Theoretical and numerical investigations towards a new geoid model for the Mediterranean Sea – The GEOMED2 project

The GEOMED 2 research group

The GEOMED 2 partnership

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The GEOMED 2 project (1/2)

- The project aims at estimating the geoid over the area

$$30 < \varphi < 48 \qquad -10 < \lambda < 40$$

with a resolution of 3’×3’

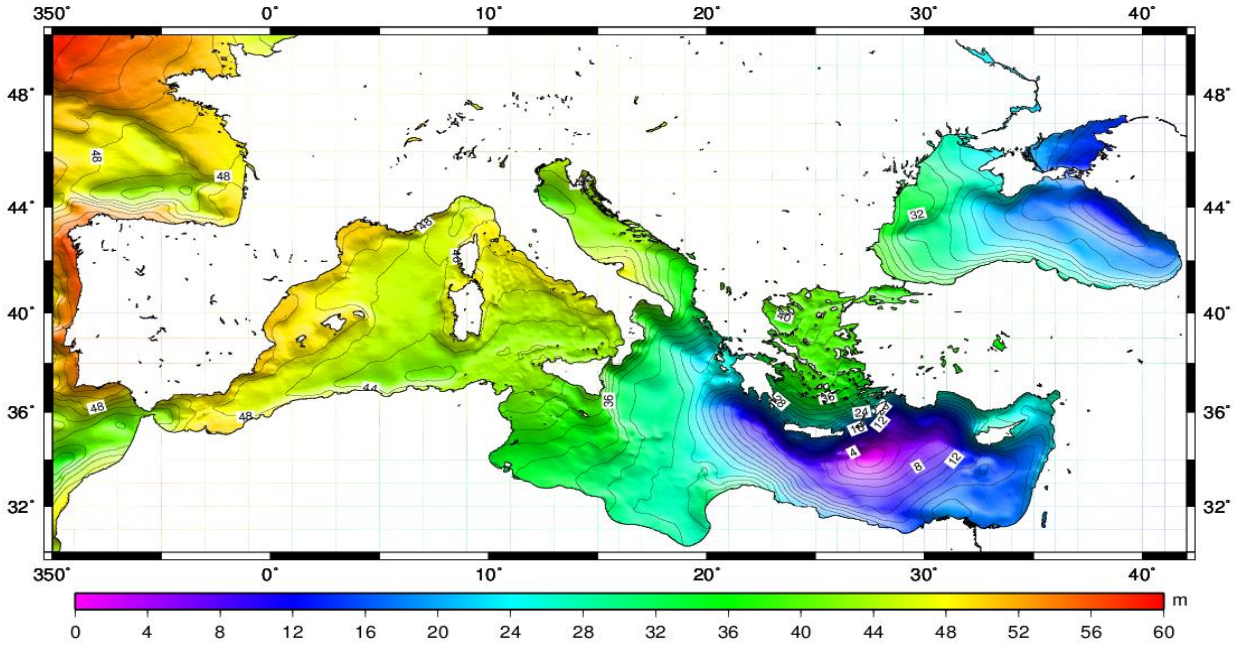
- ***Gravity data only will be used in the computation***

- Methods to be used in the geoid computation:

i) Collocation
ii) Stokes
iii) Stokes-FFT

The GEOMED 2 project (2/2)

- DOT will be then computed by difference with existing MSS altimetry derived estimates (e.g. the DTU2013)



The DTU2013 MSS over the Mediterranean Sea

- The circulation in the Mediterranean Sea will be also estimated

The DTM/DBM over the Mediterranean area

$(28 < \varphi < 50 \qquad -12 < \lambda < 42)$

- SRTM3 on land

- Different DBMs have been re-gridded and merged with SRTM3 aver the entire Mediterranean area

a) DTU10 (1'x1')
b) SRTM-PLUS15 (15"x15")
c) EMODNET (7.5"x7.5")

- Tests in the central Mediterranean area ($33 < \varphi < 50 \qquad 8 < \lambda < 24$) have been performed on gravity residuals based on **GOCE-DIR5** (d/o **230)**, **EIGEN6c4** (d/o **1000)** and RTC

- These tests proved that, in the selected area, the three DBMs are practically equivalent in reducing the data

- The EMODNET bathymetry was then selected being the most recent and detailed one

The Adriatic Sea test

- The selected area

$$36 < \varphi < 48 \qquad 10 < \lambda < 22$$

- Gravity data selected with a mean spacing of 2’×2’ from the following databases:

i) BGI
ii) SHOM
iii) Croatia
iv) Greece
v) Italy
vi) EGM2008 (void areas along the Eastern edge)

