European Vertical Reference Network (EUVN) considering CHAMP and GRACE gravity models

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Introduction

- CHAMP and GRACE static gravity fields models on the territory of Europe considering EUVN network,
- European Vertical Reference Network (EUVN) data from EUVN-UELN95/98 solution are used in analysis,
- EUVN comparison with 7 CHAMP, 3 GRACE and EGM96 gravity models (as well EGG97),
- EUVN and CHAMP, GRACE geoid undulations differences as the main analysis values,
- datum differences between global geoid models and EUVN,
- the best fitting CHAMP and GRACE global gravity models (among analyzed models) to EUVN,
- EUVN data checking and comparison with EGG97 checking,
- need for more dense field of EUVN points (EUVN_DA).

Table 1. The main CHAMP, GRACE and GOCE satellite missions data

Mission	Lunch	Mission life	Starting heights	Orbit inclination	The main instruments	Mission goals
CHAMP	15.7.2000.	5 years	454 km	87,2°	GPS, accelerometer, magnetometers	gravity, magnetic field, atmosphere
GRACE	17.3.2002.	5 years	485 km	89°	microwave ranging system, GPS, accelerometer	gravity
GOCE	2006.	2 years	250 km	96,5°	GPS, 3-axes gradiometer	gravity

- **CHAMP and GRACE are defining new standards in modeling gravity field of the Earth.**

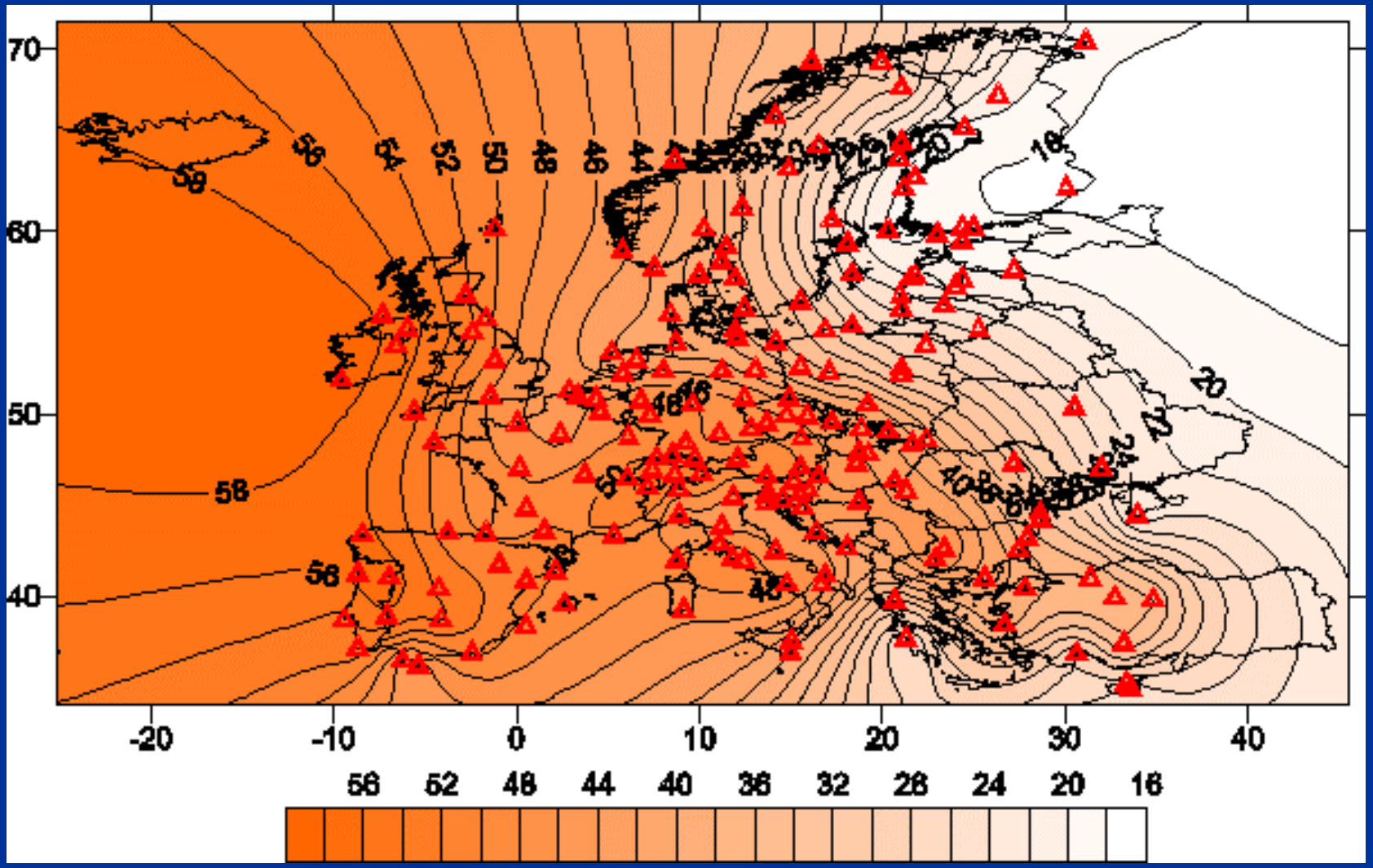
- **They are improving determination of heights datum and modeling of height reference surfaces.**

- GRACE is going to give opportunity to treat gravity field as dynamical field what is going to influence solutions of geodetic problems that also concern EUREF.
- Gravity field of the Earth is changing about 1% and is dominantly statically field. The main change is caused by water mass movements in hydrological cycles.
- Using altimetry measurements is determined that oceans are rising about 3 mm/year, and GRACE should help to give answer if the change is caused by more masses (glacier melting) or water volume expansion (warming of the water).
- GRACE is monthly sensing hydrological gravity signal in water basin. That is giving new opportunity to treat heights as time-variant, and to model "groundwater" gravimetry correction that is hard to model with terrestrial data.

