DETAILED GRAVIMETRIC GEOID FOR THE NORTH ATLANTIC

Abstract

A detailed gravimetric geoid in the North Atlantic Ocean, named DGGNA–77, has been computed, based on a satellite and gravimetry derived earth potential model (consisting in spherical harmonic coefficients up to degree and order 30) and mean free air surface gravity anomalies (35180 1° x 1° mean values and 245000 4′ x 4′ mean values). The long wavelength undulations were computed from the spherical harmonics of the reference potential model and the details were obtained by integrating the residual gravity anomalies through the Stokes formula: from 0 to 5° with the 4′ x 4′ data, and from 5° to 20° with the 1° x 1° data. For computer time reasons the final grid was computed with half a degree spacing only. This grid extends from the Gulf of Mexico to the European and African coasts.

Comparisons have been made with Geos 3 altimetry derived geoid heights and with the 5′ x 5′ gravimetric geoid derived by Marsh and Chang [8] in the northwestern part of the Atlantic Ocean, which show a good agreement in most places apart from some tilts which probably come from the satellite orbit recovery.

Introduction

The altimetry technique requires a very fine calibration of the instrument — at the 1 m level or better — with the best possible resolution on the ground. In the North Atlantic Ocean area such calibrations are possible with a geoid derived from surface gravity measurements.

For sake of computations, it is better to first take into account the long wavelength features as given by any recent combined solution of the geopotential and then to integrate the so-called "residual anomalies" by means of Stokes formula. The reference model used in this study consists of spherical harmonics up to degree and order 30 obtained from all satellite observations included in our previous GRIM 2 model [2], combined with the 35180 mean gravity anomalies over 1° x 1° squares which constitute the now well-known Defense Mapping Agency Aerospace Center (DMAAC) set, updated from the previously published 1973 set [6]; this model is therefore very similar to

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GRIM 2 and will be referred to in the following as PG3 (preliminary GRIM 3 solution). Then, the integration of Stokes formula is carried up to 20° in geocentric distance and makes use of 245000 free air gravity anomalies over 4' x 4' areas and the above mentioned 1° x 1° values of the DMAAC set.

**Method**

At each point on the Earth's surface, defined by its latitude \( \varphi \) and longitude \( \lambda \), the geoid height \( \Delta h(\varphi, \lambda) \) above a reference ellipsoid (E), defined by semi-major axis \( a_e \) and flattening \( f \), is computed as follows:

\[
\Delta h(\varphi, \lambda) = \Delta h_0 + \Delta h_1 + \Delta h_2
\]

with

\[
\Delta h_0 = R \sum_{n=2}^{N_{\text{max}}} \sum_{m=0}^{n} \left( \tilde{C}_{n,m} \cos m \lambda + \tilde{S}_{n,m} \sin m \lambda \right) \tilde{P}_{nm}(\sin \varphi)
\]

\((\tilde{C}_{n,m}; \tilde{S}_{n,m})\) = differences between the PG3 harmonic coefficients and the chosen reference ellipsoid coefficients \((\tilde{C}_{2,0}; \tilde{S}_{2,0})\) only

\[
\Delta h_1 = \frac{R}{4\pi\gamma} \int \int_{A_1} (\Delta g_1 - \Delta g_R) S(\psi) \, d\sigma
\]

\[
\Delta h_2 = \frac{R}{4\pi\gamma} \int \int_{A_2} (\Delta g_2 - \Delta g_R) S(\psi) \, d\sigma
\]

where:

- \( \Delta g_R \) ... PG3 reference gravity anomaly field
- \( S(\psi) \) ... Stokes function
- \( R = a_e (1-f)^{1/3} \) ... mean radius of the Earth
- \( \gamma = \frac{1}{\pi} \int_{-\pi/2}^{\pi/2} \gamma(\varphi) \, d\varphi \) ... mean value of normal gravity
- \( \Delta g_1 \) ... set of 4' x 4' values of gravity anomalies
- \( \Delta g_2 \) ... 1° x 1° surface gravity data
- \( A_1 \) ... set of all points at a geocentric distance \( \psi \leq 5° \)
- \( A_2 \) ... set of all points for which \( 5° < \psi \leq 20° \).

Our primary constants are:

\[
GM = 398 \, 601.3 \text{ km}^3 / \text{sec}^2 \quad \text{gravitational constant times mass of the earth}
\]