EAST MEDITERRANEAN SEA CRUSTAL STRUCTURE FROM GOCE-BASED GLOBAL GRAVITY DATA

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Introduction. The study of the crustal structure from satellite gravity data has several important applications in exploration for oil & gas as activities. For instance, it can give an important outlook on the main geological structures at regional scale that hardly can be recovered with other geophysical methods.

In the present work, funded by the European Space Agency (ESA) through the Value Adding Element (VAE) program, the Levant crustal structure is investigated starting from the inversion of gravity disturbances. In details a global geopotential model based on the GOCE satellite observations has been used constraining the inversion also with local seismic information.

The study area (see Fig. 1), which is the Easternmost part of the Mediterranean Sea, is characterized by the presence of two main basins, namely the Herodotus and the Levantine ones. The former presents an oceanic crust, while the nature of the deep crust of the latter is still matter of debate within the geophysical community. In fact, the presence of a very thick sedimentary layer, makes the study of the Levantine Basin deep structure a difficult task. A part from the above mentioned basins, the Levant is characterized by the presence of the Mediterranean Ridge (an accretionary wedge caused by the African Plate subducting under the Eurasian and Anatolian plates), as well as of the Cyprus arc and the Eratosthenes Sea-mount. A proper description of the East Mediterranean geology can be found for instance in Longacre *et al*. (2007).

Method and Theory. The inversion algorithm is based on the solution presented in Sampietro (2015) and Reguzzoni and Sampietro (2015), basically it consists in an iterative inversion which allows, once the gravitational effect of the most superficial layers has been stripped from the observations, to recover the Moho depth as well as the density distribution within the crystalline crust. The algorithm is based on the following steps:

1. Collect the local available information (e.g. seismic profiles, map of the main geological provinces on the area, densities, etc.);
2. Assign a relation that describes the crust density variation as a function of depth for each geological province. In the absence of better information, it can be inferred from the literature;
3. Reduce the gravity data for the effects of the topography, bathymetry, sediments, lateral density variation inside the crystalline crust and the upper mantle. The crystalline crust one taken from the function studied at step 2, the upper mantle taken e.g. from a global model;
4. Invert the residual field for the Moho depth, and a scale factor for each geological province density function;
5. Re-apply step 3 with the densities estimated at point 4 and iterate up to convergence.

To deal with the effect of possible errors in the data reduction, as well as, in the uncertainties related to the a-priori information required by the inversion algorithm (e.g. the shape of geological provinces, starting crustal density models, etc.) a Monte Carlo analysis is performed, thus obtaining an estimate of the accuracy of the results. Basically, a random set of Monte Carlo samples (with the same stochastic characteristics of the a-priori information) is created and for each sample the whole inversion procedure is applied thus finding the effect of the specific input uncertainty on the final Moho depth result. Finally a refinement in the density of sediments, crust and upper mantle is performed by means of a Bayesian inversion approach according to Rossi (2017).

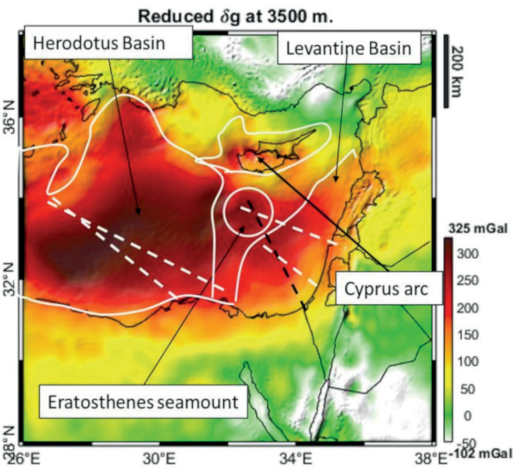

Fig. 1 - Gravity disturbances from the GECO model reduced for the effects of Topography, bathymetry, sediments and the subduction plate beneath Cyprus. White line are the limits of the main geological provinces. White dashed lines show the position of the used seismic profiles.

Data. The starting points of the inversion are gravity disturbances synthesized at 3500 m above sea level (just above the higher mountain in the study area) from the GECO global model (Gilardoni *et al*., 2016). GECO is an optimal combination between the EGM2008 model and GOCE observations. Digital elevation model has been taken from Etopo1 (Amante *et al*., 2009), and the complete terrain correction has been computed by means of the GTE software (Sampietro *et al*., 2016). As for the sediments, their thickness has been taken from Rybakov and Segev (2004), while for the densities a gradient in the vertical direction starting from 2000 kg/m^3 up to 2600 kg/m^3 has been considered. In the stripping procedure the effect of the subduction plate beneath Cyprus has also been modelled (from Ergün *et al.*, 2005) and removed. The shape of the geological provinces has been taken from Longacre *et al.* (2007) and modified to be coherent with the observed gravity disturbances reduced for the effect of topography, bathymetry and sediments (see Fig. 1). As for the crystalline crust density model both the horizontal as well as the vertical variations are considered. For each geological province, a function defining the density variation with depth is created from data documented in Chirstensen and Mooney (1995) and Carlson and Raskin (1984). Finally, the Mantle density is taken from the CRUST1.0 model (Laske *et al.*, 2013). Some interpreted seismic profiles, derived from Longacre *et al.* (2007) and Ben-Avraham *et al.* (2002) are also considered in the inversion.

