered in site fieldwork

Table 1. Observed DGPS/Precise Levelling data for all survey stations

		Geodetic coordinates		Reference point Elevation (m)	
Point no.	Reference point name	Geographic cords. (WGS 1984) (Degree)		Ellipsoidal Height (h)	Elevations above M.S.L.
L01	Eastern Hasheesh	Ø =31º20'06.26"	λ=27º20'58.98"	18.086	1.883
L02	Western Hasheesh	Ø =31º21'20.32"	λ =27º21'11.74"	19.988	3.890
L03	Andloseya	Ø =31º22'05.06"	λ =27º17'18.28"	19.086	2.867
L04	Assala	Ø =31º22'00.70"	λ =27º16'34.26"	25.544	9.303
L05	Rumel	Ø =31º21'46.73"	λ =27º15'15.81"	21.031	4.605
L06	Rumel Beach	Ø =31º21'56.40"	λ =27º14'52.82"	18.323	1.970
L07	Matrouh1	Ø =31º21'39.58"	λ =27º14'43.05"	18.182	1.795
L08	Matrouh2	Ø =31º21'27.75"	λ =27º14'26.59"	19.782	3.352
L09	Matrouh3	Ø =31º21'26.00"	λ =27º13'57.88"	25.756	9.283
L10	Matrouh4	Ø =31º21'33.41"	λ =27º13'29.61"	19.592	3.137
L11	Masiaf	Ø =31º21'52.88"	λ =27º13'09.70"	18.304	1.781
L12	Cleopatra1	Ø =31º22'16.86"	λ =27º10'47.72"	21.189	4.605
L13	Cleopatra2	Ø =31º22'19.74"	λ =27º11'40.23"	23.245	6.762
L14	El-Mehata	Ø =31º22'16.07"	λ =27º12'25.56"	25.299	8.874
L15	El-Ghram	Ø =31º22'07.64"	λ =27º13'21.27"	19.156	2.753
L16	El-Hemaya	Ø =31º21'17.60"	λ =27º09'26.28"	33.620	--------
L17	El-Kasr	Ø =31º22'21.50"	λ =27º09'22.34"	26.076	9.465

L18	El-Aseel	Ø =31º22'32.24"	λ =27º06'49.56"	20.552	3.864
L19	El-Abyad	Ø =31º22'46.08"	λ =27º05'45.26"	21.450	4.770
L20	Blue Beach	Ø =31º23'14.21"	λ =27º04'06.35"	18.780	------
L21	Om El-Rakhm	Ø =31º24'17.56"	λ =27º03'16.14"	25.278	8.749
L22	Ageeba	Ø =31º24'43.25"	λ =27º00'36.63"	21.714	5.011
L23	El-Sowynat1	Ø =31º26'21.57"	λ =26º55'39.95"	21.734	5.056
L24	Abo Lahw	Ø =31º26'22.05"	λ =26º51'07.91"	29.571	12.677
L25	El-Sowynat2	Ø =31º28'04.55"	λ =26º44'50.60"	32.498	15.526
L26	El- Zoghyrat1	Ø =31º29'22.41"	λ =26º39'08.81"	21.503	4.409
L27	El- Zoghyrat2	Ø =31º29'14.95"	λ =26º36'18.81"	31.994	14.737
L28	Barany1	Ø =31º36'55.68"	λ =25º57'36.97"	22.289	4.264
L29	Barany2	Ø =31º37'07.33"	λ =25º55'09.61"	32.400	14.313
L30	ElSaloum1	Ø =31º32'38.63"	λ =25º09'55.02"	23.916	3.963
L31	ElSaloum2	Ø =31º33'46.44"	λ =25º09'45.78"	23.980	3.193
L32	Meyami	Ø =31º16'22.11"	λ =27º22'53.23"	19.841	3.196
L33	Alealamieen	Ø =31º15'39.98"	λ =27º23'07.32"	19.559	2.802
L34	Al-Noran	Ø =31º15'18.49"	λ =27º23'26.19"	19.540	2.704
L35	Kasr El-Shouk	Ø =31º12'23.00"	λ =27º30'06.82"	19.055	2.352
L36	Almaza	Ø =31º11'54.04"	λ =27º33'27.83"	20.071	3.507
L37	Sidi Henish	Ø =31º10'50.23"	λ =27º38'25.23"	21.928	5.525
L38	Yagosh	Ø =31º10'33.14"	λ =27º40'10.45"	21.034	4.684
L39	Ras El-Hekma	Ø =31º12'27.37"	λ =27º51'51.91"	26.498	10.873
L40	Etai	Ø =31º05'42.51"	λ =27º54'31.43"	26.630	10.570
L41	Royal Beach	Ø =31º04'57.07"	λ =27º58'33.72"	49.666	33.756

