

# National Report of Greece to EUREF 2011

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## 1 Introduction

KTIMATOLOGIO S.A is a state-owned company responsible for the establishment and operation of the Hellenic Cadastre. The company has established and operates the HEPOS network. The underlying geodetic reference system (HTRS07) of HEPOS is a realization of ETRS89. During the last months the main geodetic activities undertaken in Greece related to EUREF include:

- participation in the EUREF-TWG project for monitoring the official ETRF coordinates on the EPN site
- installation of a new EPN station
- establishment of geodetic connection between Greece and FYROM
- computation by KTIMATOLOGIO S.A. of a geoid model to be used with HEPOS.

This national report describes the aforementioned activities and also presents the evolution in the usage of HEPOS.

## 2 KTIMATOLOGIO S.A. joined EuroGeographics

In October 2010 KTIMATOLOGIO S.A. became the 56<sup>th</sup> member of EuroGeographics. It is now the third Hellenic Agency that is member of EuroGeographics, together with HMGS (the Hellenic Military Geographical Service) and HEMCO (the Hellenic Mapping and Cadastre Organization).

## 3 Monitoring national ETRF coordinates

The coordinates of the HEPOS stations have been computed in ETRS89 using 14 days of continuous observations collected in October 2007 (Gianniou (2010)). This campaign, called “EUREF GR 2007”, was validated by EUREF in May 2010 (EUREF (2010)). Three EPN sites had been included in the campaign, i.e. AUT1 in Thessaloniki, NOA1 in

Athens and TUC2 on Crete. The coordinates estimated for these EPN stations within the campaign are submitted to the TWG for inclusion in the project for monitoring the official ETRF coordinates on the EPN site (Brockmann (2009)). Figures 1-2 depict the horizontal and vertical differences between the coordinates obtained by the campaign and the latest EPN solution (November 2010). As can be seen in Figure 1, the horizontal difference for AUT1 is less than 1 cm while the differences for NOA1 and TUC2 do not exceed 2 cm. These values have also been verified by the computations made at KTIMATOLOGIO S.A. The higher values for NOA1 and TUC2 are due to the significantly higher ETRS89 velocities of these stations with respect to AUT1. In any case, the level of consistency between the two solutions is quite satisfactory, especially if the strong tectonic activity in Greece is considered.

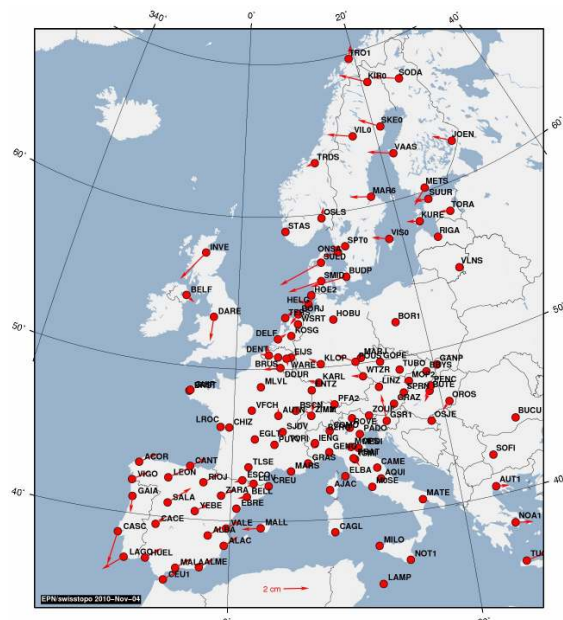
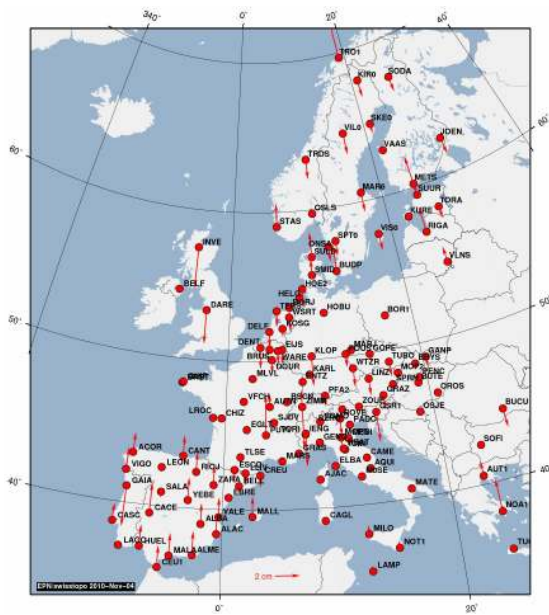


Fig. 1 Horizontal differences between national ETRF coordinates and EPN solution (source: EPN site)



**Fig. 2** Vertical differences between national ETRF coordinates and EPN solution (source: EPN site)

#### 4 EPN station LARM

In January 2011 the 6th Greek EPN station was installed. The station, named LARM, is situated at the University of Thessaly, and covers the area of Central Greece as can be seen in Figure 3. The station was installed by Professors A. Fotiou and C. Pikridas from the Department of Geodesy and Surveying, Aristotle University of Thessaloniki, who also installed and operate EPN stations AUT1 and DUTH (Fotiou et. al (2010)). Table 1 summarizes the main information on station LARM. It is worth mentioning that the receiver tracks GPS and GLONASS signals and is, in addition, ready to track GALILEO signals.

