National Report of Greece to EUREF 2014

M. Gianniou, D. Mastoris, E. Mitropoulou
National Cadastre and Mapping Agency S.A.
Mesogion Ave. 288, 15562 Athens, Greece

1. Introduction

During the last months the main activities undertaken in Greece related to EUREF include:

- Reorganization of the Agencies responsible for National Cadastre, Geodesy and Cartography in Greece
- Aspects related to the maintenance of HEPOS, i.e. overcoming electromagnetic interferences at a station and permanent displacements caused by the Cephalonia Earthquakes in 2014
- Contribution to the EUREF Working Group on Deformation Models
- Monitoring of the ionospheric activity over Greece.

This national report describes the aforementioned activities.

2. Reorganization of Agencies

KTIMATOLOGIO S.A. was a state-owned company responsible for the establishment and operation of the Hellenic Cadastre. Moreover, the company had established and was operating HEPOS, the Hellenic Positioning System. Since its establishment KTIMATOLOGIO S.A. was acting in collaboration with HEMCO, the Hellenic Mapping and Cadastre Organization.

In June 2013, HEMCO was merged with KTIMATOLOGIO S.A. which was then renamed to National Cadastre and Mapping Agency S.A. (NCMA S.A.). Thus, HEMCO's geodetic and cartographic responsibilities have been transferred to NCMA S.A. The rest of HEMCO's responsibilities have been taken over by the Ministry of Environment, Energy and Climate Change.

3. Maintenance of HEPOS

3.1 Dealing with electromagnetic interferences

On July 7, 2012 the satellite tracking performance at station 030A (Andravida, NW Peloponnese, see Fig. 1) became suddenly problematic. Tracking of L2P signals of satellites at elevation angles below about 30^{o} became almost impossible. Furthermore, the Signal to Noise Ratio (SNR) on L1 and L2 sank roughly 10 dB. This low SNR values clearly indicate bad signal quality, which was verified by a big number of arisen unresolved cycle slips. The impact of such a problematic tracking on the network performance is obvious. RTK operations require dual frequency observations of at least 5-6 satellites available both at the reference station and the rover. During observation windows with less than five satellites above approximately 30^{o}, no sufficient data were available to perform RTK measurements. Besides Single-Base RTK this problem affected also network-RTK in the area around the station 030A.

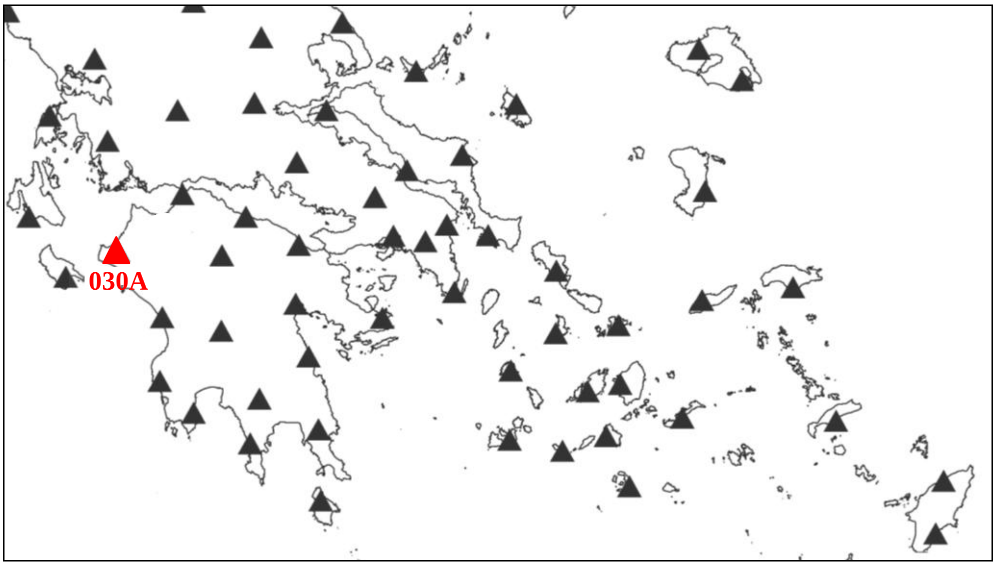

Fig. 1. Location of station 030A in NW Peloponnese.

An example of problematic tracking conditions at station 030A is shown in Fig. 2. As one can see, from a total of nine visible satellites, L2P tracking was possible only for four of them (at elevations from 28.8^o to 73.7^o). On the contrary, for the remaining five satellites (at elevations between 11.0^o and 35.4^o) the receiver, a Trimble NetRS, could not track L2P.

Another important fact is the ability of the receiver to track L2C, even for the satellites for which L2P was not tracked. In the example shown in Fig. 2 L2C is being tracked for satellites PRN 31, 24 and 5, for which L2P tracking was not possible. This was always the case for all satellites transmitting L2C, i.e. Block IIR-M and Block II-F satellites. These results confirm the superiority of L2C signal over the legacy L2P(Y) signal in challenging environments, which is well documented in the literature (e.g. Fontana et al., 2001).

System	PRN	Elev [°]	Az [°]	SnrCA [dB]	SnrP2 [dB]	CA	L2C
GPS	31	35.4	310.0	42	0	4449	4449
GPS	21	16.7	198.0	35	0	855	0
GPS	24	11.7	162.3	34	0	23332	23332
GPS	14	12.5	250.5	38	0	11026	0
GPS	29	68.5	288.1	47	25	9999	9999
GPS	25	73.7	32.3	47	23	13660	13660
GPS	12	40.2	96.8	45	19	20553	20553
GPS	2	28.8	49.1	42	16	13204	0
GPS	5	11.0	97.3	38	0	484	484

12:31:31 Ιούλιος 29 2013 GMT Standard Time

Fig. 2. Example of problematic tracking conditions at station 030A due to the interference: The superiority of L2C over P2 is obvious.

