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*Publication date:*
2010

*Document Version*
Publisher's PDF, also known as Version of record



*Citation (APA):*
Herceg, M., Knudsen, P., Andersen, O. B., & Tscherning, C. C. (2010). *Full Resolution Geoid from GOCE Gradients for Ocean Modeling*. Poster session presented at European Geosciences Union General Assembly 2010, Vienna, Austria.

# Full Resolution Geoid from GOCE Gradients for Ocean Modeling

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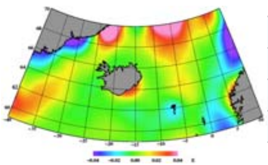
Poster number: EGU2010-10737

## Introduction

The main objective of the study is to improve the methodology for combining GOCE gravity field models with satellite altimetry to derive optimal dynamic ocean topography models for oceanography. Since dynamic ocean topography determination is the difference between the sea surface and the geoid, the definition of both surfaces is of great significance.

Here a method for geoid determination, using point mass method, is used for the regional determination of the gravity field that is not recovered by the planned global GOCE gravity model of spherical harmonic coeficients up to degree and order 200. Since no real GOCE data are available at this time, simulated gradient data are used taken from deliverables of GOCINA project.

**Fig. 1. GOCINA region**



| | |
|---|---|
| Min | -0.05m |
| Max | 0.04m |
| Mean | 0.00m |
| St. D. | 0.025 |

**Fig. 2. Vertical gradients relative to the EGM96 model to harmonic degree 200**

## Point mass method

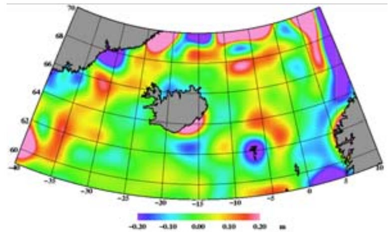
The Earth anomalous gravity field, $T$, at point $Q$ is modeled by the set of base functions, each obtained as the anomalous gravity potential from each point mass $m_i$ located at the position $P_i$ on the surface of the ellipsoid with radius $R_{M1}$ = 10 km and $R_{M2}$ = 70 km smaller than the Earth mean radius $R_E$. Using the least squares inverse method and formula for second order derivatives of gravitational potential, where masses are unknowns, grids of point masses on the two dierent level below the ellipsoid were created.

$$\frac{\partial^2}{\partial z^2}T_i(Q)=\frac{\partial}{\partial z}Gm_i\frac{1}{|P_i-Q|}=-Gm_i\frac{1}{\left(s_i^2+z_i^2\right)^{\frac{3}{2}}}+3Gm_i\frac{z^2{}_i}{\left(s_i^2+z_i^2\right)^{\frac{5}{2}}}$$

At both depths point masses are located at regular grids having spacing of 0.25 degrees and 0.5 degrees in latitude and longitude respectively. Those grid spacing's were chosen to model the gravity field associated with harmonic degrees between 200 and 400 where the main improvements are expected to occur. The solution for the two burried mass grids were then used for geoid determination.

## Results

To produce residual gradient grid, the reference EGM96 gradients up to degree 200 were subtracted from the GOCINA gradients (Figure 2).
From the burried point mass grids the residual geoid heights were computed. Calculated geoid is shown in Figure 3.

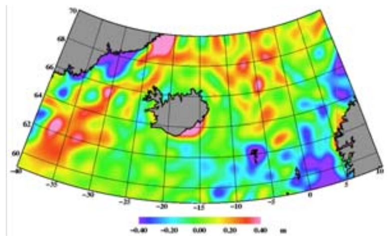


| | |
|---|---|
| Min | -1.52m |
| Max | 1.26m |
| Mean | 0.00m |
| St. D. | 1.210 |

**Fig. 3** Residual geoid calculated using point mass method

Compared with the Figure 2 the geoid heights show the same general pattern as the gradients. However, the geoid heights show more short wavelengths features than the gradients.

The geoid solution was compared to the GOCINA geoid filtered using Gaussian filtering with a width of 1 degree to filter out short wavelength features of the geoid that may not be recovered from gradients at 258 km altitude.

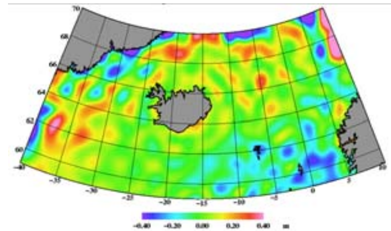


| | |
|---|---|
| Min | -2.46m |
| Max | 2.13m |
| Mean | 0.00m |
| St. D. | 0.380 |

**Fig. 4** Filtered GOCINA geoid relative to the EGM up to degree 200

Compared to the result of the point mass solution, both geoid models show similar features with relatively high values southeast of Greenland as well as in the northern part of the region. The magnitude of the geoid based on the point mass solution is smaller and it appears to be smoother.

Figure 5 shows the difference between the geoid based on the point masses and the GOCINA geoid described above.



| | |
|---|---|
| Min | -0.84m |
| Max | 0.89m |
| Mean | 0.00m |
| St. D. | 0.190 |

**Fig. 5** Diference between the two residual geoid solutions

The magnitude of the unknown part of the simulated geoid is reduced from 38 cm to 19 cm. The short wavelength features are still present in the differences, but the main positive values southeast of Greenland and in the norther part of the region have been reduced. Also the negative values in the southeastern part of the region have been reduced. Hence, this preliminary test of the point mass method demonstrates its ability to recover parts of the gravity field that are not recovered by a spherical harmonic expansion truncated at harmonic degree and order 200.

## Discussion

The preliminary results show that parts of the gravity field associated with harmonic degrees larger than degree 200 may be recovered using this method. Hence, the gravity gradients contain more valuable signal than will be recovered in the planned harmonic expansion up to degree 200, so this method led to improvements in the estimation of the geoid. The enhanced geoid may serve as a reference surface for satellite altimetry and provide improvements in the mean dynamic topography which in turn may be used to improve the modeling of the ocean circulation. Further studies on how to structure the point masses as dipoles within the earth to optimize the estimation are needed. Also, the error propagation should be studied rigorously, so that the contribution from the other components of the GOCE gradients can be studied properly.

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