National Report of Greece to EUREF 2009

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1 Introduction

In 2007, KTIMATOLOGIO S.A (Hellenic Cadastre) established HEPOS, the HEllenic POsitioning System, to facilitate the cadastral activities in Greece. The system supports network-based techniques like VRS, FKP and MAC and has already proved its high potential. At the same time, HEPOS modernizes the geodetic infrastructure of the country. The coordinates of the 98 reference stations of the network are determined in ETRF2005. Thus, the geodetic reference frame of HEPOS (HTRS07: Hellenic Terrestrial Reference System 2007) is a realization of ETRS89. A national GPS campaign was carried out and a coordinate transformation model between HTRS07 and the Hellenic Geodetic Reference System of 1987 (HGRS87) was estimated. This report describes these activities.

2 Establishment of HEPOS

2.1 Preparation and Time-plan

The establishment of HEPOS is part of the project "Information and Technology Infrastructure for a modern Cadastre" which is run by KTIMATOLOGIO S.A. The purpose of HEPOS is dual: First, to realize a reference frame that allows the determination of high-precise and homogeneous coordinates and second, to offer an inexpensive and effective way for GPS-surveying.

KTIMATOLOGIO S.A. devoted 18 months preparing the development of HEPOS. The initial phase included the strategic planning, the detailed design of the system, the estimation of an accurate budget and the preparation of the documents for the international tender. Careful preparation proved to be essential for the success of the project; namely the establishment of a well-operating system according to the specifications and concordant with the time-plan and the budget. The time needed for the installation and testing of the system was less than a year. Details on the preparation and the time-plan of the project can be found in other articles (Gianniou, 2008a).

The services of HEPOS are available to the contractors of KTIMATOLOGIO S.A. (production of orthophoto-maps) since February 2008. Besides the cadastral activities, HEPOS can also be used by any professional for various geodetic applications. In March 2009, KTIMATOLOGIO S.A. made HEPOS available to the dealers of geodetic equipment to prepare the wide use of the system. The objective was to let them familiarize themselves with HEPOS and discover its full potential. Furthermore, before making the system widely available, KTIMATOLOGIO S.A. decided to develop an official model for the coordinate transformation between the reference system of HEPOS and the national system HGRS87. As described in section 5, this model has been published and HEPOS is widely available since May 2009.

2.2 Site selection

One of the most demanding tasks of the project was the selection of suitable sites for the installation of the reference stations (RS). Successful site selection is based on the fulfilment of numerous requirements like satellite visibility, good signal reception, safety and stability of installation etc. In countries with rough terrain, like Greece, the desired satellite visibility for elevation angles above 5 degrees cannot be easily achieved. To overcome this issue, a GIS application was developed which allows the computation of satellite visibility at a particular location for a given elevation mask. At potential sites, where obstacles at 5 degrees could hardly be avoided, the visibility was checked for higher values, like 7 or 10 degrees. In difficult areas, obstacles at these elevation values were accepted, provided that they affect a limited part of the horizon, e.g. the case depicted in Figure 1.

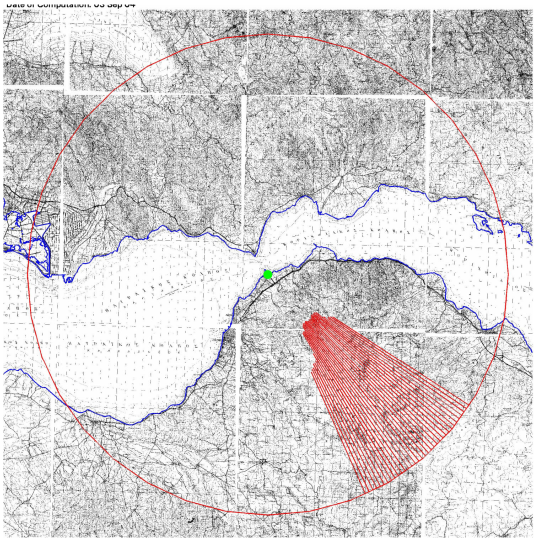

Fig. 1 Estimated visibility for elevation angles above 7 degrees at the site of RS 013A.

Following this procedure, KTIMATOLOGIO S.A. determined the pre-selected sites for the installation of the reference stations. The pre-selection of sites proved to be quite accurate, since there was little change between the candidate and final locations of the reference stations.

