Assessing a new velocity field in Greece by combining GNSS campaigns towards the establishment of a new Reference Frame

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Introduction

The current official geodetic datum in Greece is the Greek Geodetic Reference System 1987 (GGRS87), a static datum based mainly on classical geodetic observations of more than thirty years and connected to modern ITRFs with a one to two-meter level accuracy. Since 2009 an auxiliary system adopted by Hellenic National Cadastre & Mapping Agency (NCMA), called HTRS07 (Hellenic Terrestrial Reference System 2007, epoch 2007.5) and based only on GPS observations, has been used to transform GNSS/GPS coordinates from HTRS07 to GGRS87 by means of grid-based transformation parameters for horizontal control, giving finally TM projection coordinates in GGRS87 with an uncertainty of some cm for a limited area of some km. HTRS07 which is a realization of ETRF05, is also a static geodetic system.

The need for the establishment of a new modern and satellite based geodetic datum becomes more and more obvious as the high geodynamic activity in Greece creates serious inhomogeneous crustal deformations. In this effort, the role of a reliable velocity field is very important. The last years, the GNSS-QC team of Aristotle University of Thessaloniki (AUTh) estimates and periodically updates an accurate velocity model for the earth crust in Greece, based on GNSS observations of almost 150 stations, most of them permanent.

The main aim of the present study is the assessment of the periodically updated new velocity model through the unification of four GNSS individual campaigns consisting of a big number of points, more than 3500, to provide a set of coordinates in a common frame. Using predicted velocities, all point coordinates of each campaign are transformed to a common epoch, e.g. 2016.01, at the same (initial) frame. Therefore, a Helmert transformation between different couples of campaign-frames, reflects on the fitting accuracy. This transformation is also applied for the same couples except that the used coordinates are the initial ones, not the transformed to the common epoch. The comparison between the transformation results (fitting measures) of the same couples, i.e. transformation with the velocity model versus with no velocity model, shows the effectiveness of the used model in case the improvement is significant.

Data Sets

The last decades various GNSS campaigns have been accomplished by various scientific organizations and agencies, as by the Hellenic Military Geographical Service (HMGS), the GNSS-QC research team of AUTh and the NCMA. These campaigns were carried out in different time periods and the derived results related to positioning, e.g. point coordinates, were expressed in different Local and International Terrestrial Reference Frames (ITRFs).

