Gravimetric geoid model development in the Mediterranean Sea within 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 2'×2'

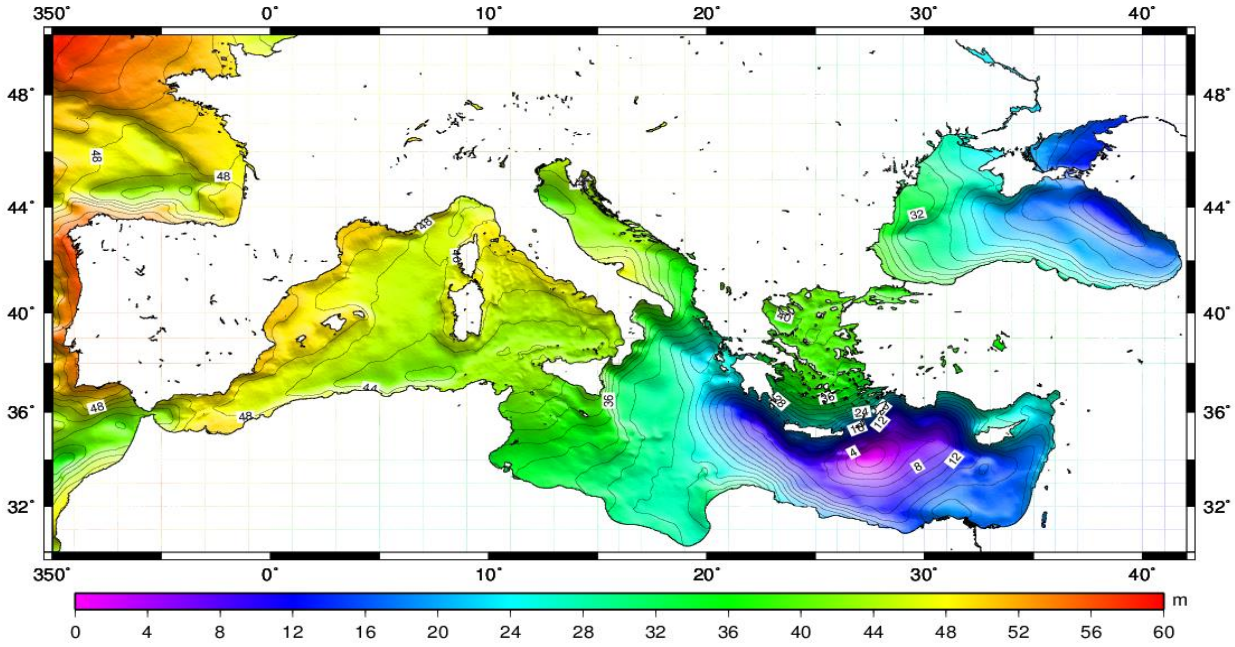
- ***Gravity data only will be used in the computation***

- 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° < φ < 50° -12° < λ < 42°)

- SRTM3 on land

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

a) DTU10 (1'x1')
b) SRTM15_PLUS (15"x15")
c) EMODNET (7.5"x7.5")

- Tests in the central Mediterranean area (33° < φ < 50° 8° < λ < 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***

Geoid estimation in the Western-Central Mediterranean area

- The computation area

$$30° < \varphi < 48° \qquad -10° < \lambda < 25°$$

- Gravity data selected with a mean spacing of 1'×1' from the following databases:

i) BGI
ii) SHOM
iii) Croatia
iv) Greece
v) Italy

- Geoid estimate based on the Remove-Restore method

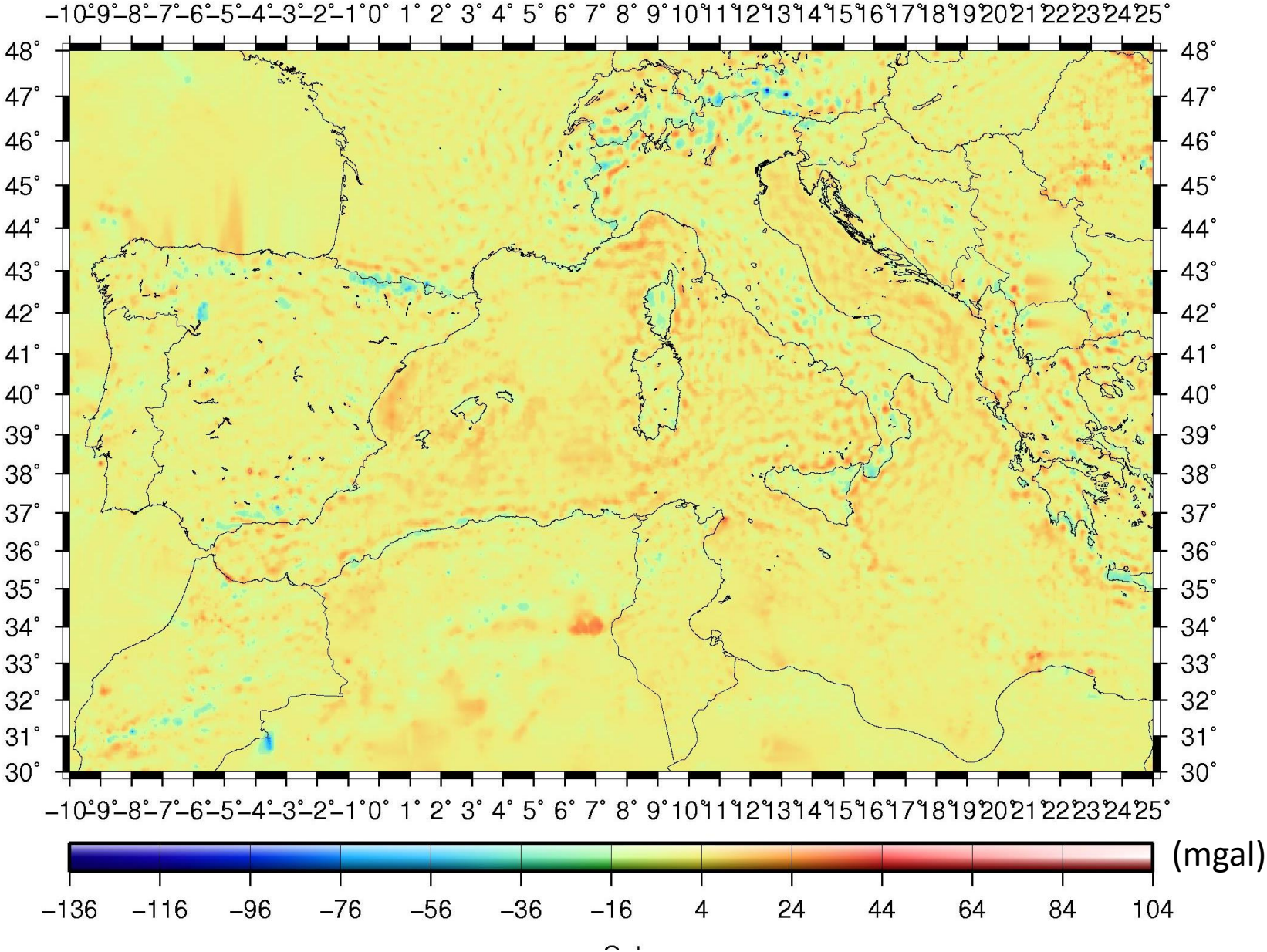
- **EIGEN6c4** to d/o **1000** has been used to model the long wavelength gravity/geoid information

- 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 (8’ for EIGEN6c4)

- Residual gravity values were gridded using the ***GRAVSOFT GEOGRID*** program on a regular 2’×2’ geographical grid in the area

$$30° < \varphi < 48° \qquad -10° < \lambda < 25°$$

The residual gravity field (w.r.t. EIGEN6c4 to d/o 1000)



The statistics of the remove step

(with respect to **EIGEN6c4** @d/o 1000)

Croatian data	Δg_{obs}	$\Delta g_R=\Delta g_{obs}-\Delta g_{MOD}$	$\Delta g_r=\Delta g_{obs}-\Delta g_{MOD}-\Delta g_{RTC}$
N	16397	16397	16397
E(mgal)	18.608	-6.220	-0.447
σ(mgal)	31.644	22.610	9.317
min(mgal)	-130.710	-153.620	-198.351
max(mgal)	203.950	137.507	70.844