		Geodetic coordinates		Reference point Elevation (m)	
Point no.	Reference point name	Geographic cords. (WGS 1984) (Degree)		Ellipsoidal Height (h)	Elevations above M.S.L.
L42	Mountain View	Ø =31º05'08.28"	λ =28º01'48.15"	21.910	6.071
L43	Teba	Ø =31º04'57.20"	λ =28º05'57.53"	43.276	27.648
L44	El-Kanaria	Ø =31º03'28.53"	λ =28º14'54.36"	48.973	33.483
L45	La-Viesta	Ø =31º04'11.64"	λ =28º21'22.54"	30.221	15.021
L46	Palma de Mayorika	Ø =31º04'58.84"	λ =28º23'34.17"	18.232	3.034
L47	Kato	Ø =31º00'49.58"	λ =28º35'17.15"	24.397	9.325
L48	Ghazala	Ø =31º01'08.22"	λ =28º36'01.13"	18.778	3.701
L49	Marina	Ø =30º59'40.28"	λ =28º40'08.21"	41.168	26.203
L50	Orkidia	Ø =30º59'19.53"	λ =28º42'57.23"	18.368	3.409
L51	Heliopolis	Ø =30º57'18.77"	λ =28º47'55.43"	19.607	4.642
L52	La Zordi	Ø =30º57'10.52"	λ =28º49'37.16"	18.545	3.612

The GPS observations for the 52 stations were taken at different times. The mission was done through many sessions; each session consists of four stations to form good baseline geometry. Therefore, the stations have been observed through these sessions during June 2013.

2. Methods

For the length of each rover's observation location, a dual frequency Trimble 5700 DGPS geodetic receiver was used in relative static mode on the base reference station. This resulted in the acquisition of the geodetic coordinate data, which included ellipsoidal heights, latitudes, and longitudes. In order to post-process the information that was gathered, TBC planning software that could be accessed online was used.

With an accuracy of 0.003 meters, ellipsoidal heights have been determined for each station throughout each session using the Trimble TBC 3.2 GPS data processing program. At each session, the projected 2D coordinates (UTM east and north) for each GPS station have been calculated with an accuracy of 0.002 meters. This was done for each GPS station.

The Leica NA2 exact level was used to acquire the precise levelling data, and the first-order levelling loops were tied to the national vertical datum of Egypt. The maximum permissible error for the accurate levelling is 3L mm, where L is the distance in kilometers that separates each pair of stations. The "AllTrans v.3.002" EGM08 geoid calculator program has been used for EGM08 geoid undulations. Additionally, the International Center for Global Earth Models (ICGEM) has been utilized for EGM96 geoid undulations, by the min1x1 Tidefree SEL 1 x 1 database.

Results

The ellipsoidal heights obtained from the static DGPS were superior. It seems to reason that more accurate geoidal undulation would result in more accurate orthometric height calculations (Awka, et. Al., 2018).