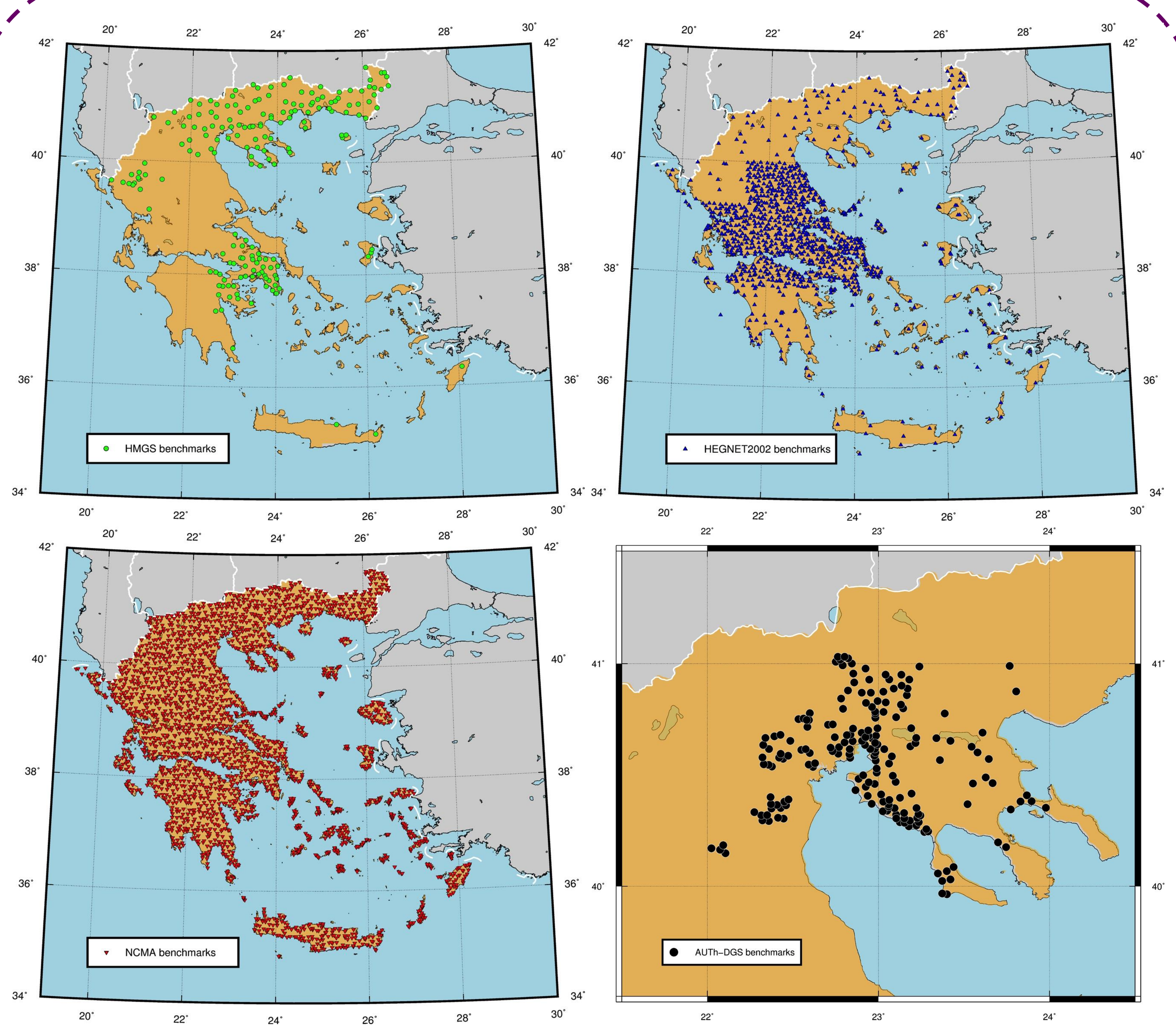

Fig 1 - Spatial distribution of the trigonometric benchmarks of the four individual data sets: HMRF16 (top left), HEGNET2002 (top right), NCMA (down left) and AUTh - GNSS-QC (down right)

Name of Network	Time Period	Number of Benchmarks	Reference frame
HMRF16	2015, 2016	186	IGS08
HEGNET2002	2000-2008	1007	ITRF96
NCMA	March – Sept. 2007	2427	ITRF2000
AUTh (GNSS-QC)	1993-2016	189	IGS08

Methodology

The position of each i point at an initial epoch t_0 is transformed to a different epoch t by the following equation:

$$X^i_{TRF^{yy}}(t) = X^i_{TRF^{yy}}(t_0) + \dot{X}^i_{TRF^{yy}} \cdot (t - t_0)$$

where, $X^i_{TRF^{yy}}(t_0)$ is the position vector at the initial reference epoch t_0 for each TRF, t is the common epoch 2016.01 and $\dot{X}^i_{TRF^{yy}}$ the geocentric cartesian velocity vector expressed in IGS08, ITRF2000 and ITRF96, where the GNSS campaigns carried out, using the most recent Greek horizontal velocity model (Bitharis et. al. 2016). The methodology is described by the data flow depicted in Figure 3. In our analysis, only the horizontal predicted velocities were used.

In order to test the compatibility between each data set (HEGNET2002, NCMA, AUTh) with the latest HMRF16 which is taken as a reference, we used the Helmert transformation model between the pairs:

- HMRF16 - HEGNET2002 (7-param.)
- HMRF16 – NCMA (7-param.)
- HMRF16 – AUTh (3-param.)

We note that the above datasets were previously transformed to the common epoch 2016.

