IMPROVING GEOID DETERMINATION OVER MOROCCO AREA USING GOCE LEVEL 2 DATA

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ABSTRACT

Spatial gravity mission GOCE provided new global geopotential model with enhanced precision. Using GOCE User Toolbox we compute geoid undulations and gravity anomaly grids according to Time Wise, Space Wise and Direct models for the study area that include Morocco.
Using GPS leveling points we compare geoid grids from GOCE to old geoid grids computed on the north area of Morocco using global models and land measures.
GOCE geoid grids give also, the advantage of covering the entire surface of Morocco with good accuracy. This was not possible before, due to the unavailability of land measured gravity data in the south area of Morocco.
On the north part of Morocco we use land gravity data from BGI with global DTM to improve the geoid grids from GOCE by taking into account the Terrain effects.
Results show enhanced accuracy of geoid determination, with sufficient precision for leveling determination with GPS on some areas of Morocco. Testing the geoid grids all over Morocco, need unfortunately more existing GPS leveling measured points, especially in mountains area.

INTRODUCTION

Using Global Navigation Satellite Systems (GNSS) for leveling in engineering tasks would improve range and time parameters and enhance therefore the efficiency of survey operations.
To convert ellipsoidal height to orthometric height we need geoid undulations with centimeter precision. The aim of this project is to compute a geoid surface over Morocco area; we use Global Geopotential Models (GGM) from Gravity field and steady-state Ocean Circulation (GOCE) mission **[7]** provided by European Space Agency (ESA) to perform this task.

1. STUDY AREA

We consider the area between latitude 20° and 37° and between longitude -17° and 0°. This includes all the country of Morocco.

2. AVAILABLE DATA

1.1. Global gravity models

We use new GGM from GOCE mission to compute long and medium wavelength until 200 km as announced by ESA. Data was provided in NetCDF Format by ESA. Three models are used in this work:

- GOCE model computed by Direct method (GOCE DIR) **[1] [4]**
- GOCE model computed by Time-Wise method (GOCE TIM) **[11] [12]**
- GOCE model computed by Space-Wise method (GOCE SPW) **[10] [13]**

1.2. Global relief model

Elevations are needed in the process of computing geoid for evaluating the terrain effects and performing gravimetric reductions. We use 5 Arc Minutes ACE2 Global Digital Elevation Model (GDEM) with GOCE User Toolbox (GUT) to determine the surface of the earth for the height anomaly computing.
In order to do Residual Terrain Model (RTM) gravity reduction from the free air anomaly we need relief information in both land and marine area. We use 1 arc minute global relief model ETOPO1 provided by National Geophysical Data Center (NGDC).

1.3. Land and marine gravity data

For computing short wavelength of the geoid we need land and marine measured gravity data. 6500 land gravity measured points are provided by International Gravimetric Bureau (BGI). These include elevation, gravity, free air anomaly and simple bouguer anomaly according to 2.67 g/cm3 density. In marine domain we use 27500 free air anomaly measured points with bathymetry information.

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1.4. GPS leveling points

It is difficult to find enough Global Positioning System (GPS)/leveling measured points over the study area for testing geoid grid obtained either from GGMs or from gravimetric methods. To do this we use 10 points from Cartography National Agency (ANCFCC) Morocco over the area of Casablanca and 10 other GPS leveling points from references on ancient geoid models computed on the study area.

2. METHODOLOGY AND RESULTS

2.1. GOCE Geoid

We first compute geoid height and gravity anomaly grids from the three GOCE models over the study area with resolution of 1.5 arc minute. Fig 1 shows the contour map of geoid height according to SPW method. A map of differences between GOCE DIR geoid and GOCE SPW geoid is shown in Fig 2.