2.3 Architecture of HEPOS

HEPOS consists of 98 reference stations distributed throughout Greece. The locations of the stations are depicted in Figure 2; the connections between stations denote the areas where network solutions are available. As can be seen, the 78 RSs located in the mainland and nearby islands and the 9 RSs on Crete form two distinct areas where network solutions are available. The 11 RSs that are sited on the islands of Eastern Aegean Sea can hardly be used for network solutions because of a) their distribution and b) the long distances between them (more than 70 Km). Hence, they are treated as single RSs.

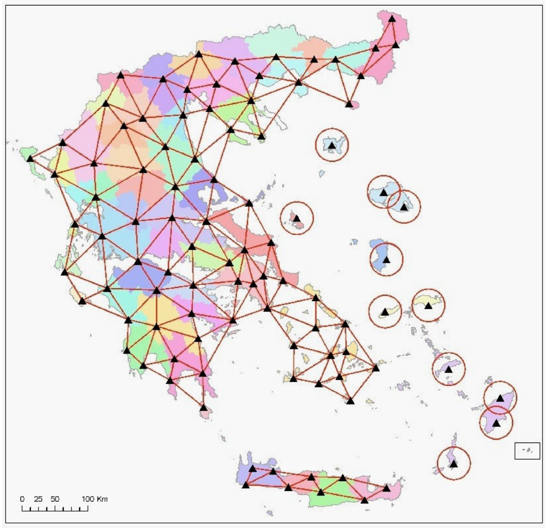

Fig. 2 The 98 reference stations of HEPOS.

All reference stations are equipped with Trimble NetRS receivers and Zephyr Geodetic antennas with spherical domes (Figure 3). The main connections of the stations to the control centre are realized by ADSL lines in a MPLS VPN network. For every RS there is also a backup GSM connection. The fact that the main and backup lines are based on different infrastructures eliminates the possibility of both connections failing at the same time. Every device at a RS is powered via a Network Power Switch. This feature enables the administrators to remotely reboot every device of the RS, which in many cases is sufficient to resolve malfunctions.

The Control Centre of HEPOS is situated at the headquarters of KTIMATOLOGIO S.A. in Athens. The network software used is Trimble GPSNet. One of the 98 reference stations is installed at the control centre. The data from this station are directly fed into the system, having, practically, zero latency. Thus, the relative delays of the data from the other RSs with respect to the RS at the control centre are very close to the absolute values (Gianniou et al., 2009). Moreover, the RS at the control centre densifies the network in the metropolitan area of Athens. More details on the architecture of HEPOS can be found in *Gianniou* (2008a).

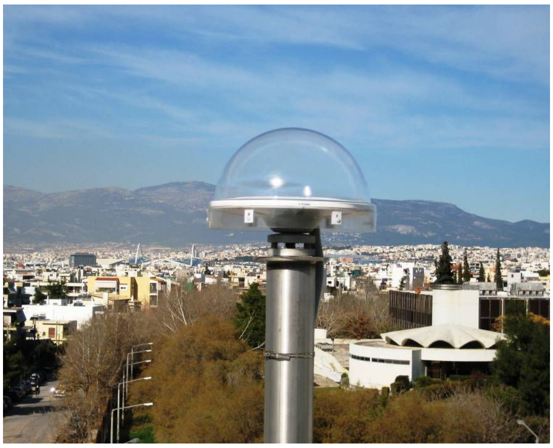

Fig. 3 A typical reference station of HEPOS.

2.4 Services of HEPOS

HEPOS supports all common GPS-techniques for post-processing and real-time surveying. In particular, for network-based positioning the techniques of VRS, FKP and MAC are supported. For post-processing applications, RINEX and Compact RINEX files are provided for RS and VRS at observation intervals of 1, 2, 5, 10, 15, 20, 30 or 60 sec. The supported techniques for real-time applications as well as the respective formats are given in table 1. HEPOS supports both GPRS and GSM connections.

Mode	Technique	Format
DGPS	Single-Base	RTCM 2.3
	Network	RTCM 2.3
RTK	Single-Base	RTCM 2.3
	Network (VRS)	CMR+
	Network (FKP)	RTCM SAPOS
	Network (VRS)	RTCM 2.3
	Network (VRS)	RTCM 3.0
	Network (MAC)	RTCM 3.1

Table 1. Real-time services offered by HEPOS.

HEPOS is operating for more than a year and is used for various applications. Some initial tests regarding the system performance can be found in *Gianniou et al.* (2009).

