Bollettino di Geofisica Teorica ed Applicata Vol. 40, n. 3-4, pp. 255-259; Sep.-Dec. 1999

Comparison between EGM96 and FCUL96B tailored geopotential model for the north-east Atlantic

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(Received October 4, 1998; accepted August 5, 1999)

Abstract. A new geopotential model tailored to gravity data in the north-east Atlantic was developed. The new geopotential model (FCUL96B), completed to degree and order 360, has been calculated using a new set of 30' × 30' mean free-air gravity anomalies obtained from several ocean gravimetric missions which took place from 1975 to 1990. The calculation of the tailored model was based on the OSU91A coefficient set that was used as a start model. The comparison of EGM96, OSU91A and FCUL96B, with altimetric data obtained from ERS1 and TOPEX, reveals a slightly better accuracy for the FCUL96B model. In this area, the EGM96 geopotential model reveals a better fit to the gravity field than the OSU91A one but not as good as the tailored model FCUL96B. From the results we obtained, we verify that a tailored model can provide an improved reference surface for local and regional solutions, if the gravity data used in the tailoring process is improved in quality or in density.

1. Introduction

Geopotential models have long been used in combination with other data types for gravity field modelling, in particular for precise geoid computation. In the past two years, several studies have been performed, in the north-east Atlantic region (Azores- Iberian Peninsula), concerning geoid determination with sub-decimetre level (Catalão and Sevilla, 1994, 1997). Several different data types, the OSU91A geopotential model (Rapp and Pavlis, 1990), observed gravity anomalies and bathymetric data have been used for gravity field modelling and geoid determination. It is well known that geopotential models may contain long wavelength errors (Kearsley and Forsberg, 1990), which affect the geoid heights obtained from these models. It is also true that a direct relation between the quality of the geopotential model reference surface for geoid heights, and the precision of the geoid solution exists.

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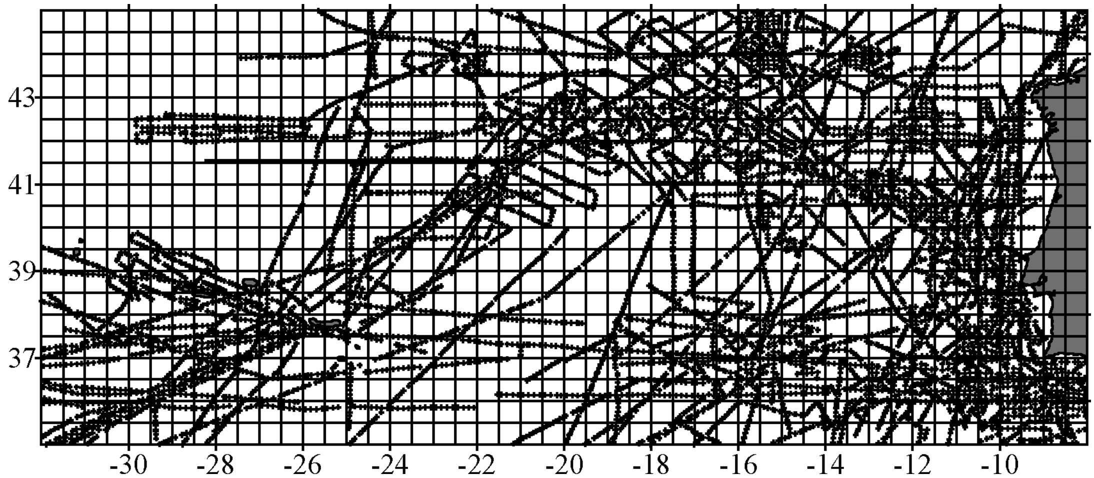

Fig. 1 - Gravity data distribution in the north-east Atlantic (Azores - Iberian Peninsula). One observation in each cell of 6' × 7.5'. Grid lines interval 30'.