The reduced SNR levels and the ability to track L2C while L2P(Y) tracking was not possible, were indicating that the problem was caused by RF interferences. Some first tests with GPS rover receivers showed that the problem became less intense when moving away from the station. This was indicating that the source of interference was close to the station. In Fig. 3 the area around station 030A is shown. The defective device that was causing the interference has been located by the Hellenic Telecommunications and Post Commission using portable radiomonitoring device with directional antenna. The interference was caused by a malfunctioning TV antenna amplifier installed on a building next to the station (Fig. 4). The central frequency of the spurious signal was 1568 MHz, which is within the tracking bandwidth for L1 (1575.42 MHz). This explains the reduced SNR level in L1 as well as the cycle slips in L1. In general, problems in tracking L2P(Y) due to strong interferences in L1 can be expected under Anti-Spoofing, particularly for receivers using cross-correlation techniques to get access to L2P(Y). If L1 tracking is seriously degraded, low SNR and cycle slips may be expected also in L2, as it was the case for station 030A.

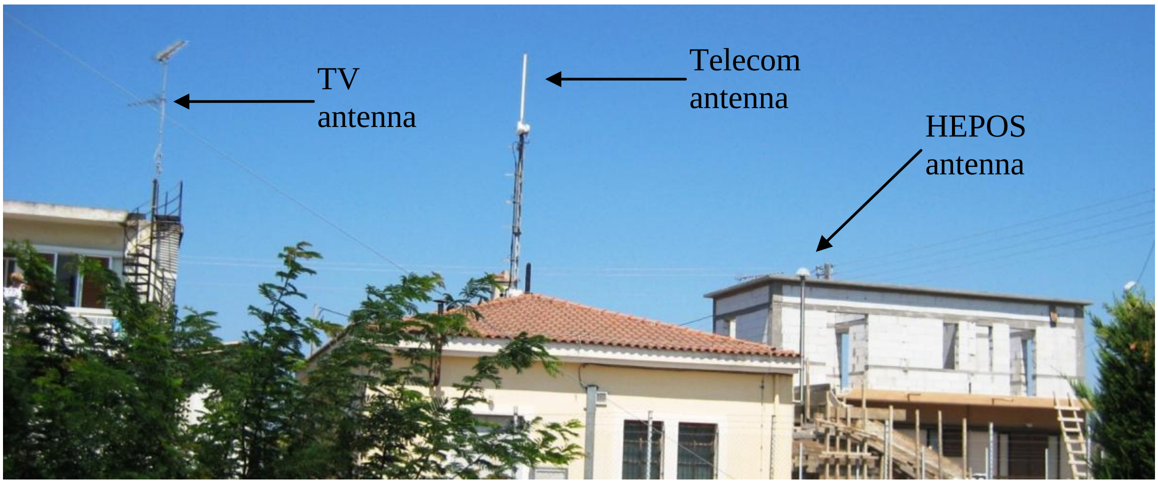

Fig. 3. Station 030A and surrounding area.

Fig. 4. Locating the source of interference (malfunctioning TV antenna amplifier) using portable radiomonitoring device.

After removing the interfering amplifier, the normal tracking performance of the receiver was restored. In Fig. 5a the SNR of satellite PRN 15 is given for the day when the interference has been removed. An improvement of 10 dB at the time of removing the interference (09:07 Local Time) is obvious. One can also see that up to 08:48, L2P could not be tracked at all, although the satellite was visible. Fig. 5b gives the L1 and L2 SNR values on the next day, where the same satellite could be tracked on both frequencies as soon as it became visible and with considerably higher SNR.

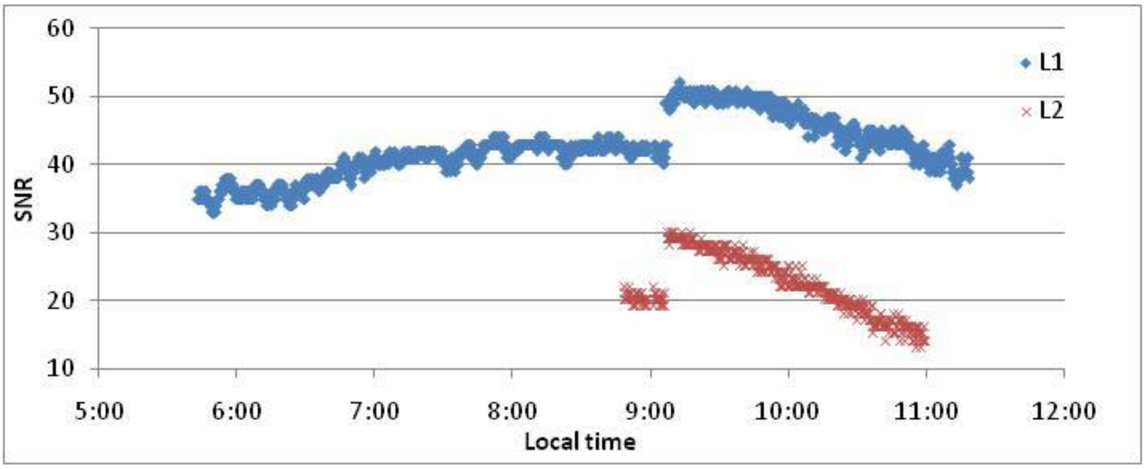

Fig. 5a. SNR of satellite PRN 15 on the day of removing the interference.

