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The high-resolution gravimetric geoid of Morocco: MORGEO

V. Corchete [a,*], M. Chourak [a], D. Khattach [b], E.H. Benaïm [c]

[a] Higher Polytechnic School, University of Almeria, 04120 Almeria, Spain
[b] Faculté des Sciences, University of Mohamed I, Oujda, Morocco
[c] Institut Agronomique et Vétérinaire Hassan, B.P. 6202 Rabat Instituts, Rabat, Morocco

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Abstract

In spite of the difficulty to obtain data for the African continent, the necessary measurements for the determination of a high-resolution geoid for Morocco have been collected. In Morocco, since the publication of most recent geoid (MGG97) a new geopotential model is available (EIGEN-CG01C, released on October 29, 2004) and a new high-resolution digital terrain model (SRTM 90M obtained from the Shuttle Radar Topography Mission), has been developed for the whole earth. Logically, these new data represent improvements that must be included in a new geoid for Morocco. For this reason, a new gravimetric geoid determination has been carried out including these new data. The method used in the computation of the geoid has been the Stokes integral in convolution form, because it is an efficient method to reach the proposal objective. The terrain correction has been applied to the gridded gravity anomalies, to obtain the corresponding reduced anomalies. The indirect effect has been also taken to account. Thus, a new geoid is provided as grid data distributed for Morocco from 27° to 37° of latitude and −14° to 0° of longitude (extending $10 \times 14°$), on a 401×561 regular grid with a mesh size of $1.5' \times 1.5'$ and 224961 points in the GRS80 reference system. This calculated geoid and previous geoids existing for this study area (MGG97 and EIGEN-CG01C), are compared to the geoid undulations corresponding to 6 GPS/levelling points on Morocco. The new geoid shows an improvement in precision and reliability, fitting the geoidal heights of these GPS/levelling points with more accuracy than the other previous geoids.

Keywords: Gravity; Geoid; FFT; GPS/levelling; Morocco

1. Introduction

In Morocco and surrounding area, several studies have taken as objective the geoid computation (Balmino et al., 1989; Groten and Roehrich, 1989; Benaim, 1995; Sevilla, 1995; Sevilla, 1997; Benaim et al., 1998). Unfortunately, only MGG97 (Benaim et al., 1998) covers completely Morocco, the others geoids only cover the northern part partially. MGG97 is actually the official geoid model used in Morocco for the calculation of the geoid undulations. This geoid is supplied as a grid over the Moroccan area, from 30° to 38° of latitude and −10.5° to 0° of longitude, with a mesh size of $5' \times 5'$ ($97 \times 126 = 12222$ points) in the GRS80 reference system. The computation of MGG97 is based on a data set consisting of 60448 free-air gravity anomalies and the OSU91A geopotential model. The terrain effect was not considered to compute this geoid. This is a severe error in the computation of this geoid, because terrain corrections are very important to obtain a precise geoid.

Since the publication of MGG97 a new geopotential model (EIGEN-CG01C) is available and a new high-precision DTM for the whole earth topography is supplied by the Shuttle Radar Topography Mission (SRTM 90M). Logically, these new data represent improvements that must be included in a new geoid of Morocco. With this goal in mind, we have carried out a new gravimetric geoid determination in which these new data have been included.

* Corresponding author. Fax: +34 950 015477.
E-mail address: corchete@ual.es (V. Corchete).

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The method used in the computation of the new geoid has been the Stokes integral in convolution form (Haagmans et al., 1993). There are several methods for the calculation of a gravimetric geoid, but the FFT solutions are obtained much more quickly than the numerical integration solutions without loss of accuracy. Thus, we have considered here the Stokes integral computation by the one-dimensional FFT. The necessary terrain correction has been applied to obtain the gridded reduced gravity anomalies. The corresponding indirect effect has been taken to account. The terrain correction and the indirect effect have been computed by means of the two-dimensional FFT on the plane (Schwarz et al., 1990; Sideris, 1990).