3 Realization of ETRS89 in Greece

The coordinate system of HEPOS is called HTRS07 (Hellenic Terrestrial Reference System 2007) and it is a realization of ETRS89. HTRS07 is realized by the coordinates of the RSs of HEPOS. These coordinates were computed by processing 14 days of continuous observations of the RSs using the BERNESE software. The coordinates are expressed in ETRF2005, which was the current frame at the time of computations. The reference epoch is 2007.5, which represents the mean time of the national GPS campaign used for the computation of the transformation model between HTRS07 and the national reference system HGRS87 (Hellenic Geodetic Reference System 1987). A detailed description of HTRS07 can be found in *Katsampalos et al.* (2009).

4 National GPS Campaign

HTRS07 was defined and realized considering that it should replace the national reference system HGRS87 in the near future. In any case, a transformation model between HTRS07 and HGRS87 had to be established. For this reason, a GPS campaign has been carried out to estimate the ETRS’89-coordinates of trigonometric points of the national network and, hence, to compute the transformation model.

Approximately 2470 trigonometric points have been measured during this campaign. These points are evenly distributed all over Greece and correspond to about 10% of the total number of the national network’s trigonometric points. The measured points are shown in Figure 4. The measurements were carried out during 2007, in less than 6 months.

According to the specifications, the sampling interval was 15 seconds, the elevation mask 15 degrees and the minimum observation time was 1 hour. The 1-hour minimum duration had to be extended under poor DOP or difficult signal reception conditions, due to e.g. obstacles or electromagnetic interferences. It is considered that - under normal conditions - this observation time is enough for achieving 1-2 cm accuracy horizontally and slightly lower accuracy in the vertical position. These levels of accuracy are satisfactory when measuring a classical triangulation network, where the heights have been mainly determined using trigonometric leveling techniques. To ensure the lowest possible noise in the observations, the specifications required the use of modern GPS receiver models. The contractor used 12 Trimble 5700-5800 receivers. The use of receivers of the same architecture and antennas of the same kind was for the benefit of precision, as unmodelled differential antenna phase-centre effects have been eliminated.

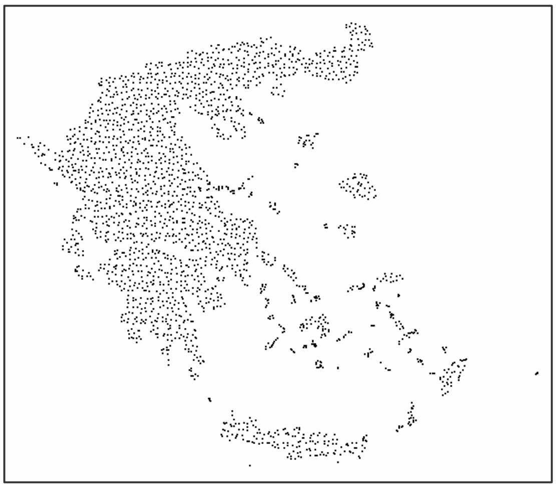

Fig. 4 The 2470 trigonometric points measured during the national GPS-campaign.

For reasons that had to do with the requirements of other cadastral projects, the campaign had to take place before the establishment of HEPOS. Therefore, existing points have been used as reference stations. The coordinates of these reference stations were computed using EUREF-EPN stations in Greece. Every point has been measured from at least two reference stations and the baseline length was limited to approximately 40 Km. This computation process was carried out by the Department of Geodesy and Surveying at the Aristotle University of Thessaloniki, Greece under a research collaboration. The processing of the baselines from the reference stations to the trigonometric points has been done by the contractor. All baselines have been processed using IGS precise orbits.

5 Coordinate Transformation model

5.1 Requirements of the model

The basic requirements for the transformation model to be adopted were:

- allow bidirectional transformation
- ensure minimum residuals
- capability to be implemented in commercial products like office-software and RTK receivers.

A key issue for choosing the most appropriate mathematical model was the homogeneity of HGRS87. The internal consistency of the trigonometric network could be easily assessed by means of the residuals of a nation-wide 7-parameter Helmert trans-formation. The residuals are shown in Figure 5. The maximum values reach about 2.5 m. The behavior of the residuals is typical for trigonometric networks that have been established by means of conventional geodetic triangulations. Similar residuals have been revealed in many other European countries (Cai (2000), Kasser and Breton (2003), Greaves and Cruddace (2001)).

5.2 Transformation model

The transformation model is based on the combined use of a 7-parameter 3D similarity transformation and a correction surface that is realized by two correction grids (for Easting and Northing). Details on the transformation model can be found in *Katsampalos et al.* (2009).

