National Report of Greece to EUREF 2013

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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:

- Development of an approach for mitigating the influence of the tectonic movements on both the operation of HEPOS and the production of coordinates in the national coordinate system (GGRS87: Greek Geodetic Reference System 1987)
- Evaluation of HEPOS transformation model
- Evaluation of the geoid model computed by KTIMATOLOGIO S.A. to be used with HEPOS
- Monitoring of the ionospheric activity over Greece.

This national report describes the aforementioned activities.

2 HEPOS network

This chapter describes operational aspects of the HEPOS network, i.e. the usage of the system, certain hardware maintenance that took place in 2012. In addition this chapter outlines the development of an approach that mitigates the influence of the tectonic movements on the operation of HEPOS and ensures stability in the production of coordinates in the national coordinate reference system GGRS87.

2.1 Usage of the system

Figure 1 depicts the increment in the number of the issued user licenses. As can be seen, the number is steadily increasing. Until May 2013, after four years of operation, 1240 user licenses had been issued. These numbers meet our expectations and are quite satisfactory.

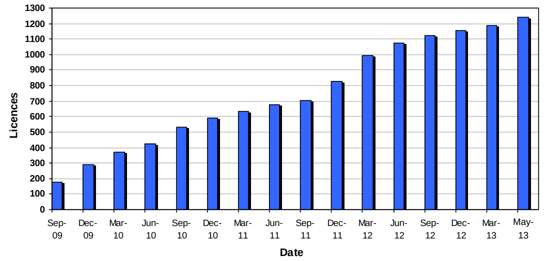

Fig. 1 User licenses issued within the first four years of operation of HEPOS.

Figure 2 shows the locations where HEPOS users made RTK measurements during the first four years of operation of the network. This geographic distribution shows that HEPOS is being used all over the country. Moreover, there is a considerable increment of the connection time to the system. Figure 3 depicts the RTK connection time for each month during the first four years of operation of HEPOS. As can be seen, values reaching 120000 minutes per month have been reached.

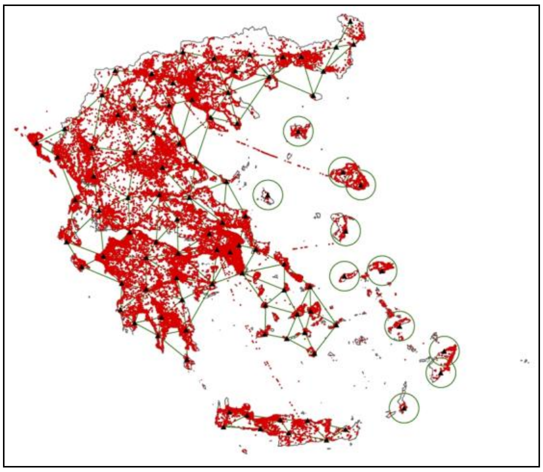

Fig. 2 RTK usage (spatial distribution) within the first four years of operation of HEPOS.

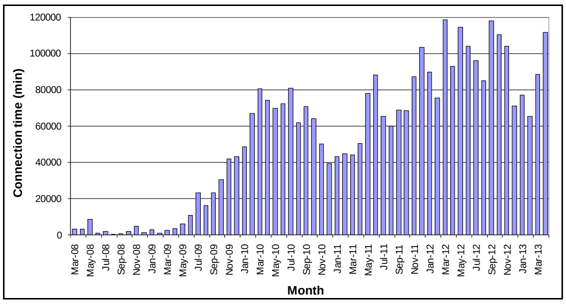

Fig. 3 RTK usage (connection time) within the first four years of operation of HEPOS.

2.2 Hardware maintenance

In order to keep the availability and reliability of HEPOS services on the highest level possible, the following hardware components at the reference stations have been preventively replaced in 2012:
- All (97) battery packs for the UPS systems
- All (97) routers (the replaced routers remained on site as backup).

2.3 Maintenance of Reference Frame

Greece lies in the boundary region between two major tectonic plates, the Eurasian and the African plate. Furthermore, the southern part of Greece lies on the Aegean plate, a smaller plate which is moving southwest (Papazachos et al., 2000). Thus, the deformation field in Greece is not homogeneous throughout the country. For KTIMATOLOGIO S.A. this constitutes a major challenge both for the maintenance of the ETRS89 coordinates in Greece and the operation of HEPOS.