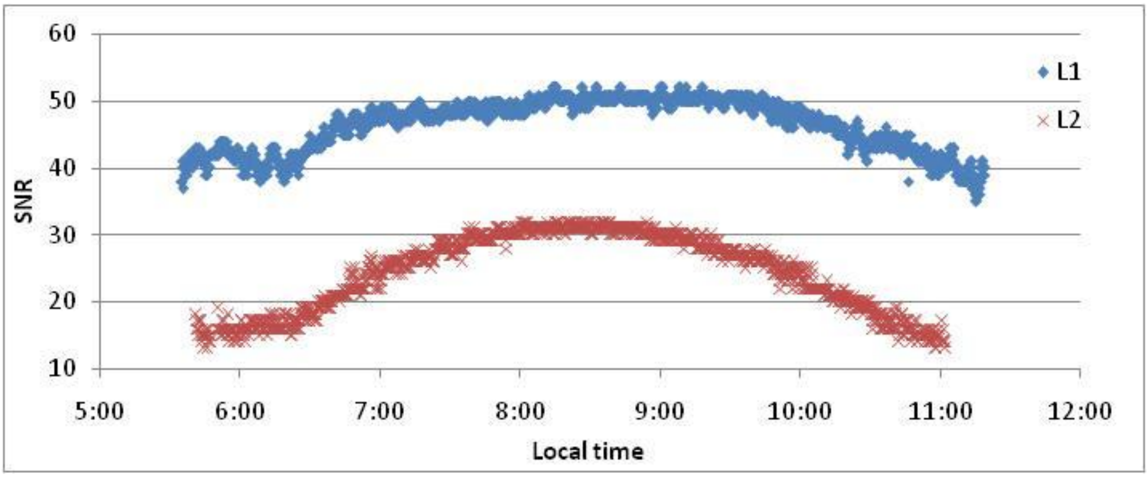

Fig. 5b. SNR of satellite PRN 15 on the next day.

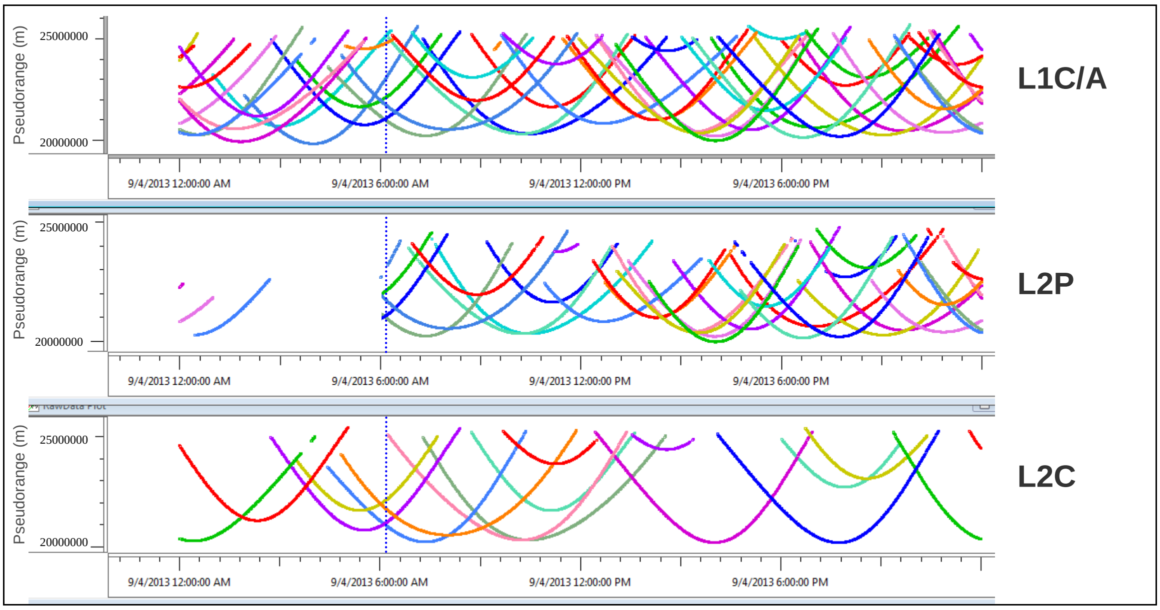

Fig. 6. Pseudorange observations (L1C/A, L2P and L2C) on the day of removing the interference (the vertical dashed line at 6:07 GPS time indicates the moment of removing the interference).

3.2 Displacements caused by the Cephalonia 2014 earthquakes

On 26.1.2014 and on 3.2.2014 two strong earthquakes ruptured the western Cephalonia Island, Greece. The two events had magnitudes Mw 6.0 and Mw 5.9, respectively (Papadopoulos et al., 2014). In addition. in the evening of January, 26 an earthquake of magnitude Mw 5.3 took place. The epicenters of these events are shown in Fig. 7.

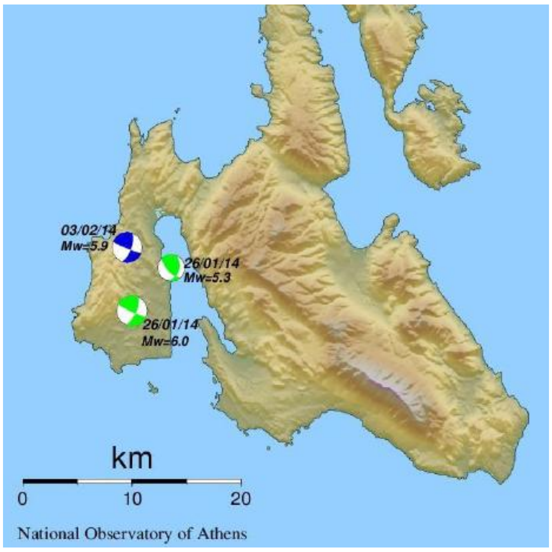

Fig. 7. Epicenters of the biggest earthquakes on Jan. 26 and Feb. 3 2014 (*source: Papadopoulos et al., 2014*).