We have compared our geoid MORGEO (MORoccan GEOid) with the gravimetric geoids developed in this study area: the Moroccan Geoid MGG97 (Benaim et al., 1998) and the global geoid model EIGEN-CG01C. This comparison shows an improvement in precision and reliability, because the new geoid shows minor discrepancy with the observed geoid undulations of the GPS/levelling points available for Morocco, than the previous geoids. Thus, when the final solution obtained by us, has been compared with other geoids available for the study area, we have observed that the accuracy reached by our geoid is better than that of anyone of the other geoids. For this reason, the final geoid obtained in this study is considered as the best geoid available now for Morocco. This new high-resolution gravimetric geoid for Morocco is shown in this paper as a contour map, in the GRS80 reference system.

2. Data set

For the gravimetric geoid computation a complete data set is necessary consisting of: (1) free-air gravity anomalies; (2) a geopotential model for computing the long-wavelength contribution to geoid and gravity anomaly; (3) a high-precision DTM for the computation of terrain corrections and indirect effect in the study area; and (4) observed geoid undulations for testing of the geoid model obtained. The data set used for the computation of the Moroccan geoid is detailed below.

2.1. Land and marine gravity data bank

The land and marine gravity data used in this study have been provided in by the National Geophysical Data Center (NGDC), the Bureau Gravimetrique International (BGI) and the United States Geological Survey (USGS). NGDC contributed with a data set consisting of 2665 points (all points over Iberia), BGI data set in the study area has 91052 points (7694 on land and 83358 at the sea) and USGS supplied 70465 points in Morocco and the Gibraltar strait. The whole data set consisting of 164182 points of free-air gravity anomalies (80824 on land and 83358 at sea) are distributed in the Moroccan area from 27° to 37° on latitude, and from −14 to 0° on longitude. The accuracy of all these data ranges from 0.1 to 0.2 mgal. The gravity data have been checked to remove repeated points letting 162541 points, distributed over the study area as is shown in the Fig. 1. All the data are in the GRS80 reference system and the atmospheric correction has been taken to account (Wichiencharoen, 1982; Kuroishi, 1995).

2.2. Geopotential model

EIGEN-CG01C geopotential model represents a major advancement for modelling the Earth's geoid. Therefore, this model is the geopotential model that must be considered for computing the long wavelength contribution to geoid and gravity anomaly, if we wish to obtain a high-precision geoid in the study area. This new global model has been developed by Reigber et al. (2004), who have combined CHAMP (860 days mission) and GRACE (200 days mission) satellite gravity data, with $0.5 \times 0.5°$ surface data (gravimetry and altimetry), to generate the high-resolution global gravity field model EIGEN-CG01C. CHAMP (CHAllenging Minisatellite Payload) is a German small satellite mission for geo-scientific and atmospheric research. GRACE (Gravity Recovery and Climate Experiment) is a joint project between the National Aeronautics and Space Administration (NASA) and the Deutsches Zentrum für Luft- und Raumfahrt (DLR).

2.3. Digital terrain model (DTM)

Any gravimetric geoid computation based on the Stokes's integral must use anomalies that have been reduced to the geoid, usually by means of Helmert's second method of condensation. This involves the computation of the terrain correction and the indirect effect on the geoid, which are computed from a DTM. A DTM is also necessary to compute the Residual Terrain Model reduction (RTM reduction), as will be described in the next section. That is applied to the point anomaly data in order to obtain smooth gravity anomalies, which are more easily gridded. For the present study, we have a suitable gridded topography with a mesh size of ($3'' \times 3''$) (90 m × 90 m, approximately) from SRTM 90M, but we do not have a bathymetry with the same

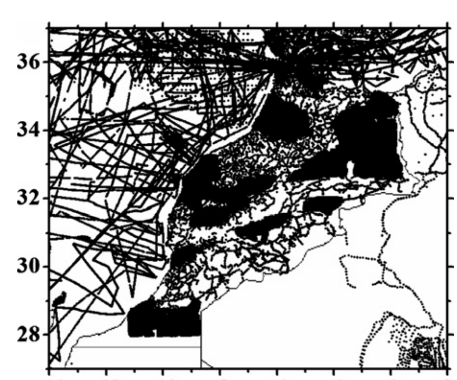

Fig. 1. Geographical distribution of the observed free-air gravity data over the study area (162541 points).