National Report of Greece to EUREF 2010

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1 Introduction

The HEllenic POsitioning System (HEPOS) is an RTK network consisting of 98 reference stations that cover the entire area of Greece. HEPOS was established in 2007 by KTIMATOLOGIO S.A. (Hellenic Cadastre). At the first stage, the system was solely used by the contractors of KTIMATOLOGIO S.A. for the production of coordinates in HTRS07 (Hellenic Terrestrial Reference System 2007), which is the geodetic reference system of HEPOS and a realization of ETRS89 in Greece. After the issue of an official coordinate transformation model, connecting HTRS07 to the national system GGRS87 (Greek Geodetic Reference System 1987, also known as HGRS87 or EGSA87), KTIMATOLOGIO S.A. made HEPOS services available to the broad surveying community.

The first part of this report describes the usage of HEPOS during the first year of operation, i.e. from 5/2009 to 5/2010. Statistical data about the increase of users, the usage of the different services and the spatial distribution of the requests are given.

The second part of the report deals with the EUREF GR 2007 campaign, i.e. the computation of the HEPOS network in ETRS89 using EPN stations. The results of this campaign have been recently validated by the Technical Working Group (TWG) of EUREF.

The last part of the report describes the computation of a geometric geoid model to be used with HEPOS. This model is currently under development by KTIMATOLOGIO S.A.

2 Usage of HEPOS

HEPOS supports post-processing as well as real-time applications using both single-base and network-based techniques (VRS, FKP, MAC). Details about the system can be found in *Gianniou* (2008) and *Gianniou* (2009).

2.1 Number of Users

In November 2008 KTIMATOLOGIO S.A. published the transformation model for the bidirectional transformation between HTRS07 and GGRS87, encouraging the GNSS manufacturers to incorporate the model into their geodetic receivers and software. A few months later, most of the major geodetic GNSS firms had already implemented the model in their products. Furthermore, KTIMATOLOGIO S.A. made available a standalone software that implements the official transformation model. In this way, all GNSS users were able to exploit HEPOS for determining coordinates in the national system.

On 25/5/2009 the services of HEPOS were made available to the surveying community. Figure 1 depicts the steady increment of the issued user licences. As can be seen, the number of user licences is continuously increasing. Until May 2010, after one year of operation, 430 user licenses had been issued, corresponding to 275 different users. These numbers meet our expectations and are quite satisfactory.

