Estimation of Velocity Field using seven years GNSS permanent station data. Application to Hellenic area

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Abstract: The Hellenic area is one of the most geodynamic areas in the world and the first in Europe. The main active faults that characterize the Hellenic area are the Anatolian fault, the North Aegean Sea and the Ionian Sea fault. Nowadays, the utilization of GNSS data from permanent networks in order to study crustal deformations is one of the most accurate techniques.

The aim of the present study is the improvement of the first velocity model that the research team had estimate and announced in several conferences. First model was based on 85 permanent GNSS stations data cover a time window of three years. In order to do this, daily data from 145 permanent stations were processed for a time span of seven years (2008-2014) applying the proposed processing strategy which performs the European Analysis Centers. According to the derived results the North part of Greece is more stable and complies with the motion of Eurasian plate while the South part shows different behavior based on velocity values and angular directions. Moreover, velocity estimation values can found significant information for further analysis on reference frame realization for the geodetic and geosciences in general community. The Auth research team, (GNSS-QC) has already started the relevant case study on that topic.

1. Introduction

The Hellenic crust which covers an area of 700 × 700 Km is one of the most active geodynamic in global scale, provides displacements velocities at the order of 40mm per year (maximum) (Floyd et.al., 2010). According to recent geological studies the Hellenic area can't characterized as solid body with homogeneous velocity field, but as a region which composed from several smaller blocks including almost all types of faults. The most significant tectonic parameters are found on faults of Anatolian, Thessaly, Corinth Gulf and Ionian islands. As a result, the Greek territory and mainly the Aegean Sea is one of the most deforming areas at Eurasian Plate with a long history in geodetic methods for crustal displacement monitoring.

From the middle of year 2010 until nowadays the research team (GNSS-QC) con-

sisting by A. Fotiou (research coordinator), D. Rossikopoulos and C. Pikridas, collects and process GNSS data from the European Permanent Network (Euref Permanent Network/EPN), from MetricaNet-SmartNet Greece of Metrica SA (official representative of Leica-Greece) and from HermesNet of Aristotle University of Thessaloniki (Fotiou A. et al., 2010). In order to improve one of the latest's velocity model that which had been already announced on national and international conferences (Chatzinikos et al. 2013), daily rinex data covering seven years period (2008 to 2014) was compromise to the research team by various permanent networks operated by universities and research institutes (like, NTUA-Net and NOA-Net). In addition, 44 GPS stations of HEPOS network were also compromised, but only for the time span 2008 until 2010. The total number of the processed stations reached the number of 145. Also, the processing scheme includes 24 (fiducial) stations from EPN and IGS network (International GNSS Service). The geographic distribution of the Hellenic permanent stations is shown in figure 1.

The process of GNSS data was performed with the use of BERNESE software v5.2. Additional solutions were also derived using GAMIT (Herring et al. 2010) for results validation. The processing strategy and specific parameters during are in compliant with the EUREF Analysis Centers.

2. Process of GNSS data and displacement estimation.

Resent years the research team having as one of main aims the crustal deformation study of Hellenic area, has already developed and continuously update a velocity estimation model using data from permanent GNSS stations and multi years various campaigns. (Rossikopoulos et al. 1998, Pikridas 1999, Fotiou et al. 2003, Chatzinikos et al. 2013). Crustal deformation studies require long time period and high accuracy data too. Due to the fact that data have a bulk of volume and in order to optimize each session solution a new a high performance server (Dell-PowerEdge series) is installed and used with proper properties. For example, it is possible that processing will happen in parallel by having different scripts running at the same time with appropriate wait conditions. As a consequence, parallel Process Control Files (PCFs) are slightly more complicated than linear PCFs. They have the advantage that they can split up a single task into multiple tasks, each of which may be executed on a separate (in our case) Central Processing Unit cluster. With parallel scripts, it is possible to divide up the observation files into groups and have different computers/cpu's working on different groups of files, improving the speed process.