- Geoid estimate based on the Remove-Restore method

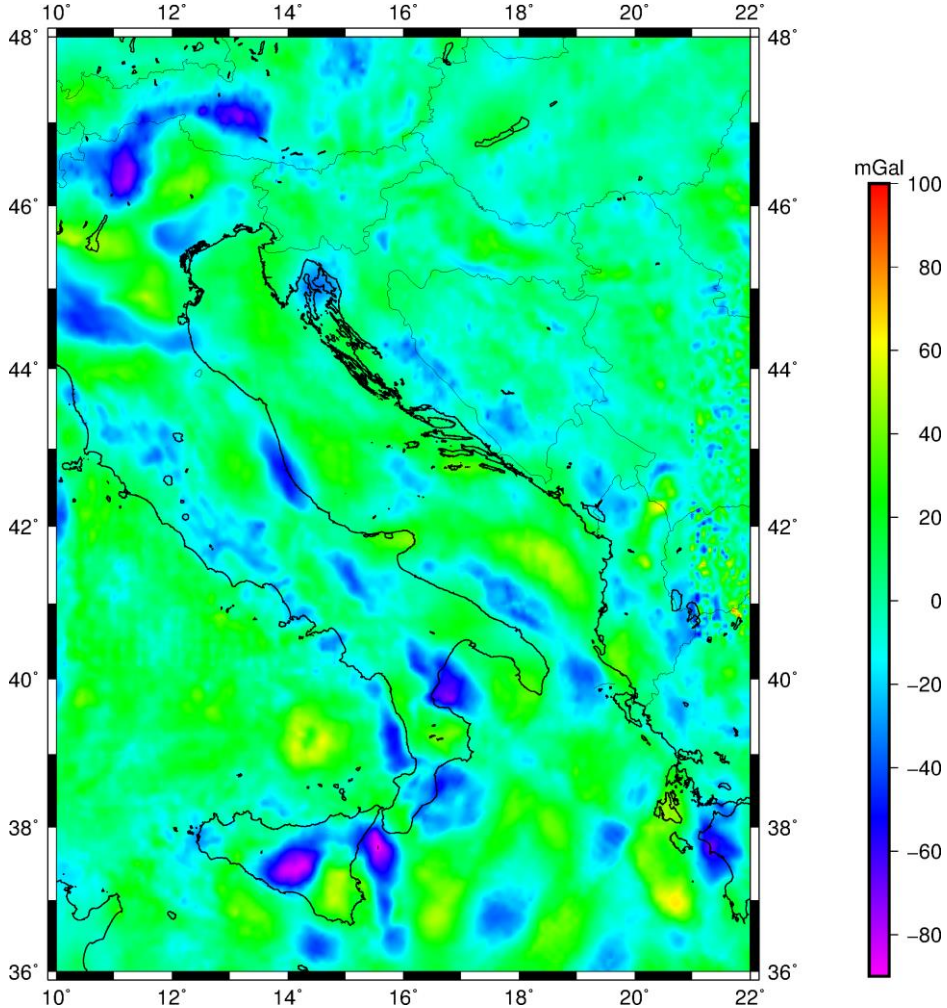
- **GOCE-DIR5** to d/o **230** and **EIGEN6c4** to d/o **1000** have been tested to model the long wavelength gravity/geoid information

- RTC effect was computed using the ***GRAVSOFT TC*** program (r=100 km from each computation point, data point heights equal to DTM). The reference DTM was estimated by low-pass filtering the detailed DTM (using a 22’ cap for GOCE-DIR5 and 8’ for EIGEN6c4)

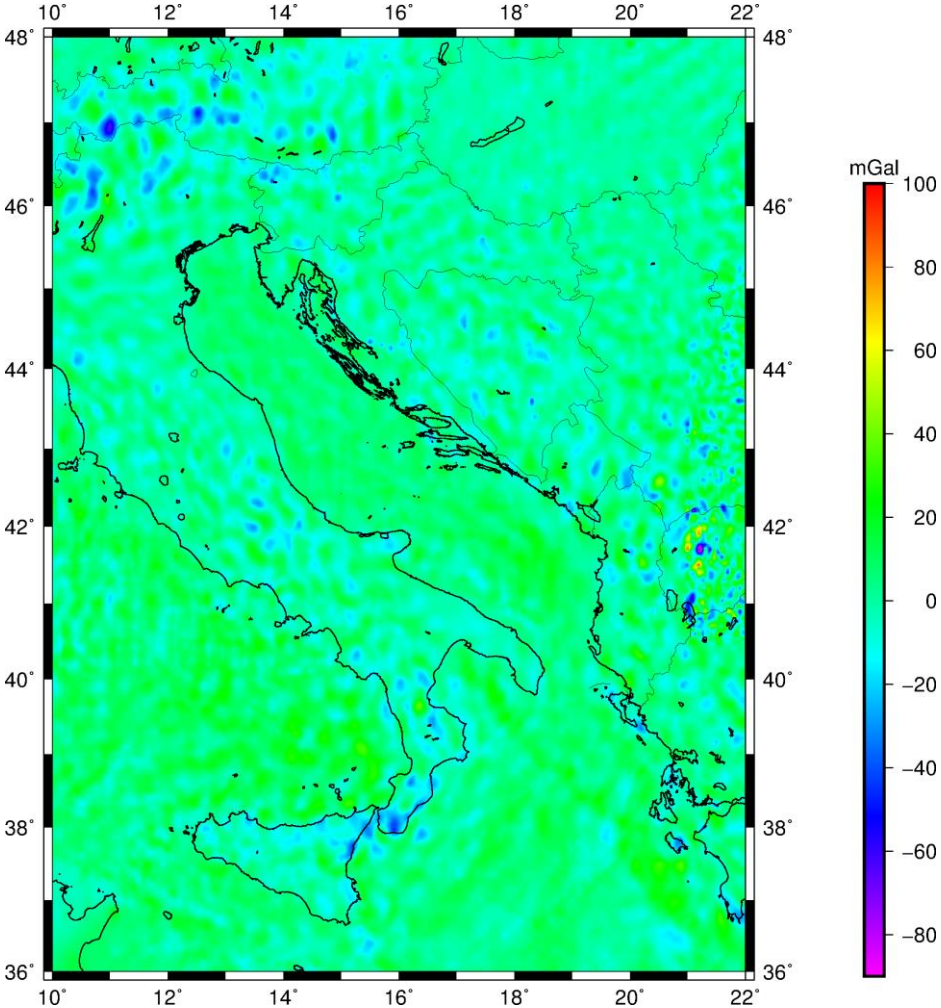
- Residual gravity values were gridded using the ***GRAVSOFT GEOGRID*** program on a regular 3’×3’ geographical grid in the area