The above mentioned seismic events mostly affected the western side of the island, the Paliki peninsula. In order to investigate the effects of the seismic activity on HEPOS station 040A located near the airport of Cephalonia, daily solutions have been computed for a period of three weeks. A first analysis of these preliminary solutions yielded considerable permanent displacements of 0.023m (after Jan. 24) and 0.038m after Feb, 3. Both values refer to the position of the station before the earthquakes, i.e. the displacement vector of 0.038m incorporates also the first translation vector of 0.023m. Fig. 8 depicts the location of station 040A as well as the estimated displacements.

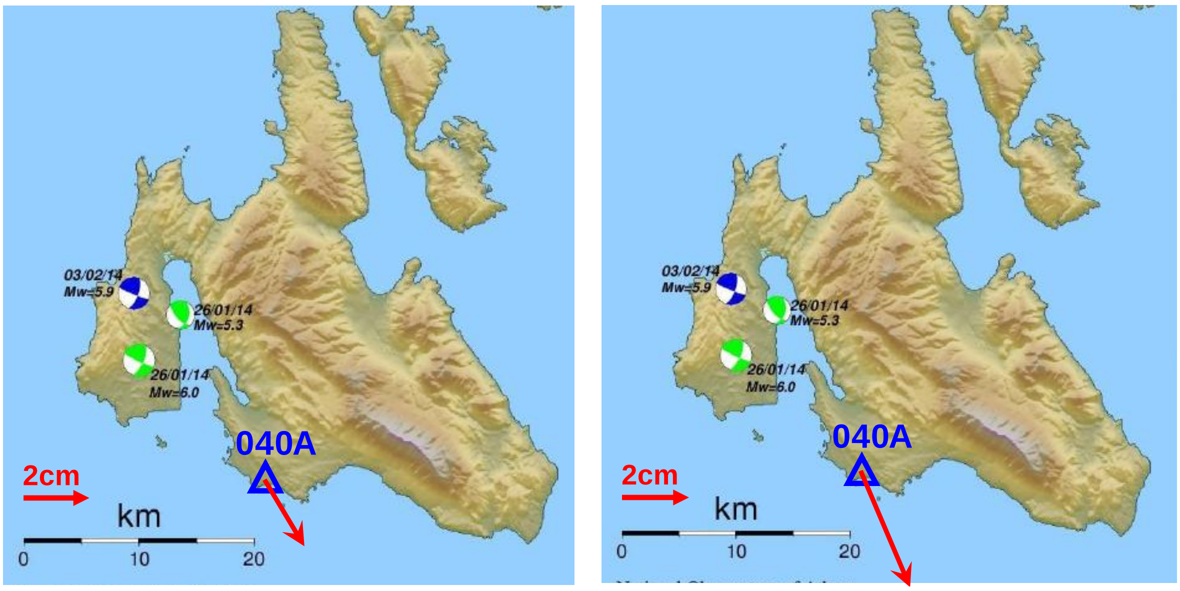

Fig. 8. Estimated displacement (preliminary results) due to the earthquakes of Jan. 26 (left) and due to all earthquakes up to Feb. 4, 2014 (right).

Besides the permanent displacements, also co-seismic displacements have been estimated by processing 1-Hz GPS data using Precise Point Positioning (PPP). Figures 9-11 depict the obtained coordinates for three HEPOS stations that are close to the epicenter of the strong earthquake on 3.2.2014. The dynamic displacements at station 040A in Cephalonia exceed 3cm, whereas at stations 060A (Leykada) and 028A (Zakynthos) the displacements are at the level of 2 cm.

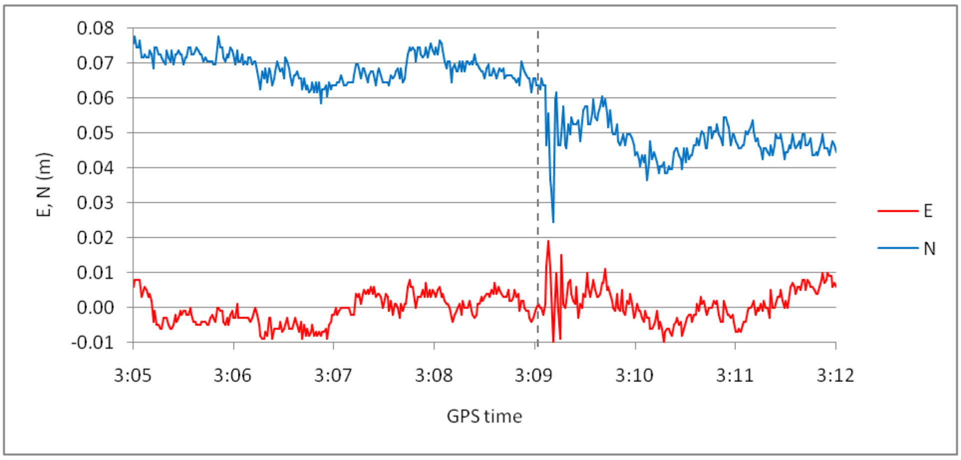

Fig. 9. Co-seismic displacements at HEPOS station 040A in Cephalonia on 3.2.2014 (the vertical dashed line at 3:09 GPS time indicates the moment the EQ stroke).