This option is primary used as state-of-the art technique by many GNSS Analysis Centers. As it is already announced, by the middle of September 2014, GNSS_QC started the operation of the first analysis center in Greece (GNSS Analysis Center)

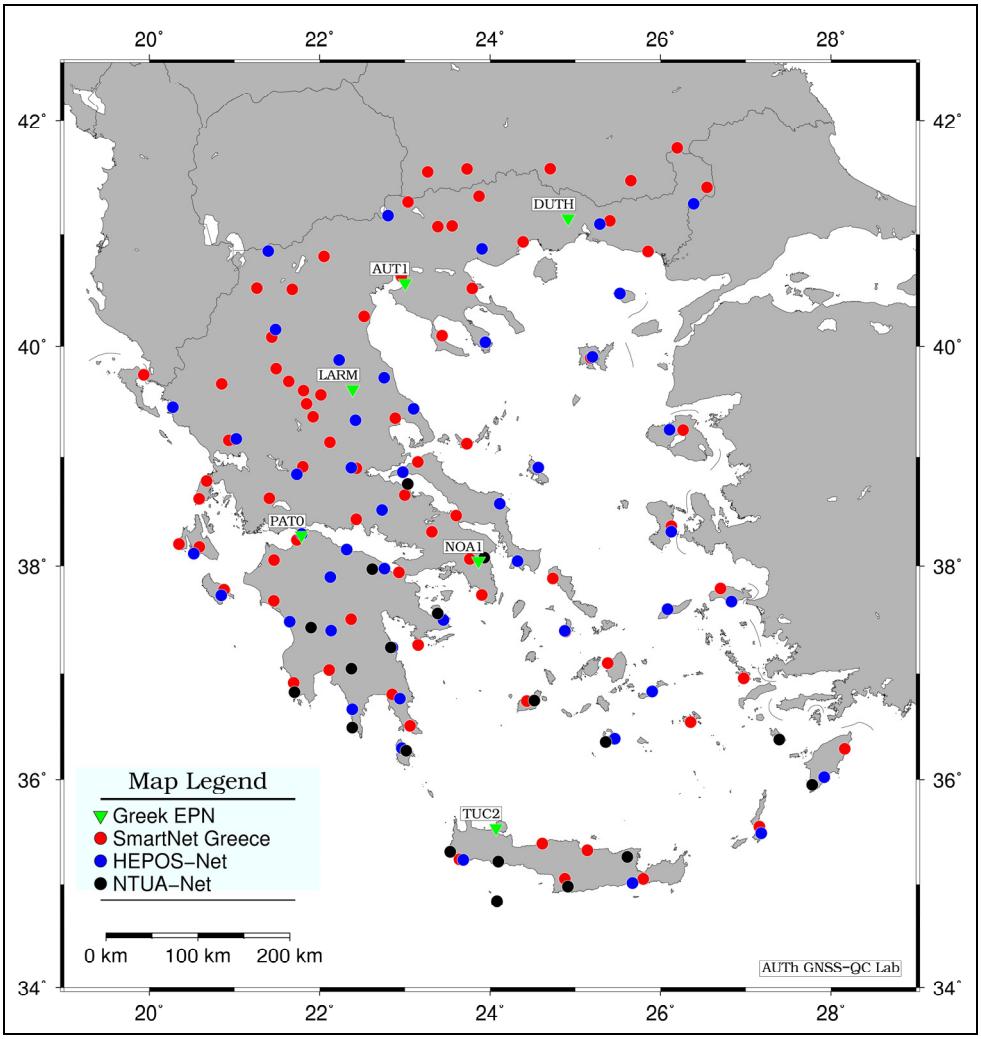

Figure 1. *Geographic distribution of permanent GNSS stations.*

with main target the estimation of tropospheric products. Additional scripts were also developed for the estimation and monitoring of coordinate's quality, velocity estimation and for ionospheric products too. Figure 2 shows the GNSS station clustering during parallel process of all permanent networks.

As it concerns the processing parameters, the data was analyzed using a satellite elevation cut-off angle of 10 degrees, final precise orbit information which refers to the IGS08 reference frame was obtained from the IGS directory. The new IGS_08.atx model with absolute antenna calibration values was applied. The Saastamoinen model with the (dry+wet) GMF mapping function was used in processing. All the initial phase ambiguities of carrier frequencies were resolved at a