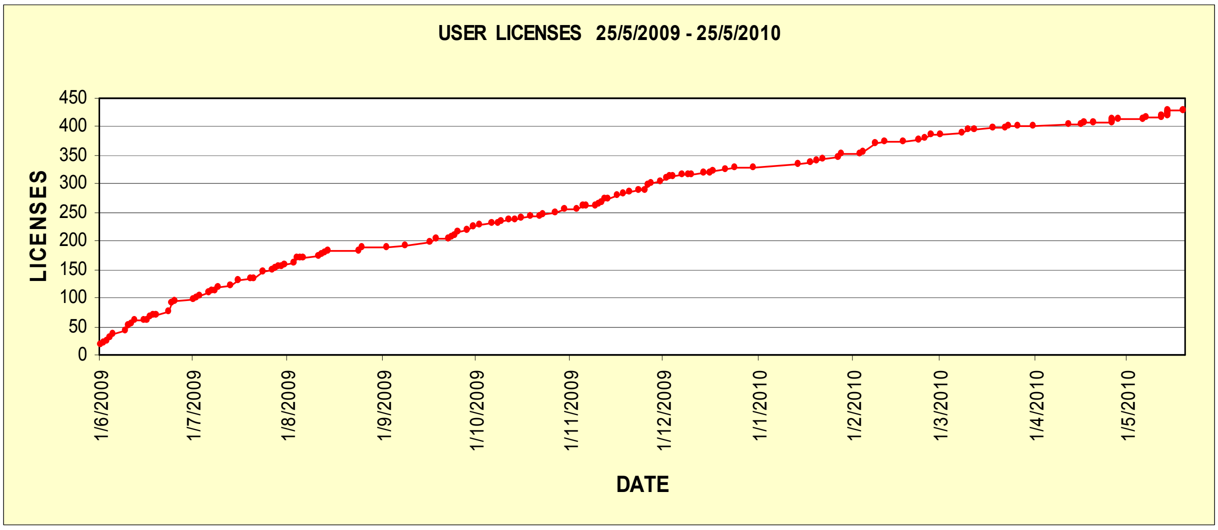

Fig. 1 User licences issued within the first year of operation of HEPOS

2.2 User preferences regarding RTK techniques and format

HEPOS supports multiple RTK techniques, namely single-base, VRS, FKP and MAC. In addition, the HEPOS users can choose among various formats, i.e. RTCM 2.3, RTCM 3.0, RTCM 3.1, RTCM SAPOS and CMR+. Figure 2 gives the statistics from the first year of operation of HEPOS. The left part of Figure 2 refers to the preferences regarding the RTK technique. As can be seen, more than 50% percent of the RTK connections requested VRS corrections. The relatively high percentage of the Single-Base connections is mainly due to the 11 Single Reference stations on the islands of east Aegean Sea, which support solely network-based techniques. The right part of Figure 2 shows the statistics regarding the format. We can see that all offered formats are being used and mostly RTCM 3.0. This was expected because the data rate of RTCM 3.0 is quite low and this reduces the telecommunication cost of the GRPS connections.

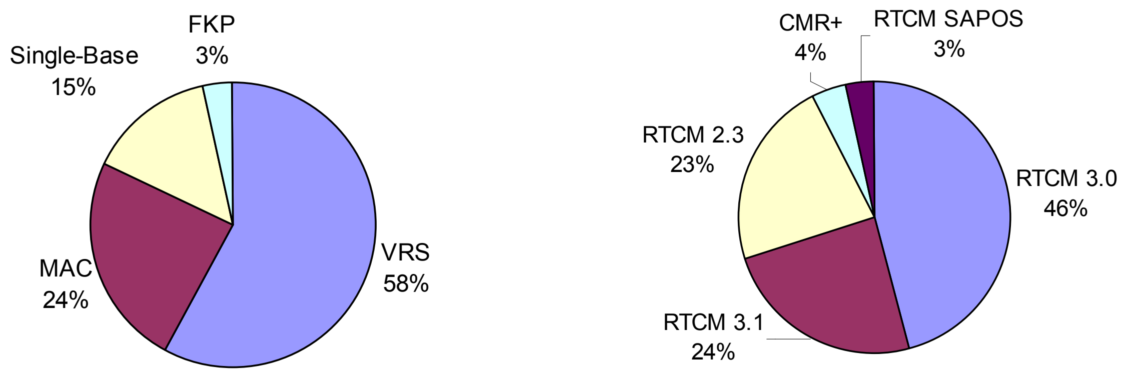

Fig. 2 Usage of different RTK techniques and formats. Statistics from the first year of operation of HEPOS.

Regarding the post-processing applications 51% of the ordered RINEX files were VRS RINEX and 49% RINEX from physical reference stations. With respect to the observation interval, 57% of the requests were for interval of 5, 10 or 15 seconds.

2.3 Spatial distribution of usage

Besides the ability to easily produce accurate coordinates in the national coordinate system, another important advantage of HEPOS is its country-wide coverage. Figure 3 shows the locations where HEPOS users made RTK measurements during the first year of operation. It is noted that the areas in central and northern Greece without red dots correspond mostly to mountainous and unpopulated regions. Thus, it can be concluded that the system is being used throughout the country.