In order to monitor the coordinates of the HEPOS stations, the complete HEPOS network is being adjusted on a monthly basis. These computations have revealed a detailed deformation field for the entire country (Gianniou, 2010). Two major parts of the country can be distinguished: the northern part with ETRS89 velocities in the order of 1 cm/y and the southern part with velocities in the order of 3 cm/y. From a strictly scientific point of view, the maintenance of the reference frame would require the regular update (e.g. every 1-2 years) of the stations coordinates, leading to a dynamic datum, or the use of a semi-dynamic datum where the coordinates are being backdated (or updated) to refer to a certain reference epoch (see e.g. Blick et al. 2009). However, such solutions would dramatically complicate the production and use of coordinates in the daily practice.

Taking into account these implications and considering the specific deformation pattern of the country, an alternate approach is currently followed in HEPOS. Based on the tectonic velocities of the stations, two sub-networks have been formed. The two sub-networks are depicted in Fig. 4 as well as their overlap zone. Splitting the network in two parts ensures internal consistency in each part, which is managed by a separate network processor. Thus, a coordinate update can be avoided. The first experiences of using this approach are quite encouraging. A detailed description and discussion of the aforementioned approach can be found in *Gianniou et al.* (2013).

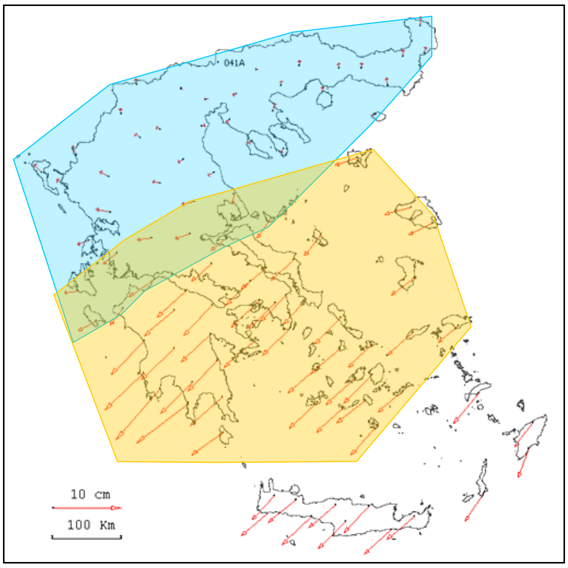

Fig. 4 The two sub-networks considered in HEPOS in order to account for the inhomogeneity of the velocity field (Crete has always been treated as a separate network for the network-RTK computations).

3 Evaluation of HEPOS transformation models

In 2011 KTIMAOLOGIO S.A. started an in-house project for the evaluation of:
- the transformation model between HTRS07 (the geodetic reference system of HEPOS) and GGRS87 (the national Coordinate Reference System) (Katsampalos et al. 2010).
- the HEPOS geoid model used for height transformations (Gianniou, 2011).

Details about the project as well as some first results can be found in *Gianniou et al.* (2012b). The project is in progress and new points have enriched the data sample, which now comprises 727 points.

3.1 Transformation HTRS07-GGRS87

For the time being, 700 benchmarks have been used for the evaluation of the transformation model between HTRS07 and GGRS87. Their locations are depicted in Fig. 5. The computed horizontal errors are given in Fig. 6. The corresponding statistics are summarized in Table 1. Big errors are mainly due to problematic points, rather than model deficiencies, as explained in detail in *Gianniou et al.* (2012b).

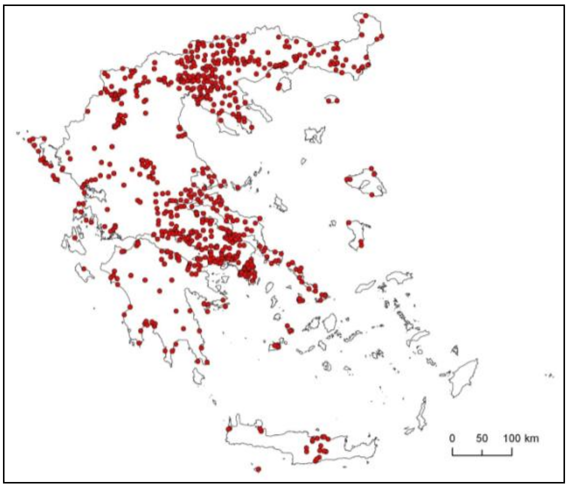

Fig. 5 The 700 benchmarks used for the evaluation of the transformation model HTRS07-GGRS87.

