



**Operational Program “Education and Lifelong Learning”  
ARCHIMEDES III Support of Research Groups at Technological  
Educational Institutions**

**Project title:**

***Evaluation of the Hellenic Vertical Network in the frame of the European Systems and Control Networks Interconnection – Application in the areas of Attica and Thessaloniki***

**Research Head:** *V. Pagounis*<sup>1</sup>

**Main research team:** *G. Vergos*<sup>2</sup>, *M. Gianniou*<sup>1</sup>, *I. Tziavos*<sup>2</sup>, *G. Fotopoulos*<sup>4</sup>,

**Research fellows:**

*V. Andritsanos*<sup>1</sup>, *O. Arabatzi*<sup>3</sup>, *V. Grigoriadis*<sup>2</sup>, *E. Zacharis*<sup>3</sup>, *D. Anastasiou*<sup>3</sup>, *D. Gaifillia*<sup>1</sup>, *A. Katsadourou*<sup>2</sup>, *I. Kolivaki*<sup>2</sup>, *T. Koutsosimos*<sup>1</sup>, *S. Palaiokrasas*<sup>1</sup>

- 1 Lab of Geodesy and Surveying, Technological Educational Institute of Athens  
2 Department of Rural & Surveying Engineering, Aristotle University of Thessaloniki  
3 School of Rural & Surveying Engineering, National Technical University of Athens  
4 Department of Geological Sciences & Geological Engineering, Queen’s University

**Host Institute:**

Technological Educational Institute (TEI) of Athens  
Laboratory of Geodesy and Surveying

**Implementation:** 01.03.2012 - 30.06.2015

**Budget:** 71.000 €

**Research Frame:**

The total of the technical work of a country is based on well established horizontal reference networks as well as vertical ones. The knowledge of the location where an event took place is crucial to a crisis management. On the other hand, the precise knowledge of an incident place is possible to lead to more equitable confrontation from the authorities. With the applications of modern technology, the horizontal determination is feasible with particularly high precision. With respect to the vertical control networks their confrontation is different: the effect of the earth's gravity field, due to the inherent connection of the height information with the direct natural environment, complicates the processes of measurement and utilization of leveling data. The importance of height information is extremely high; it is enough one to think the human activities dependent on this. The control and re-evaluation of the Hellenic vertical network is the object of the project. Today, with the pan-European effort for the establishment of a common European Vertical Network, the validation of the Hellenic network seems a one way road decision.

**Scientific Results:**

The internal as well as the external accuracy of the Hellenic vertical network is investigated in this project. The internal accuracy is based on various solutions at GPS/leveling benchmarks of the network using a variety of commercial as well as scientific software packages. The contribution of the global geopotential model EGM2008 is utilized in order to assess the external accuracy of the network. Two test areas are chosen in Central and Northern Greece containing 233 benchmarks.

Based on the discussion of the GPS processing some conclusions can be drawn related to each processing software results. The commercial software packages perform better in the case of short length – short observation time baselines than the scientific one. Especially, under unfavorable measurement conditions (reduced satellite visibility and/or poor signal reception) there are noticeable differences in the performance of problematic baselines. The requirement of increased number of data for the proper modeling of a large number of parameters using the scientific software is the main reason of the differences in the estimated solutions. Differences exist among the commercial software packages based on the solution strategy of each one of them, depending on the baseline length and the observation period.

The difficult measurement environment affects the precision of the final result. This fact states for all software packages used in our study. The precision degradation is found higher for the horizontal coordinates which underlines the importance of the environment conditions during a usual GPS campaign. Nevertheless, generally speaking, the horizontal closure errors are smaller than the vertical closures. However, certain software programs provided on the balance slightly better results in the vertical component.

The validation of the vertical datum in both test areas is performed using external information from the state-of-the-art global geopotential model EGM2008. The results in Attica show an agreement between “geometric” and “physical” geoid better than 10 cm, in terms of the standard deviation of the differences. In Thessaloniki, this agreement is of the order of 15 cm. A bias between the average difference of Attiki and Thessloniki is observed, which can be attributed to the datum offset between the Greek datum and the datum used for the development of EGM2008. This bias presents different characteristics in Attica than in Thessaloniki, resulting a 20 cm offset, approximately, between the average differences at the two areas. The abovementioned offset is related to the LVD used in each area and it is the subject of ongoing work. The use of additional geopotential models, especially the recent available satellite models from GOCE satellite, will contribute to the efficient validation of the height datum with respect to its spectral characteristics.