The aim of this study was the development and evaluation of a tailored geopotential model for local geoid solutions. The new geopotential model, complete to degree and order 360, has been calculated using a new set of 30'×30' mean free-air gravity anomalies obtained from several ocean gravimetric missions which took place from 1975 to 1990. A tailored model computation was based on the OSU91A coefficient set that was used as a start model, following the method proposed by Weber and Zomorrodian (1988). Thus, three solutions were obtained depending on the harmonic degree to which the correction coefficients were applied to OSU91A. In this study, the evaluation of the above-mentioned geopotential models is attempted. The tailored model is compared with ERS-1 and TOPEX/Poseidon altimetric data and with the EGM96 geopotential model (Lemoine et al., 1996).

2. The data

The original data bank used for validation purposes was obtained by merging BGI, NGDC and DMA gravimetric data. The complete data set, obtained from a simple merge of data files, with 87 657 data points were gleaned from repeated missions and recorded in different data banks, resulting in a new data set with 60 070 data points (Sevilla and Catalão, 1993). Most of the data were acquired from institutions in the USA, the United Kingdom and France in the period going from 1970 through to 1990. The geographic limits are -32°: -8° in longitude and 35°: 45° in latitude. All data were transformed to the IGSN71 system and the anomalies converted to GRS80. Data validation was done by detecting crossovers of different missions and adjusting the crossover errors.

Validated data were sampled in small rectangular cells of 6'×7.5', with one observation for each cell. Mean anomalies representing an area of 30'×30' were obtained by making a simple average of the inside gravity anomalies, see Fig. 1. Considering the predefined limits, with a sample rate of 30', 1029 mean anomalies (21 × 49) were expected, but in fact, we obtained only 703 mean anomalies due to the fact that there are several cells do not have any observation.

3. Model development

Following Weber and Zomorrodian (1988), mean gravimetric anomalies Δg' are computed from the geopotential coefficients of the reference model $\Delta C'_{nm}$, $\Delta C'_{mm}$. These mean anomalies are subtracted from the observed mean anomalies Δg yielding the difference: δΔg'=Δg-Δg'. The initial differences δΔg', between mean free-air anomalies and mean OSU91A anomalies in 30'×30' cells, are developed in spherical harmonic through degree 360.

The correction coefficients ($\delta\Delta C'_{nm}$, $\delta\Delta S'_{nm}$) are then added to the original OSU91A coefficients. These coefficients represent a new model named FCUL96, which is, because of its construction, a model tailored to this region. The simple adding of the correction coefficients, of all degrees, to the OSU91A did not seem adequate, since, as we know, the low degree coefficients are not well determined from gravity anomalies only, in particularly in such a small area.

It was decided to construct three different models differing in the degree to which the correction coefficients were applied to OSU91A. Ba šić et al. (1989) have suggested the application of a weight function dependent on the harmonic degree, which are null in the first seven elements and increase to the unit between degree 7 and 20. The resulting set of coefficients was denoted as FCUL96A. The second set of coefficients was obtained considering the first 50 of OSU91A as correct. The correction coefficients were only applied to the coefficients ranging from 51 to 360, thus yielding model FCUL96B. The third set of coefficients, FCUL96C, was obtained from the introduction of the correction coefficients to the OSU91A model from degree 15 to 360, according to the dimension the working area.

4. Evaluation of the model

4.1. Gravity anomalies

The three computed solutions were analysed through the comparison with observed free-air gravity anomalies and with OSU91A and EGM96 model anomalies. The results of this comparison are presented in Tab. 1. The model that best fits to the observed gravity field is the FCUL96A, the standard deviation drops from 41.0 mGal to 18.73 mGal and the signal amplitude range is considerably smaller. The global models, OSU91A and EGM96, do not reveal such good results in all parameters analysed. In particular, in this area, the EGM96 model does not seem to introduce any improvement relatively to OSU91A model, in fact the standard deviation increases from 21.5 mGal to 22.9 mGal and the signal amplitude are almost the same with a shift of 20 mGal.

4.2. Geoid heights

The geoid height obtained from OSU91A, EGM96, and the three solutions, were compared

Table 1 - Results of the comparison between observed gravity anomalies and the gravity anomalies obtained from geopotential models.