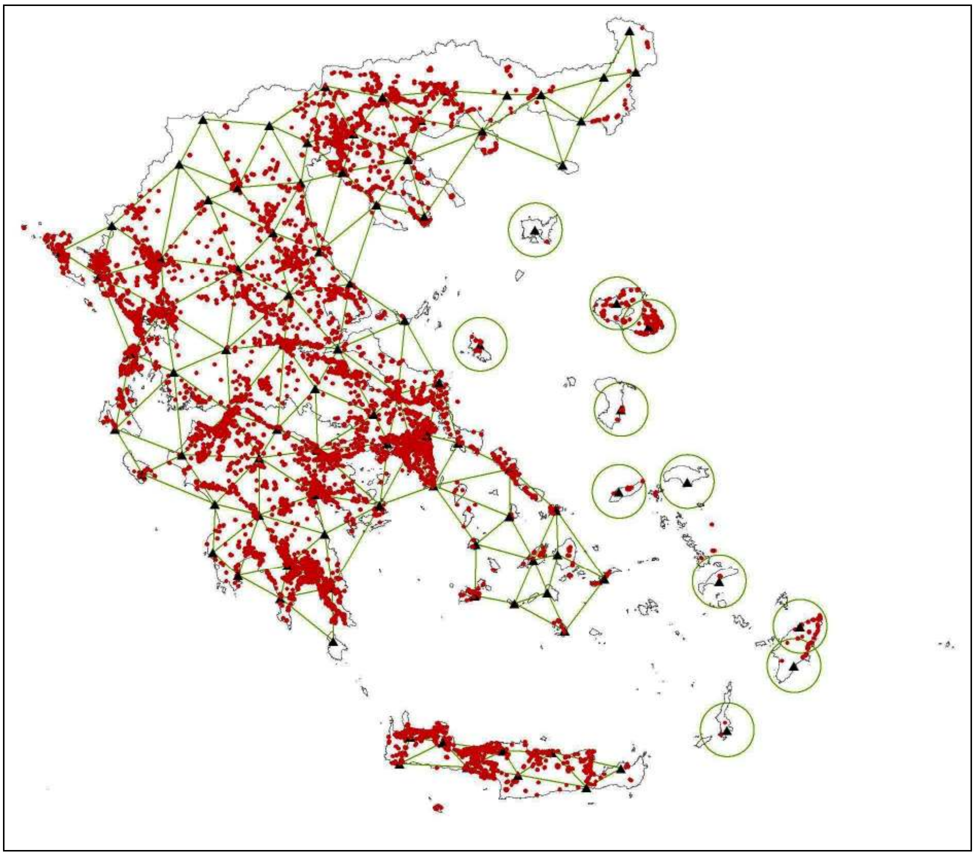

Fig. 3 RTK usage within the first year of operation of HEPOS

3 EUREF GR 2007 Campaign

The geodetic reference system of HEPOS is called HTRS07 (Hellenic Terrestrial Reference System 2007) and is a realization of ETRS89 in Greece. Prof. K. Katsambalos and C. Kotsakis (Aristotle University of Thessaloniki) assisted KTIMATOLOGIO S.A. in the definition of HTRS07 and the computation of a transformation model between HTRS07 and the national system. The coordinates of the HEPOS stations have been computed in HTRS07 using 14 days of continuous observations collected in October 2007. This campaign is called "EUREF GR 2007 Campaign". The processing of the observations was done by IGN-Spain. This is because KTIMATOLOGIO S.A. had procured the establishment of HEPOS as a turn-key solution including the computation of the station coordinates, a task which the contractor (Trimble Europe B.V.) assigned to IGN-Spain.

As HTRS07 is a realization of ETRS89, KTIMATOLOGIO S.A. asked TWG for a validation of the EUREF GR 2007 Campaign. In order to get the HEPOS campaign validated by the TWG, the campaign has been reprocessed following the current EUREF standards, i.e. the "Specifications for reference frame fixing in the analysis of a EUREF GPS campaign, Version 7" (Boucher and Altamimi, 2008) and the "Guidelines for EUREF Densifications ver. 1: 26-05-2009" (Bruyninx et al., 2009).

In the following, a comprehensive description of the campaign and the obtained results are given. A detailed documentation is not in the scope of this report.

3.1 Description of the campaign

A total number of 113 permanent Reference Stations were involved in the densification project, namely the 98 RSs of HEPOS and 14 additional EPN/IGS stations[1]. The locations of the stations are depicted in Figure 4. Station TRAB was not used in the recent computation because it is meanwhile classified as EPN class B station. According to the current EUREF standards, it should not be used as fiducial point in densification projects. The remaining 13 EPN stations have been used to constrain the solution in ITRF2005. These stations were selected because they surround the densification area and are in reasonable distances from the HEPOS stations. As can be seen in Figure 4, three of the fiducial stations (AUT1, NOA1 and TUC2) are situated in the densification zone.