5.3 Implementation of the model

The developed transformation model can be used by the users in two different ways:

- by means of a software that is freely available at the web-site of HEPOS (www.hepos.gr)
- by means of implementations of the model in commercial GNSS-software for office and field applications.

The freely available software is useful for users whose GPS equipment does not support the transformation model or for non-GPS users who need to transform coordinates. However, the majority of the HEPOS users will benefit by the implementations of the model in commercial products. Half a year after the publication of the detailed transformation algorithm, the first GNSS manufacturers have already implemented the model.

5.4 Geoid model

In order to facilitate the determination of orthometric heights by means of HEPOS measurements, KTIMATOLOGIO S.A. plans to develop a nation-wide geoid model in collaboration with the Aristotle University of Thessaloniki (AUTH) and the National Technical University of Athens (NTUA). As a first step, the data from the national GPS campaign were used in order to evaluate EGM08 in Greece (Kotsakis et al, 2008).

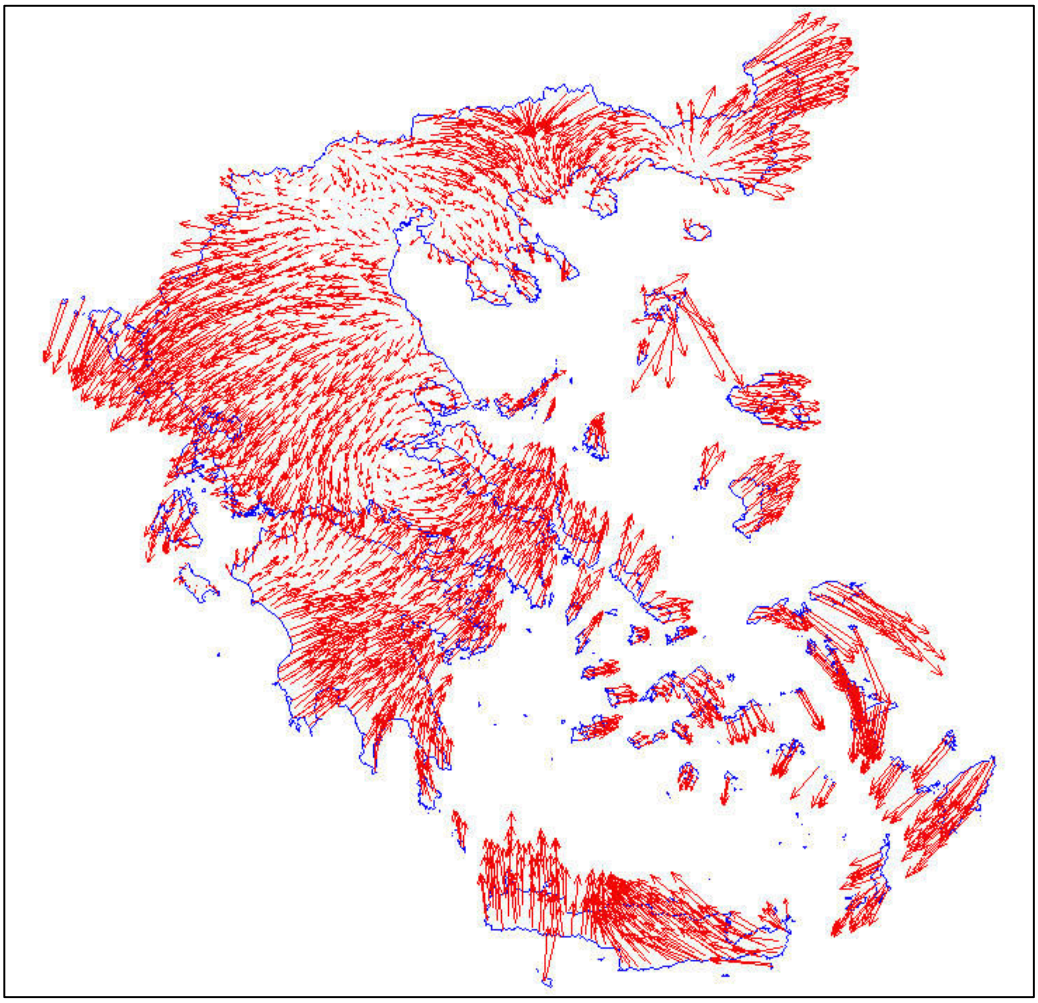

Fig. 5 The Residuals of the nation-wide 7-parameter similarity transformation between ETRS89 (HRTS07) and the national Greek Coordinate Reference System (HGRS87). Maximum residuals are in the order of 2.5 m.

Acknowledgments

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