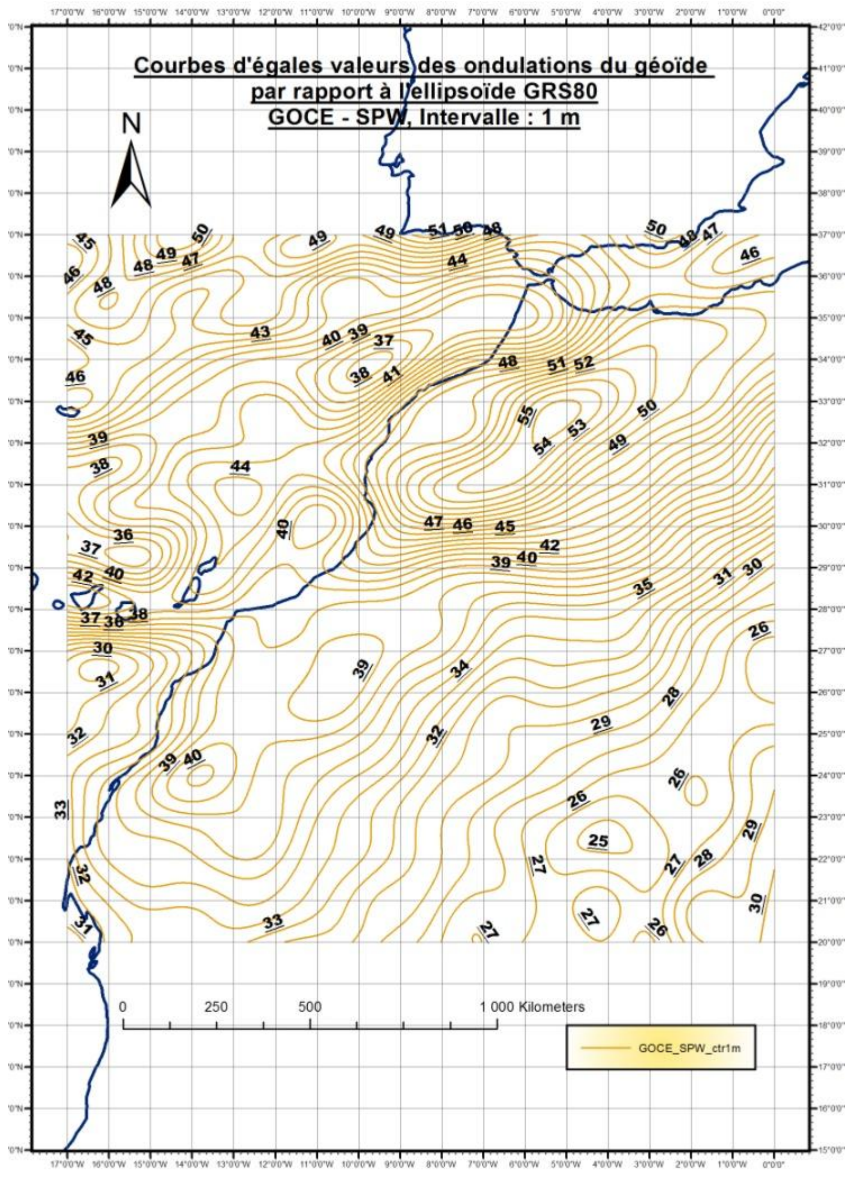

Figure 1: Contour Map for geoid height above GRS80 computed from GOCE SPW Geopotential Model (Interval 1 m) **[6]**