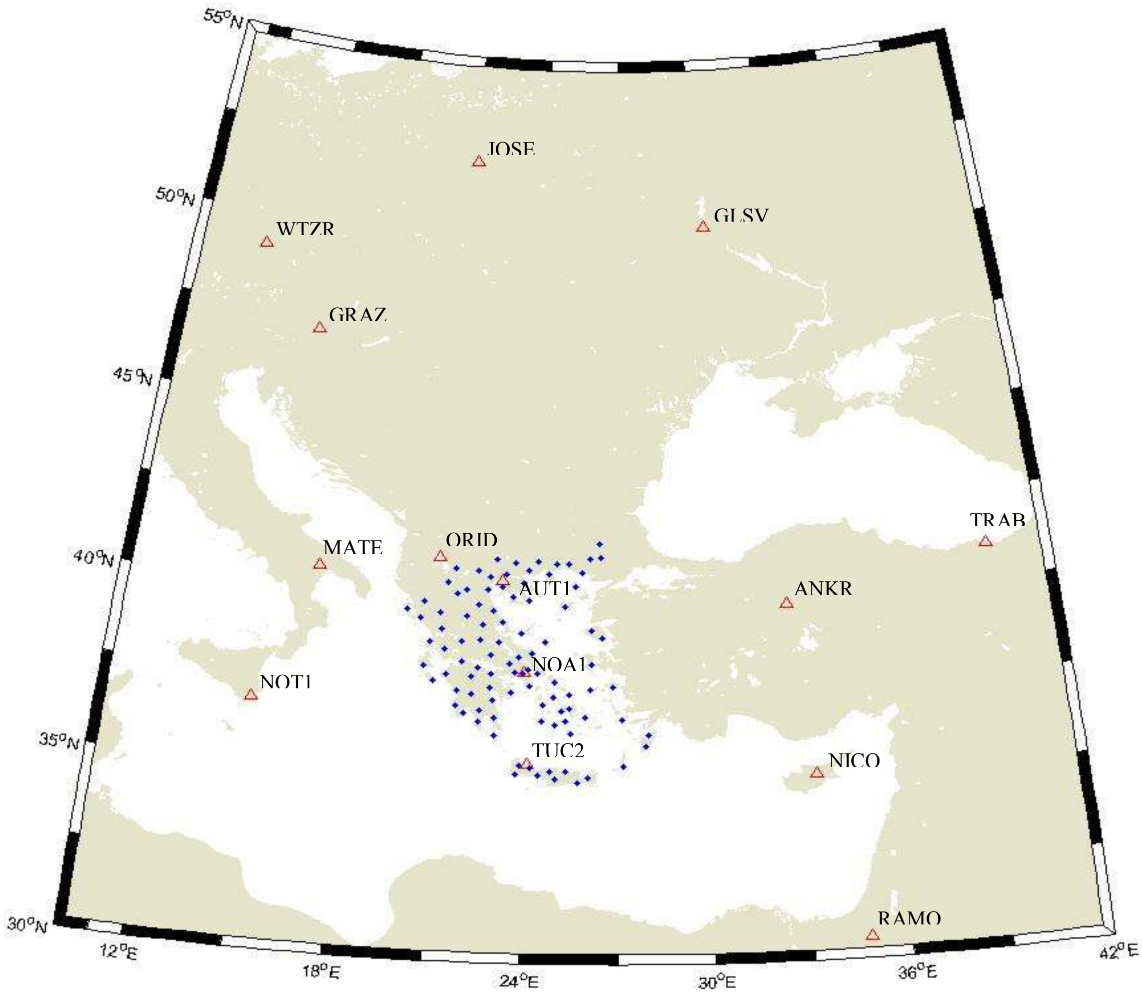

Figure 4: Map of the stations involved in the project.

[1] Station 018 had to be relocated a few meters away form its initial position. So, both initial (018A) and final (018B) locations are involved.

3.2 Processing parameters

The network has been processed using Bernese version 5.0. The main processing parameters are given in the following.

Orbits and ERPs: IGS final orbit and ERP information have been used.

Datum definition: The solution has been obtained using minimal constraints through three translation conditions on the network's barycentre. This strategy has the advantage that small errors in the coordinates of a reference site do neither distort the network geometry nor significantly degrade the datum definition per se (Dach et al., 2007).

Pre-processing: Phase pre-processing in a baseline by baseline mode using triple differences. In most cases cycle slips are fixed looking simultaneously at different linear combinations of L1 and L2. If a cycle slip cannot be fixed reliably, bad data points are removed or new ambiguities are set up.

Basic Observable: Carrier phase, code only used for receiver clock synchronization.

Elevation angle cutoff: 3 degrees and elevation dependent weighting with cos-z.

Data sampling: For ambiguity resolution: 30 s, for final processing: 180 s.

Modeled observable: Double-differences, ionosphere-free linear combination.