Table 2. The main characteristics of used global gravity models

Model	Max. degree	Mission	References
EIGEN-2	140	CHAMP	Reigber et al, 2003b
EIGEN-3p	140	CHAMP	Reigber et al, 2003c
TUM-1S	60	CHAMP	Földvary et al, 2003a
TUM-2Sp	60	CHAMP	Földvary et al, 2003b
ITG-CHAMP01E	75	CHAMP	Ilk K.H. et al, 2003a, Mayer-Gürr, et al, 2004
ITG-CHAMP01S	70	CHAMP	Ilk K.H. et al, 2003a, Mayer-Gürr, et al, 2004
ITG-CHAMP01K	70	CHAMP	Ilk K.H. et al, 2003
EIGEN-GRACE01S	140	GRACE	GFZ, 2003
GGM01S	120	GRACE	Tapley et al, 2003
GGM01C	200	GRACE	UTEX, 2003
EGM96	360		Lemoine et al, 1998

CHAMP and GRACE gravity fields models on the territory of Europe

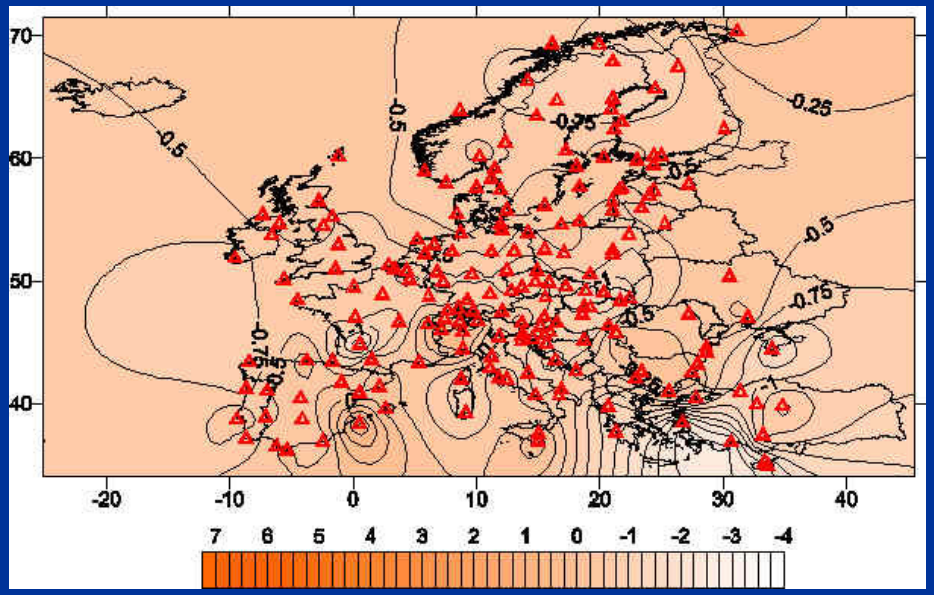


GRACE-GGM01C gravity model in EUVN points

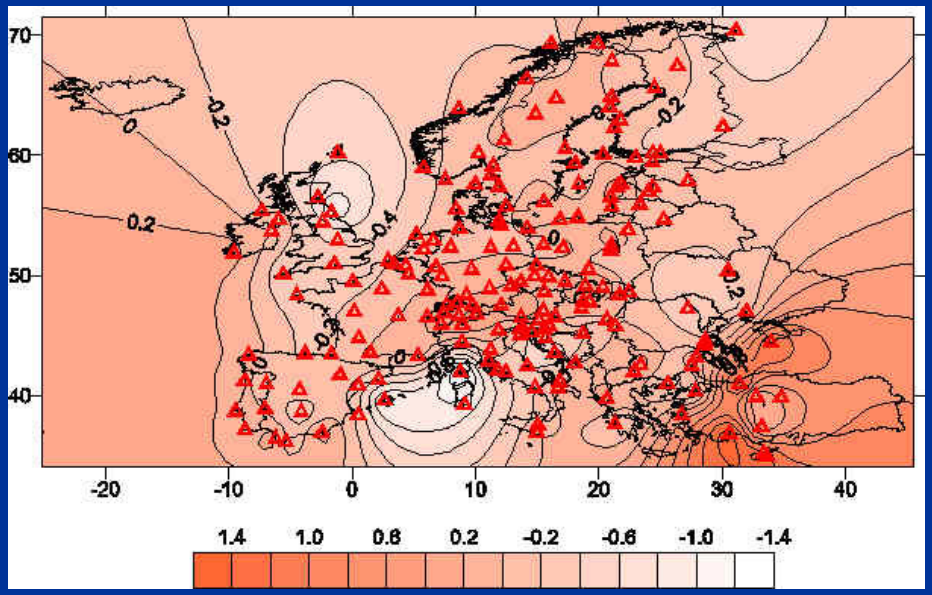
Table 3. The main statistical characteristics of gravity models in EUVN-points

Model	Nr. of points	Min.	Max.	Average	St. dev.
		[m]	[m]	[m]	[m]
EGM96	186	17.90	58.72	40.75	10.35
EIGEN-2	186	17.58	59.34	40.57	10.34
EIGEN-3p	186	17.00	58.86	40.59	10.46
TUM-1S	186	17.06	60.18	40.55	10.42
TUM-2Sp	186	17.75	59.83	40.52	10.38
ITG-CHAMP01E	186	17.56	59.24	40.58	10.44
ITG-CHAMP01S	186	17.49	59.04	40.59	10.46
ITG-CHAMP01K	186	17.50	59.51	40.56	10.42
EIGEN-GRACE01S	186	18.26	58.48	40.67	10.43
GGM01S	186	18.10	58.78	40.64	10.44
GGM01C	186	17.82	59.00	40.76	10.39

