Spectral behavior of global gravitational models considering EUVN network

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Abstract

Spectral behavior of Earth's gravitational models is analyzed considering EUVN network Earth's. Gravitational models CG01c, CHAMP03s, GGM01c, GRACE02s, EGM96s and EGM96 are used. To judge their inside structure their spectral behavior in discreet EUVN points is analyzed. Spectral behavior of CHAMP/GRACE/terrestrial data Earth's gravitational model CG01c in high resolutions spectrum part is showing inside fluctuations of recent global gravitational models. It is giving opportunity to judge inside accuracy of the model. To have overview in behavior of global models not only in discreet points, but on the territory of Europe, animation of spectral development of CG01c in 15'x15' undulations raster over the Europe is made. Big errors of EUVN network are checked considering CG01c, EGM96 and EGG97 gravitational models. Connections between EUVN and global models datums are analyzed. One of the recent CHAMP/GRACE/terrestrial data model CG01c developed up to 360 degree and order is put in focus as a model that can replace models before CHAMP/GRACE era.

1. Introduction

In the analysis is used more global gravitational model developed up to different maximum degree and order (s. table 1). Active CHAMP and GRACE satellite missions are giving data for defining new standards in the modeling of the Earth's gravity field.

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Earth Gravitational Model 1996 (EGM96) is satellite and terrestrial data model. Terrestrial gravity anomalies, satellite altimetry data (ERS-1 TOPEX/POSEIDON, ERS-1 and GEOSAT), laser satellite measurements, GPS measurements data, data of NASA Tracking and Data Relay Satellite System (TDRSS), DORIS and US Navy TRANET Doppler data are used in modeling (Lemoine et all, 1998). It is developed up to 360 degree and order.

Table 1. Used global gravitational models

Model	Max. degree	Data	References
EGM96	360	Satellite/ Terrestrial	Lemoine et all, 1998
EGM96s	70	Satellite	Lemoine et all, 1998
CHAMP03s	140	CHAMP	Reigber et all, 2004a
GRACE02s	150	GRACE	Reigber et all, 2004c
GGM01c	200	GRACE	UTEX, 2003
CG01c	360	CHAMP/ GRACE/ Terrestrial	Reigber et all, 2004b

EGM96s is EGM96 only satellite data model (Lemoine et all, 1998). It is developed up to the degree and order 70.

CHAMP03s is a CHAMP data global gravitational model (Reigber et all, 2004a). It is derived from GPS and accelerometer data. Data in period from October 2000 through June 2003 are used.

GRACE02s is GRACE data global gravitational model (Reigber et all, 2004c). It is derived from 110 days of GRACE satellite-to-satellite tracking data.

GGM01c is GRACE gravitational model made at the University of Texas, Center for Space Research. It is based on the GGM01s Earth's gravitational model. Combination of GGM01s and TEG4 models is used. TEG4 model uses surface gravity data, altimetric sea surface heights and 80 days of CHAMP attitude and accelerometer data (Tapley at all, 2001). GGM01c coefficients are fully normalized (UTEX, 2003).

One of the latest Earth's gravitational model CG01c is made using CHAMP, GRACE and terrestrial data (Reigber et all, 2004b). It is developed up to degree and order 360. In the model are used 860 days of CHAMP measurements, 109 days of GRACE measurements and 0.5° x 0.5° surface anomalies. Surface anomalies are obtained by gravimetry measurements and on the oceans from the satellite altimetry (Reigber et all, 2004).

2. Spectral behavior of global gravitational models in discreet points

To judge inside behavior of the Earth's gravitational models, their spectral development is made in discreet points (Hećimović and Bašić, 2004). Spectral development of undulations is calculated using formula

$$N = \frac{GM}{r\gamma}\left\{\sum_{l=2}^{\infty}\left(\frac{a}{r}\right)^{l}\sum_{m=0}^{l}\left(\Delta\bar{C}_{l,m}\cos m\lambda + \Delta\bar{S}_{l,m}\sin m\lambda\right)\bar{P}_{l,m}(\cos\theta)\right\} \quad (1)$$

Spectral developments in discreet EUVN points IT04 and KOSG are showing characteristic behavior of global gravitational models (s. fig. 1 and 2).