Ground antenna phase center calibrations: Absolute antenna phase center corrections based on IGS05 model (exceptions for stations with individual absolute calibrations listed in epnc_05.atx) considering antenna radome codes. If antenna/radome pair has no available calibrations, the corresponding values for the radome code "NONE" are used.

Satellite antenna phase center calibrations: Absolute antenna phase centre corrections based on IGS05 model calibrations.

Troposphere: Dry-Niell as a-priori model, estimation of zenith delay corrections at 1 hour intervals for each station, using the wet-Niell MF, no a-priori sigmas. Horizontal gradient parameter estimated/day/station (TILTING), no a-priori constraints. Compute daily TRO files with fixed cumulative. Coordinates input from weekly solution.

Ionosphere: Regional ionospheric model calculated. Only used for QIF ambiguity resolution. Not modeled in final solution (ionosphere eliminated by forming the ionosphere-free linear combination of L1 and L2).

Planetary Ephemeris: DE200

Tidal model: Solid earth tidal displacements are modeled according to displacements IERS conventions 1996.

Ocean loading: Using Ocean-Loading-Model computed by H.G.Scherneck, Onsala Space Observatory FES2004 model for each station.

3.3 Processing results

The processing results are quite satisfactory and fulfill the EUREF standards. The repeatability values for North, East and Up are given in Figures 5-7. The estimated ITRF2005 coordinates are compared to the coordinates resulting from the EPN_A_ITRF2005_C1570 solution. Table 1 gives the compared XYZ coordinates of the two solutions and the respective differences. In Table 2 the coordinate differences are given in North, East and Up.

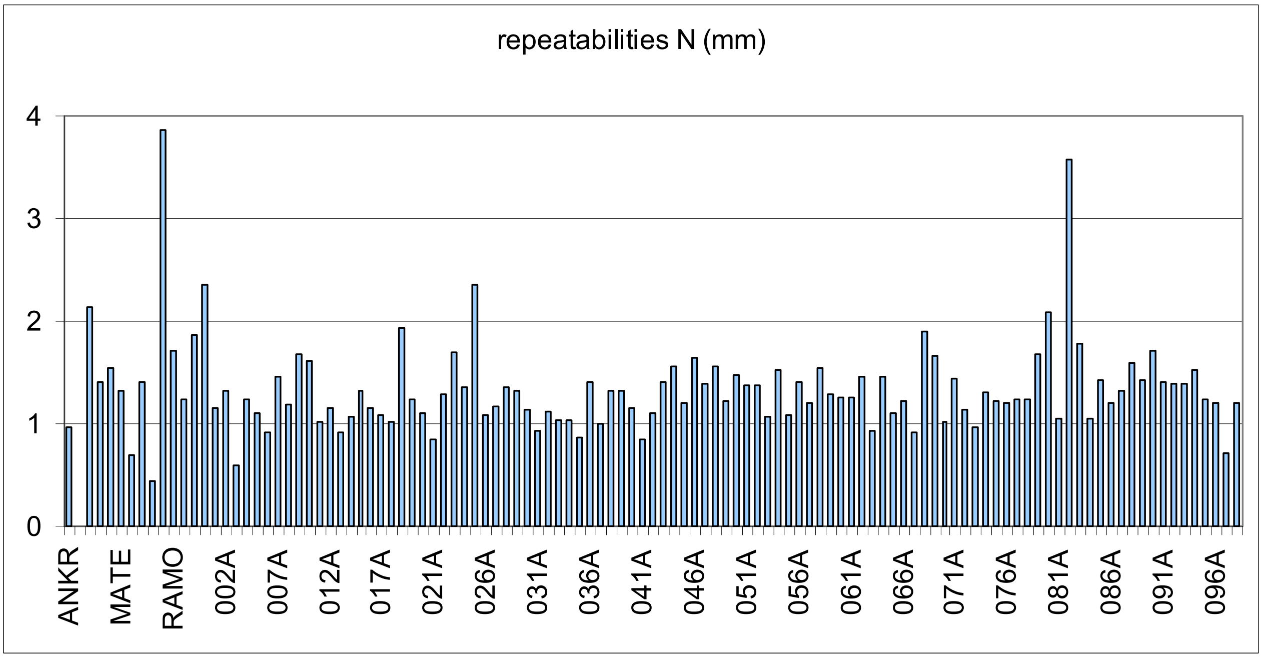

Figure 5: Coordinate repeatability values (North).