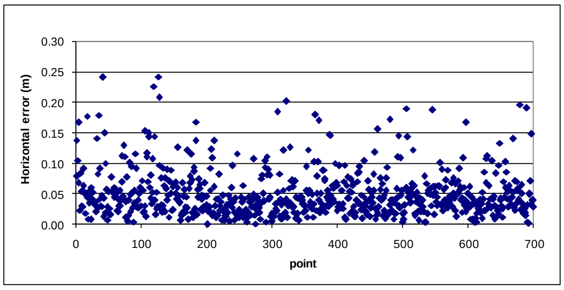

Fig. 6 The horizontal errors of the 700 points used for the evaluation of the transformation model HTRS07-GGRS87.

Table 1 Statistics (m) of the horizontal errors of the 700 points used for the evaluation of the transformation model HTRS07-GGRS87.

Min	Max	Percentiles			
		50th	90th	95th	99th
0.000	0.242	0.041	0.097	0.133	0.191

3.2 HEPOS Geoid model

For the evaluation of the HEPOS geoid model 360 benchmarks have been used. Their locations are shown in Fig. 7. The computed errors in the orthometric heights are given in Fig. 8 and the corresponding statistics are summarized in Table 2. Big errors are mostly related to problematic benchmarks and local phenomena like subsidence etc. (Gianniou et al., 2012b). For an extended evaluation of the Hellenic vertical network the reader is referred to *Kotsakis et al.* (2009) and *Kotsakis et al.* (2010).

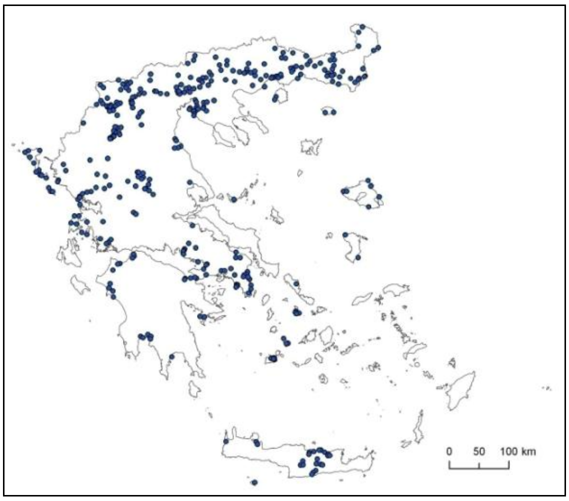

Fig. 7 The 360 benchmarks used for the evaluation of HEPOS geoid model.

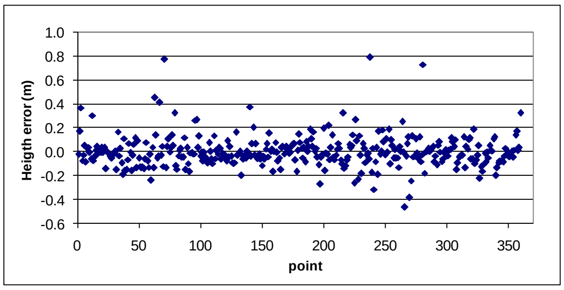

Fig. 8 The vertical errors of the 360 points used for the evaluation of the HEPOS geoid model.

Table 2 Statistics (m) of the height errors of the 360 points used for the evaluation of HEPOS geoid model.

Min	Max	Percentiles			
		50th	90th	95th	99th
0.000	0.793	0.056	0.176	0.260	0.455

4 Monitoring of the ionospheric activity

Since 2011, HEPOS RTK-users often need longer initialization times than in the previous years due to the ionospheric activity which is increasing as we are approaching the maximum of the 24th Solar Cycle. The relationship between the ionospheric activity and the initialization time has been investigated extensively in the framework of operation of HEPOS. For this purpose RTK measurements and post-processing results have been analyzed as described in detail in *Gianniou and Mitropoulou* (2012). In the above mentioned investigations the I_{95} index (Wanninger, 1999) has been used as a measure of the ionospheric activity. The I_{95} index of HEPOS proved to describe efficiently the ionospheric conditions that affect RTK performance.