$$36 < \varphi < 48 \qquad 10 < \lambda < 22$$

The residual gravity field (DIR-R5 @d/o 230 and EIGEN6c4 to d/o 1000)



DIR-R5 residual gravity field



EIGEN6c4 residual gravity field

The statistics of the remove step

(relative to **DIR-R5** @d/o230)

	Δg_{obs}
n	132137
E(mgal)	11.09
σ(mgal)	50.06
min(mgal)	-184.80
max(mgal)	269.71

	$\Delta g_R=\Delta g_{obs}-\Delta g_{MOD}$	$\Delta g_r=\Delta g_{obs}-\Delta g_{MOD}-\Delta g_{RTC}$	Δg_r(GRID)
N	132137	132137	58081
E(mgal)	-4.07	0.91	1.02
σ(mgal)	33.79	18.38	17.22
min(mgal)	-245.22	-103.70	-91.10
max(mgal)	216.94	106.61	106.61

The statistics of the remove step

(relative to **EIGEN6c4** @d/o1000)

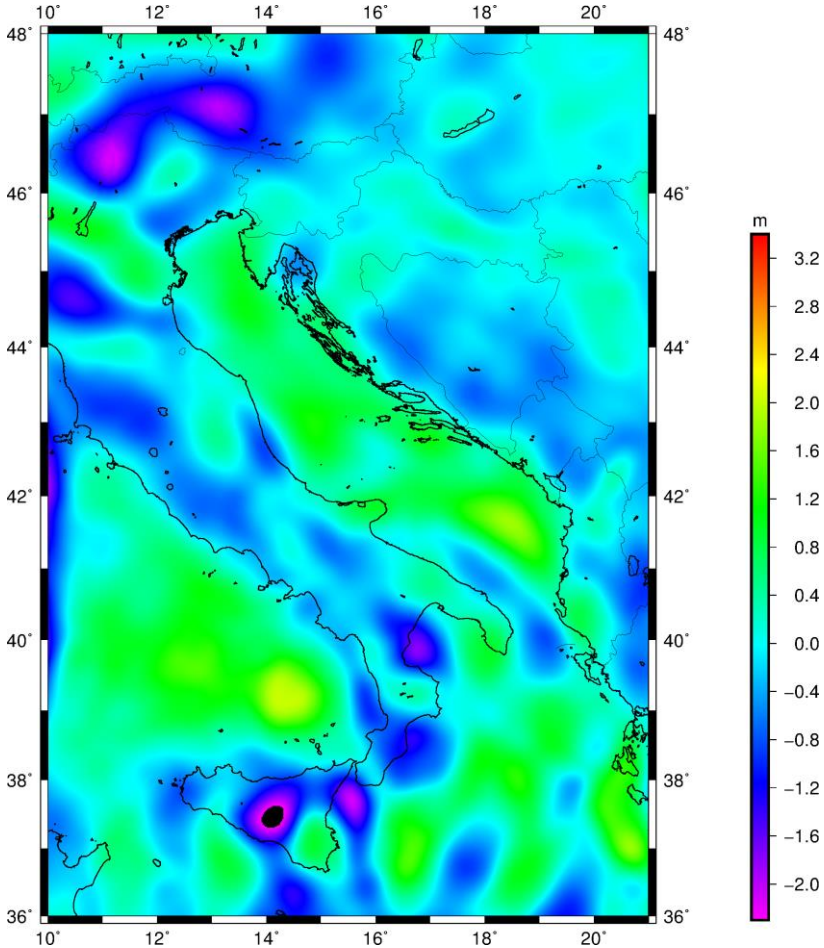
	Δg_{obs}
n	132137
E(mgal)	11.09
σ(mgal)	50.06
min(mgal)	-184.80
max(mgal)	269.71

	$\Delta g_R = \Delta g_{obs} - \Delta g_{MOD}$	$\Delta g_r = \Delta g_{obs} - \Delta g_{MOD} - \Delta g_{RTC}$	Δg_r(GRID)
N	132137	132137	58081
E(mgal)	-4.04	1.48	1.60
σ(mgal)	23.64	9.82	8.84
min(mgal)	-216.66	-96.61	-96.61
max(mgal)	137.51	93.97	93.97