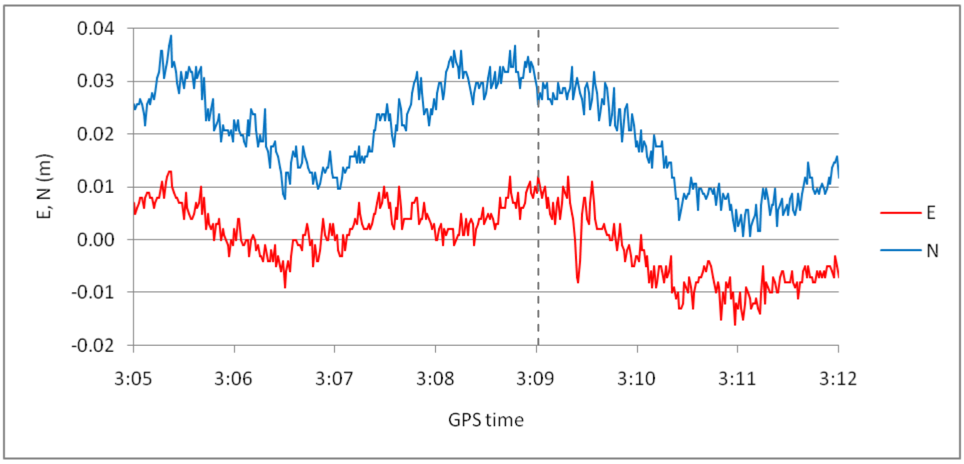

Fig. 10. Co-seismic displacements at HEPOS station 060A in Leykada on 3.2.2014 (the vertical dashed line at 3:09 GPS time indicates the moment the EQ stroke).

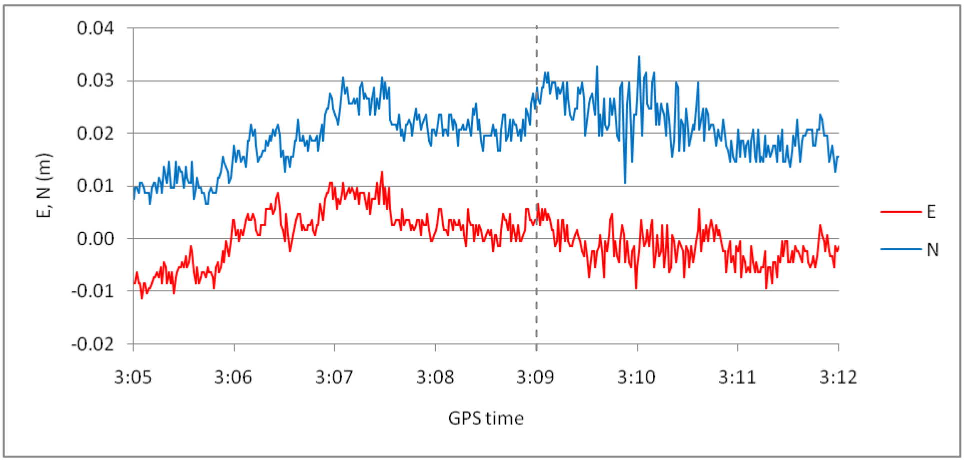

Fig. 11. Co-seismic displacements at HEPOS station 028A in Zakynthos on 3.2.2014 (the vertical dashed line at 3:09 GPS time indicates the moment the EQ stroke).

4. Contribution to the Working Group on Deformation Models

In 2012 EUREF created the working group (WG) on deformation modeling (Bruyninx, 2013). The main objectives of the WG are (Steffen and Lidberg, 2013):

- Evaluation of available GNSS-derived velocity fields
- Inventory and evaluation of available crustal deformation models for Europe or selected parts of it
- Consideration of a deformation model in maintenance and use of national realizations of the ETRS89

The NCMA S.A. is carefully studying for years the tectonic deformations in Greece as they have an immediate effect on the operation of HEPOS (Gianniou, 2010). Thus, for the WG and for the NCMA S.A tectonic deformations are a field of common interest. NCMA S.A. is collaborating with the WG and has made available data from 20 HEPOS stations (Fig. 12), spanning from 2008 to 2010. These stations are of particular importance for the estimation of a European velocity field due to the complex and strong tectonic motions in Greece. The above mentioned stations together with other stations belonging to the GNSS network of the Geodynamic Institute of the National Observatory of Athens will allow a good estimation of the velocity field in the area.

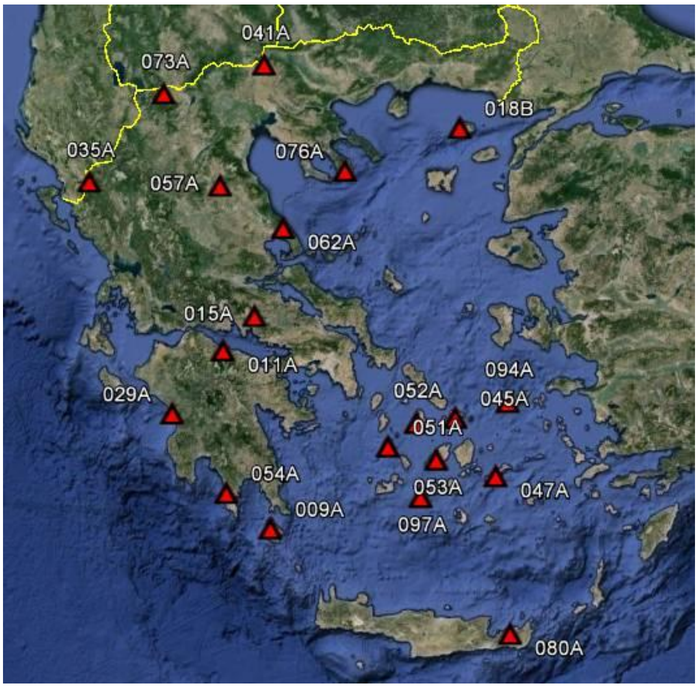

Fig. 12. The 20 HEPOS stations that will be used for the estimation of a velocity field.

5. Monitoring of the ionospheric activity over Greece

During 2011 and 2012 intense ionospheric activity seriously affected RTK applications in Greece, mainly in the Southern part of the country. RTK-users had often needed longer times to obtain fixed solution than in the previous years. Sometimes, initialization could hardly be achieved (Gianniou and Mitropoulou, 2012). As the maximum of the 24th Solar Cycle was (initially) expected in 2013, the ionospheric activity has been continuously monitored at NMCA S.A. in order to support the HEPOS users in the most efficient way. For the monitoring of the ionospheric activity the index I95 is being used. Time-series of daily I95 values are available covering 4.5 years

(January 2010 to May 2014). Analyzing these data some interesting results have been found, which are described in the following.