**Table 1.** LARM site information

EPN station: LARM	
City	Larisa
Province	Thessaly
Site Name	Larisa
Four Character ID	LARM
IERS DOMES Number	12610M002
Date Installed	2011-01-15
EPN Inclusion	2011-05-01
Receiver Type	LEICA GRX1200+GNSS
Satellite System	GPS+GLONASS
Antenna Type	LEIAR25
Antenna Radome Type	LEIT



**Fig. 3** The six Greek EPN stations

#### 5 Geodetic connection with FYROM

In August 2010 FYROM conducted a campaign to compute a realization of ETRS89. This campaign, which is called “EUREF MAKPOS 2010”, was validated by EUREF in May 2011 (EUREF (2011)). In order to establish a geodetic connection in ETRS89 between Greece and FYROM, KTIMATOLOGIO S.A. supplied data from 3 HEPOS stations along the common borders. The stations used for this purpose, i.e. 041A, 066A and



**Fig. 4** The three HEPOS stations (in red) used for the connection between Greece and FYROM.

073A are shown in red in Figure 4. Data for a one-week period (15-21 August, 2010) have been supplied to Lantmäteriet (the Swedish mapping, cadastral and land registration authority) that processed the campaign for AREC, the Agency for Real Estate Cadastre of FYROM. At the time of writing, the processing of the HEPOS data is pending.

## 6 HEPOS Network

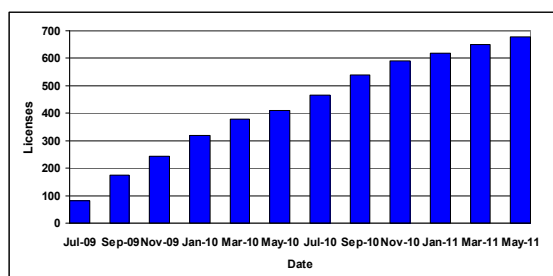
HEPOS supports post-processing as well as real-time applications using both single-base and network-based techniques (VRS, FKP, MAC). On 25/5/2009 the services of HEPOS were made available to the surveying community. Based on the experience we gathered with the users, the most important reasons for choosing HEPOS are:

- ability to easily produce accurate coordinates
- high and homogeneous accuracy
- supported network-solutions
- country-wide coverage
- reliability of the system.

The above mentioned advantages lead to an increased number of users from places throughout the country.

### 6.1 Number of Users

Figure 5 depicts the increment in the number of the issued user licenses. As can be seen, the number is steadily increasing. Until May 2011, after two years of operation, 680 user licenses had been issued, corresponding to 470 different users. These numbers meet our expectations and are quite satisfactory.

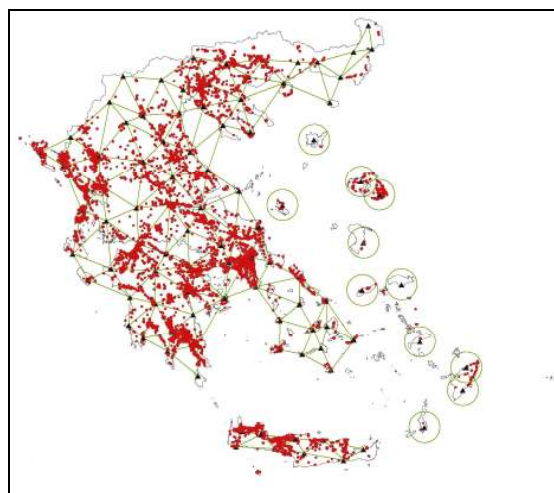


**Fig. 5** User licenses issued within the first two years of operation of HEPOS.

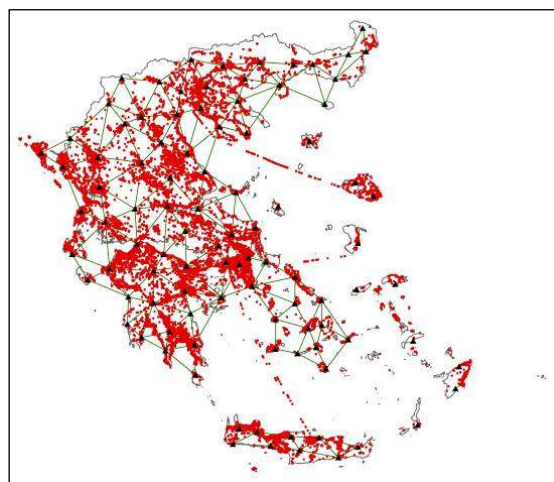
### 6.2 Spatial distribution of usage

Figure 6 shows the locations where HEPOS users made RTK measurements during the first year of operation.