Gravimetric and DGPS/Precise levelling geoid undulations along the Mediterranean Western Coastal Line from El-Salloum to El- Alameen have been compared, and the results have been tabulated and shown in Table 2. Table 3 presents statistical information on the undulations that vary between gravimetric and DGPS/Precise geoid measurements.

The following list summarizes some key findings from this research:

2.1 Undulations and Heights of the Geoid (N)

The geoid height, denoted by the symbol N, is necessary for the most important and fundamental application of the transition between GPS-derived ellipsoidal heights and orthometric heights. After the data from the DGPS have been post-processed by the TBC planning software, the geoid undulation is calculated using both the GGMs and the DGPS/levelling observed heights.

2.1.1. From GGMs

The EGM08 geoid undulations have been calculated for each of the four approaches that were researched using the table that can be seen below. It has been observed that the EGM08-BiLinear Interpolation Method is almost consistent. In addition to that, the undulations of the EGM96 geoid have been calculated as well.

According to Equation (1) (Yazid et al., 2016), the estimated geoid heights acquired from EGM08 were computed as follows:

$$\Delta N = \frac{GM}{r\lambda} \sum_{n=2}^{n} \left(\frac{a}{r}\right)^{n} \sum_{m=0}^{n} (C_{nm} \cos m\lambda + S_{nm} \sin m\lambda) P_{nm} (\cos \theta) \quad (1)$$

An early comparison and analysis of four distinct approaches to EGM08 (Bi-Linear Interpolation, Bi-Quadratic Interpolation, Triangulation, Nearest Neighbour). These methods have been compared with accurate DGPS/precise leveling derived undulations over 52 station in the Northern-Coastal line of Mediterranean Sea, Egypt.

Where ΔN_{GGM} = the geoid heights derived from the globalgeopotential model *(GM)*.

GM = the product of the Earth's mass and the gravitational constant.

r = the radial distance to the computation point, *a* is thesemi-major axis of the reference ellipsoid.

C_{nm} and S_{nm} = fully normalized harmonic coefficients.

P_{nm} = the fully normalized Legendre function.

$Ø$ & λ = the geodetic latitude and longitude of the computationpoint.

2.1.1. From DGPS/Levelling Observations

In order to calculate the geoid undulation (N), the ellipsoidal height (h) obtained from the DGPS is joined with the observed orthometric (H) obtained from the precise levelling. The findings are shown in Table 2.

The N is supplied by Heiskanen and Moritz (1967) and Eteje

et al (2018) as:

$$N = h\text{-}H \qquad (2)$$

2.1.2. The Geoid Undulation Differences

From computations, the differences between both GGMs and DGPS/Precise levelling derived geoid undulations are also shown in Table 2.

The differences are calculated as follows:

$$Undulation\ Difference = N^{GGMs} - N^{DGPS\text{-}Precise\ Levelling} \qquad (3)$$

Table 2. N^{Obs} & N^{GGMs} & Undulation Differences ($N^{GGMs} – N^{DGPS\text{-}Precise\ Levelling}$)