The ionospheric activity over Greece in 2013 was intense, but at levels comparable to that of 2011 and 2012. So, the expectation of highest solar activity in 2013 was not met. Actually, the high activity in late 2011 was clearly exceeded only in 2014. This can be seen in Fig. 13 which gives the daily maximum I95 value for Crete and for rest of the HEPOS network (mainland and islands). Comparing the period of late 2011 to March of 2014 there is no significant difference with respect to the maximum I95 values. But if we compare the mean levels of the activity in these two periods, there is a major difference. This can clearly be seen in Fig. 14 which gives the mean daily I95 values (smoothed using a moving average filter with a span of 7 days). Undoubtedly, the mean level of ionospheric activity reached its maximum around March 2014. These results are in agreement with the observed sunspot number (see Fig. 15) that reveal a double-peaked Solar Cycle in which the second peak in sunspot number was larger than the first (*http://solarscience.msfc.nasa.gov/predict.shtml*).

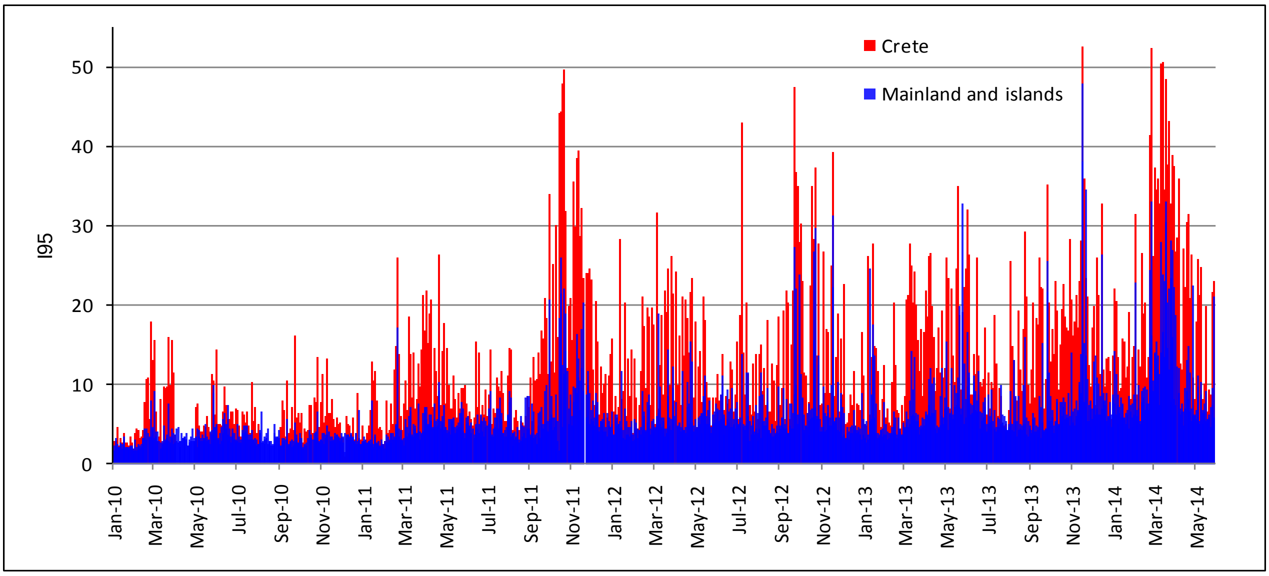

Fig. 13. Maximum daily I95 index estimated from HEPOS.

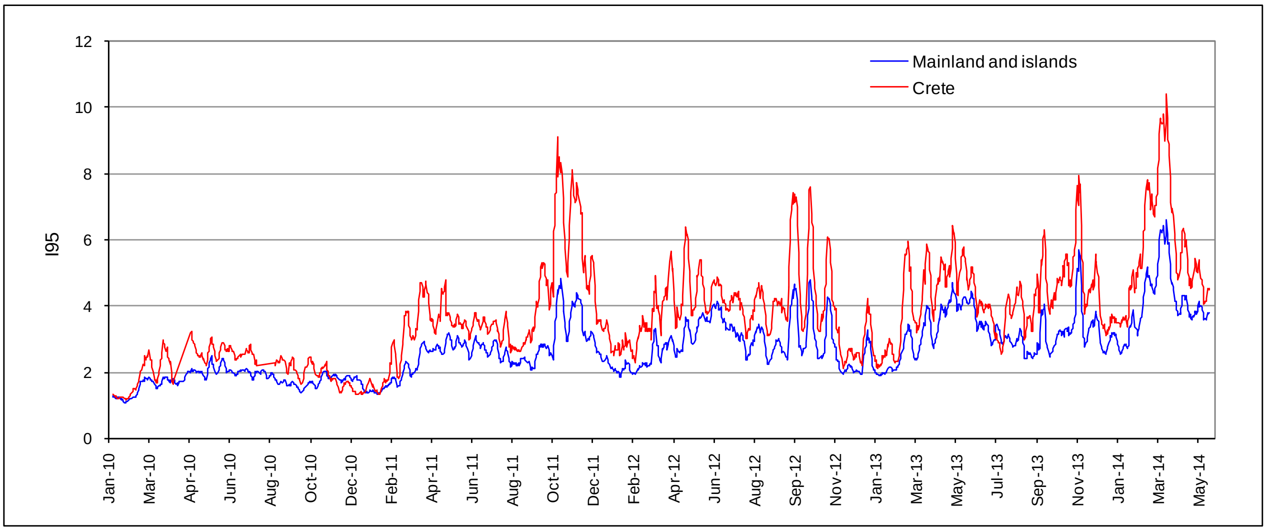

Fig. 14. Mean daily I95 index estimated from HEPOS.