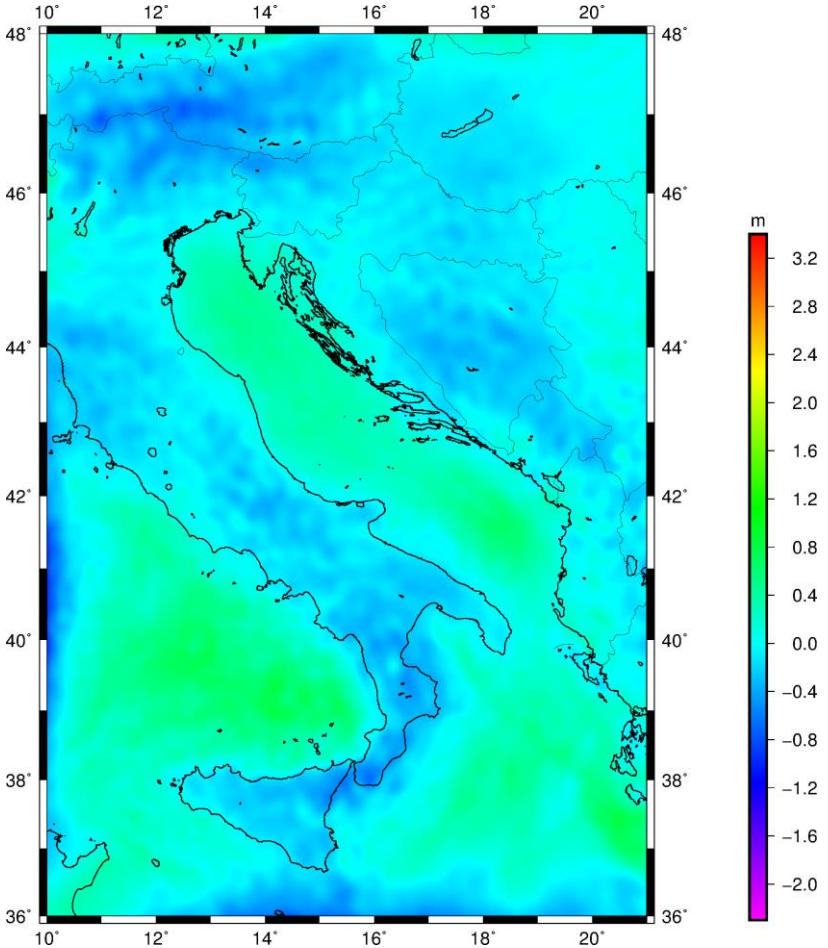
The applied geoid estimation methods

FastCollocation (Bottoni and Barzaghi, 1993)