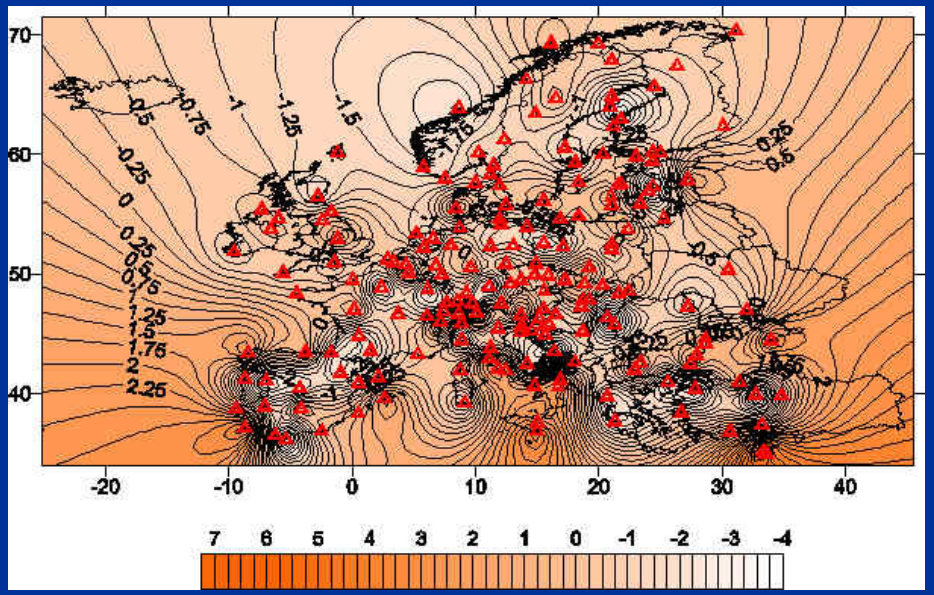
Differences between EUVN and CHAMP and GRACE gravity models