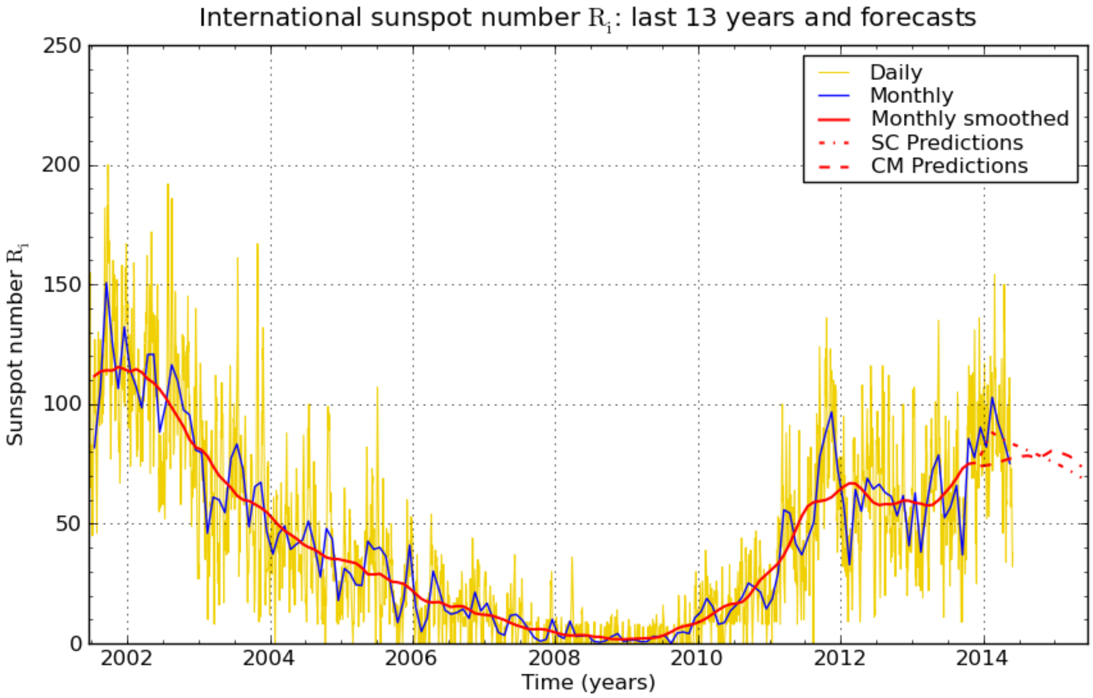

Fig. 15. Sunspot number (source: Royal Observatory of Belgium, http://sidc.be)

In Fig. 14 we can see the mean values for Crete are considerably higher than in the mainland and the islands. This is expected as Crete is much closer to the (geomagnetic) equator. However, if we take a closer look around the end of 2010, we can see that the I95 values are smaller for Crete. In order to investigate this unusual behavior, we analyzed CODE's Global Ionospheric Maps (GIM) for particular days of this period. Figures 16 – 18 show the VTEC distribution over Europe for 15.11.2010, 1.12.2010 and 2.1.2011, respectively (plotted with GpsTools; Takasu & Kasai, 2005). These are examples of unusual VTEC distribution over Greece, as the TEC does not increase towards south. Such geographic distributions can explain the lower I95 values registered for Crete in the end of 2010. A typical example of VTEC distribution is shown in Fig. 19. Based on our data analysis it comes out that unusual TEC distributions may more frequently occur late in the night and particularly during periods of low ionospheric activity.

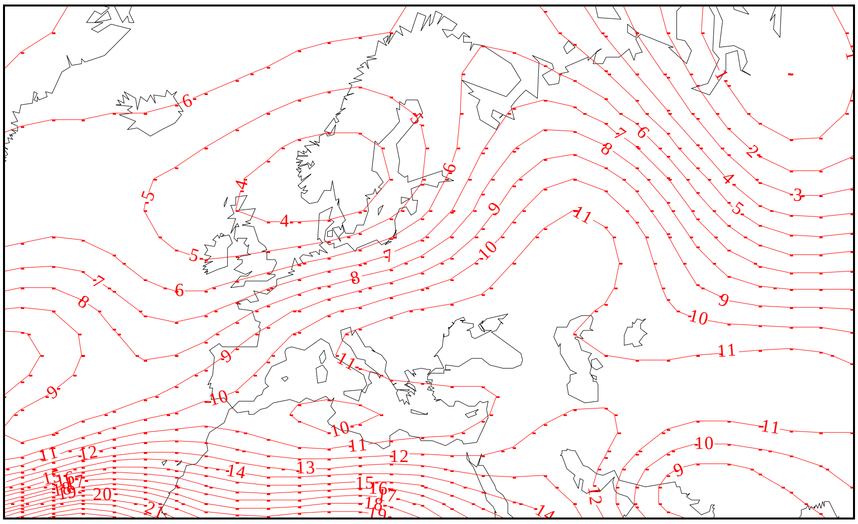

Fig. 16. VTEC (TECU) over Europe on Nov. 15, 2010 (22:00).