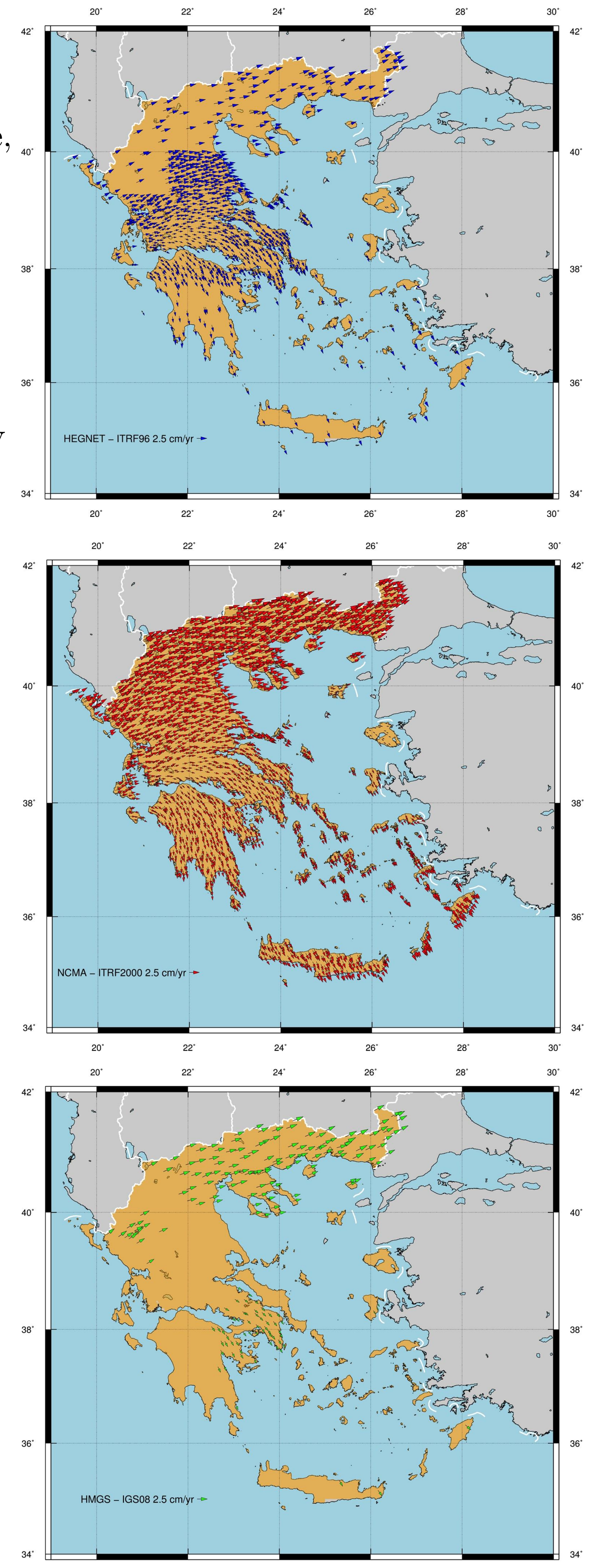

Fig 2 - The predicted geodetic velocities, based on the recent Greek horizontal velocity model, in ITRF96 for HEGNET2002 (top), ITRF2000 for NCMA (middle) and IGS08 for HMRF16 (bottom).