Station No.	N^{Obs} (m)	Undulation [N^{GGM}] & Undulation Differences ($N^{GGM} – N^{Obs[DGPS\text{-}Precise\ Levelling]}$) (m)									
		EGM2008 (WGS84)								EGM96 (WGS84)	
		Bi-Linear Interpolation		Bi-Quadratic Interpolation		Triangulation		Nearest Neighbour			
		N (m)	Dif. (m)	N (m)	Dif. (m)	N (m)	Dif. (m)	N (m)	Dif. (m)	N (m)	Dif. (m)
L01	16.203	16.744	0.541	16.752	0.549	16.743	0.540	16.830	0.627	15.799	-0.404
L02	16.098	16.500	0.402	16.555	0.457	16.496	0.398	16.830	0.732	15.701	-0.397
L03	16.219	16.601	0.382	16.684	0.465	16.599	0.380	16.830	0.611	15.658	-0.561
L04	16.242	16.660	0.418	16.741	0.499	16.657	0.415	16.830	0.588	15.667	-0.574
L05	16.426	16.783	0.357	16.858	0.432	16.779	0.353	16.830	0.404	15.692	-0.734
L06	16.354	16.776	0.422	16.848	0.494	16.781	0.427	17.431	1.078	15.682	-0.672
L07	16.387	16.839	0.452	16.902	0.515	16.842	0.455	17.431	1.044	15.705	-0.682
L08	16.430	16.892	0.462	16.949	0.519	16.895	0.465	17.431	1.001	15.722	-0.708
L09	16.473	16.926	0.453	16.983	0.510	16.929	0.456	17.431	0.958	15.727	-0.746
L10	16.455	16.932	0.477	16.993	0.538	16.935	0.480	17.431	0.976	15.720	-0.736
L11	16.523	16.892	0.369	16.963	0.440	16.895	0.372	17.431	0.908	15.696	-0.827
L12	16.584	16.963	0.379	17.046	0.462	16.964	0.380	17.431	0.847	15.679	-0.905
L13	16.483	16.901	0.418	16.984	0.501	16.903	0.420	17.431	0.948	15.670	-0.813
L14	16.425	16.866	0.441	16.947	0.522	16.868	0.443	17.431	1.006	15.670	-0.756
L15	16.403	16.835	0.432	16.912	0.509	16.838	0.435	17.431	1.028	15.675	-0.728
L16	-	17.228	-	17.281	-	17.227	-	17.431	-	15.800	-
L17	16.611	17.037	0.426	17.122	0.511	17.036	0.425	17.431	0.820	15.683	-0.928
L18	16.688	17.164	0.476	17.253	0.565	17.156	0.468	17.431	0.743	15.687	-1.001
L19	16.680	17.191	0.511	17.284	0.604	17.179	0.499	17.431	0.751	15.678	-1.002
L20	-	17.211	-	17.313	-	17.224	-	18.035	-	15.700	-
L21	16.529	17.077	0.548	17.192	0.663	17.091	0.562	18.035	1.506	15.577	-0.952
L22	16.703	17.175	0.472	17.296	0.593	17.178	0.475	18.035	1.332	15.568	-1.135
L23	16.678	17.251	0.573	17.301	0.623	16.986	0.308	16.297	-0.381	15.489	-1.189
L24	16.894	17.585	0.691	17.670	0.776	17.578	0.684	17.105	0.211	15.545	-1.349
L25	16.972	17.729	0.757	17.809	0.837	17.718	0.746	17.760	0.788	15.497	-1.475
L26	17.094	17.887	0.793	17.914	0.820	17.860	0.766	17.760	0.666	15.486	-1.608
L27	17.257	18.028	0.771	18.074	0.817	17.998	0.741	17.760	0.503	15.548	-1.709
L28	18.025	18.168	0.143	18.214	0.189	18.070	0.045	17.743	-0.282	15.942	-2.083
L29	18.087	18.223	0.136	18.265	0.178	18.139	0.052	17.743	-0.344	16.010	-2.077
L30	19.953	20.109	0.156	20.120	0.167	20.108	0.155	20.283	0.330	18.199	-1.754
L31	20.787	20.040	-0.747	20.054	-0.733	20.038	-0.749	20.283	-0.504	18.128	-2.659
L32	16.645	16.992	0.347	17.097	0.452	16.977	0.332	16.830	0.185	16.078	-0.567
L33	16.757	17.046	0.289	17.156	0.399	17.028	0.271	16.830	0.073	16.130	-0.627
L34	16.836	17.062	0.226	17.173	0.337	17.041	0.205	16.830	-0.006	16.155	-0.680
L35	16.703	16.970	0.267	17.009	0.306	16.970	0.267	17.232	0.529	16.355	-0.348
L36	16.564	16.869	0.305	16.892	0.328	16.880	0.316	17.232	0.668	16.387	-0.177
L37	16.403	16.773	0.370	16.794	0.391	16.771	0.368	16.808	0.405	16.464	0.061
L38	16.350	16.732	0.382	16.746	0.396	16.732	0.382	16.808	0.458	16.486	0.136
L39	15.625	15.935	0.310	16.007	0.382	15.934	0.309	16.369	0.744	16.383	0.758
L40	16.060	16.373	0.313	16.467	0.407	16.360	0.300	16.369	0.309	16.847	0.787
L41	15.910	16.180	0.270	16.207	0.297	16.176	0.266	16.450	0.540	16.912	1.002
L42	15.839	16.002	0.163	16.056	0.217	16.002	0.163	15.729	-0.110	16.915	1.076
L43	15.628	15.837	0.209	15.850	0.222	15.837	0.209	16.019	0.391	16.949	1.321
L44	15.490	15.625	0.135	15.633	0.143	15.611	0.121	16.019	0.529	17.092	1.602
L45	15.200	15.383	0.183	15.412	0.212	15.390	0.190	15.698	0.498	17.091	1.891

