# GOCE+++

*Height System Unification, Dynamic Ocean Topography and gravity field determination with GOCE*

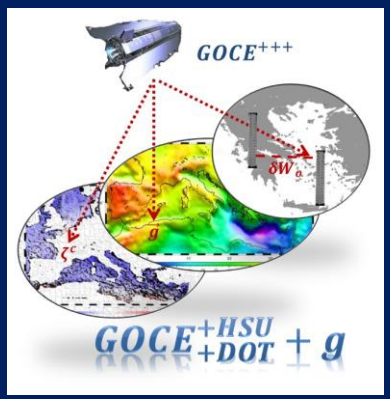
Newsletter Issue 1/30.09.2016

## GOCE+++

The **GOCE+++**is funded by the European Space Agency (ESA) within its Scientific Experiment Development Program (PRODEX) following a successful application to the General Secretariat for Research & Technology (GSRT) after an invitation to the Greek scientific community. GOCE+++ is a continuation of the successfully completed GOCESeaComp Project, launched and funcded in response to the 1st PRODEX Programme Call for Greece.

Contract: C400106380 CN3

Duration: February 2016 – July 2017




*The GOCE+++ Project Logo*

## THE GOCE+++ GPS/LEVELING OBSERVATIONS

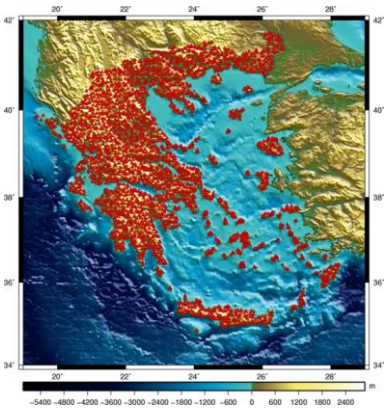


*Figure 1: Spatial distribution of the GPS/leveling point values.*

For mainland and islandic Greece, a total number of 2430 GPS/Leveling BMs is available and refer to stations belonging to the Hellenic Triangulation Network. The leveling data were measured by the HMGS using spirit and trigonometric leveling. Although each orthometric height is accompanied by an accuracy value, the experience of the project team has shown that these values may not be reliable. Additionally, there is no scientific documentation available for the vertical datum of Greece and inconsistencies are known to exist between the mainland and the islands. On the other hand, the GPS data (geodetic coordinates - φ, λ, h) originate from measurements carried out using Geodetic GPS receivers in the frame of the HEPOS project (Gianniou 2008). The GPS data from the HEPOS project were measured at 2430 trigonometric benchmarks and refer to ITRF00 - epoch 2007.236. Their horizontal accuracy is estimated to be between 1 and 4 cm, while their estimated vertical accuracy ranges from 2 to 5 cm. These data cover the mainland and some of the islands of Greece as presented in **Error! Reference source not found.**.

All available data were first scanned for missing or invalid values. Six records were removed because they did not contain an orthometric height. The next step was to remove outliers with the aid of the EGM08 and a 3σ test. In order to perform the 3σ test, differences ( $\Delta N$ ) were computed between geoid undulations from the GPS/leveling data and the EGM08 in a tide-free system, according to the following equation:

$$\Delta N = h_{TF}^{GPS} - H_{TF}^{lev} - N_{TF}^{EGM08}$$

where $h_{TF}^{GPS}$ is the geometric height as obtained from GPS measurements, $H_{TF}^{lev}$ the orthometric height as obtained from leveling and $N_{TF}^{EGM08}$ is the geoid undulation obtained from the EGM08 GGM. Based on the 3σ test, a total of 41 values were rejected and removed. Most of the rejected stations are located on islands or in coastal areas (see **Error! Reference source not found.**).

## DETERMINATION OF WO OVER THE GREEK ISLANDS

The determination of $\widehat{W}_{o\,i}^{LVD}$ LVD for the Greek islands was simpler, given that only few BMs exist in each one. It was based on the 888 BMs (see Figure 1 and Figure 2) over 83 Greek islands and isles. Some of them have a large number of BMs available, like Crete with 156, Rhodes with 34, Evia with 84, while others have only two. In most cases, the available number of BMs is at least 6-8, therefore a more robust $\widehat{W}_{o\,i}^{LVD}$ LVD for each island can be performed. The same procedure as in the preceding section has been followed, i.e., first the optimal zero-level geopotential for each island was carried with the pure GOCE and GOCE/GRACE models, and then the spectrally enhanced models have been employed.

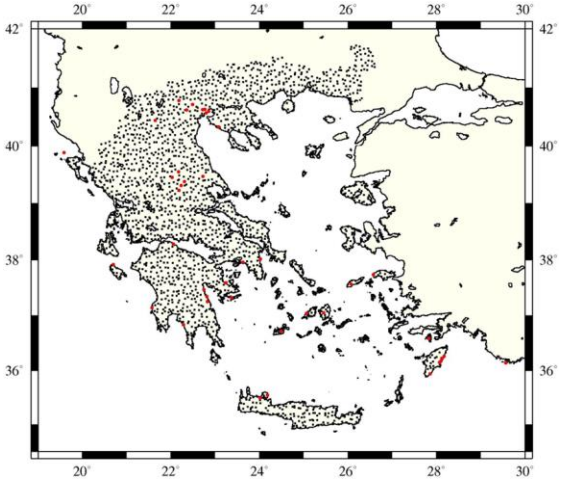



*Figure 2: Distribution of GPS/leveling point values (black dots) and the ones rejected by the 3σ test (red dots).*

The island with most BMs available is Crete, in South Greece, therefore the datum tilt investigation was performed for that region as well. Table 23 presents the statistics of the residual orthometric heights before and after the adjustment with the simple tilt model, along with the statistics of the parametric surface itself. Of interest are the plots of the residuals and of the tilt correction, where it can be seen from Figure 49, Figure 50 and Figure 51 that a North-South trend exists as well, with larger correction values in the South, where the area is much more mountainous, and smaller corrections in the North of the island.