Lower harmonics characterize satellite data. Only satellite data models (EGM96s, CHAMP03s and GRACE02s) are showing after some degree irregular behavior (s. fig. 1 and 2). EGM96s is developed up to the 70 degree and order, but after about 50 degree and order it is behaving irregularly. CHAMP data model CHAMP03s is developed up to the 140 degree and order, but after about 110 degree and order it starts to behave irregularly.

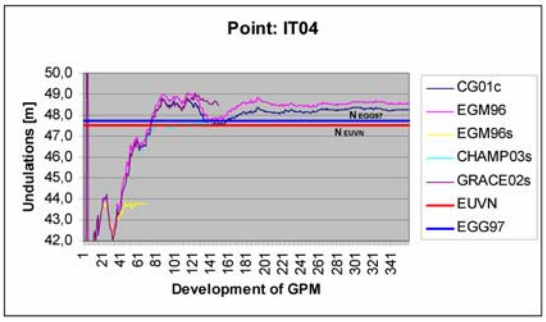

Fig. 1 Spectral development of Earth's gravitational models in EUVN point IT04

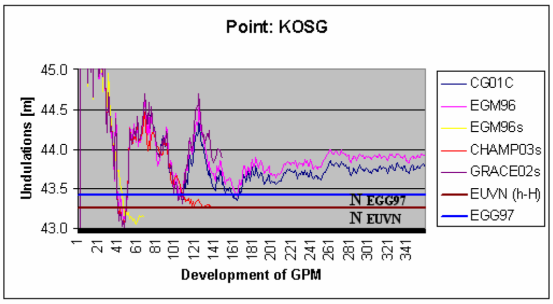

Fig. 2 Spectral development of Earth's gravitational models in EUVN point KOSG

Models EGM96 and CG01c are also using terrestrial data. They have similar behavior, but systematic difference is characteristic for their high spectrum part. Models are showing about decimeter fluctuations in higher part of spectrum. These fluctuations characterize inside accuracy of global model. More realistic judgments of their quality can be made making comparison between EUVN and EGG97 undulations, because it is including datum and other systematic errors.

3. Spectral behavior of global gravitational models on the area of Europe

To judge behavior of CG01c global gravitational model on the territory of Europe spectral behavior of undulations in 15'x15' raster is made (s. fig. from 3 to 7). To preserve smooth transition from low frequency band (satellite data) to high frequency band (surface data) special band-limited transition is made.

