# Improved representations of the Mediterranean Geoid within the GEOMED 2 project. Contributions of local gravity, GOCE and Cryosat2 data


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## Introduction and Problem

The Mediterranean Sea has always been a lab for geosciences, given its geodynamic peculiarities, the large short-scale variations of the gravity field and the complex circulation.

Within the GEOMED 2 project, new improved representations of the Mediterranean marine geoid have been deemed as necessary, so that the Mean Dynamic sea surface Topography (MDT) and the circulation can be modelled with higher accuracy and resolution.

This is possible given the availability of gravity-field related satellite data from GOCE, improved models of the land topography and bathymetry and the compilation of a Mediterranean-wide gravity database.

The data employed within GEOMED 2 for the determination of the marine geoid are land and marine gravity data, GOCE/GRACE based Global Geopotential Models and a combination of EMONET and SRTM/bathymetry terrain models.

The processing methodology was based on the well-known remove-compute-restore method following both stochastic and spectral methods for the determination of the geoid.

Classic least-squares collocation (LSC) with errors has been employed investigating both spherical and planar analytical covariance functions models, along with Fast Fourier Transform (FFT)-based techniques and the KTH approach.

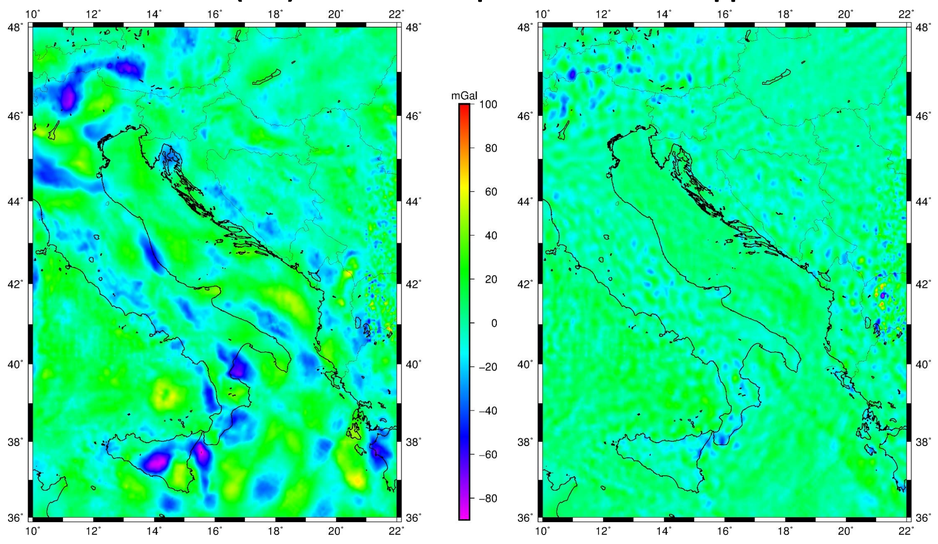


**Figure 1: The residual gravity field to DIR-R5 @d/o 230 (left) and EIGEN6c4 to d/o 1000 (right)**

## Gravity preprocessing and geoid estimation

In this work, the pre-processing steps consisting in merging and validating all the available gravity observations for the wider Mediterranean.

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-Compute-Restore method for the area $36^o \le \phi \le 48^o$ & $10^o \le \lambda \le 22^o$.

Various DTM/DBM model combination have been tested to conclude on the best one to use at 3"×3" in the window $33^o \le \phi \le 50^o$ & $8^o \le \lambda \le 24^o$.

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=80 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 25' cap).