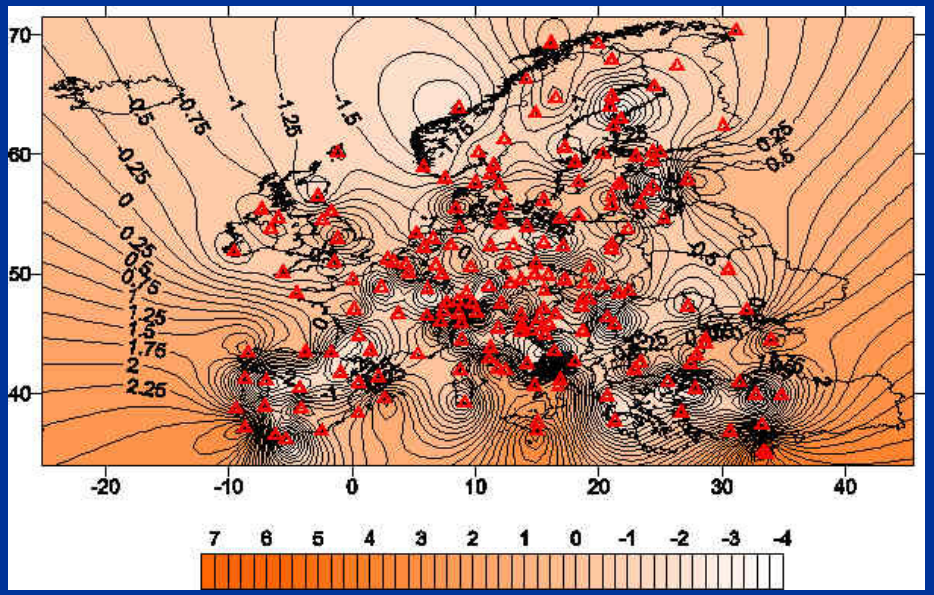
Diff. of EUVN and EGM96



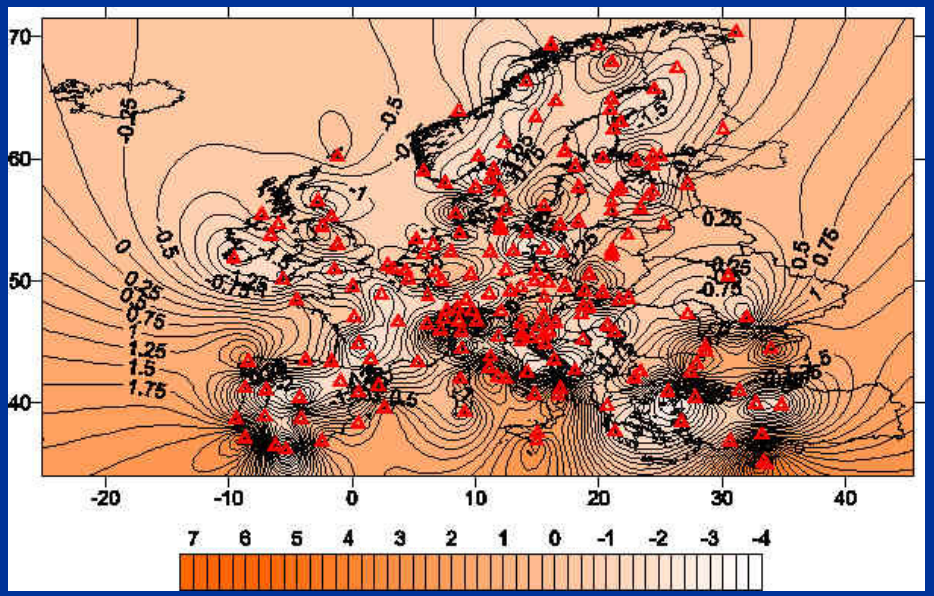
Diff. of EGG97 and EUVN



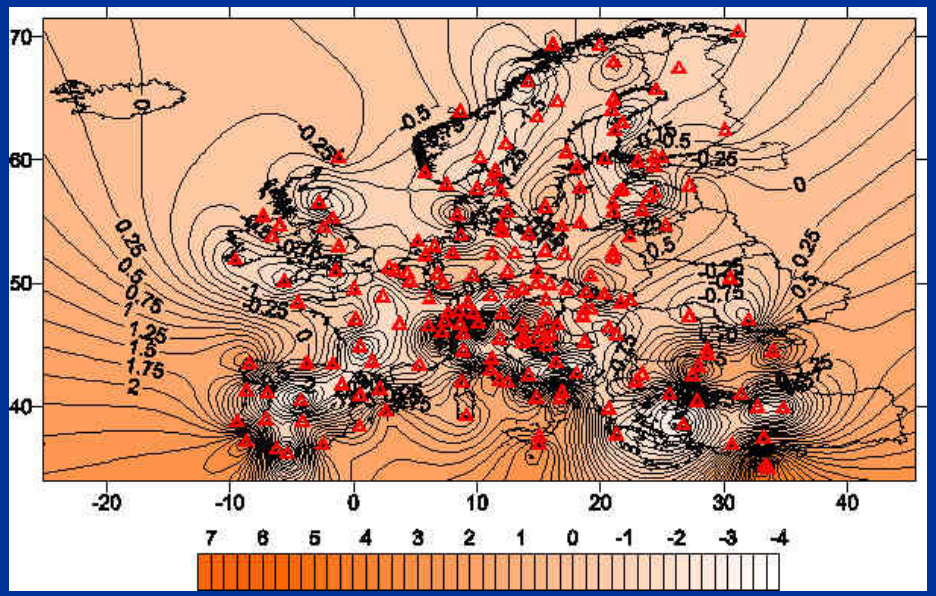
Diff. of EUVN and EIGEN-2



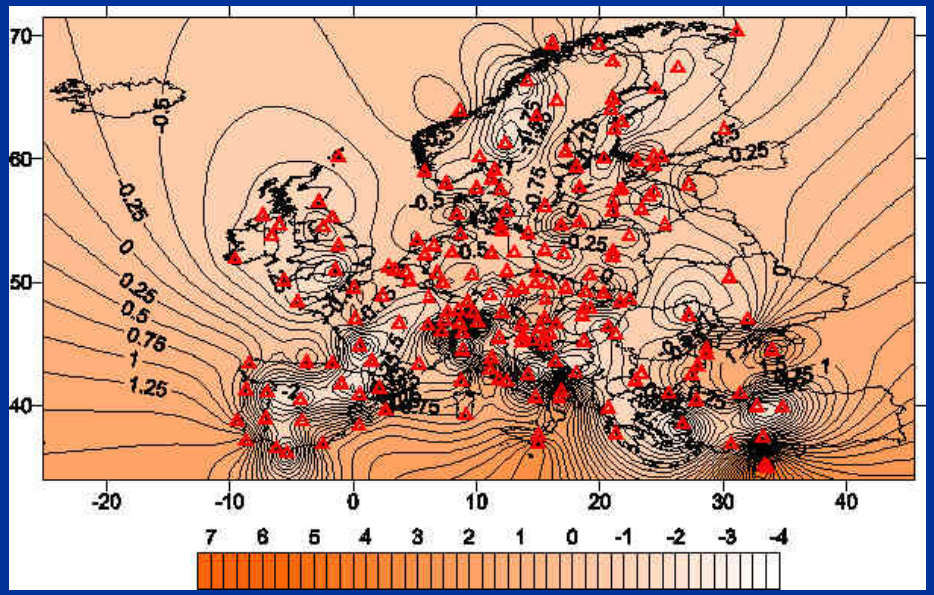
Diff. of EUVN and EIGEN-3p



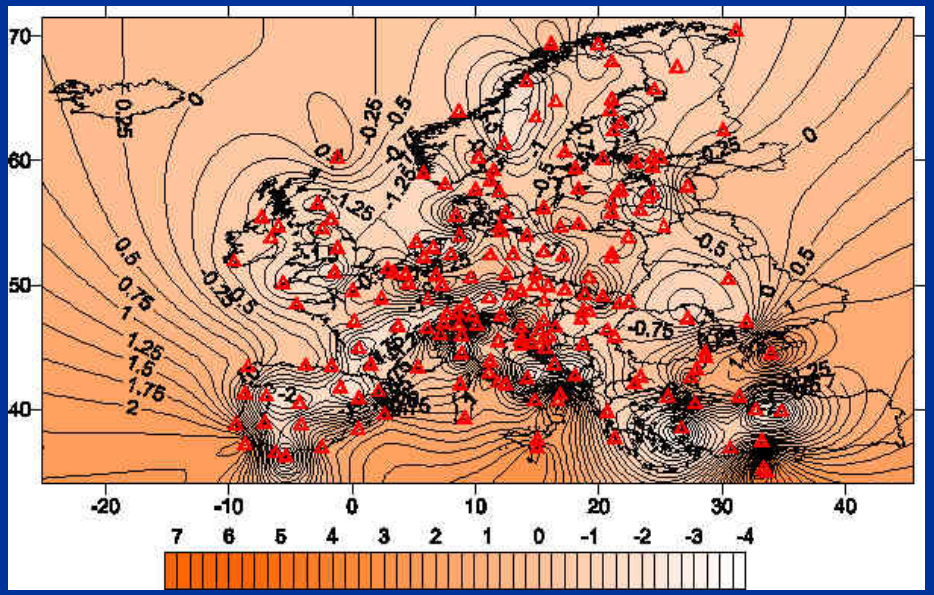
Diff. of EUVN and TUM-1S



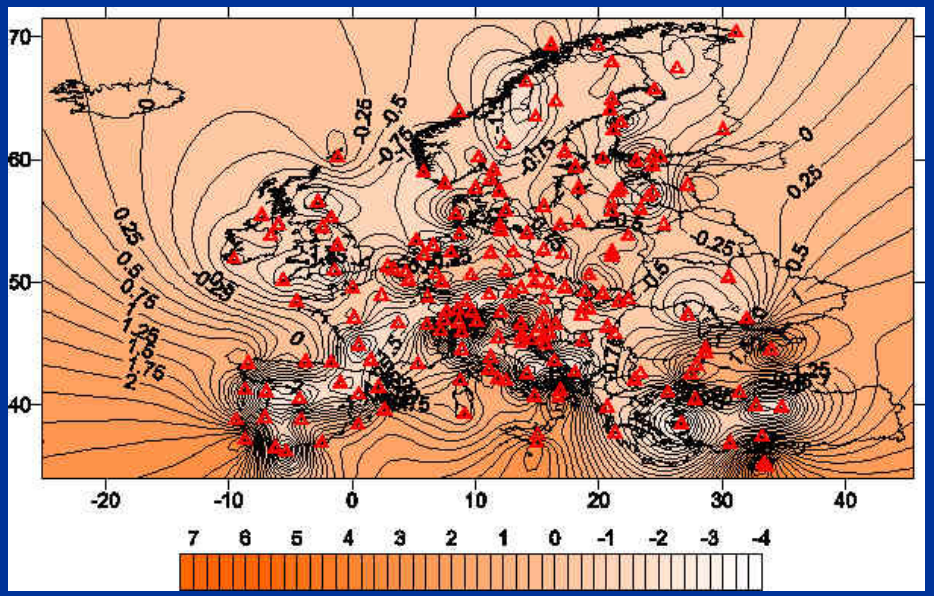
Diff. of EUVN and TUM-2Sp



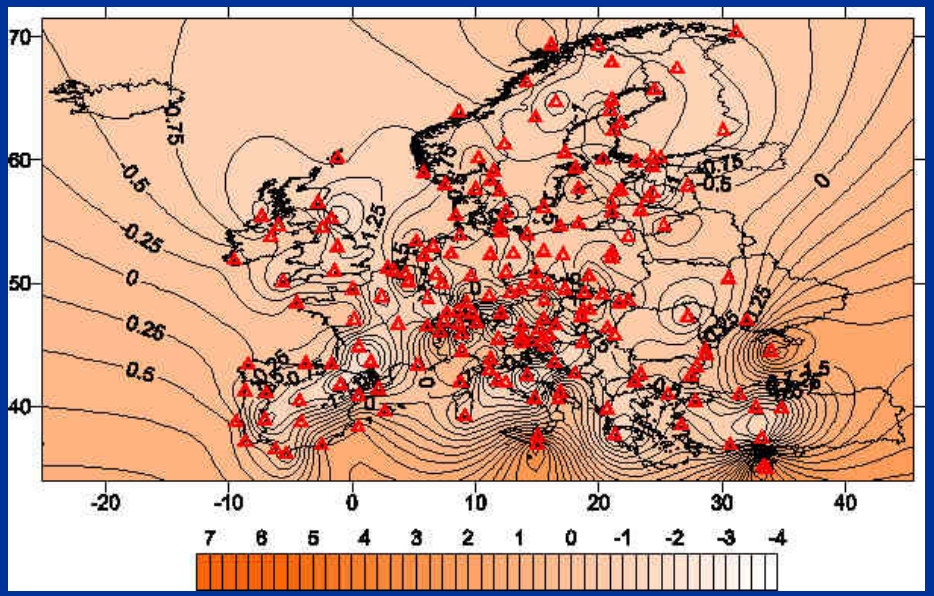
Diff. of EUVN and ITG-CHAMP01E



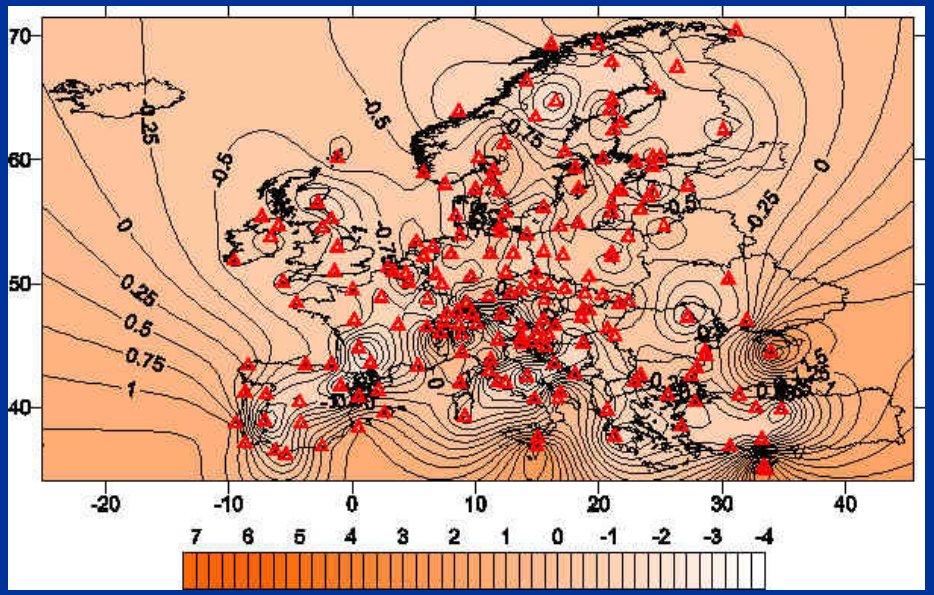
Diff. of EUVN and ITG-CHAMP01S



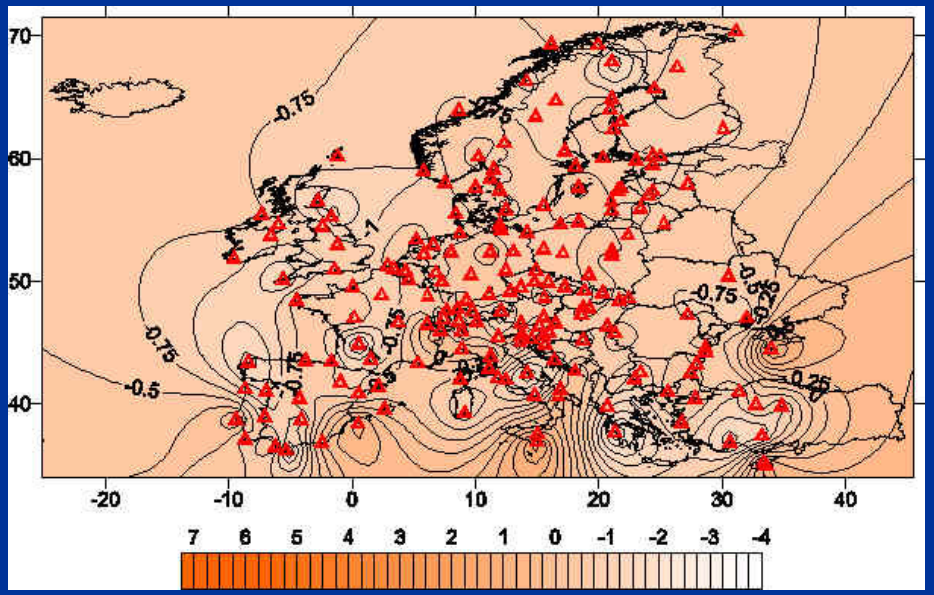