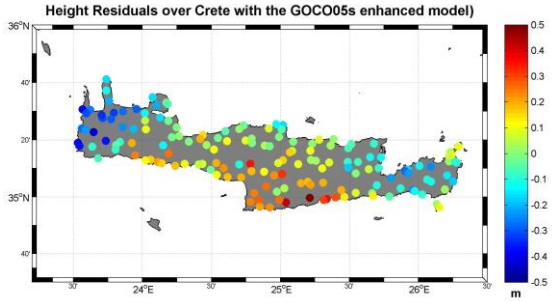



*Figure 3: Distribution of height residuals in Crete from the enhanced GOCO05s $\widehat{W}_{o}^{LVD}$ estimation.*

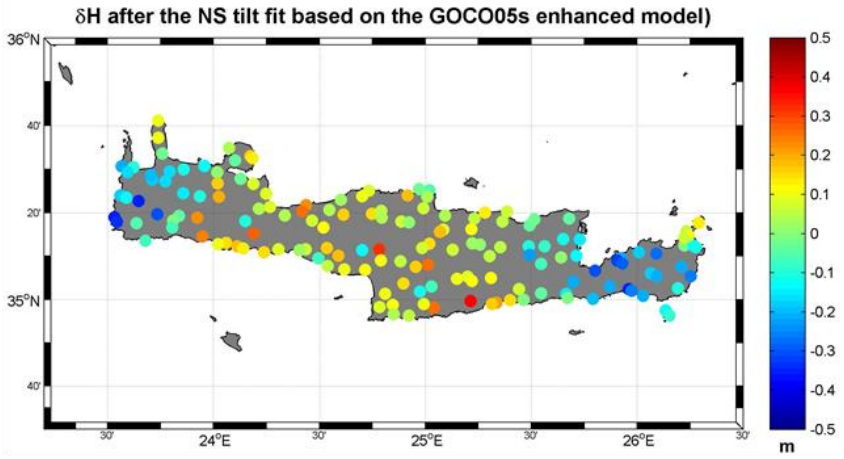



*Figure 4: **D**istribution of height residuals in Crete from the enhanced GOCO05s $\widehat{W}_{o}^{LVD}$ estimation after the tilt correction.*

Table 1 presents the for the Greek islands based on EGM2008. From these early results it can be noticed that the local LVDs of the islands, as realized by the assigned Helmert orthometric heights on the trigonometric BMs, deviate considerably from the LVD of the country.

For some islands, like Evia, the local datum deviates by only a few cm from the one of mainland Greece, but in general most of them deviate by tens of cm. From the pure GOCE models it becomes evident that omission error in the GOCE models and the band-limited nature of the GOCE signal to wavelengths of ~90 km introduce large errors. This is why for many islands

there is a reversal in the sign of the LVD w.r.t. to the CVD one by IAG, i.e., their LD instead of being above the WHS one is below.

| **Study Area (Greek Islands)** | **Geoid Height Residuals** ($N_{GPS/lev.}-N_{model}$) | | | | | **Gravity Potential and offsets relative to** $W_o = \cdots 53.4000\ m^2/s^2$ | |
|---|---|---|---|---|---|---|---|
| EGM08 (d/o 2190) | **min** | **max** | **mean** | **std** | **rms** | $\widehat{W}_o^{LVD}$ ($m^2/s^2$) | $\approx \delta\widehat{W}_o^{LVD}$ (cm) |
| CRETE | -125.2 | -31.7 | -82.1 | 18.0 | 84.0 | 62636860.7702±0.0705 | -73.7 |
| RHODES | -125.2 | -18.5 | -72.7 | 24.7 | 76.8 | 62636856.2443±0.1511 | -28.4 |
| SAMOS | -174.3 | -62.6 | -82.7 | 27.9 | 87.0 | 62636862.4542±0.2355 | -90.5 |
| CHIOS | -69.1 | -21.7 | -39.9 | 12.7 | 41.8 | 62636858.8076±0.1799 | -54.1 |
| LESVOS | -90.1 | -54.2 | -75.0 | 9.1 | 75.5 | 62636861.7996±0.1411 | -84.0 |
| LIMNOS | -90.9 | -51.7 | -75.4 | 9.1 | 75.9 | 62636860.6447±0.2078 | -72.4 |
| THASOS | -67.3 | -47.6 | -56.4 | 6.2 | 56.7 | 62636859.6481±0.3117 | -62.5 |
| EYVOIA | -103.3 | -37.4 | -69.6 | 11.7 | 70.5 | 62636859.4835±0.0979 | -60.8 |
| ZAKYNTHOS | -90 | -66.9 | -76.2 | 5.8 | 76.4 | 62636860.8914±0.2544 | -74.9 |
| KEFALONIA | -82.2 | -40.8 | -63.0 | 9.7 | 63.7 | 62636859.7018±0.1971 | -63.0 |
| CORFU | -101.5 | -45.2 | -84.2 | 16.8 | 85.8 | 62636862.0126±0.2138 | -86.1 |

## Contact Us

**GeoGrav - AUTh**
Department of Geodesy and Surveying, Aristotle University of Thessaloniki
University Campus, University Box 440, GR-54124
Thessaloniki, Greece
**T**: ++302310996125 | **F**: ++302310995948
tziavos@topo.auth.gr vergos@topo.auth.gr
http://olimpia.topo.auth.gr/GOCE_HSU_DOT_G/