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

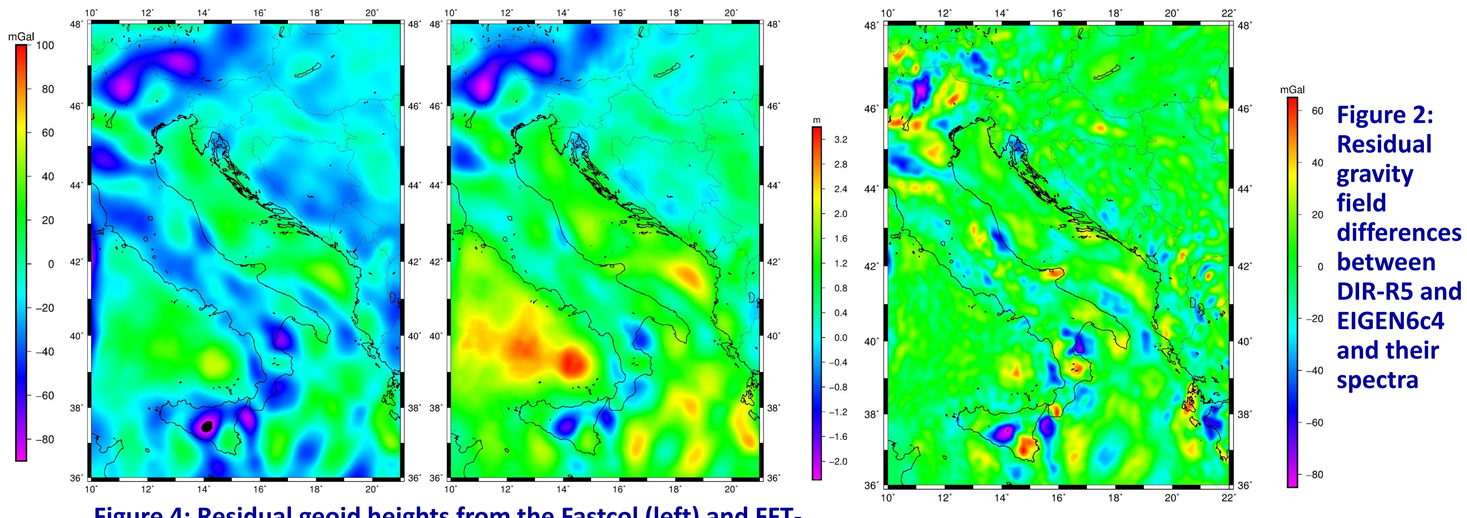


**Figure 4: Residual geoid heights from the Fastcol (left) and FFT-based (right) methods relative to DIR-R5.**

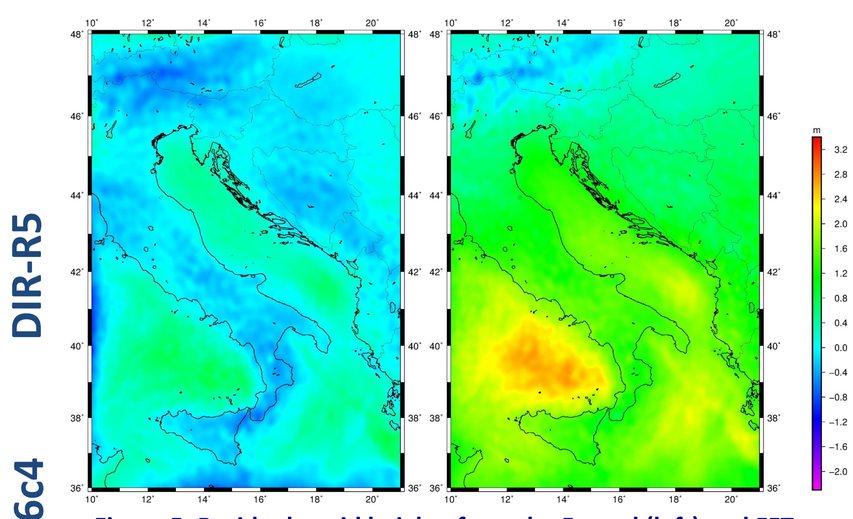


**Figure 5: Residual geoid heights from the Fastcol (left) and FFT-based (right) methods relative to EIGEN6c4.**

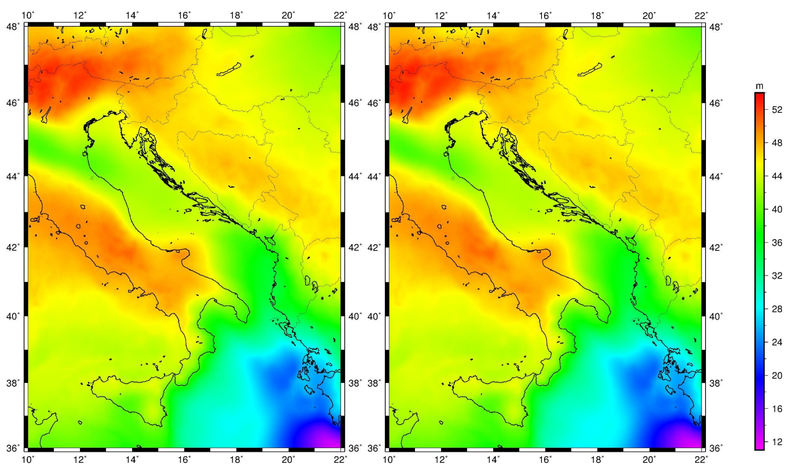


**Figure 6: Geoid heights from the KTH (left) and FastCol (right) methods relative to EIGEN6c4.**

## Remove-Compute-Restore

**Statistics of original $\Delta g_{obs}$, reduced and residual fields relative to DIR-R5 (d/o 230) and EIGEN6c4 (d/o 1000) [mGal]**