Diff. of EUVN and ITG-CHAMP01K



Diff. of EUVN and EIGEN-GRACE01S



Diff. of EUVN and GGM01S



Diff. of EUVN and GGM01C

- GRACE models are fitting better to EUVN network than CHAMP models (some preliminary models are also used).
- GRACE-GGM01C model has almost the same characteristic as EGM96 model that is developed up to degree 360.
- Extreme values should be treated before further analysis.

Table 4. The main statistical characteristics of EUVN and EGG97, EGM96, CHAMP and GRACE undulation differences

Model	Nr. of points	Min.	Max.	Average	St. dev.
		[m]	[m]	[m]	[m]
EGG97	186	-1.51	1.57	-0.02	0.36
EGM96	186	-2.54	1.14	-0.60	0.46
EIGEN-2	186	-3.87	6.63	-0.45	1.61
EIGEN-3p	186	-3.15	6.24	-0.47	1.34
TUM-1S	186	-3.85	6.82	-0.42	1.60
TUM-2Sp	186	-3.81	7.22	-0.39	1.60
ITG-CHAMP01E	186	-3.34	6.85	-0.45	1.38
ITG-CHAMP01S	186	-3.84	6.43	-0.47	1.42
ITG-CHAMP01K	186	-3.66	6.35	-0.43	1.47
EIGEN-GRACE01S	186	-3.84	6.43	-0.47	1.42
GGM01S	186	-2.76	4.22	-0.51	0.93
GGM01C	186	-2.28	1.74	-0.64	0.55

- EUVN datum is lower than datum of all gravity models

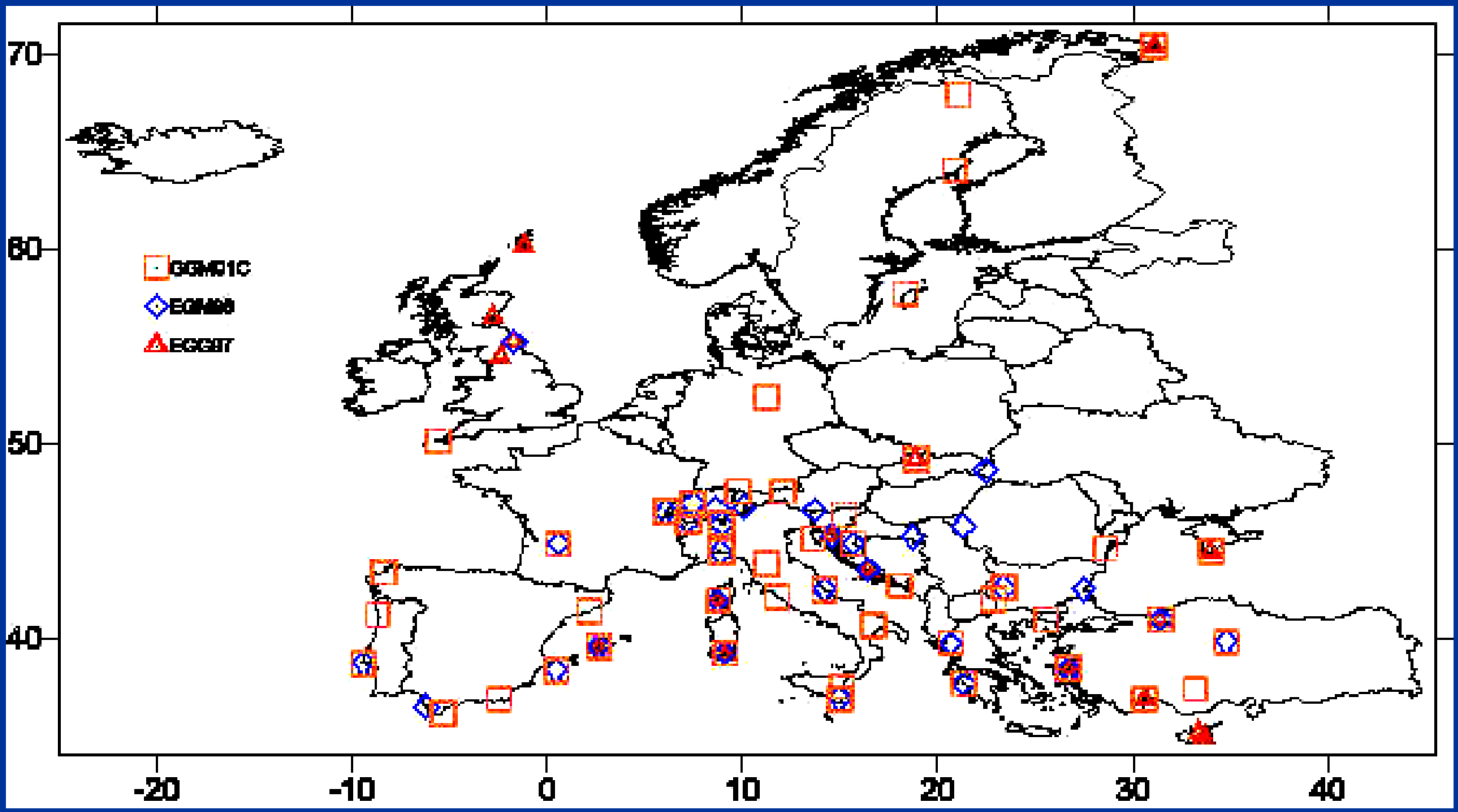
EUVN data checking and comparison with EGG97 checking