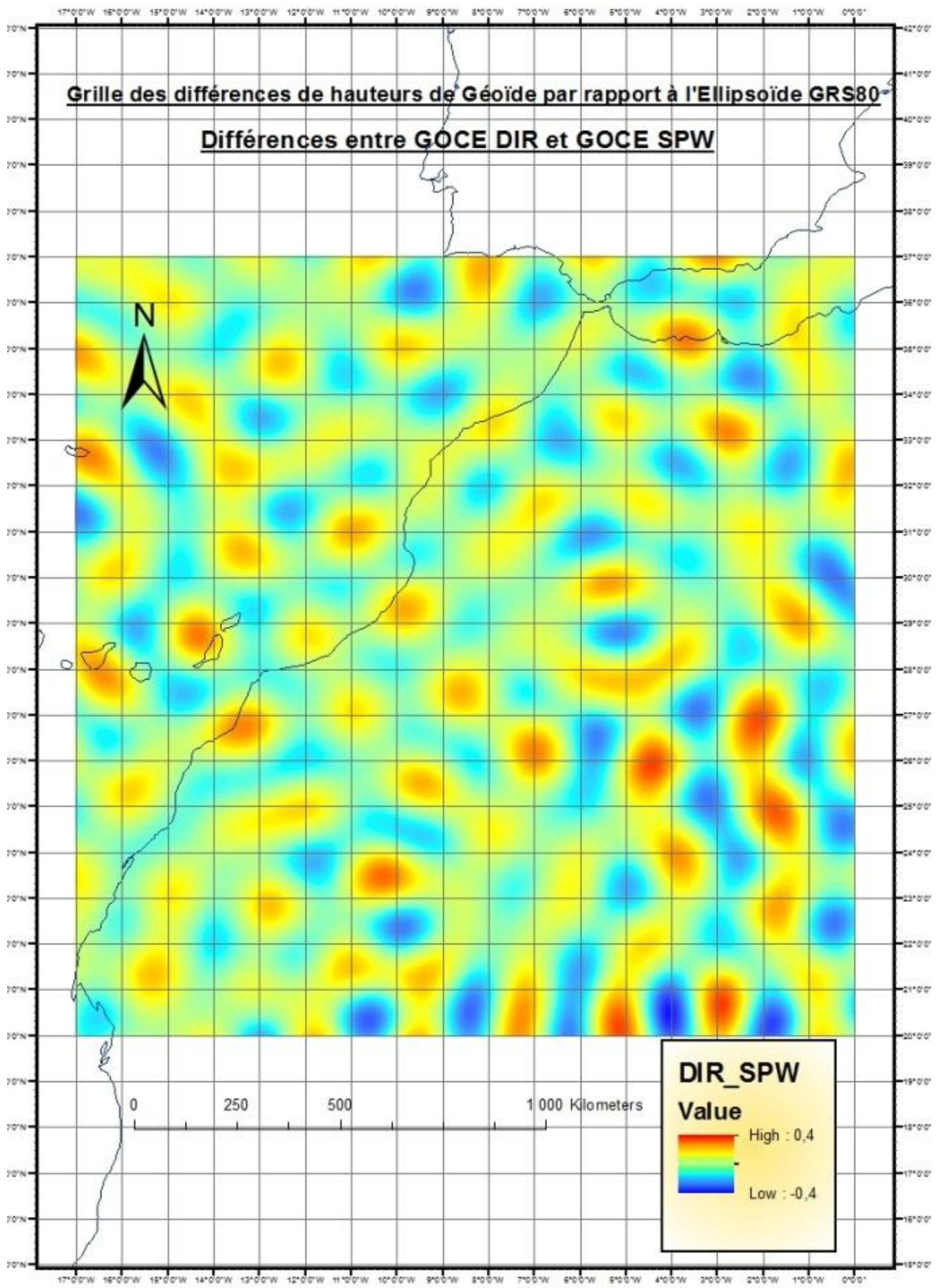

Figure 2: Map of geoid height differences from GOCE DIR and GOCE SPW **[6]**

We compare the geoid height grids to GPS leveling undulations from the 20 available points. Results are summarized in Tab 1. We also perform a test with only the 10 points provided by ANCFCC. Results are in Tab 2

	GOCE DIR	GOCE TIM	GOCE SPW
Mean	0,34	0,27	0,25
Minimum	-0,46	-0,62	-0,58
Maximum	0,82	0,74	0,80
Variance	0,09	0,09	0,08
Standard Deviation	0,29	0,30	0,29

Table 1: Statistics of Geoid height differences using the 20 available GPS leveling points

	GOCE DIR	GOCE TIM	GOCE SPW
Mean	0,39	0,32	0,23
Minimum	0,30	0,22	0,15
Maximum	0,49	0,44	0,34
Variance	0,00	0,01	0,00
Standard Deviation	0,07	0,08	0,07

Table 2: Statistics of Geoid height differences using 10 GPS leveling points from ANCFCC on the region of Casablanca

2.2. Gravimetric geoid

Once the wavelength until 200 km are computed and evaluated using GOCE models we try to enhance the result obtained using land and marine measured data. We then compute a gravimetric geoid according to the remove restore process. We use the GRAVSOFT software package provided by International Geoid Service (IGES) to perform these tasks.
We get a grid of quasigeoid as result from this process. We use Bouguer anomaly data and elevations to convert height anomalies to geoid undulations.
On land area we have simple Bouguer anomalies provided by BGI. In marine area we calculate the simple Bouguer anomalies from the free air anomalies and bathymetry using a density of 1.64 g/cm3.
Due to the lake of land data in the south of Morocco we reduce the study area to the latitude between 28° and 37°. Data is also still unavailable partially in some parts of the north of Morocco.
Tab 3 shows the results of comparing obtained grid geoid height to the 10 GPS leveling points from ANCFCC in the area of Casablanca. We remark an enhancement of 4.5 cm from the results in Tab 2.
We also do a test for all the 20 GPS leveling points. Tab 4 shows the results obtained. Standard deviation is greater than results in Tab 1.
To resolve this problem we fit our gravimetric geoid to GPS leveling. The result is enhanced as shown in Tab 4 column 4.
Fig 3 shows the final geoid grid of 3'x3' computed over the area between 28° and 37° of latitude and between -17° and 0° of longitude. Statistics of the geoid height obtained are in Tab 5