| | $\Delta g_{obs}$ | $\Delta g_R=\Delta g_{obs}-\Delta g_{MOD}$ | $\Delta g_r=\Delta g_{obs}-\Delta g_{MOD}-\Delta g_{RTC}$ | $\Delta g_r$(GRID) |
|---|---|---|---|---|
| nr | 132137 | 132137 | 132137 | 58081 |
| E | -0.217 | -3.602 | 0.909 | 1.017 |
| σ | 51.283 | 44.722 | 18.379 | 17.254 |
| min | -236.300 | -197.914 | -103.700 | -91.103 |
| max | 269.710 | 216.938 | 106.614 | 106.514 |

| $\Delta g_R=\Delta g_{obs}-\Delta g_{MOD}$ | $\Delta g_r=\Delta g_{obs}-\Delta g_{MOD}-\Delta g_{RTC}$ | $\Delta g_r$(GRID) |
|---|---|---|
| 132137 | 132137 | 58081 |
| -2.027 | 1.477 | 1.599 |
| 19.055 | 9.820 | 8.895 |
| -216.662 | 93.972 | -96.613 |
| 135.507 | -96.613 | 93.972 |

**Statistics of residual geoid heights relative to DIR-R5 (d/o 230) and EIGEN6c4 (d/o 1000) [m]**

| | $N_r$ (DIR-R5) | $N_r$ (DIR-R5) | $N_r$ (DIR-R5) | $N_r$ (EIGEN6c4) | $N_r$ (EIGEN6c4) | $N_r$ (EIGEN6c4) |
|---|---|---|---|---|---|---|
| | 1D FFT | FastCol | 2D FFT | 1D FFT | FastCol | 2D FFT |
| nr | 58081 | 58081 | 58081 | 58081 | 58081 | 58081 |
| E | 0.763 | 0.014 | 0.000 | 1.174 | 0.017 | 0.000 |
| σ | 0.803 | 0.584 | 0.300 | 0.643 | 0.248 | 0.076 |
| min | -2.267 | -2.608 | -1.384 | -0.629 | -0.973 | -0.482 |
| max | 3.315 | 2.020 | 1.473 | 2.727 | 0.821 | 0.439 |