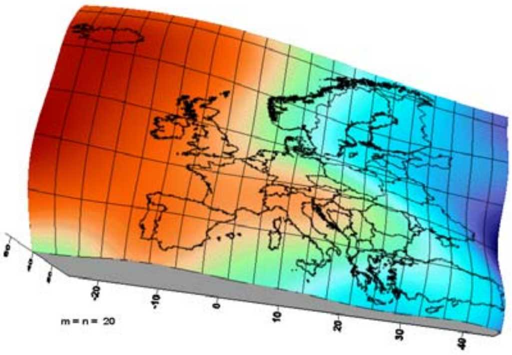

Fig. 3 CG01c for m = n = 20

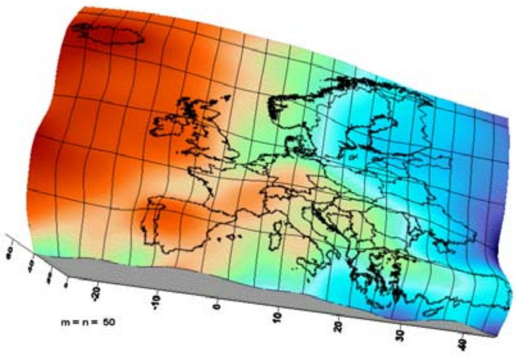

Fig. 4 CG01c for m = n = 50

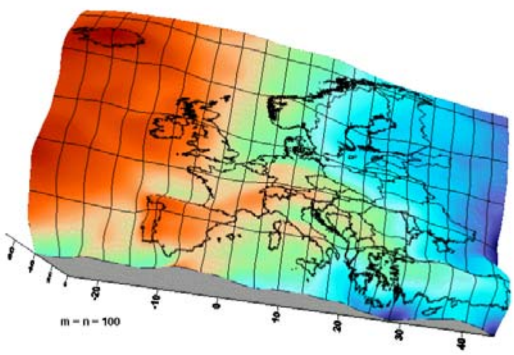

Fig. 5 CG01c for m = n = 100

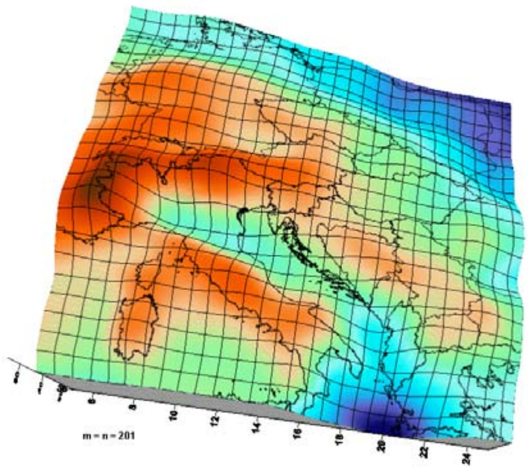

Fig. 6 CG01c for m = n = 201

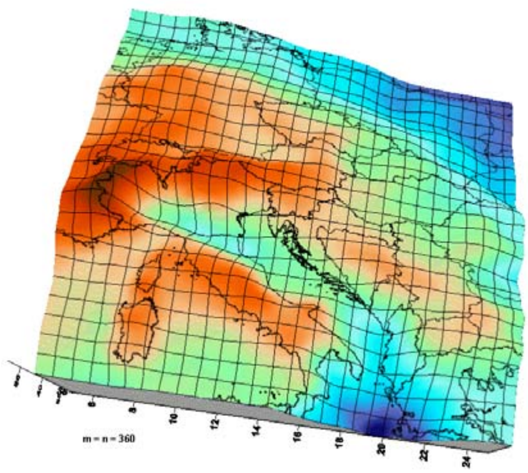

Fig. 7 CG01c for m = n = 360

On the Internet site http://www.geof.hr/~zhecimovic/EUVN/EUCG01c.html animation of CG01c spectral behavior could be found.

4. EUVN big errors considering global gravitational models

To judge quality of fitting global gravitational models to EUVN network, EUVN undulations are compared, and they are also used to check big errors in the EUVN network.

Big errors of EUVN are defined as EUVN and other gravitational model undulation differences bigger than 0,5 m (Ihde and Sacher, 2002a, Ihde and Sacher, 2002b, Ihde et all, 2002).

Using CG01c is 25 big EUVN errors found, with EGM96 31 big errors and with

GGM01c 47 big errors (s. table 2). Global gravitational model CG01c is indicating the smallest number of EUVN big errors.

Recent CHAMP/GRACE/terrestrial data global gravitational model CG01c is showing better characteristics than previous only CHAMP and GRACE models (Hećimović et all, 2004).

CG01c is the new generation CHAMP/GRACE/terrestrial data global gravitational model that can replace global gravitational models before CHAMP and GRACE era. Terrestrial data used for modeling CG01c were anomalies, but already with today available terrestrial data, it is possible to make finer model. New global gravitational models based on CHAMP/GRACE data with specific characteristics can be expected.