The extensive evaluation of the latest GOCE, GOCE/GRACE and combined GGMs have been carried out using GPS/levelling benchmarks at two regions, one in Central (Attica) and another in Northern (Thessaloniki) Greece. Local parametric models have been tested in order to remove the inherent datum inconsistencies, between the ellipsoidal, orthometric and geoid heights. Six parametric models have been selected and the GGMs signals has been used to its maximum power, as well as to lower degrees given the truncation of the spherical harmonic expansion. The GOCE/GRACE GGMs signal has been filled-in with EGM08 up to its maximum degree and order of expansion, representing the high frequency content of the gravity field spectrum. The 5th release of GOCE models estimated by the Direct as well as the Time-Wise approach and filled by EGM08 signal outperformed any other case, in terms of the standard deviation and the range of the differences at GPS benchmarks. A third order polynomial improved the results of the differences by 1 cm in the Attica and 2 cm in the Thessaloniki area, in terms of standard deviation. The truncation to degree 140 was selected based on various tests and previous studies. The 5th release of GOCE data showed an

improvement at the low frequency band of the gravity spectrum when compared with GPS/levelling data at benchmarks. This improvement can be identified considering the statistics of the differences even before any parametric model application. The latter EIGEN-6C4 GGM gave slightly worse statistics (3 mm in terms of std of the differences) than the synthetic GOCE(140)+EGM08 model.

The incorporation of GPS/levelling signal to the final combined geoid is feasible through MIMOST. A combined GPS/levelling/GGM geoid model using the geoid information from GOCE DIR-R5 to a degree 140 and EGM08 residual signal has been estimated. The combined geoid contains a minimal effect of datum inconsistencies, since the coupling of GGM and GPS/levelling geoid heights is based on a specific minimization criterion. The comparisons showed an improvement of 1.3 cm in Attica and 3.5 cm in Thessaloniki in terms of the standard deviation of the differences before any fit. An even greater improvement was observed in the range of the differences: 10 cm in Attica and 44 cm in Thessaloniki region.

### Refereed Publications in Journals

1. V. Andritsanos, O. Arabatzi, M. Gianniou, V. Pagounis, I. Tziavos, G. Vergos, E. Zacharis, *Comparison of various GPS processing solutions towards an efficient validation of the Hellenic vertical network: The E.LE.V.A.T.I.ON project*, accepted for publication in **Journal of Surveying Engineering, 2015.**
2. G. Vergos, V. Andritsanos, V. Grigoriadis, V. Pagounis, I. Tziavos, *Evaluation of GOCE/GRACE GGMs over Attica and Thessaloniki, Greece, and Wo determination for height system unification*, **Accepted for publication in International Association of Geodesy proceedings**
3. V. Andritsanos, V. Grigoriadis, G. Vergos, V. Pagounis, I. Tziavos, *GOCE/GRACE GGM evaluation over Attica and Thessaloniki, Greece and local geoid modelling in support of height unification*, **South-Eastern European Journal Issue of Earth Observation and Geomatics, Vol4, 2015.**

### Papers in Conference Proceedings:

1. D. Anastasiou, D. Gaifillia, A. Katsadourou, I. Kolivaki, X. Papanikolaou, M.Gianniou, G. Vergos, V. Pagounis, *First Validation of the Hellenic Vertical Datum as a Prerequisite for the Efficient Disaster and Resource Management: The “ELEVATION” Project.*, **Proceedings of FIG Commission 3**

**Workshop 2012 Spatial Information, Informal Development, Property and Housing, Athens, Greece, 10-14 December 2012.**

### **Abstracts in Conferences**

1. V. Andritsanos, G. Vergos, V. Grigoriadis, V. Pagounis, I. Tziavos, Spectral characteristics of the Hellenic vertical network - Validation over Central and Northern Greece using GOCE/GRACE global geopotential models, **European Geosciences Union – General Assembly 2014 Vienna – Austria – April, 27th to May, 2nd 2014, Session G4.2 Satellite Gravimetry: GRACE, GOCE and Future Gravity missions.**
2. I. Tziavos, G. Vergos, V. Andritsanos, V. Grigoriadis, V. Pagounis, GOCE/GRACE GGM evaluation over Attika and Thessaloniki, Greece and local geoid modeling in support of height unification, **IUGG 2015 General Assembly, Symposium– “Static Gravity Field Models and Observations” June 22-July 2, 2015, Prague, Czech Republic**

ΤΕΙ ΑΘΗΝΑΣ  
ΤΜΗΜΑ ΤΟΠΟΓΡΑΦΙΑΣ  
ΕΡΓΑΣΤΗΡΙΟ ΓΕΩΔΑΙΣΙΑΣ ΤΟΠΟΓΡΑΦΙΑΣ  
ΑΓ. ΣΠΥΡΙΔΩΝΟΣ-12210 ΑΙΓΑΛΕΟ  
ΤΗΛ. 5385820-FAX 5385886



TEI of ATHENS  
DEPARTMENT of SURVEYING ENG  
LABORATORY of GEODESY & SURVEYING  
AG. SPYRIDONOS-12210 AEGALEO  
TEL. 5385820-FAX 5385866