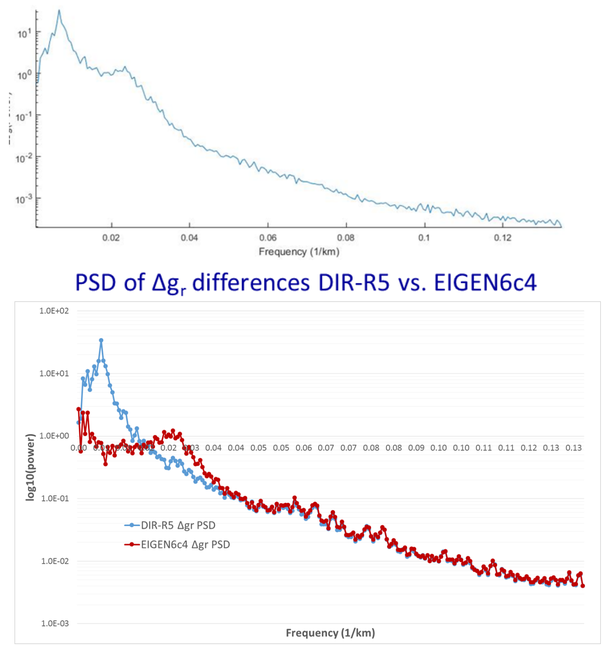


**Figure 3: PSDs of DIR-R5 and EIGEN6c4 residual gravity fields**

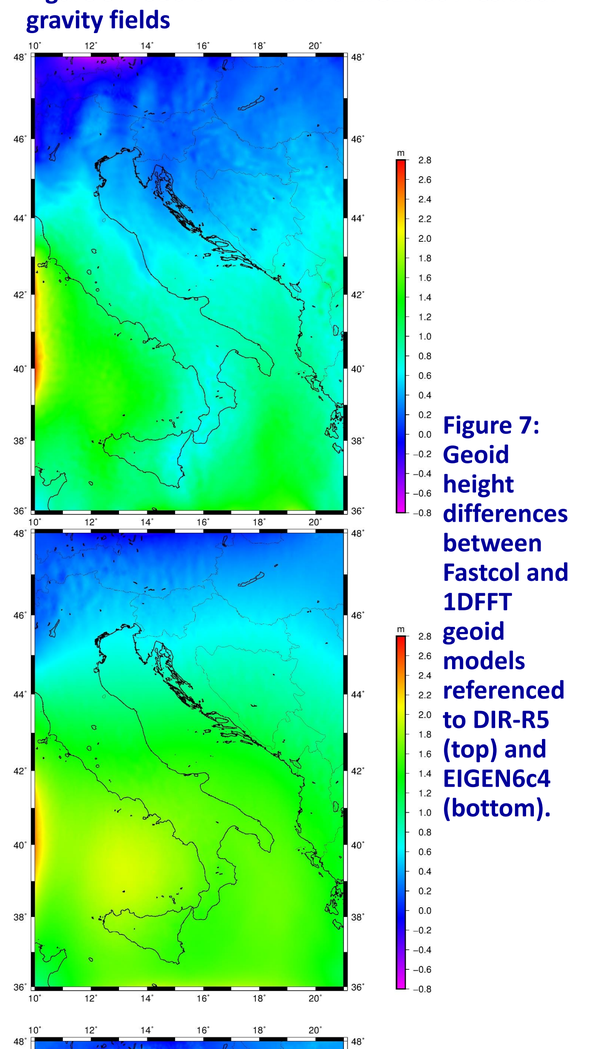


**Figure 7: Geoid height differences between Fastcol and 1DFFT geoid models referenced to DIR-R5 (top) and EIGEN6c4 (bottom).**




**Figure 9: Evaluation of EIGEN6c4 referenced geoid models and EGM2008 with GPS/Leveling data over Greece (551 BMs).**

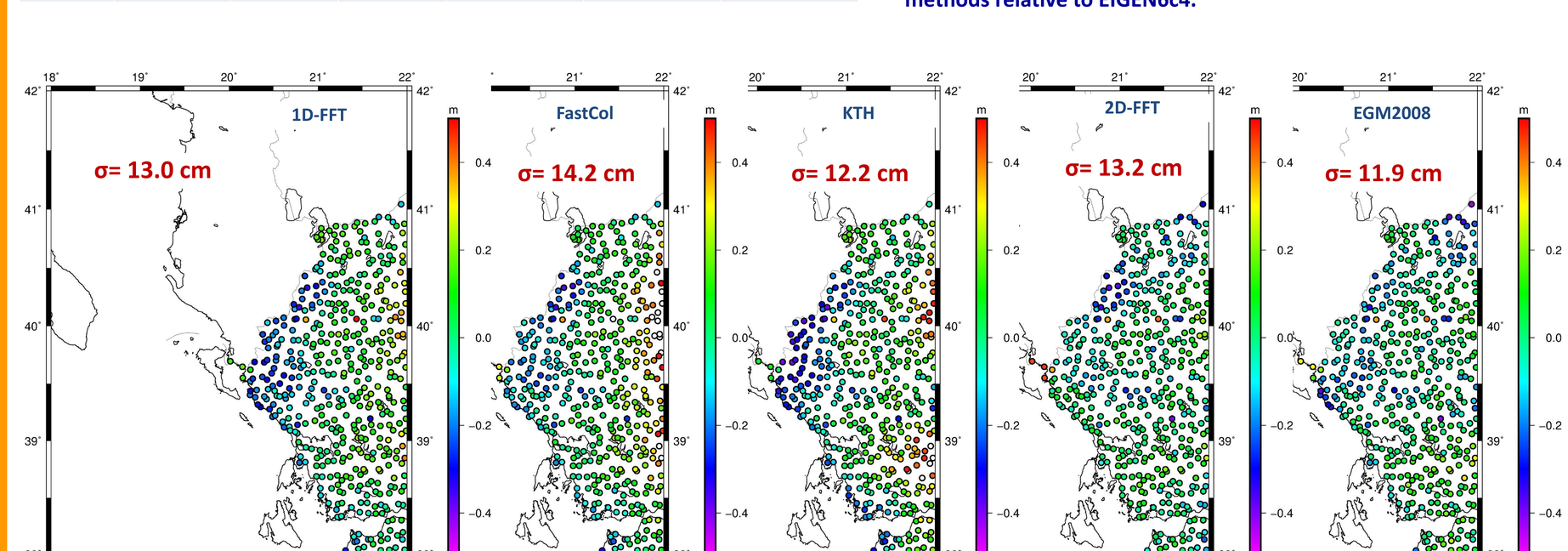


**Figure 10: Evaluation of EIGEN6c4 referenced geoid models and EGM2008 with GPS/Leveling data over Italy (604 BMs).**




**Figure 8: Geoid height differences between 1DFFT and KTH (top) and Fastcol and KTH (bottom) geoid models referenced to EIGEN6c4**

## 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 ).
- 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.
- 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)


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