Table 2. Big EUVN errors considering EGM96, GGM01c and CG01c global models

STATION	EUVN-EGM96-Bias	EUVN-GGM01C-Bias	EUVN-CG01C-Bias
	[m]	[m]	[m]
KIR0	-0.44	-1.05	-0.26
MATE	0.09	1.02	0.48
NOTO	0.83	2.37	0.32
SFER	0.68	0.22	0.21
VIS0	0.09	0.74	0.08
ZIMM	0.57	-1.63	-0.49
AT03	0.94	-0.10	0.15
AT04	0.40	-1.12	-0.56
BG01	0.63	0.31	-0.01
BG03	0.74	-0.65	-0.63
BOGI	0.38	0.07	0.60
CH02	1.55	0.67	0.61
CH03	0.81	0.61	-0.22
CH04	1.89	0.49	0.95
CH06	1.19	-0.56	-0.36
CH07	1.44	-0.03	0.59
CY01	-0.20	0.24	1.65
DE01	0.18	0.70	0.33
ES01	1.49	1.79	1.29
ES02	0.46	0.59	0.32
ES03	0.18	0.70	-0.06
ES04	0.25	-0.13	-0.58
ES05	-0.23	-1.14	-0.03
ES06	-0.65	1.59	-0.41
ES08	0.27	0.36	0.62
FR01	-1.81	1.49	-0.20
FR02	-1.42	-1.20	-1.06
GB01	-0.91	0.00	-1.16
GB04	0.24	-1.11	0.17
GB07	-0.33	0.44	-0.70
GB08	-0.38	-0.53	-0.24
GR01	0.10	0.61	-0.05
GR02	-0.58	-0.77	-0.20
GR03	-1.09	-1.39	-0.51

STATION	EUVN-EGM96-Bias	EUVN-GGM01C-Bias	EUVN-CG01C-Bias
	[m]	[m]	[m]
GR03	-1.09	-1.39	-0.51
HR01	-0.70	0.03	-0.42
HR03	0.28	0.70	0.38
HR04	-0.63	-0.13	-0.51
HR05	-1.33	0.13	-0.80
HR07	-0.08	0.92	0.17
HR08	-0.53	0.69	0.03
IT01	-0.10	0.26	0.62
IT02	0.35	1.61	0.16
IT03	0.11	0.66	-0.12
IT05	0.66	1.17	0.24
IT07	-0.33	1.26	0.32
IT09	-0.57	-0.80	-0.52
IT11	-1.14	0.56	-0.93
MK01	0.34	-0.52	-0.83
NICO	-0.14	0.28	2.95
NO09	-0.41	-0.46	-0.59
NO12	0.18	0.51	0.01
PFAN	0.49	-0.92	-0.44
PT02	0.54	0.79	0.38
PT04	-0.22	-0.54	-0.02
RO03	0.70	0.47	0.36
RO04	-0.04	0.53	0.02
SE04	-0.34	0.52	-0.21
SI01	-0.19	-0.55	-0.44
SK03	-0.03	-0.85	0.34
TR01	-0.29	-2.60	-0.90
TR03	0.13	-1.08	-0.51
TR04	-1.42	-0.59	-0.46
TR05	0.97	-1.81	-0.11
TR06	0.64	-0.86	-0.15
UK02	-0.56	-0.01	-0.12
UK04	0.19	0.83	0.95
All:	31	47	25

In the moment the finest regional European geoid model is European gravimetry geoid 1997 (EGG97). EUVN big errors discovered with EGG97 could be found in Ihde et all (2002). It is significant that all big errors detected with EGG97 are on the coast area, except in the point SK03, (s. Fig. 8). It is surprising that some big errors are not detected with global models, but only with EGG97 that is also using local data. That is indicating that local data are making problems, but to make that conclusion further numerical investigations should be made.