Greek data	Δg_{obs}	$\Delta g_R=\Delta g_{obs}-\Delta g_{MOD}$	$\Delta g_r=\Delta g_{obs}-\Delta g_{MOD}-\Delta g_{RTC}$
N	2740	2740	2740
E(mgal)	-23.232	-8.15139	1.38864
σ(mgal)	53.281	27.674	11.999
min(mgal)	-136.350	-101.704	-46.054
max(mgal)	175.680	108.590	55.213

The statistics of the remove step

(with respect to **EIGEN6c4** @d/o 1000)

Italian data	Δg_{obs}	$\Delta g_R=\Delta g_{obs}-\Delta g_{MOD}$	$\Delta g_r=\Delta g_{obs}-\Delta g_{MOD}-\Delta g_{RTC}$
N	90409	90409	90409
E(mgal)	15.781	-6.502	-1.400
σ(mgal)	68.871	24.990	8.567
min(mgal)	-162.360	-224.772	-87.391
max(mgal)	269.710	135.603	59.712

Marine data	Δg_{obs}	$\Delta g_R=\Delta g_{obs}-\Delta g_{MOD}$	$\Delta g_r=\Delta g_{obs}-\Delta g_{MOD}-\Delta g_{RTC}$
N	72463	72463	72463
E(mgal)	-6.628	2.111	2.909
σ(mgal)	41.788	9.162	7.384
min(mgal)	-232.720	-63.611	-42.910
max(mgal)	147.400	84.816	74.946

The statistics of the remove step

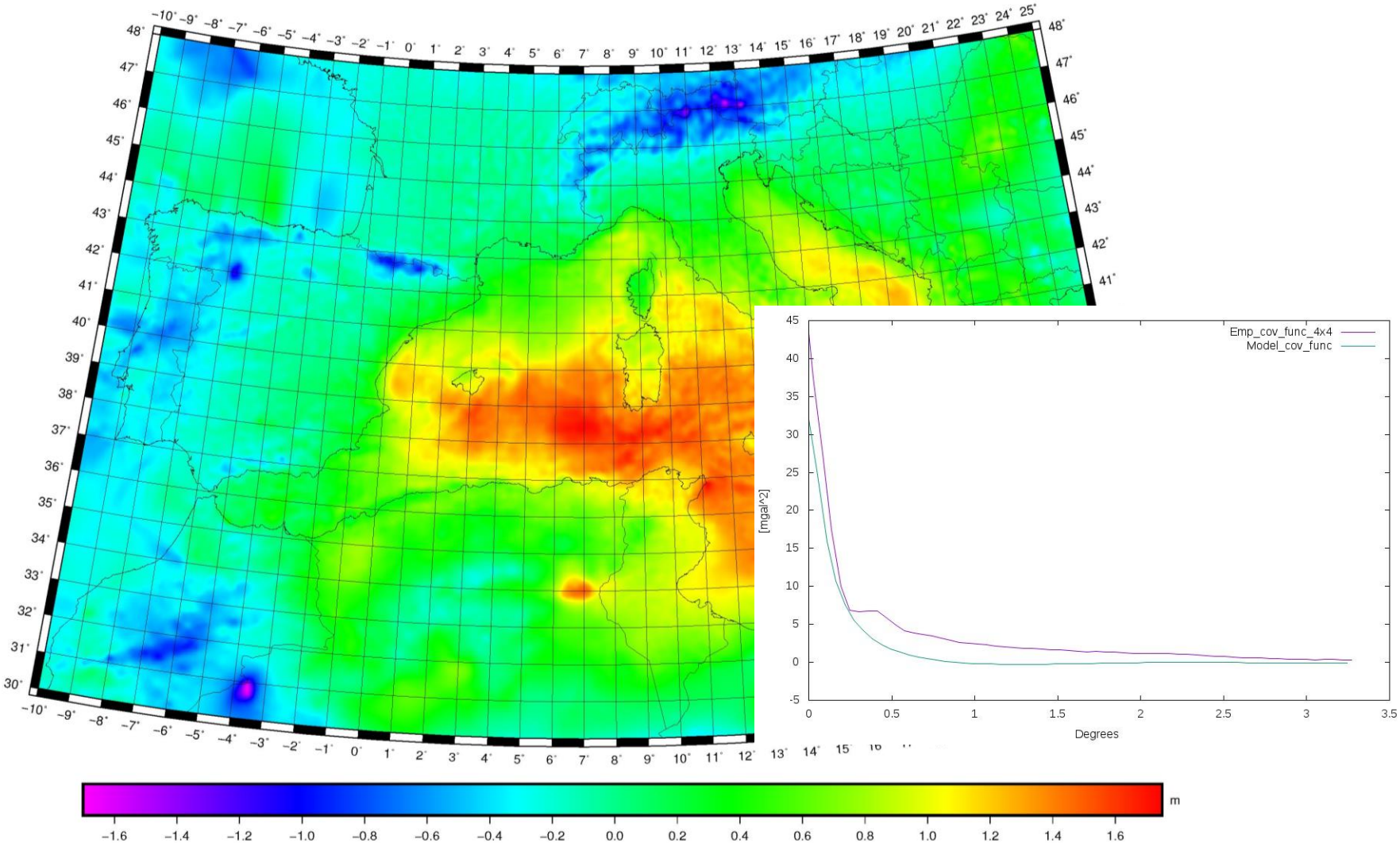
(with respect to **EIGEN6c4** @d/o 1000)