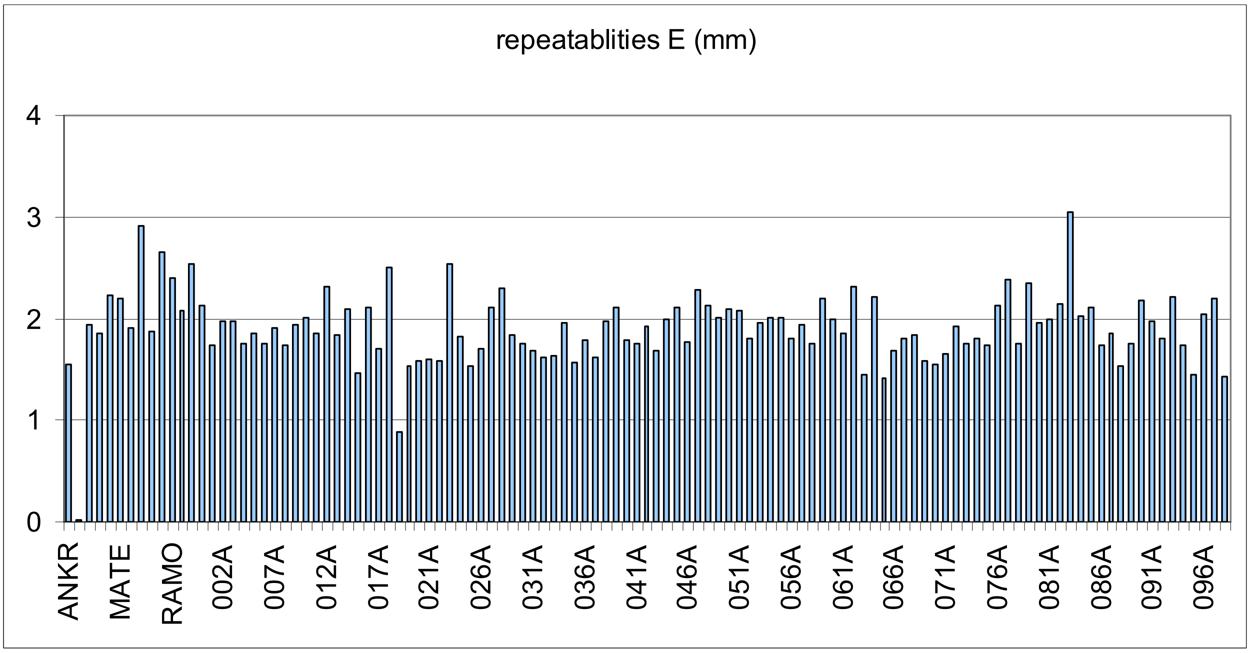

Figure 6: Coordinate repeatability values (East).