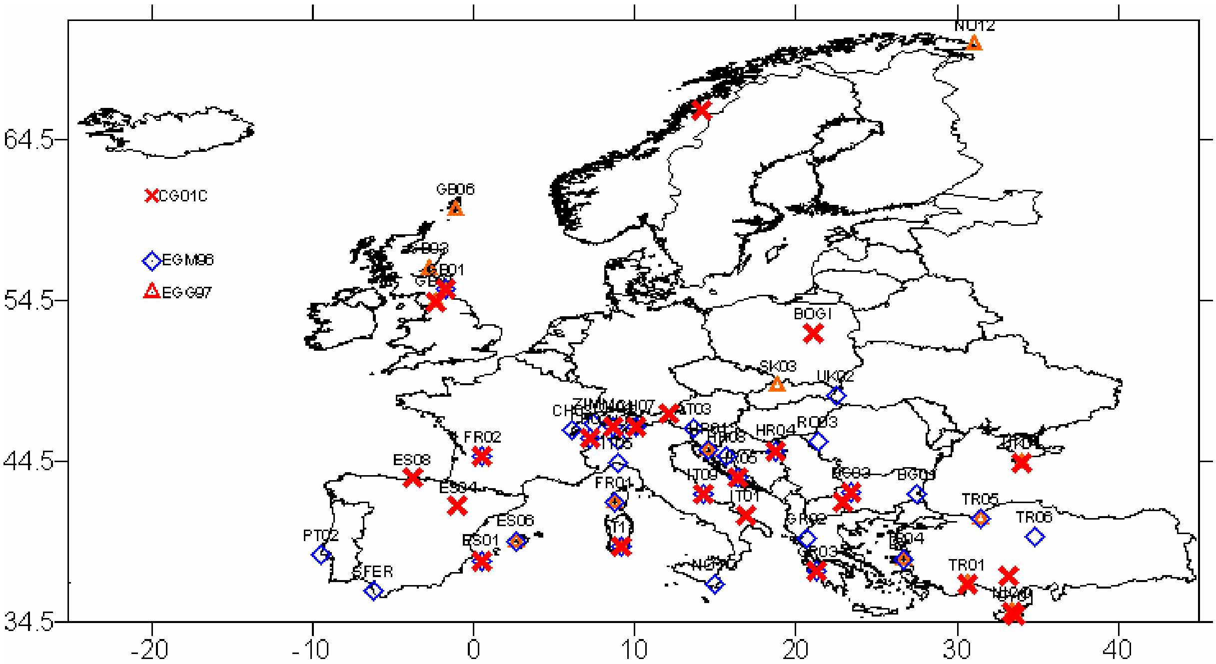

Fig. 8 EUVN points with big errors (>0,5 m) considering CG01c, EGM96 and EGG97 gravitational models

5. EUVN datum differences

Datum of EUVN undulations is defined trough fundamental bench mark in Amsterdam and referent ellipsoid of GPS heights.

The main statistical characteristics of EUVN and Earth's geopotential models undulation differences are shown in table 3. Points with big errors are neglected and 120 EUVN points is used in analysis. Average value of geoid undulation differences can be, in the first approximation, seen as datum differences.

Table 3. The main statistical characteristics of EUVN and geoid models undulation differences (120 points)

Model	Min.	Max.	Average	St. dev.
	[m]	[m]	[m]	[m]
EGG97	-0.69	0.40	-0.05	0.18
EGM96	-1.07	-0.10	-0.66	0.23
GGM01c	-1.34	-0.03	-0.69	0.23
CG01c	-1.10	-0.28	-0.69	0.18

A datum difference between EUVN and CG01c global model is showing similar behavior as by EGM96 and GGM01c global models. EGG97 has datum differences of only -5 cm because it is fitted on the European vertical network. New standards in connection of EUVN vertical datums are expected with GOCE Earth's gravity field satellite gradiometry mission.

Standard deviation of EUVN and CG01c undulation differences is the smallest, among global models (s. table 3). That is indicating that CHAMP/GRACE/terrestrial data Earth's gravitational model CG01c is the best fitting EUVN network. The same thing is confirmed by checking for big EUVN errors (s. table 2).

6. Conclusions

Spectral behavior of CG01c in high frequent part of the spectrum has fluctuations of about one decimeter and it can be seen as inside accuracy in discreet EUVN points. On these fluctuations other errors that have mostly systematical character should be added (datum errors, modeling errors, systematic data errors...).

In EUVN network is, using CG01c model, 25 big errors (>0,5 m) found, 31 big errors using EGM96 and 47 big errors using GGM01c. CHAMP/GRACE/terrestrial data global gravitational model CG01c is showing better characteristics than EGM96 global models in EUVN network. It is the new generation CHAMP/GRACE Earth's gravitational models that are replacing global models before CHAMP/GRACE era.

Vertical datum differences between EUVN and global gravitational models are about 69 cm with about decimeter oscillations.

On the Internet site http://www.geof.hr/~zhecimovic/EUVN/EUCG01c.html animation of CG01c spectral behavior, images and main explanations could be found.

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