BGI data	Δg_{obs}	$\Delta g_R=\Delta g_{obs}-\Delta g_{MOD}$	$\Delta g_r=\Delta g_{obs}-\Delta g_{MOD}-\Delta g_{RTC}$
N	214735	214735	214735
E(mgal)	7.926	-5.396	-0.054
σ(mgal)	32.293	20.144	8.833
min(mgal)	-673.04	-686.694	-635.586
max(mgal)	349.98	290.716	266.068

All data	Δg_r(sparse points)	Δg_r(GRID)
n	396744	568591
E(mgal)	0.174	0.562
σ(mgal)	8.688	6.588
min(mgal)	-635.586	-240.261
max(mgal)	266.068	140.76

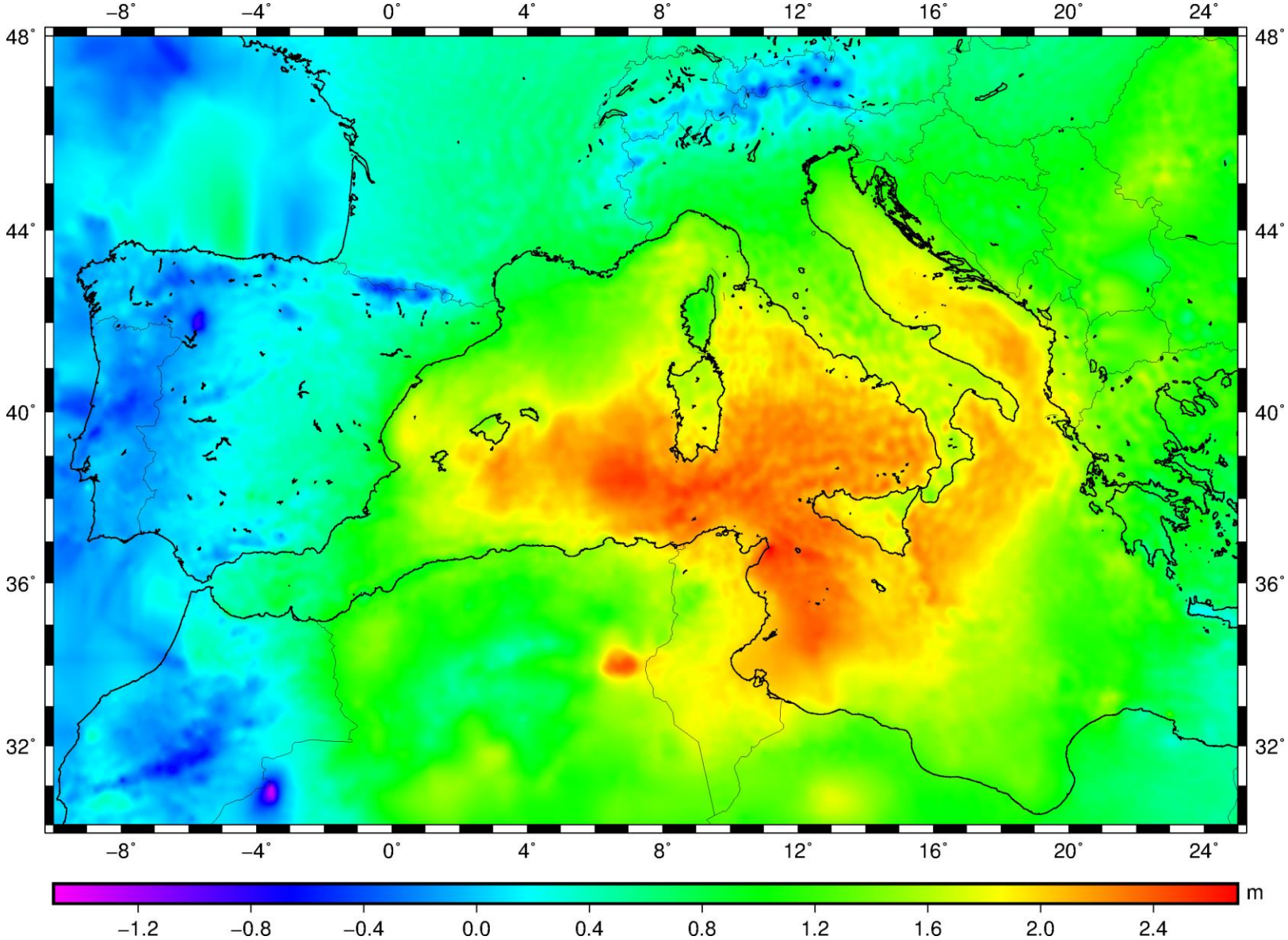
The applied geoid estimation methods (N_{RES})