N_r – DIR-R5



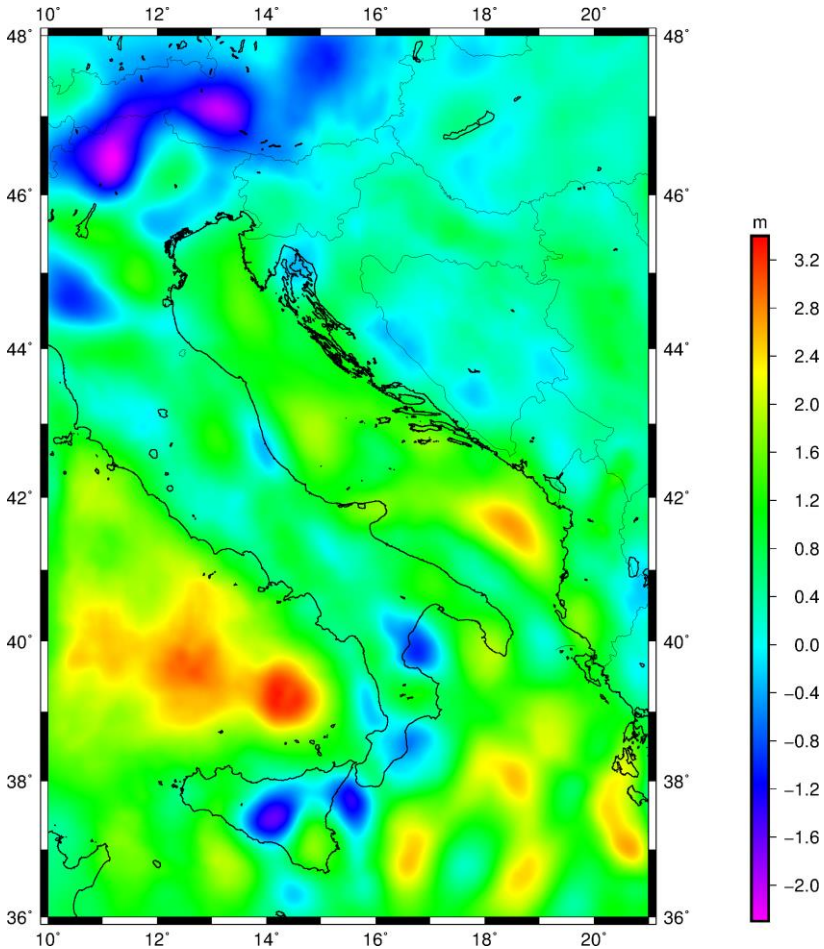
N_r – EIGEN6c4



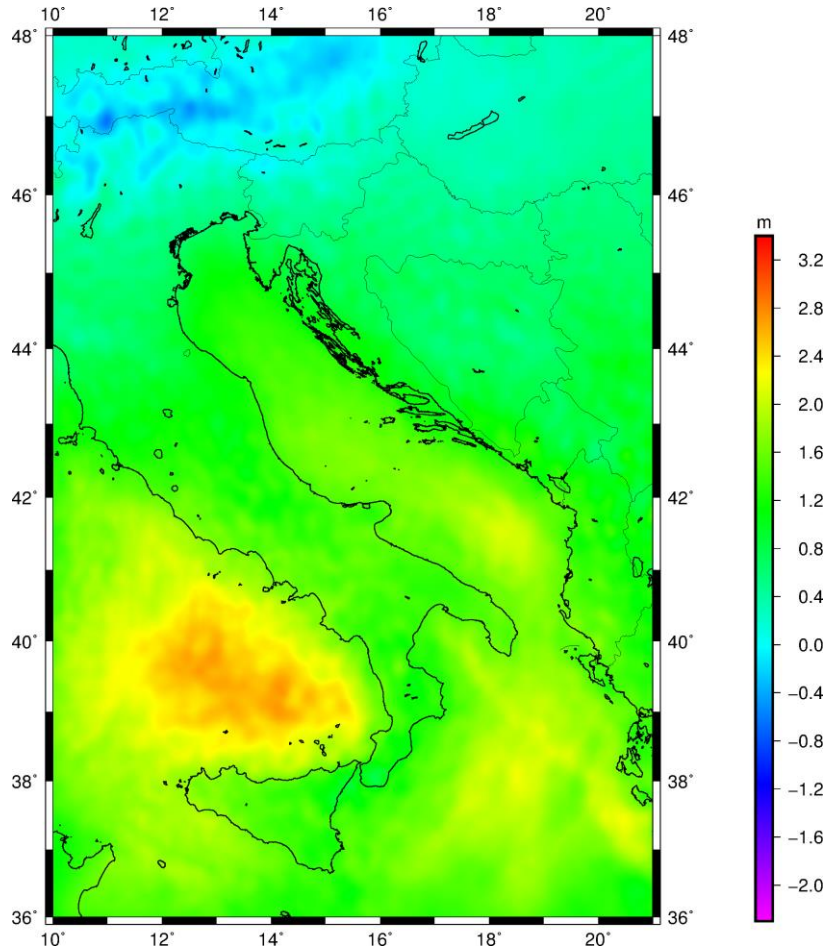
The applied geoid estimation methods

1D_FFT (Haagmans et al., 1993)

N_r – DIR-R5



N_r – EIGEN6c4

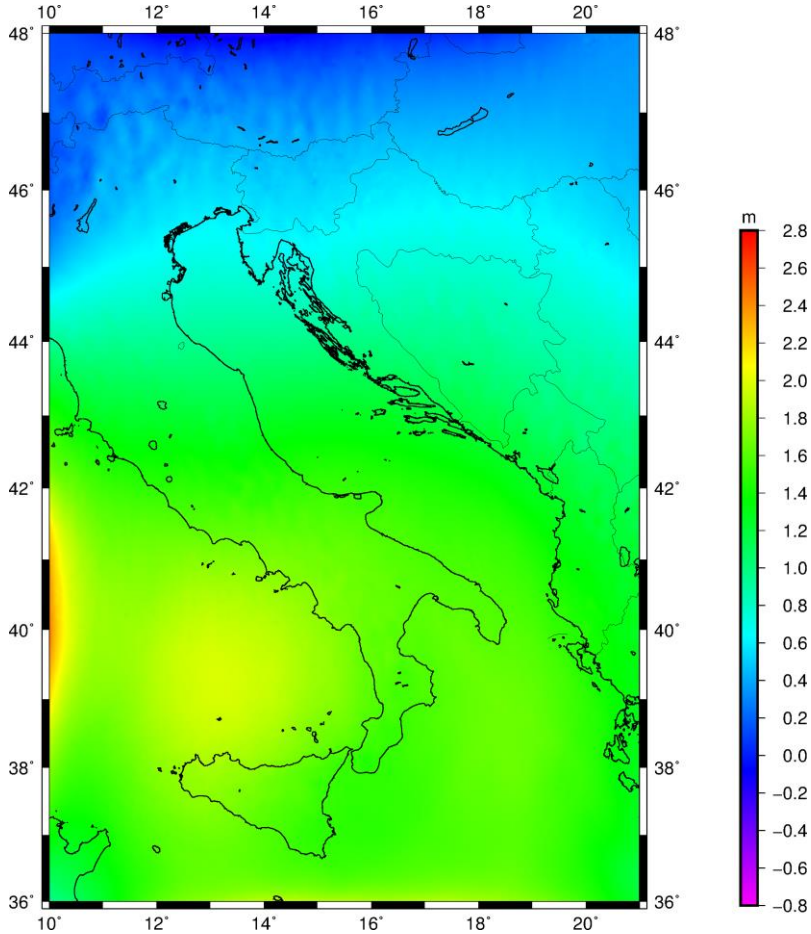


The applied geoid estimation methods: differences

i) FastCollocation (Bottoni and Barzaghi, 1993)
ii) 1D_FFT (Haagmans et al., 1993)