	QUASI GEOID	GEOID
Mean	-1,404	-1,408
Minimum	-1,441	-1,443
Maximum	-1,371	-1,374
Variance	0,001	0,001
Standard Deviation	0,024	0,024

Table 3: Statistics of Geoid height differences using 10 GPS leveling points from ANCFCC on the region of Casablanca

	QUASI GEOID	GEOID	FITTED GEOID to GPS Leveling
Mean	-1,466	-1,467	0,000
Minimum	-2,560	-2,560	-0,486
Maximum	0,533	0,535	0,483
Variance	0,304	0,304	0,025
Standard Deviation	0,551	0,551	0,159

Table 4: Statistics of Geoid height differences using the 20 available GPS leveling points

Grid Statistics			
Minimum:	27,61	Mean:	45,17
25%-tile:	41,75	Trim Mean (10%):	45,25
Median:	44,98	Standard Deviation:	5,13
75%-tile:	49,02	Variance:	26,37
Maximum:	69,73	Coef. of Variation:	0,11
Midrange:	48,67	Coef. of Skewness:	-0,12
Range:	42,12		
Interquartile Range:	7,27	Root Mean Square:	45,47
Median Abs. Deviation:	3,64	Mean Square:	2067,10

Table 5: statistics of the gravimetric geoid height grid

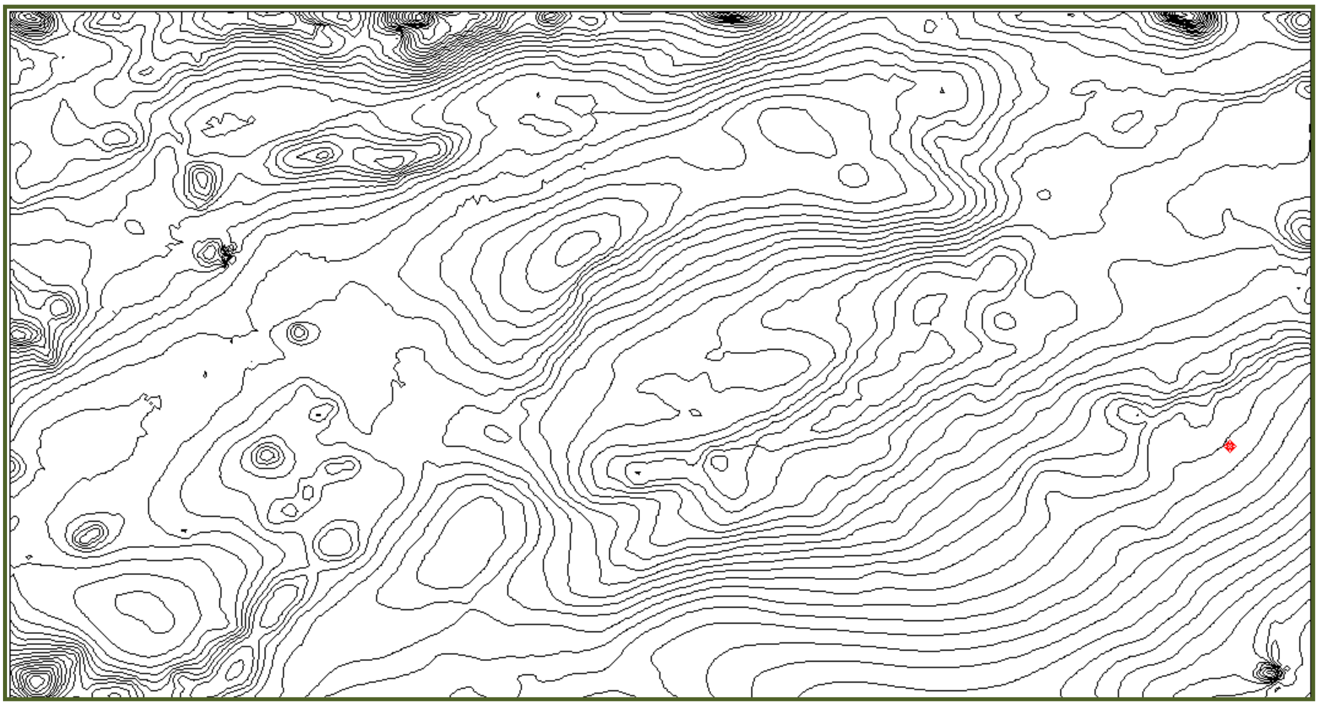

Figure 3: Contour Map for gravimetric geoid height above GRS80 based on GOCE SPW global geopotential model, ETOPO 1M relief model, land gravity data from BGI and marine gravity data from NGDC (latitude between 28° and 37°, longitude between -17 ° and 0°) (Interval 1 m)