FastCollocation (Bottoni and Barzaghi, 1993)



The applied geoid estimation methods (N_{RES})

1D_FFT (Haagmans et al., 1993)



The residual geoid statistics (N_{RES})

	1D FFT	FastCol	FastCol-1D FFT
n	568591	568591	568591
E(m)	0.975	0.258	-0.718
σ(m)	0.712	0.555	0.268
min(m)	-1.36	-1.683	-1.489
max(m)	2.7	1.734	-0.172

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

Greece (mainland)

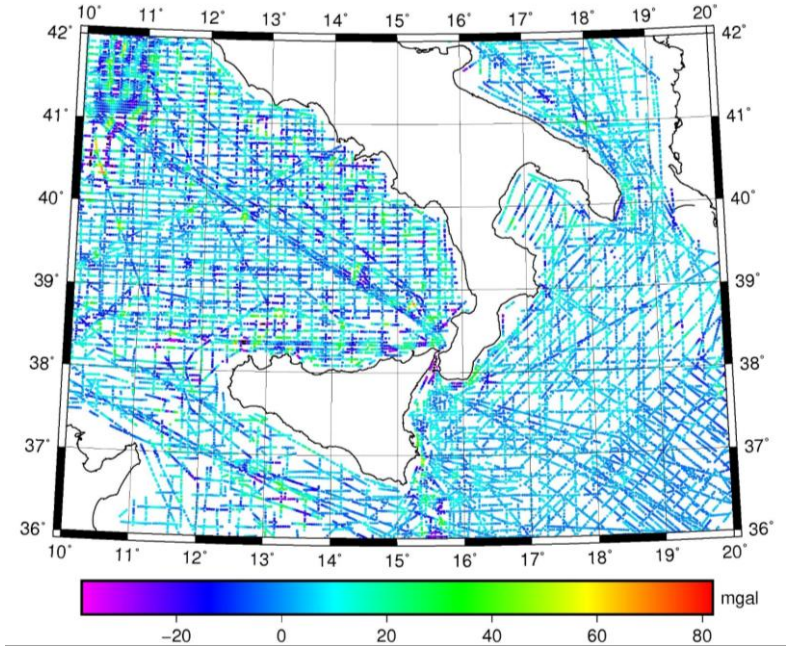
	v(EIGEN6c4) 1D FFT	v(EIGEN6c4) FastColl	v(EGM2008)
n	1429	1434	1434
E(m)	0.000	0.000	0.000
σ(m)	0.114	0.112	0.128
min(m)	-0.407	-0.408	-0.467
max(m)	0.454	0.471	0.440