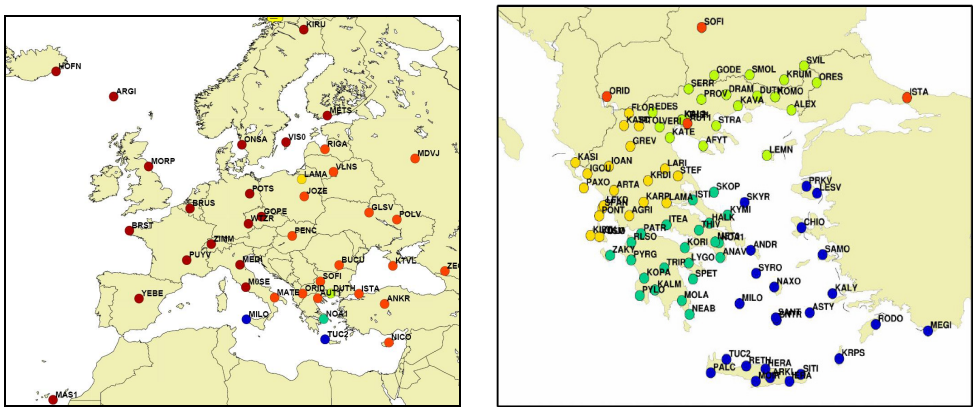

Figure 2. *GNSS permanent station clustering during parallel process.*

level >98% using the QIF strategy (Dach et. al. 2007). The derived results show repeatability equal to 1.5 mm for horizontal coordinates and equal to 3 mm for the vertical ones.

It is worth to be mentioned that the research team monitor and control session solutions and station coordinates stability. In order to control every solution, which is extracted via Bernese software (v5.2), the AUT team has developed various script scenarios.

Scripts were written in bash command interpreter and use the GMT graphic tool environment. The depicted graphics concern each processing session and refer to the ambiguity resolution success rate, rms for each baseline and the estimated baseline length variation. Also, time series for individual station coordinates and tropospheric ZHD, ZWD and ZTD are plotted.

An important issue which the team focuses on is the (coordinate) time series analysis. For that reason an automated script (after each solution) follows with main target the use of FODITS algorithm (Find Outliers and Discontinuities in Time Series) which already included in Bernese software. As an additional feature to analyze coordinate time series, FODITS is able to identify discontinuities in station velocities and may estimate periodic functions. Such a search procedure is performed for discontinuities, outliers, velocity changes, and periodic functions.

Figure 3 illustrates coordinate time series residuals of AUT1 GPS station (for each component-X, Y, Z) for a time period of several months. According to results, the high position quality is confirmed.

The final velocity values, extracted from the combined adjustment of all period data, in IGS08 reference frame are drawn on Figure 4. Expressing the estimated values in numbers we concluded that, the East component starts from -9mm and reaches the value of 29 mm while the North component varies between -18 and 15.5 mm.

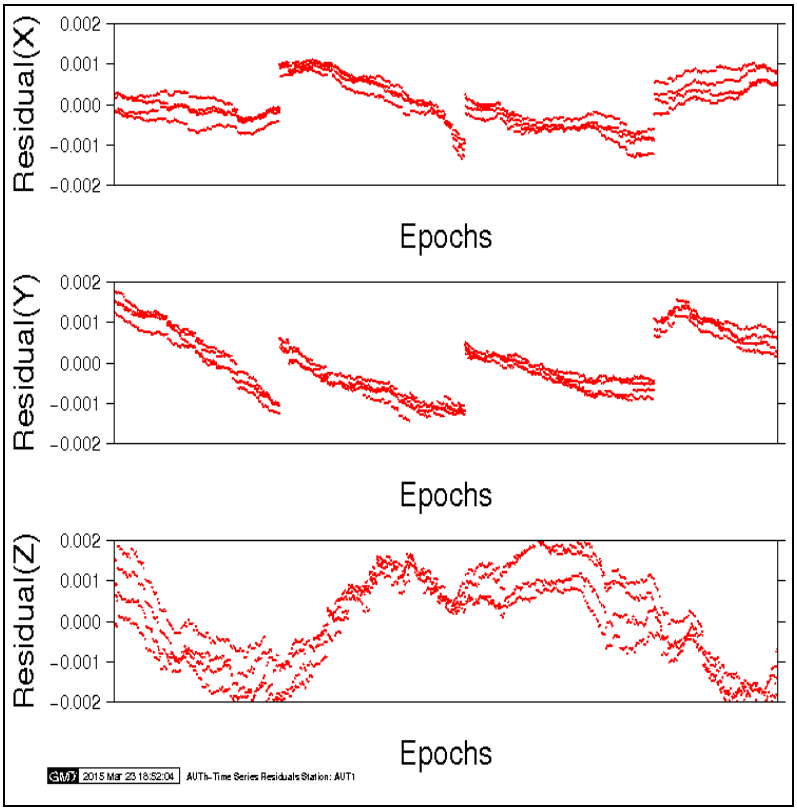

Figure 3. *Coordinate time series residuals of AUT1 permanent GPS station (in m).*