Due to its practical importance the index I_{95} is being carefully monitored as part of the operation of HEPOS, particularly during periods of high solar activity. In late 2011, exceptionally high I_{95} values have been observed. The highest I_{95} values were recorded on 19 and 20 of October 2011, reaching 48 and 49.6 respectively. Figure 9 gives the hourly I_{95} values for Crete on October 19, 2011. Figure 10 shows the TEC map over Europe for the same day (13:30-13:45 UTC). The maximum VTEC value for the area shown in the map reached 55 TECU.

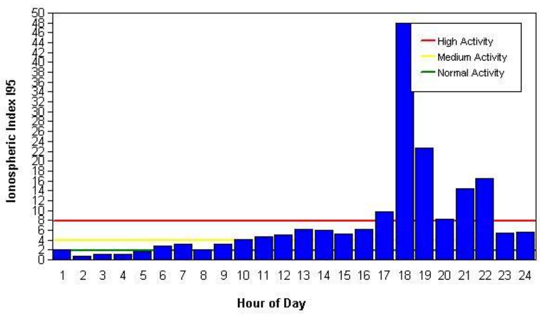

Fig. 9 I_{95} values for the area of Crete on 19.10.2011.

Initially, the maximum of the 24th Solar Cycle was expected in 2013. However, up to the time of writing (May 2013) the ionospheric activity in 2013 did not exceed the levels reached in 2011 and 2012. This can be seen in Figure 11 that gives the I_{95} index (daily maximum) for the time period Jan. 2010 to May 2013 computed by HEPOS for the area of Crete. So far, the monitored ionospheric activity in 2013 seems to be lower than expected. This is in agreement with the latest results of the observation of the sunspot number, according to which the current predictions and observations make Cycle 24 the smallest sunspot cycle since Cycle 14 (1906) (http://solarscience.msfc.nasa.gov/predict.shtml; accessed May 15, 2013). The ionospheric activity will continue to be monitored in HEPOS as it is a crucial factor for the performance of any RTK-network.

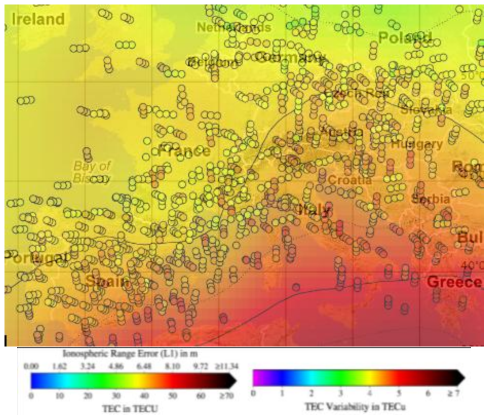

Fig. 10 TEC map over Europe for 19.10.2011 (13:30-13:45 UTC) (*source: Royal Observatory of Belgium*).

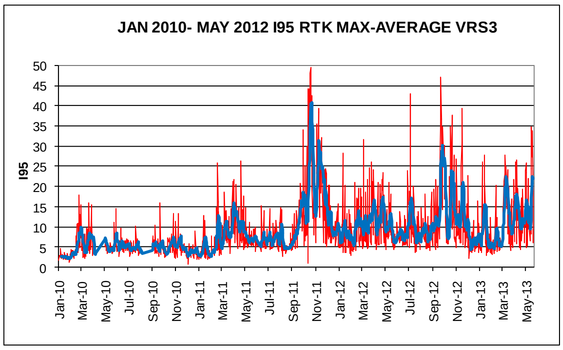

Fig. 11 I_{95} index computed by HEPOS for the area of Crete: Red line corresponds to daily maximum and blue line to smoothed values (using moving average filter with 1 week span).

Acknowledgments

For the evaluation of the HEPOS transformation model and geoid model measurements on 721 benchmarks of the national triangulation network were used: 484 originate from KTIMATOLOGIO S.A. projects and 237 from academic institutions that collaborate with KTIMATOLOGIO S.A., namely AUTH (Aristotle University of Thessaloniki), NTUA (National Technical University of Athens), TEI of Athens (Technological Educational Institute of Athens) and TUC (Technical University of Crete).

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