Results. The results of the inversion in terms of Moho depth is presented in Fig. 2 and Fig. 3.

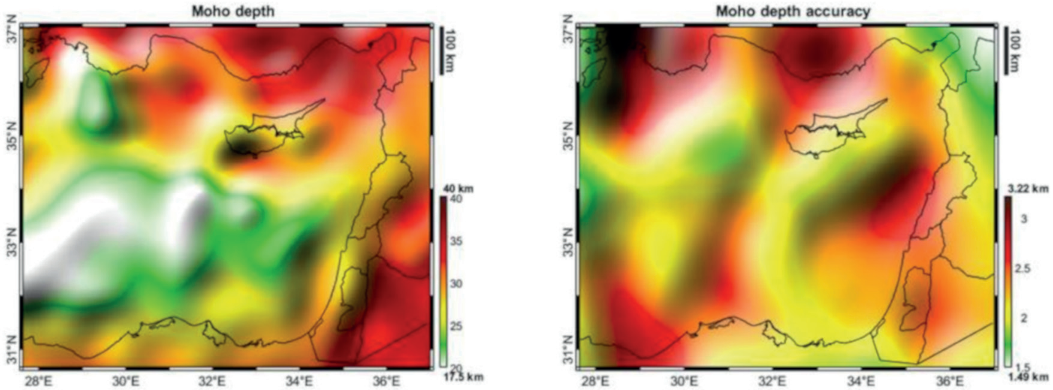

Fig. 2 - Estimated Moho depth and corresponding accuracy (standard deviation).

It can be seen the presence of a shallower Moho typical of the oceanic crust in correspondence of the Herodotus Basin, and the presence of an intermediate continental crust for the Levant Basin.

As an example of the Monte Carlo accuracy analysis we report in the following Tab. 1 the effect of the uncertainties of the most important input in terms of accuracy of the retrieved Moho depth.

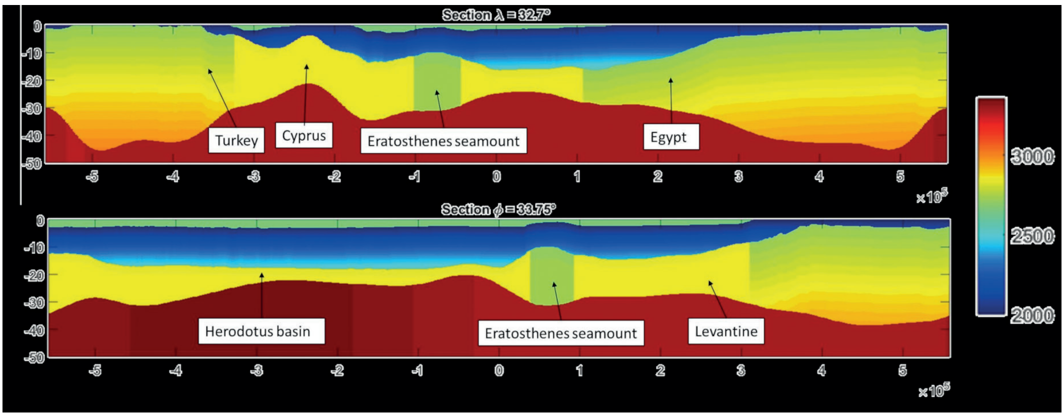

Fig. 3 - Estimated density distribution along two sections at constant Longitude equal to 23.7° (up) and constant Latitude equal to 33.75° (down).

Tab. 1 - Example of accuracy analysis from Monte Carlo samples of the effect of uncertainties in the input.

Model	Model error (std)	Effect on estimated Moho (std)
Mantle density	120 kg/m^3	0.7 km
Crystalline crust density	500 kg/m^3	2.4 km
Gravity observation error	5 mGal	0.6 km

Conclusions. The Levant basin test case has been thoroughly studied within the GIULIA project. The obtained results show how satellite-based gravity models, specifically the ESA satellite mission GOCE, can be proficiently used to obtain useful information for oil & gas exploration purposes.

In details, it can be clearly seen from the present work how the GOCE-based data can help in defining homogeneous (from the density point of view) geological regions and consequently to deliver information on the nature of the studied crust.

Moreover, the inversion of the gravitational field, properly complemented by external information such as density models, seismic profiles, etc. allows estimating both the Moho and the basement depths. Finally, the obtained results were used to develop a 3D density model for the studied region as well as to define the estimated accuracy of each discontinuity.

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