	Mean (mGal)	Std (mGal)	Minimum (mGal)	Maximum (mGal)
Δg_{Obs}	14.999	41.084	-168.80	345.85
Δg_{Obs} - OSU91A	0.636	21.582	-107.60	198.61
Δg_{Obs} - EGM96	0.624	22.964	-123.01	171.99
Δg_{Obs} - FCUL96A	0.266	18.733	-103.10	135.03
Δg_{Obs} - FCUL96B	0.770	18.831	-103.00	138.01
Δg_{Obs} - FCUL96C	0.615	18.800	-101.59	139.53

with TOPEX/Poseidon Sea Surface Height (SSH) processed by AVISO and with ERS1 (SSH) processed by Fernandes and Catalão (1996), named JF in Table 2.

The behaviour of the three local solutions is completely different going from a standard deviation of 0.43 m in solution A to 0.31 m in solution B when compared to ERS1 heights. The low-degree corrections made in solution A have the expected effect, i.e. the degradation of the reference model, in particular in the geoid height which is most sensitive to the long wavelength. The comparison of solution B with the OSU91A model reveals that the best improvement was achieved in the residual amplitude, dropping from 2.2 m in OSU91A to 0.89 m in FCUL96B.

The EGM96 model is clearly better than the OSU91A one with a smaller standard deviation (0.30m) and a smaller maximum residual (1.7 m). Comparing results of Table 2, which concerns the EGM96 and FCUL96B tailored models, we see that FCUL96B is slightly better than EGM96 on the residual amplitude.

Table 2 - Comparison between the geoid height obtained from OSU91A, EGM96 global models, the three local solutions and the SSH obtained from TOPEX/Poseidon and ERS1.

	Mean (m)	Std. (m)	Minimum (m)	Maximum (m)
$SSH_{ERS1\ (JF)}$ - $N_{FCUL96A}$	-0.433	0.430	-1.867	1.194
$SSH_{TOPEX\ (AVISO)}$ - $N_{FCUL96A}$	-0.097	0.424	-1.150	1.587
$SSH_{ERS1\ (JF)}$ - $N_{FCUL96B}$	-0.340	0.308	-1.940	0.890
$SSH_{TOPEX\ (AVISO)}$ - $N_{FCUL96B}$	-0.011	0.346	-1.550	1.271
$SSH_{ERS1\ (JF)}$ - $N_{FCUL96C}$	-0.281	0.374	-1.644	1.230
$SSH_{TOPEX\ (AVISO)}$ - $N_{FCUL96C}$	0.052	0.378	-1.185	1.637
$SSH_{ERS1\ (JF)}$ - N_{OSU91A}	-0.315	0.384	-1.679	2.220
$SSH_{TOPEX\ (AVISO)}$ - N_{OSU91A}	0.068	0.525	-1.286	2.580
$SSH_{ERS1\ (JF)}$ - N_{EGM96}	-0.330	0.300	-1.797	1.769
$SSH_{TOPEX\ (AVISO)}$ - N_{EGM96}	-0.069	0.366	-1.549	1.989

6. Conclusions

A new geopotential model tailored to gravity data in the north-east Atlantic was developed, following the method proposed by Weber and Zomorrodian (1988). The computation of the tailored model was based on the OSU91A coefficient set, which was used as a start model. The standard deviation value of the difference between observed free-air anomalies and derived free-air anomalies decreases from 21.58 mGal (OSU91A) to 18.83 mGal with FCUL96B model. The comparison of EGM96, OSU91A and FCUL96B, with altimetric data obtained from ERS1 and TOPEX, reveals a slightly better accuracy of the FCUL96B model. The residuals obtained from EGM96 have the same standard deviation of the tailored model, but more than 70 cm on the residual amplitude. In this area, the EGM96 geopotential model reveals a better fit to the gravity field than the OSU91A one but not as good as the tailored model FCUL96B.

From the results obtained, we verify that a tailored model can provide a better reference surface for local and regional solutions, if the gravity data used in the tailoring process was improved in quality or in density.

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