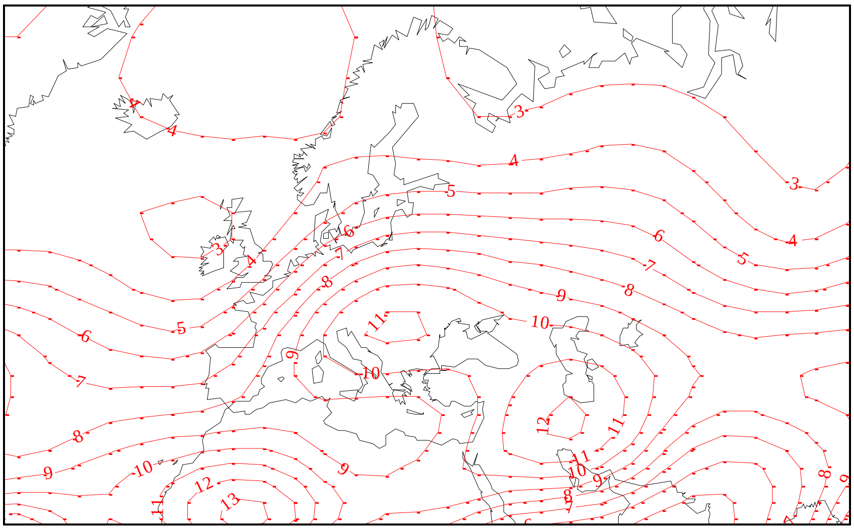

Fig. 17. VTEC (TECU) over Europe on Dec. 1, 2010 (00:00).

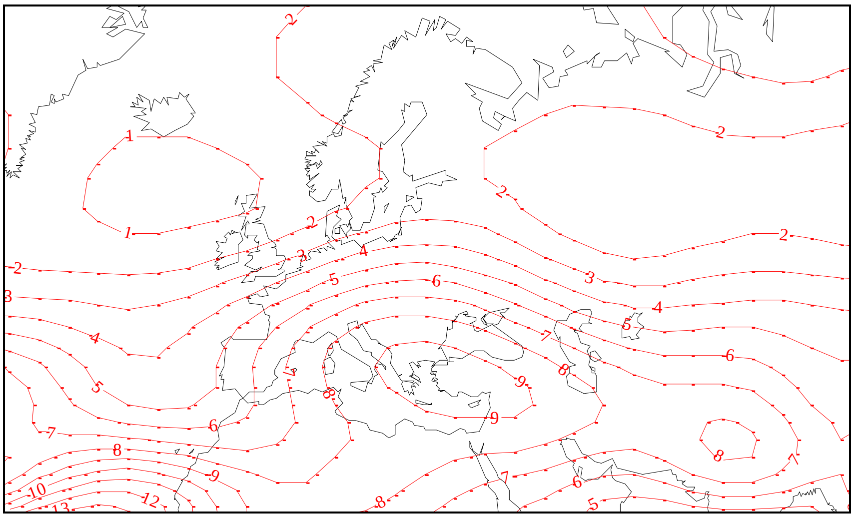

Fig. 18. VTEC (TECU) over Europe on Jan. 2, 2011 (00:00).

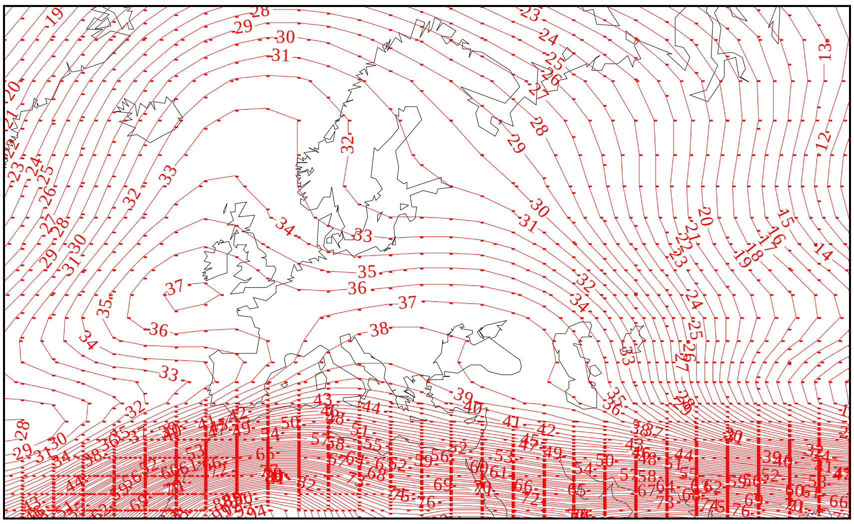

Fig. 19. VTEC (TECU) over Europe on Nov. 14, 2011 (12:00).

Closing this section, it is mentioned that the day of the most extreme I95 values was the 17th of November 2013. I95 reached 48 for the mainland and the islands and 52.6 for Crete (Fig. 20).

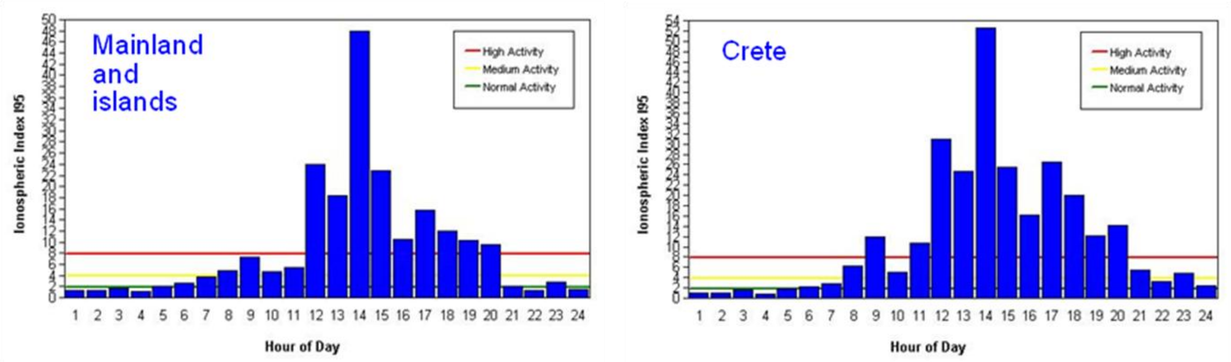

Fig. 20. Maximum I95 values reached on Nov. 17, 2013.

Acknowledgments

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