Italy (mainland)

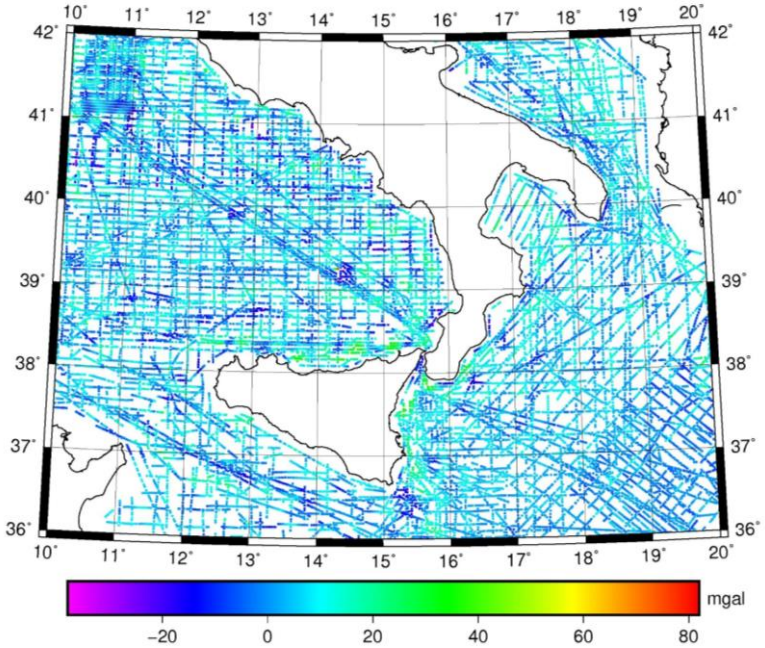
	v(EIGEN6c4) 1D FFT	v(EIGEN6c4) FastColl	v(EGM2008)
n	977	977	977
E(m)	0.000	0.000	0.000
σ(m)	0.138	0.134	0.096
min(m)	-0.388	-0.424	-0.331
max(m)	0.381	0.366	0.346