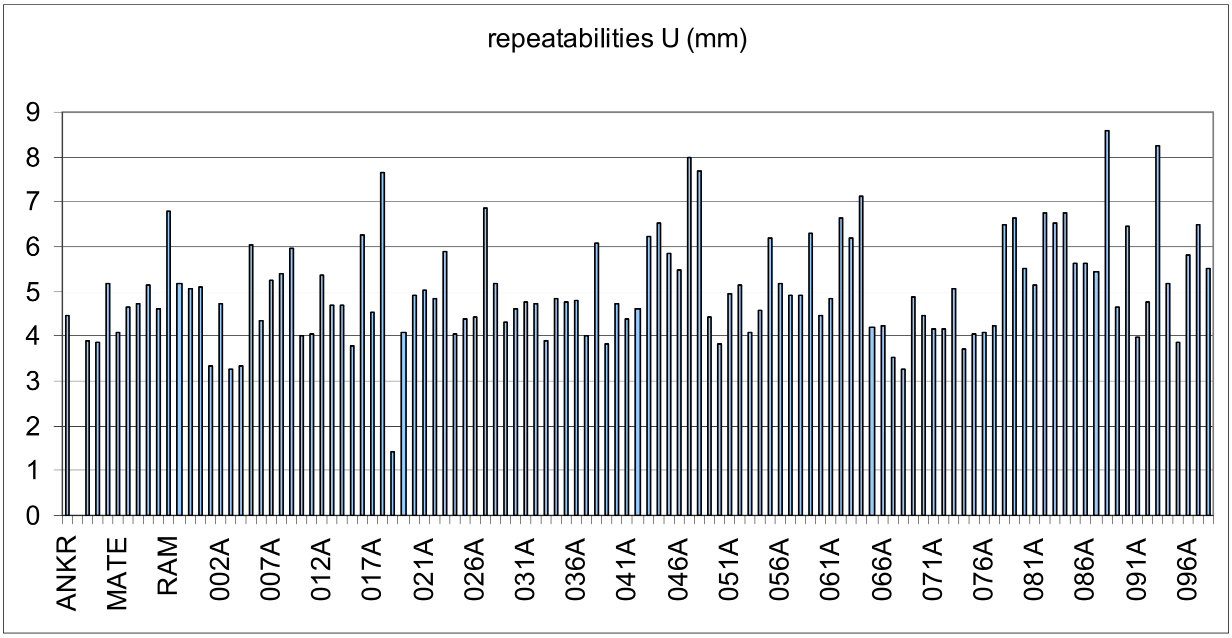

Figure 7: Coordinate repeatability values (Up).

Table 1: Comparison of ITRF2005/2007.83 coordinates in XYZ
(estimated coordinates vs. EUREF C1570).

	Estimated coordinates			EUREF C1570 ITRF05/2007.83			DIFFERENCES [m]			
Stn	X	Y	Z	X	Y	Z	DX	DY	DZ	DS
ANKR	4121948.5190	2652187.9031	4069023.7896	4121948.5164	2652187.9013	4069023.7908	-0.0026	-0.0018	0.0012	0.0034
AUT1	4466283.3895	1896166.9358	4126096.7960	4466283.3908	1896166.9387	4126096.7979	0.0013	0.0029	0.0019	0.0038
GLSV	3512888.8987	2068979.9191	4888903.2319	3512888.9032	2068979.9199	4888903.2378	0.0045	0.0008	0.0059	0.0074
GRAZ	4194423.7717	1162702.7435	4647245.4442	4194423.7757	1162702.7468	4647245.4466	0.0040	0.0033	0.0024	0.0057
JOZE	3664940.1135	1409153.9062	5009571.4134	3664940.1180	1409153.9083	5009571.4167	0.0045	0.0021	0.0033	0.0060
MATE	4641949.5074	1393045.4823	4133287.5068	4641949.5052	1393045.4825	4133287.5049	-0.0022	0.0002	-0.0019	0.0029
NICO	4359415.6675	2874117.1034	3650777.8562	4359415.6634	2874117.1027	3650777.8608	-0.0041	-0.0007	0.0046	0.0062
NOA1	4599641.9428	2034827.3433	3909890.6185	4599641.9385	2034827.3413	3909890.6134	-0.0043	-0.0020	-0.0051	0.0070
NOT1	4934546.1794	1321265.0583	3806456.1636	4934546.1764	1321265.0598	3806456.1615	-0.0030	0.0015	-0.0022	0.0040
ORID	4498451.6483	1708267.0397	4173591.8938	4498451.6498	1708267.0412	4173591.8919	0.0015	0.0015	-0.0019	0.0029
RAMO	4514721.7960	3133507.8799	3228024.7546	4514721.7866	3133507.8771	3228024.7522	-0.0094	-0.0028	-0.0024	0.0101
TUC2	4744543.7863	2119411.9239	3686258.8173	4744543.7836	2119411.9237	3686258.8139	-0.0027	-0.0002	-0.0034	0.0044
WTZR	4075580.5095	931853.8435	4801568.1658	4075580.5139	931853.8465	4801568.1681	0.0044	0.0030	0.0023	0.0058

Table 2: Comparison of ITRF2005/2007.83 coordinates in North East Up (estimated coordinates vs. EUREF C1570).

Stn	North (mm)	East (mm)	Up (mm)
ANKR	2.8	-0.2	-1.8
AUT1	-0.2	2.0	3.0
GLSV	0.4	-1.8	7.2
GRAZ	-2.0	2.0	5.0
JOZE	-2.0	0.2	5.8
MATE	-0.2	0.6	-2.8
NICO	5.8	1.6	-0.6
NOT1	-0.4	2.2	-3.4
NOA1	-1.0	0.0	-6.8
ORID	-2.8	0.6	0.2
RAMO	2.6	3.0	-9.2
TUC2	-1.2	1.0	-4.0
WTZR	-2.4	1.8	5.0

The results of the EUREF GR 2007 campaign were accepted (together with the results of EUREF Czech 2009 and EUREF IE/UK 2009 campaigns) as Class B standard by the EUREF TWG. The respective sets of points are endorsed as "an improvement and extension of ETRS89" (EUREF, 2010).