L46	15.198	15.254	0.056	15.291	0.093	15.275	0.077	15.698	0.500	17.058	1.860
L47	15.072	15.206	0.134	15.226	0.154	15.200	0.128	15.161	0.089	17.383	2.311
L48	15.077	15.161	0.084	15.185	0.108	15.154	0.077	15.161	0.084	17.370	2.293
L49	14.965	15.174	0.209	15.181	0.216	15.174	0.209	15.161	0.196	17.479	2.514
L50	14.959	15.109	0.150	15.127	0.168	15.107	0.148	15.161	0.202	17.517	2.558
L51	14.965	15.077	0.112	15.106	0.141	15.001	0.036	14.862	-0.103	17.654	2.689
L52	14.933	15.038	0.105	15.066	0.133	14.954	0.021	14.862	-0.071	17.672	2.739

3. Analysis and Discussion

The geoid undulations derived from GGM and those observed have been compared with the help of a few different stages. This research has used a total of 52 controls, and Table 2 presents the geoidal undulations obtained from both of the aforementioned sources. The results of this investigation demonstrate a wide variety of distinctions, which are outlined in Table 3.

1.540 meters for the bi-linear interpolation, 1.570 meters for the bi-quadratic interpolation, 1.515 meters for the triangulation, 2.010 meters for the nearest neighbor, and 5.398 meters for the EGM96. The findings of this investigation have shown that the RMSE values for these differences are as follows: 0.239 meters for bilinear interpolation and 0.254 meters for linear interpolation Bi-Quadratic Interpolation, a deviation of 0.241 meters for Triangulation, a deviation of 0.451 meters for Nearest Neighbor, and a deviation of 1.393 meters for EGM96. There has been a significant reduction in the total RMSE, which has gone from 45 cm (Nearest Neighbour) to 24 cm (Bi-Linear Interpolation). The orthometric heights that are acquired will be of higher quality if the range of values (between the lowest and highest NGGMs – NDGPS-Precise Levelling) is as narrow as possible. Along the Mediterranean Coastal Line, the EGM08-BiLinear Interpolation Model is now the most appropriate source of orthometric height determination for use in topographical mapping, engineering and environmental research, and other applications.

Table 3. Statistics of N^{Obs} & N^{GGMs} & Undulation Differences ($N^{GGM} - N^{DGPS/Precise\ Levelling}$)

		Min (m)	Max (m)	Mean (m)	**RMSE** (m)
Observed Undulations		14.933	20.787	16.437	1.085
EGM2008 Undulations & Undulation differences	Bi-Linear Interpolation	15.038	20.120	16.789	1.053
	Undulation Differences	-0.747	0.793	0.335	0.239
	Bi-Quadratic Interpolation	15.066	20.120	16.845	1.059
	Undulation Differences	-0.733	0.837	0.390	0.254
	Triangulation	14.954	20.108	16.775	1.050
	Undulation Differences	-0.749	0.766	0.320	0.241
	Nearest Neighbour	14.862	20.283	16.968	1.100
	Undulation Differences	-0.504	1.506	0.500	0.451
EGM96		15.486	18.199	16.257	0.777
Undulation Differences		-2.659	2.739	-0.159	1.393