Table 6. EUVN and EGG97, EGM96 and GGM01C undulations differences bigger than 0,5 m

NR.	STATION	EUVN - EGG97	EUVN-EGM96-Bias	EGG97-GGM01C-Bias
		[m]	[m]	[m]
11	KIR0	-0.07	-0.44	**-1.05**
14	MATE	0.06	0.09	**1.02**
16	NOTO	0.00	**0.83**	**2.37**
21	SFER	0.33	**0.68**	0.22
26	VIS0	-0.18	0.09	**0.74**
28	ZIMM	0.28	**0.57**	**-1.63**
30	AT03	0.27	**0.94**	-0.10
31	AT04	0.34	0.40	**-1.12**
33	BG01	0.09	**0.63**	0.31
34	BG03	0.33	**0.74**	**-0.65**
38	CH02	0.38	**1.55**	**0.67**
39	CH03	0.18	**0.81**	**0.61**
40	CH04	0.37	**1.89**	0.49
42	CH06	0.40	**1.19**	**-0.56**
43	CH07	0.47	**1.44**	-0.03
44	CY01	**1.22**	-0.20	0.24
49	DE01	-0.02	0.18	**0.70**
66	ES01	-0.25	**1.49**	**1.79**
67	ES02	0.31	0.46	**0.59**
68	ES03	-0.41	0.18	**0.70**
70	ES05	0.15	-0.23	**-1.14**
71	ES06	**-1.09**	**-0.65**	**1.59**
79	FR01	**-1.51**	**-1.81**	**1.49**
80	FR02	-0.15	**-1.42**	**-1.20**
89	GB01	**-1.00**	**-0.91**	0.00
91	GB03	**-0.69**	-0.39	-0.01
92	GB04	-0.16	0.24	**-1.11**
94	GB06	**-0.56**	-0.26	0.40
95	GB07	**-0.55**	-0.33	0.44
96	GB08	-0.41	-0.38	**-0.53**
98	GR01	-0.30	0.10	**0.61**
99	GR02	0.27	**-0.58**	**-0.77**

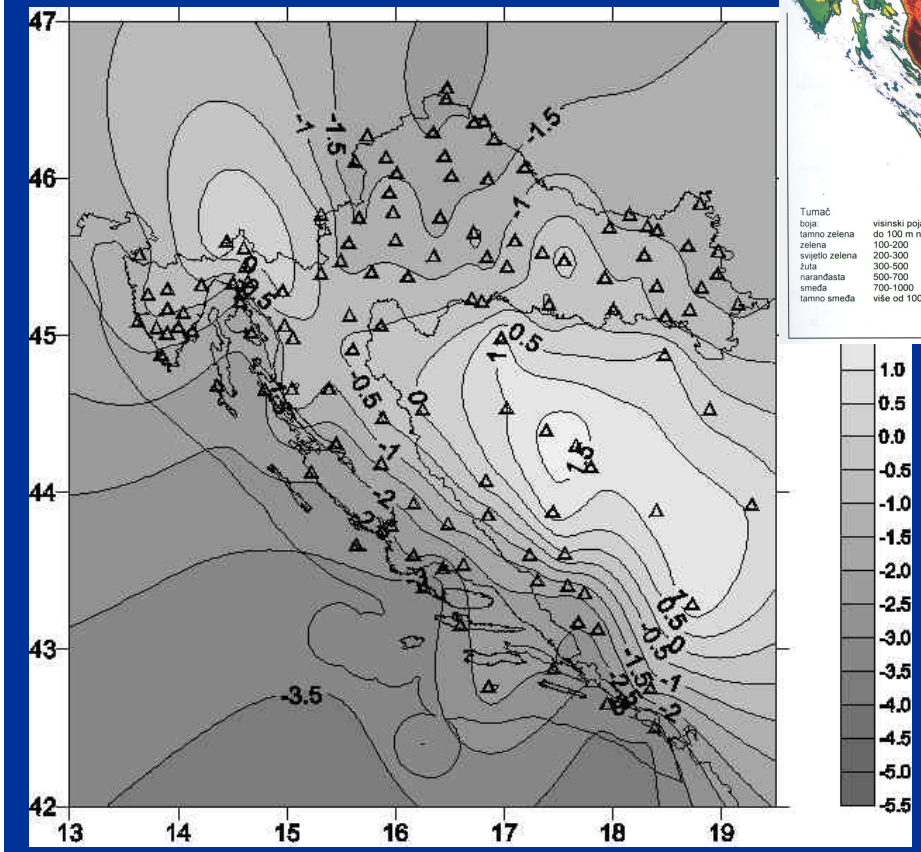
NR.	STATION	EUVN - EGG97	EUVN-EGM96-Bias	EGG97-GGM01C-Bias
		[m]	[m]	[m]
100	GR03	-0.25	**-1.09**	**-1.39**
101	HR01	**-0.51**	**-0.70**	0.03
103	HR03	0.00	0.28	**0.70**
104	HR04	-0.23	**-0.63**	-0.13
105	HR05	**-0.67**	**-1.33**	0.13
107	HR07	-0.15	-0.08	**0.92**
108	HR08	-0.28	**-0.53**	**0.69**
116	IT02	-0.15	0.35	**1.61**
117	IT03	-0.42	0.11	**0.66**
119	IT05	-0.20	**0.66**	**1.17**
121	IT07	-0.09	-0.33	**1.26**
123	IT09	-0.42	**-0.57**	**-0.80**
125	IT11	**-0.90**	**-1.14**	**0.56**
134	MK01	0.08	0.34	**-0.52**
135	NICO	**1.28**	-0.14	0.28
145	NO12	**-0.54**	0.18	**0.51**
146	PFAN	0.36	0.49	**-0.92**
154	PT02	0.17	**0.54**	**0.79**
156	PT04	0.05	-0.22	**-0.54**
160	RO03	0.00	**0.70**	0.47
161	RO04	-0.18	-0.04	**0.53**
164	SE04	0.01	-0.34	**0.52**
168	SI01	0.17	-0.19	**-0.55**
173	SK03	**0.61**	-0.03	**-0.85**
176	TR01	**1.57**	-0.29	**-2.60**
178	TR03	0.21	0.13	**-1.08**
179	TR04	**0.52**	**-1.42**	**-0.59**
180	TR05	**1.46**	**0.97**	**-1.81**
181	TR06	0.44	**0.64**	**-0.86**
183	UK02	-0.08	**-0.56**	-0.01
185	UK04	**1.25**	0.19	**0.83**
	SUM=	**17**	**31**	**47**