CONCLUSION

Two ancient gravimetric geoids were computed on the north part of Morocco. The first one, called MGG97 **[3]**, was based on OSU91A. The second one, called MORGEO **[5]** was based on the GGM EIGEN CG 01C. GOCE GGM with only satellite data improves gravimetric geoid MGG97. Results are also better than EIGEN CG 01 C and few centimeters less than gravimetric geoid MORGEO. These results are based on comparing undulations from geoids grids with GPS leveling determinations. Details are in **[6].**

As short wavelengths are considered, we compute this effect using gravimetric methods based on GOCE GGM, also in the north part of Morocco. The result obtained shows an improvement in the area of Casablanca. After fitting gravimetrc geoid obtained to GPS leveling determinations we remark enhancement of results for all the area tested by the 20 GPS leveling points used in this work.

We conclude that GOCE mission introduce an improvement in the determination of local geoids. The advantage for Morocco is that we could have a geoid grid all over the country with sufficient precision and not only in the north. However, we need other tests for the resulting grids all over the area of Morocco, especially in mountains area. To do this enough GPS leveling points should be available.

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- Land Gravimetric data are provided by BGI – International Association of Geodesy
- ETOPO1M and Marine Gravimetric data are provided by NGDC
- Gravimetric geoid is computed by GRAVSOFT package provided by IGES

REFERENCES

[1]. Abrikosov O. and Schwintzer P. (2004). Recovery of the Earth’s gravity field from GOCE satellite gravity gradiometry: a case study. In: *GOCE, the geoid and oceanography. ESA-SP569*, ESA Publications Division, ESTEC, Nordwijk.

[2]. Amante C. and Eakins B.W. ETOPO1 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis. *NOAA Technical Memorandum NESDIS NGDC-24*, 19 pp, March 2009.

[3]. Benaim E.H., Swassi A.M. and Sevilla M.J. (1997). The First Northern Moroccan Gravimetric Geoid. *Journal of Physics and Chemestry Of the Earth*, Vol. 23, No 1, pp 65-70. Ed Pergamon.

[4]. Bruinsma S., Marty JC. and Balmino G. (2004) Numerical simulation of the gravity field recovery from GOCE mission data. *Proceedings of 2nd international GOCE user workshop, Frascati, Italy, 8–10 March 2004. ESA SP-569*.

[5]. Corchete V., Chourak M., Khattach D. and Benaim E.H. (2007). The high-resolution gravimetric geoid of Morocco: MORGEO. *Journal of African Earth Sciences*, 48, pp 267-272.

[6]. EL Brirchi E.H. and EL Azzab D. (2011). Calcul d’un nouveau Géoïde au Maroc à partir des données de la mission de gravimétrie spatiale GOCE et utilisation des SIG pour sa validation par GPS et Nivellement. *Geo Observateur Journal* N° 19, CRTS, Rabat (IN PRESS)

[7]. Europeen Space Agency (ESA). (1999). Gravity field and steady-state ocean circulation mission. *ESA publication division, ESA SP-1233 (1), c/o ESTEC*, Noordwijk, Netherland.

[8]. Heiskanen WA. and Moritz H. (1967). *Physical Geodesy*. Freeman, San Francisco London.

[9]. Hofmann-Wellenhof B. and Moritz H. (2005). *Physical Geodesy*. SpringerWienNewYork, Autriche.

[10]. Migliaccio F., Reguzzoni M. and Sansò F. (2004) Space-wise approach to satellite gravity field determination in the presence of coloured noise. *Journal of Geodesy*, vol.78, pp 304–313.

[11]. Pail R., Goiginger H., Mayrhofer R., Schuh WD., Brockmann JM., Krasbutter I., Hoeck E. and Fecher T. (2010). GOCE gravity field model derived from orbit and gradiometry data applying the time-wise method. *Proceedings of the ESA Living Planet Symposium, 28 June - 2 July 2010*, Bergen, Norway

[12]. Pail R., Schuh WD. and Wermuth M. (2005) GOCE gravity field processing. In: Jekeli C, Bastos L, Fernandes J (eds) *International association of geodesy symposium. ‘Gravity, geoid and space missions’*, vol.129. pp 36–41. Springer, Berlin

[13]. Reguzzoni M. and Tselfes N. (2008). Optimal multi-step collocation: application to the space-wise approach for GOCE data analysis. *Journal of Geodesy*, 83, pp 13–29.