It is worth to be mentioned that the northern region in Greece is the most stable and identical to the movement of the Eurasian plate in contrast with the region of the southern part and the Aegean Sea. According to the results, the estimated horizontal geodetic velocities are heterogeneous between northern and southern Greece with significant differences both in magnitude and direction. This fact plays an important role for Greek datum transformations and relations with other international terrestrial frames Figure 5 depicts the Greek seismic events during the period of seven years (2008-2014) as they provided by the relevant database of department of Geophysics (Pavlides S., Caputo R., Sboras S., Chatzipetros A., et al., 2010, Caputo R., Chatzipetros A., et al., 2012), in addition the focal mechanisms as they retrieved from the Global Centroid-Moment-Tensor –CMT, (http://www.globalcmt.org/) project were also combined. Currently, the research team is working on modeling the elastic lithospheric block rotations and internal strains, locking on block-bounding faults, and transient sources such as earthquakes, afterslip, slow-slip, combing GPS velocities with all the related geophysical parameters and source data.

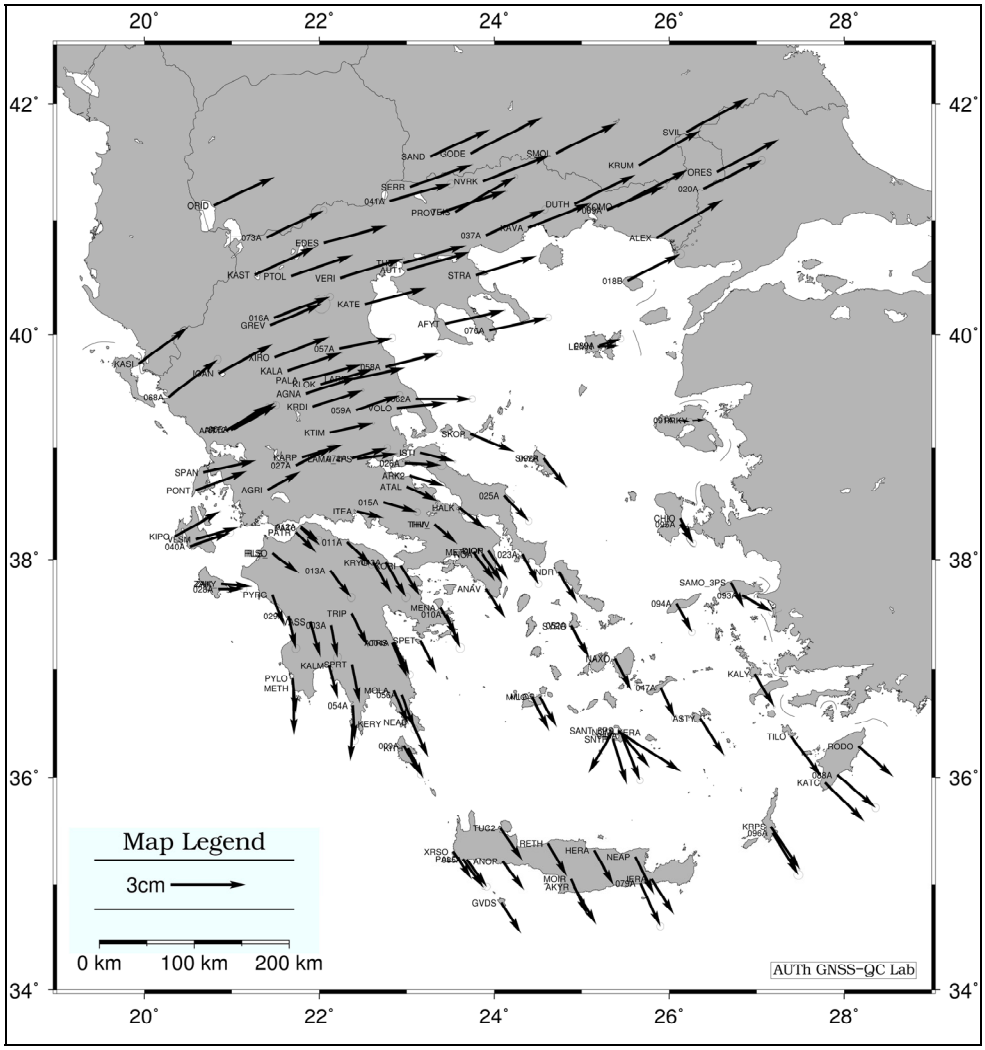

Figure 4. *Velocities vectors of the permanent GNSS stations in IGS08.*

Conclusions

We estimated a rigorous new horizontal velocity model for Greece with respect to ITRF2008 using seven years duration of cGPS data from (145) a well distributed permanent GPS network. The estimated model extracted through rigorous processing parameters using guidelines of the European analysis centers. The results confirmed the significant and inhomogeneous geodynamic activity oh the Hellenic area.

This behavior can be continuously monitored through the process and analysis of permanent GNSS stations data that the research team is performed.

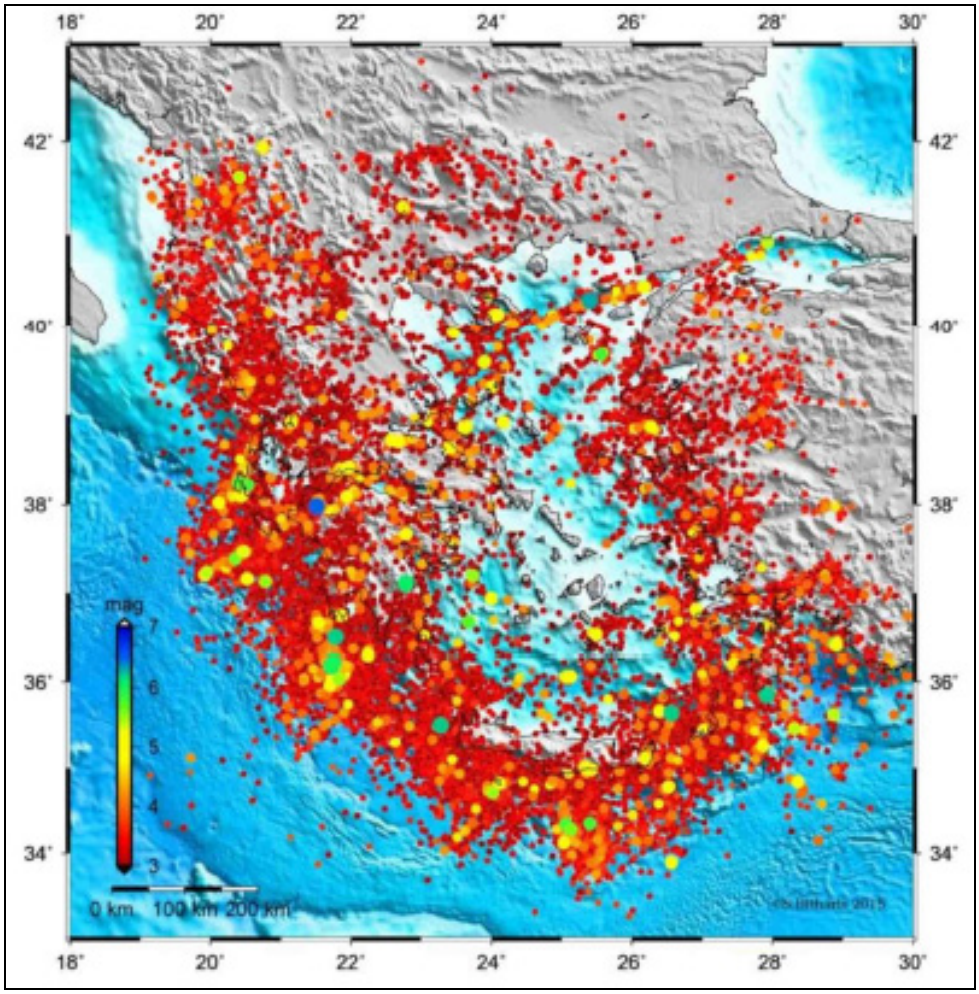

Figure 5. *Seismic events and their epicenters during period 2008 to 2014.*

A specific geodynamic activity which found at Corinthian Gulf and Santorini volcano are of special case studies for the research team and specific GNSS campaigns are under design. Our model could be an official velocity model for Greek datum transformations especially for GNSS geodetic applications and relations with other international terrestrial frames.

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