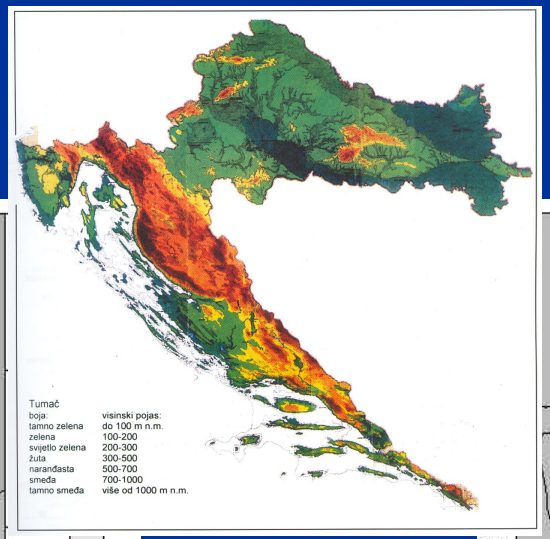
EUVN geoid undulations diff. bigger than 0,5 m

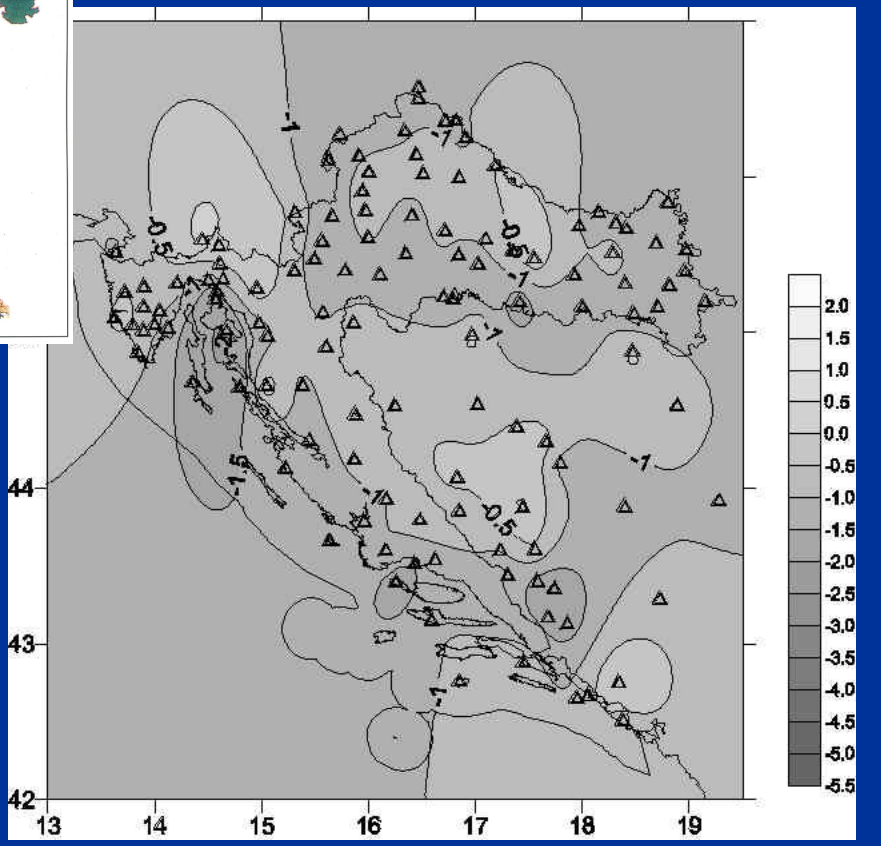


- Some points are detected only by EGG97.

Need for more dense field of EUVN points
(Case study - local Croatian territory)







Diff. GPS/leveling undulations and undulations of CHAMP EIGEN-3p model

Diff. GPS/leveling undulations and undulations of GRACE GGM01C model

- Differences of GPS/leveling with CHAMP model undulations are correlated with topography because CHAMP undulations do not contain detail topography signal, but GRACE undulations contain more topography gravity signal and differences are not so correlated with topography. This effect could not be recognized in EUVN points, first of all because differences between points is too large.

- GOCE gravity model will have accuracy of 1 cm/100 km, and the problem of modeling gravity field is going to be more and more problem of modeling high resolution (topography) wavelength. GPS/leveling undulations and other gravity data should be collected dense enough that topography can be recognized in the data and global models improved.

Conclusions

- EUVN datum is lower than datums of all global gravity models,
- GRACE-GGM01C model is fitting EUVN the best, among analyzed models,
- GRACE gravity models are fitting better EUVN gravity field than CHAMP gravity models, but combined model EIGEN-CG01C is announced (CHAMP + GRACE + topography data),
- Some EUVN points are detected only by EGG97 as outliers,
- Europe need more dense field of EUVN points (USA > 5000 GPS/leveling points),
- Need for realization of EUVN_DA project (Satellite gravity field data are going to be better than terrestrial?).

- GRACE is giving new opportunity to treat heights as time-variant considering gravity changes caused by hydrological cycles, and to model "groundwater" gravimetry correction that is hard to model with terrestrial data.

- GPS/leveling undulations and other gravity data should be collected dense enough that topography can be recognized in the data and that global models can be improved.

- CHAMP is German, GRACE is USA/German and GOCE is ESA satellite mission. Europe is going to take advantage in satellite gravity field sensing technology (quantum gradiometer is new generation of gravity field sensors that is under development - JPL/NASA). EUREF is defined in domain of GNNS satellite radio navigation, but it has interest in gravity field and there is interest to contribute to this European gravity field sensing trend.