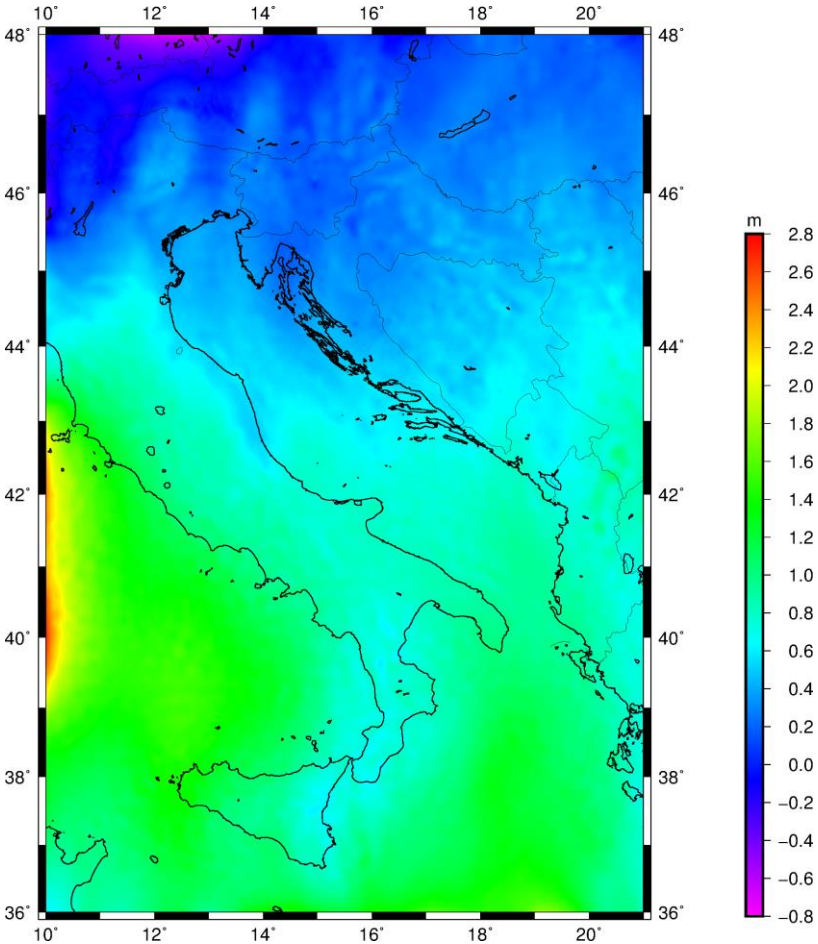
Relative to DIR-R5 (@d/o230)

N_r – diffs. between FastColl and 1DFFT



Relative to EIGEN6c4 (@d/o1000)

N_r – diffs. between FastColl and 1DFFT



The residual geoid statistics

	N_r (DIR-R5)	N_r (DIR-R5)	N_r (EIGEN6c4)	N_r (EIGEN6c4)
	1D FFT	FastCol	1D FFT	FastCol
n	58081	58081	58081	58081
E(m)	0.76	0.01	1.17	0.02
σ(m)	0.80	0.58	0.64	0.25
min(m)	-2.27	-2.61	-0.63	-0.97
max(m)	3.31	2.02	2.73	0.82

The statistics of the differences w.r.t. GPS/lev points

$$v = (N_{grav} - N_{GPS/lev}) - m$$

$$q = 90° - j\,; \quad N_{GPS/lev} = h - H$$

μ – mean removal only

Greece (mainland)

	v(DIR-R5) 1D FFT	v(DIR-R5) FastColl	v(EIGEN6c4) 1D FFT	v(EIGEN6c4) FastColl	v(EGM2008)
n	551	551	551	551	551
E(m)	0.00	0.00	0.00	0.00	0.000
σ(m)	0.16	0.23	0.13	0.14	0.12
min(m)	-0.37	-0.43	-0.34	-0.37	-0.43
max(m)	0.33	0.65	0.24	0.37	0.40

The statistics of the differences w.r.t. GPS/lev points

$$v = (N_{grav} - N_{GPS/lev}) - \Delta N(\theta,\lambda) = (N_{grav} - N_{GPS/lev}) - dx \sin\theta \cos\lambda + dy \sin\theta \sin\lambda + dz \cos\theta$$