RTC at sea points: problems and distortions

$\Delta g - \Delta g_{model}$

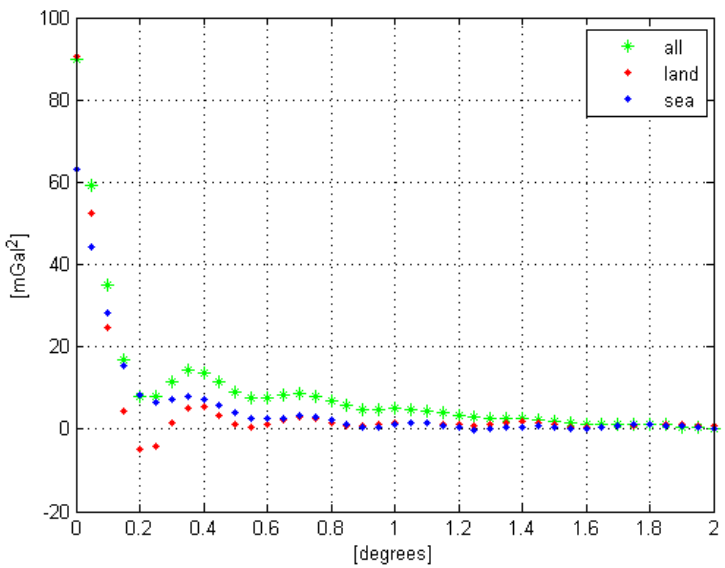


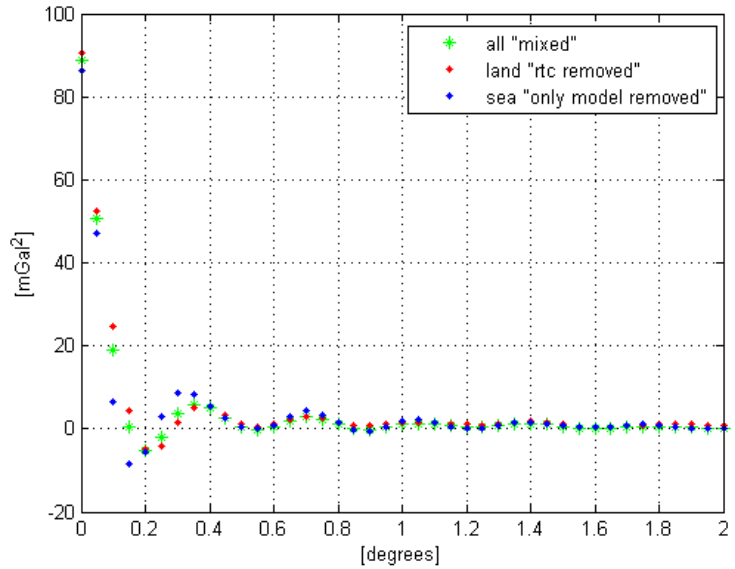
$\Delta g - \Delta g_{model} - \Delta g_{RTC}$



	$\Delta g - \Delta g_{model}$	$\Delta g - \Delta g_{model} - \Delta g_{RTC}$
# Values	22966	22966
Mean	3.160	3.775
St Dev	9.794	7.280
Min	-53.942	-38.399
Max	84.816	74.946

RTC at sea points: problems and distortions





Covariance function over the whole area (land and sea) or over land only or sea only, considering EIEGEN-6c4 geopotential model and the DTM based on EMODNET bathymetry. It is possible to observe that the covariance function over land only has a more regular behaviour.

Covariance function over the whole area (land and sea) or over land only or sea only, considering EIEGEN-6c4 geopotential model and the DTM based on EMODNET bathymetry.

In this case the data over land have been completely reduced ($\Delta g - \Delta g_{model} - \Delta g_{RTC}$), while the data over sea have been only partially reduced ($\Delta g - \Delta g_{model}$). It is possible to observe that the behaviour of the covariance function has improved, implying that the matter is to be ascribed to the RTC component over sea.

Comments and conclusions

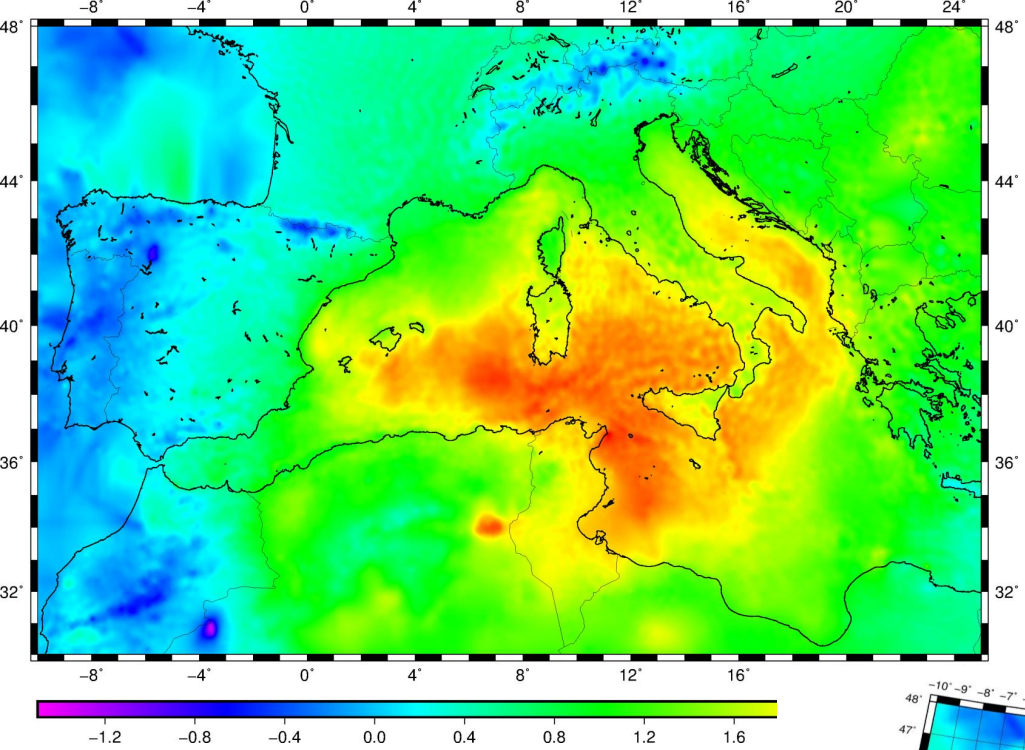
- The Adriatic Sea Test proved that further checks on the gravity data are needed (consistency among different gravity databases)