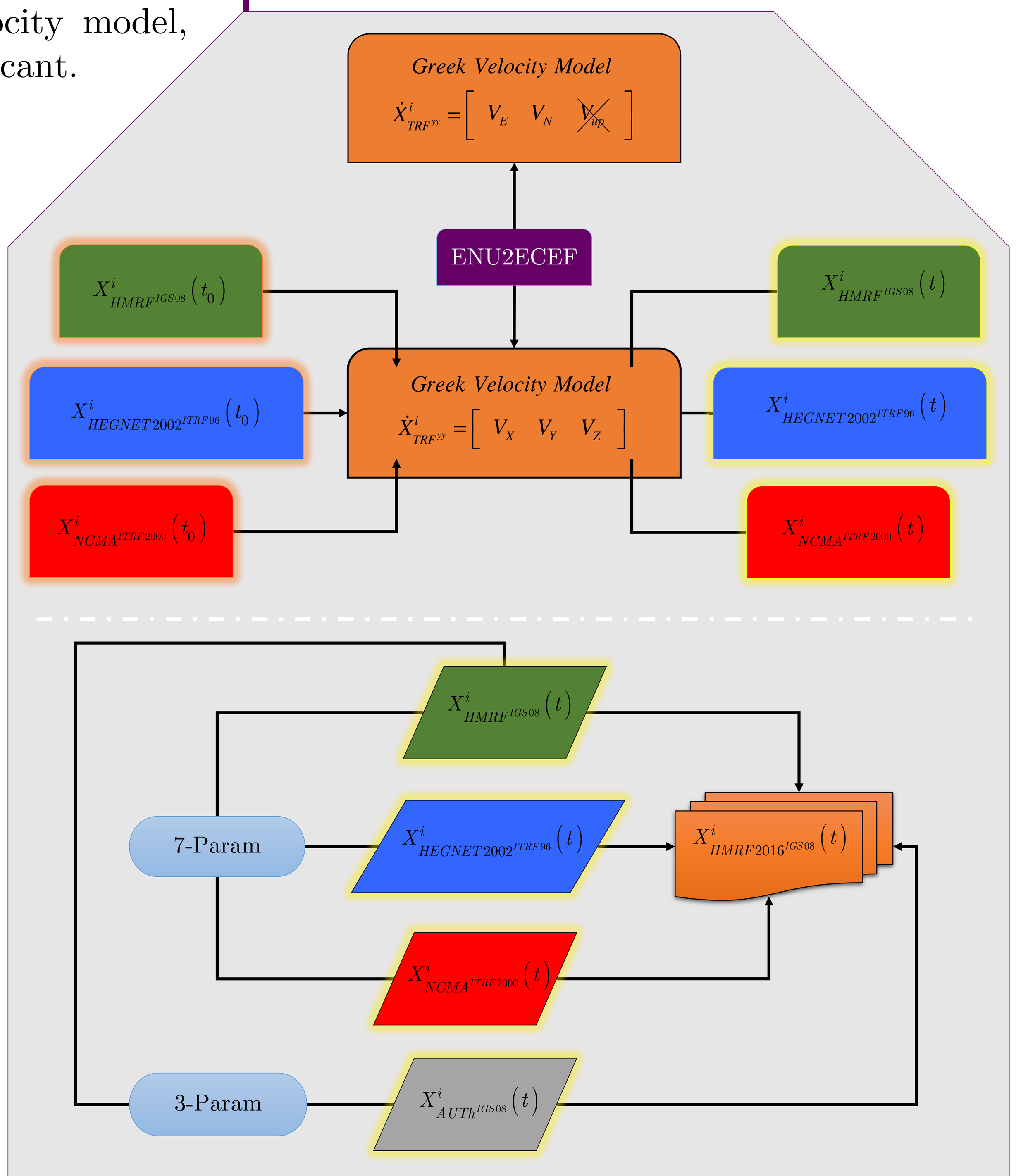

Fig 3 – Data flow which describes the steps of the methodology followed in the present study

Discussion

According to the results, the implementation of the new velocity model improves significantly the fitting-compatibility between the different campaign frames by more than 60% as far as the horizontal component is concerned. Therefore, this study can provide a feasible method of different datum transformations to a new modern and semi-dynamic datum (ITRF-based), necessary for all geodetic and mapping activities in Greece. The adoption of the AUTh's (GNSS-QC) velocity model as the official model for high accuracy geodetic activities is a proper choice. A future goal is to improve the vertical velocity estimation using more sophisticated models.

Residuals of Transformation (m)	Horizontal component	Vertical component	3D Vector
HMRF16 - HEGNET2002	0.05 ±0.03	0.08 ±0.11	0.11 ±0.07
HMRF16 - HEGNET2002 (No Model*)	0.13 ±0.05	0.08 ±0.11	0.16 ±0.07
HMRF16 – NCMA	0.03 ±0.03	0.08 ±0.10	0.09 ±0.06
HMRF16 - NCMA (No Model*)	0.08 ±0.04	0.08 ±0.10	0.12 ±0.06
HMRF16 - AUTh (GNSS-QC)	0.04 ±0.04	0.08 ±0.08	0.09 ±0.06

* Scenario without Greek Velocity Model implementation in order to predict velocities

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Acknowledgments

The authors would like to thank all the data providers: METRICA S.A., National Observatory of Athens, National Cadastre and Mapping Agency S.A.

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