$$\theta = 90° - \varphi \; ; \quad N_{GPS/lev} = h - H$$

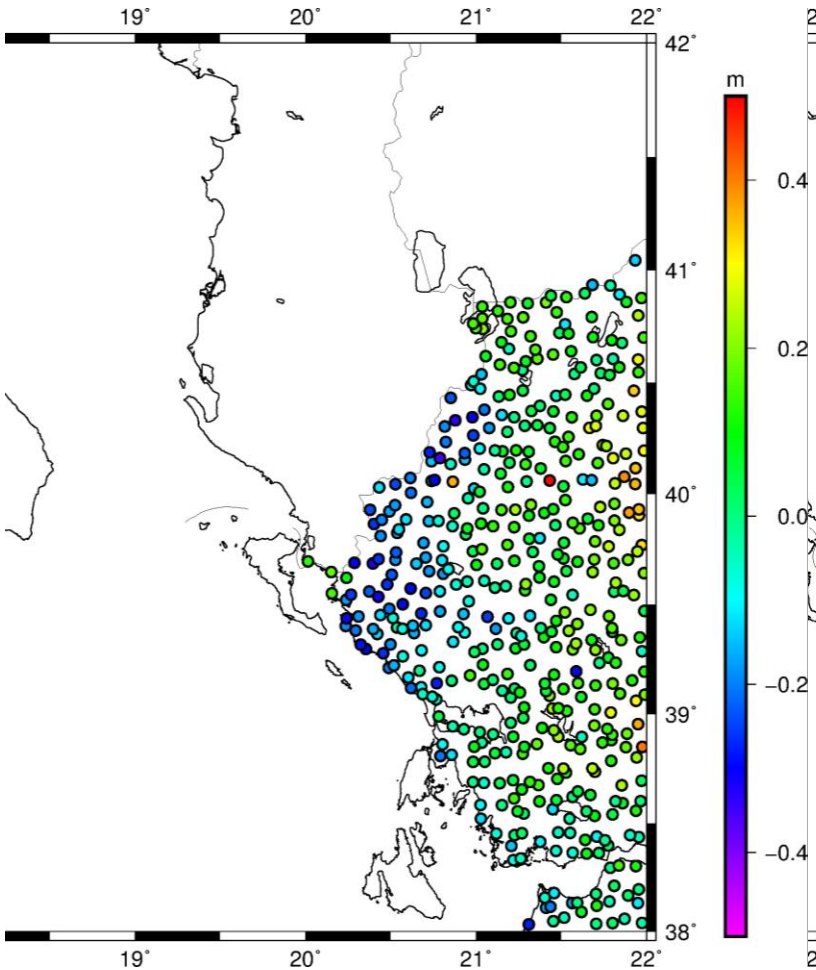
(dx,dy,dz) datum shift translation

Italy

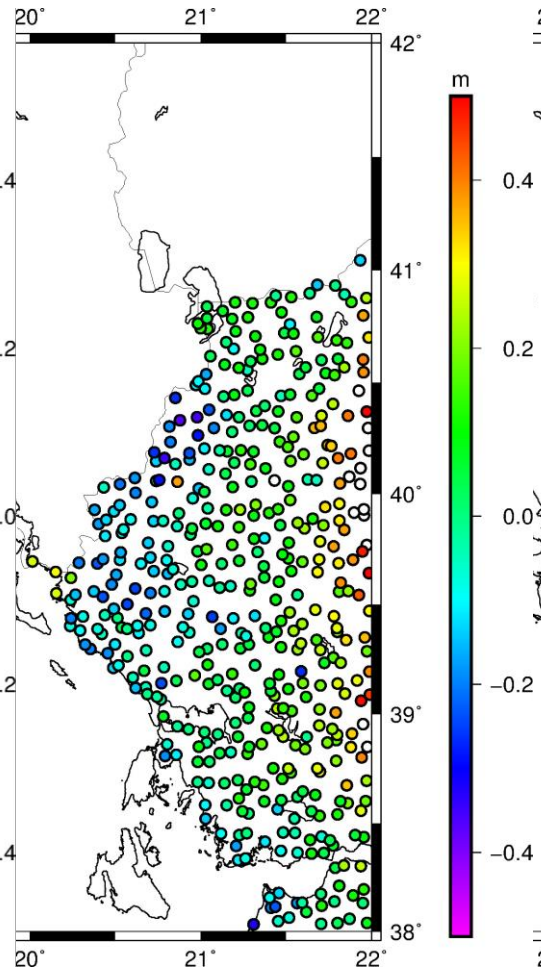
	v(DIR-R5) 1D FFT	v(DIR-R5) FastColl	v(EIGEN6c4) 1D FFT	v(EIGEN6c4) FastColl	v(EGM2008)
n	590	590	603	578	595
E(m)	0.00	0.00	0.00	0.00	0.00
σ(m)	0.11	0.14	0.11	0.08	0.08
min(m)	-0.29	-0.36	-0.27	-0.21	-0.23
max(m)	0.29	0.34	0.26	0.20	0.28