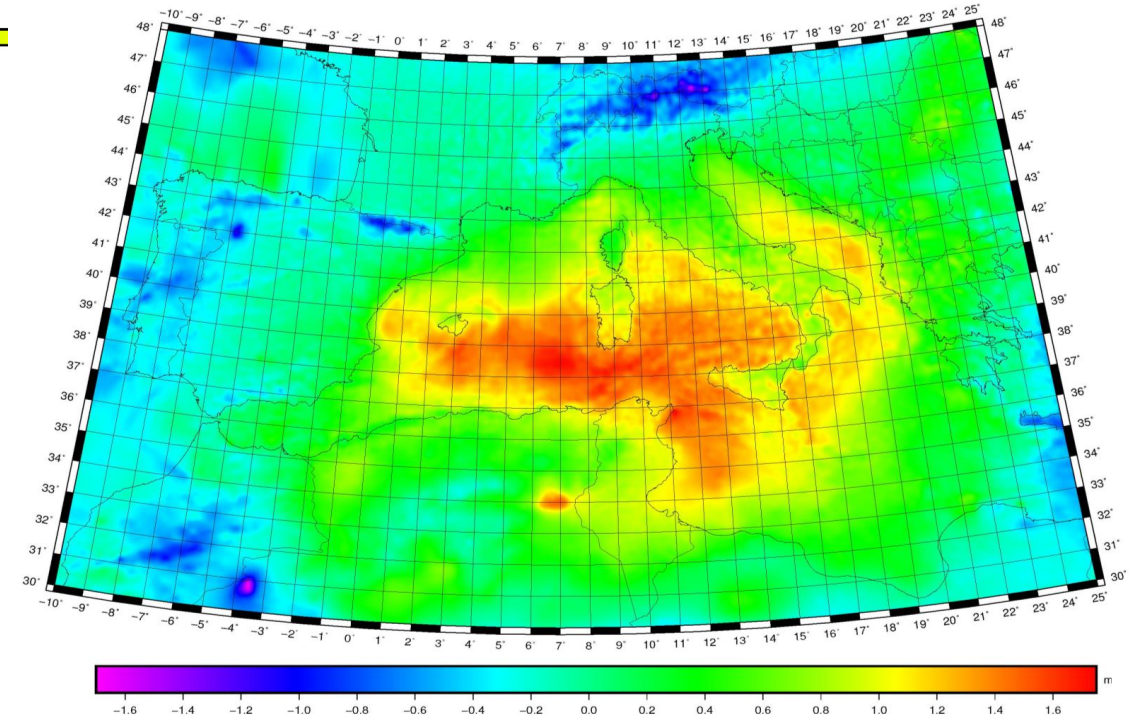
- The processing chain seems to be satisfactory but some refinements must be implemented (possibly a denser gravity database should be selected based on a 1'x1' selection grid)

- 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


−8° −4° 0° 4° 8° 12° 16° 20° 24°
48° 44° 40° 36° 32°
−1.2 −0.8 −0.4 0.0 0.4 0.8 1.2 1.6


−10° −9° −8° −7° −6° −5° −4° −3° −2° −1° 0° 1° 2° 3° 4° 5° 6° 7° 8° 9° 10° 11° 12° 13° 14° 15° 16° 17° 18° 19° 20° 21° 22° 23° 24° 25°
48° 47° 46° 45° 44° 43° 42° 41° 40° 39° 38° 37° 36° 35° 34° 33° 32° 31° 30°
−1.6 −1.4 −1.2 −1.0 −0.8 −0.6 −0.4 −0.2 0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6
m