The spatial distribution of the RTK usage within the first two years of operation can be seen in Figure 7. By comparing Figures 6 and 7, it becomes evident that HEPOS is being progressively used in more and more areas of the country. Of particular importance are the areas with low population, like the small islands, as they prove the wide use of HEPOS.



**Fig. 6** RTK usage within the first year of operation of HEPOS.



**Fig. 7** RTK usage within the first two years of operation of HEPOS.

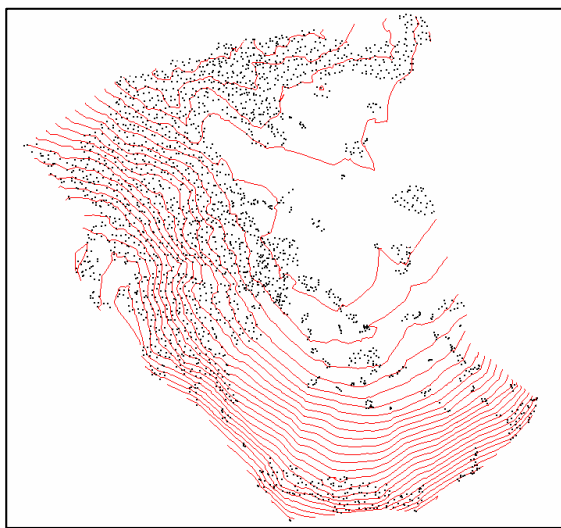
## 7 Geoid model

As the number of the users of HEPOS increases, the interest in the determination of orthometric heights using HEPOS becomes higher. Existing global geoid models are not sufficient for surveying applications. This is also the case for EGM08,

although it offers a remarkable improvement compared to EGM96. A detailed evaluation of EGM08 over the entire Hellenic mainland showed a reduction in the standard deviation of residuals  $N^{GPS/leveling} - N^{model}$  by a factor of three with respect to EGM96 (Kotsakis et. al (2009)). However, the EGM08 residuals (after a least squares constant bias fit) can reach up to  $\pm 50\text{cm}$ , which does not fulfill typical surveying requirements.

In order to cover the needs of HEPOS users to estimate orthometric heights KTIMATOLOGIO S.A. developed a geoid model to be used with HEPOS. This geoid has been computed based solely on geometric information, i.e. ellipsoidal heights obtained by GPS at points with known orthometric heights. For this purpose the measurements from the national GPS campaign carried out in 2007 have been used. During this campaign approximately 2470 trigonometric points were measured. These points are evenly distributed all over Greece and correspond to about 10% of the total number of the national network's trigonometric points (Gianniou (2009)). In addition to these data, measurements collected by Aristotle University of Thessaloniki, National Technical University of Athens and Technological Educational Institute of Athens have been exploited for the computation of the geoid model. These measurements have been conducted on about 210 points of the national triangulation network and selected leveling points.

All GPS measurements have been connected to HEPOS to obtain ellipsoidal height in ETRS89 (HTRS07). The complete set of the about 2700 points used for the computation of the geoid model



**Fig. 8** The geoid model developed by KTIMATOLOGIO S.A.

is depicted in Figure 8. In the same figure the estimated geoid undulations are given with isolines at 1 m intervals. A detailed evaluation of the model using external information is currently underway.

The developed geoid model is implemented in a new transformation software that has been developed by KTIMATOLOGIO S.A. This software (HEPOS Transformation Tool) performs 3D transformations and computes orthometric heights based on the new geoid model. The software is freely available on the HEPOS website ([www.hepos.gr](http://www.hepos.gr)).

## Acknowledgments

Professor A. Fotiou and Acct. Professor C. Pikridas, Dept. of Geodesy and Surveying, Aristotle University of Thessaloniki installed the new EPN station LARM and are acknowledged for supplying the relevant details. The colleagues from the geodetic department of KTIMATOLOGIO SA I. Stavropoulou and C. Danezis are acknowledged for assisting the geoid computations and writing the source code for HEPOS Transformation Tool, respectively. The HEPOS project is part of the Operational Program “Information Society” and is co-funded by the European Regional Development Fund.

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