The statistics of the differences w.r.t. GPS/lev points over Greece

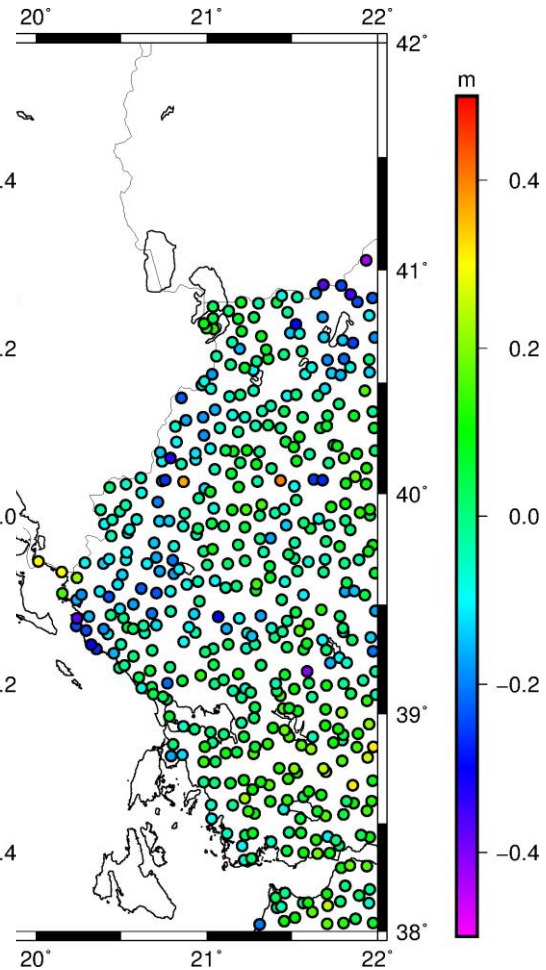
Relative to EIGEN6c4 (@d/o1000)
1D FFT



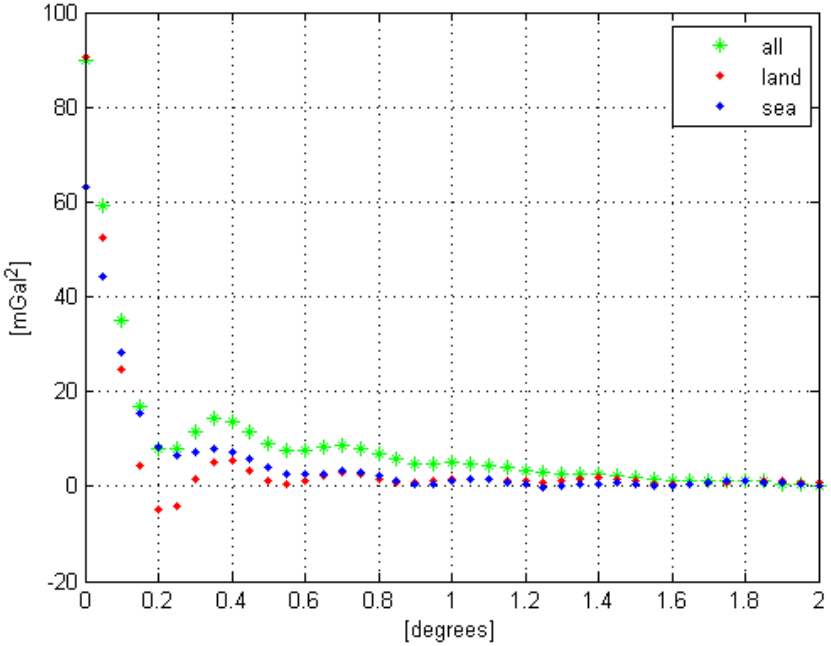
Relative to EIGEN6c4 (@d/o1000)
FastColl



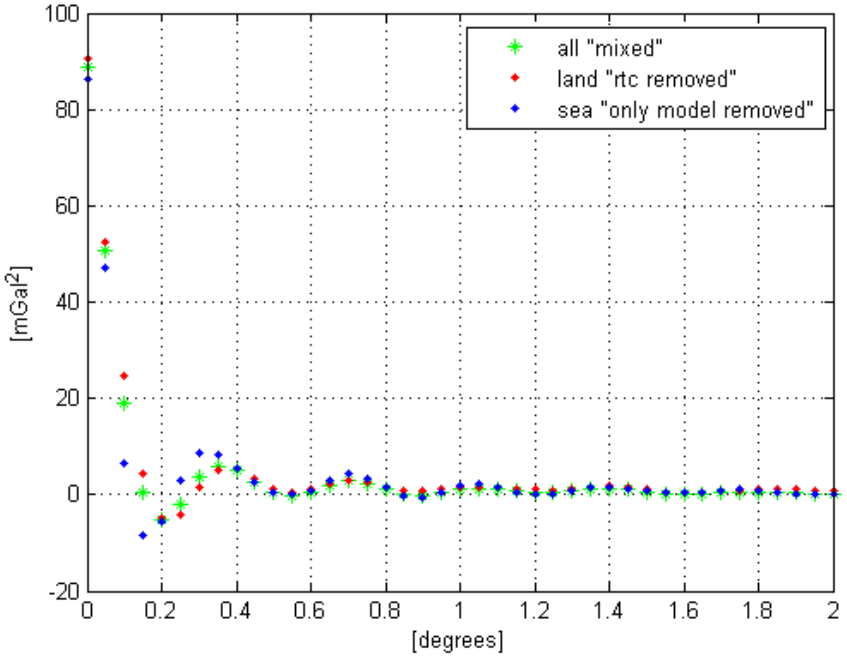
Relative to EGM2008



RTC problems at sea points (EIGEN6c4 residuals)



ECFs with RTC both on land&sea



ECFs with RTC on land points only

	Δg_{obs}	$\Delta g_R=\Delta g_{obs}-\Delta g_{MOD}$	$\Delta g_r=\Delta g_{obs}-\Delta g_{MOD}-\Delta g_{RTC}$
E(mgal)	-3.46	3.23	5.49
σ(mgal)	41.86	9.62	8.15
min(mgal)	-184.80	-88.86	-41.29
max(mgal)	132.04	84.82	62.91

Statistics on sea points (EIGEN6c4 model)

Comments and conclusions

- The Adriatic Sea Test proved that further checks on the gravity data are needed (consistency among different gravity databases)

- The processing chain seems to be satisfactory but some refinements must be implemented (possibly a denser gravity database should be selected based on a 1'x1' selection grid)

- The GOCE-DIR5&EIGEN6c4 GGMs allows an effective data reduction; other solutions will be also tested in the future (e.g. time-wise and space-wise solutions)

- Differences in the geoid computation methods are quite large and, to some extent, unexpected (ad hoc analysis will be devised to come to more coherent solutions)

- RTC at sea points is not fully effective and gives residuals with poor statistical indexes; possible problems in the data and/or in the selected bathymetry

GGHS

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International Symposium on
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Thessaloniki, Greece

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