4 Geometric geoid model

HEPOS allows the estimation of homogeneous and highly accurate coordinates. Furthermore, the use of the official transformation model ensures that for any point, all users will determine practically the same horizontal GGRS87 coordinates irrespective of the – physical or virtual – reference station that is being used each time. Besides the horizontal coordinates, the users are also highly interested in the determination of orthometric heights. The coordinates of the HEPOS station are expressed in HTRS07. Thus, a geoid model is needed, in order to transform ellipsoidal to orthometric heights.

KTIMATOLOGIO S.A. plans a nation-wide campaign in order to conduct the necessary gravity measurements and complementary high precision spirit leveling. These data will be used, together with all other available data (e.g. tide gauges data), for the computation of a combined geoid model. The whole procedure is expected to take about two years. Meanwhile, KTIMATOLOGIO S.A. will make available a geoid model that will be based purely on geometric information, i.e. ellipsoidal and orthometric height on common points (Figure 8). This geoid model is currently under development.

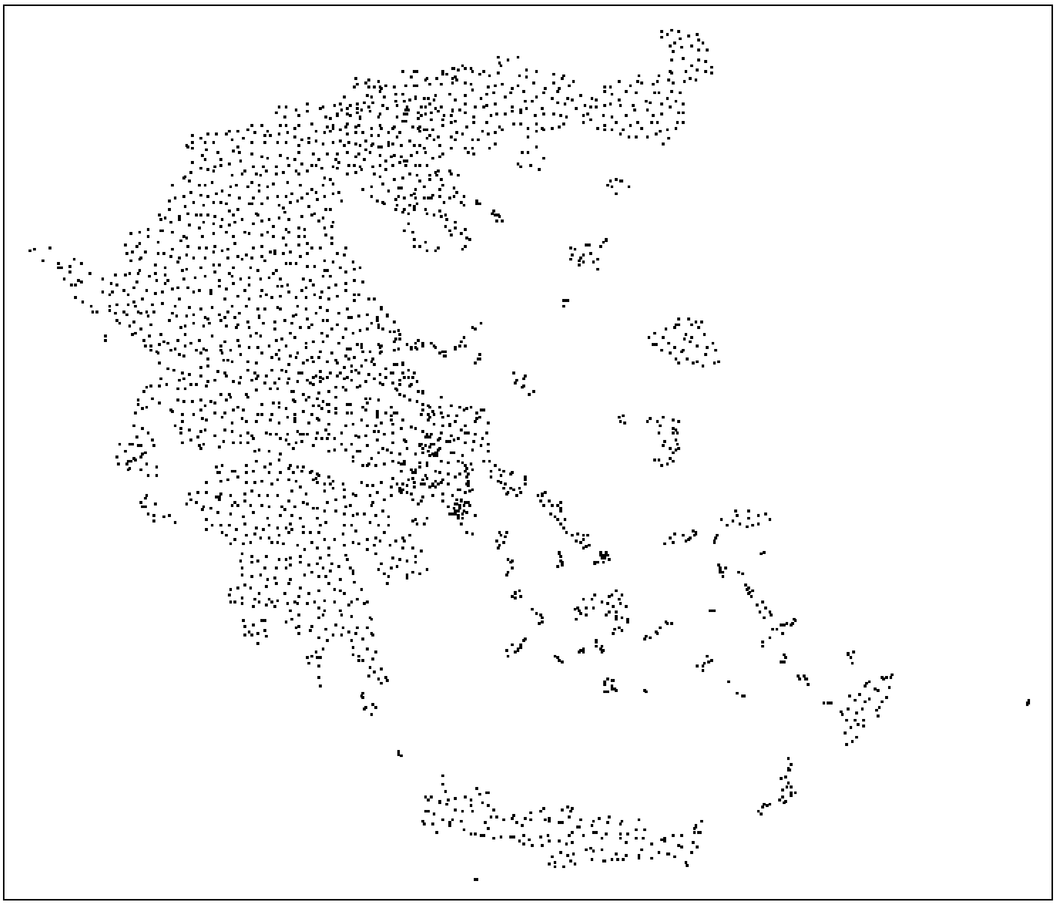

Fig. 8 Points to be used for the computation of the geometric geoid model.

Acknowledgments

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