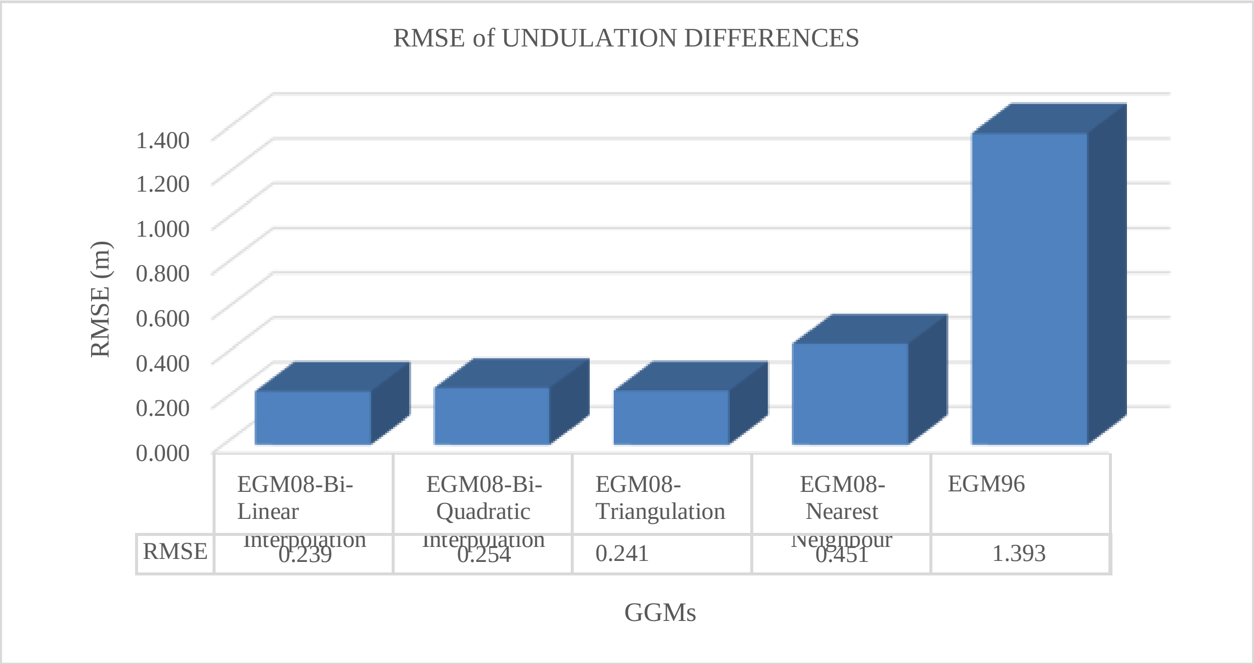


Figure 4. RMSE for GGMs different Models

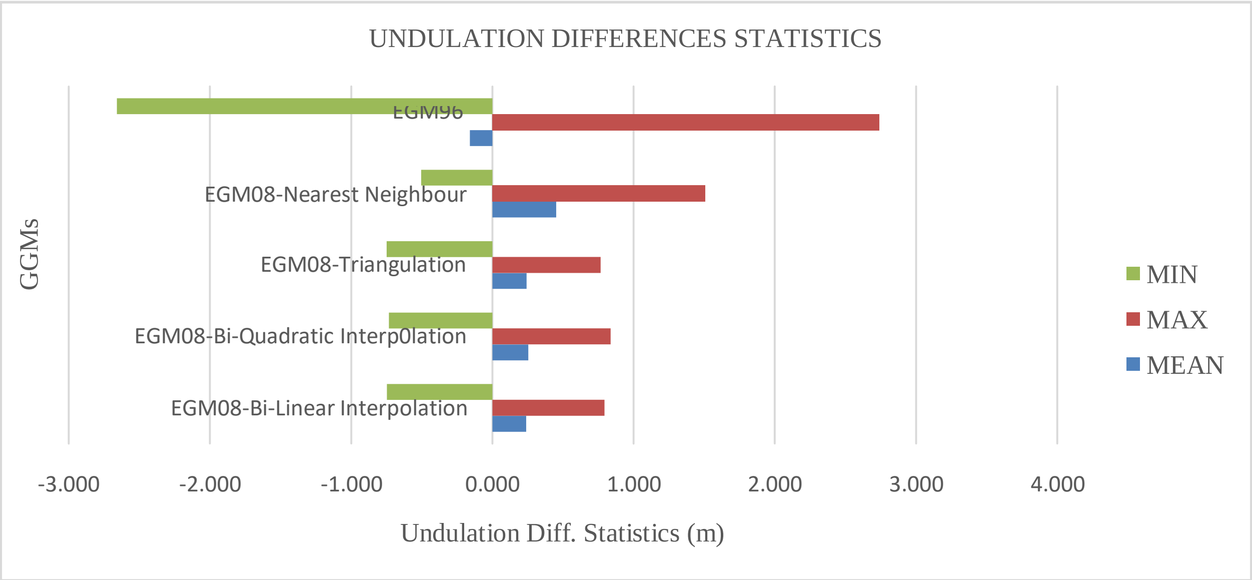


Figure 5. Statistics of GGMs different Models

Table 4. ASPRS Topographic Elevation Accuracy Requirement for Well-Defined Points

Contour Interval (m)	Class I(M) High Accuracy/ Standard Deviation Accuracy	Class II(M) Lower Than Class I Accuracy Standard Deviation	Class III(M) Lower Than Class II Accuracy Standard Deviation
0.5	0.08	0.16	0.25
1.0	0.17	0.33	0.50
2.0	0.33	0.67	1.00
4.0	0.67	1.33	2.00
5.0	0.83	1.67	2.50

Source: American Society of Photogrammetry and Remote Sensing (ASPRS 1993).

Technical Requirements for the Topographical Survey

The standard deviation of the differences between the contours and the specifications provided by the American Society of Photogrammetry and Remote Sensing (ASPRS 1993), which are displayed in Table 4, can be used to determine the accuracy limits for the contours. These limits can be obtained by referring to the table.

It can be seen from Table 4 that the EGM08-Bi-Linear Interpolation with =0.239m, after being checked against the specification that was presented earlier, can be used to produce a topographical map with a contour interval of 2 meters for an intermediately accurate survey. However, this method is insufficient for survey applications that require a high level of accuracy.

4. Conclusions

The dissemination of the EGM08 GGM marks a significant milestone in the evolution of geoidal modeling on a worldwide basis. The precision level of the EGM08 models is estimated to be 0.239m for Bi-Linear Interpolation, 0.254m for Bi-Quadratic Interpolation, 0.241m for Triangulation, and 0.451m for Nearest Neighbor in comparison to 1.393m for EGM96. These estimates are based on several comparisons against DGPS/levelling data sets. The total RMSE of the EGM08 models has significantly decreased from 45cm (Nearest Neighbour) to 24cm, indicating a significant leap in accuracy (Bi-Linear Interpolation). This research also suggested that the EGM08-Bi-Linear Interpolation and EGM08-Triangulation techniques are better to utilize for determining orthometric heights.

It was also discovered that the EGM08-Bi-Linear Interpolation Model may be used to create topographical mapping with a contour interval of 2 meters for surveys that need just intermediate precision; however, this model is insufficient for surveys that demand a high level of accuracy. Instead of adopting a model that is not sufficient for accurate geo-data collections, it is possible that it would be beneficial to stimulate the development of a geometric geoid model for local applications.

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