Crustal block modelling using combination of Euler pole and cluster analysis of GNSS velocities in Greece

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Abstract. In this study, we focused on GNSS velocities clustering using the Euler pole and clustering methodology for block modelling definition. Greece is characterized by an inhomogeneous geodetic velocity field due to complex tectonics and high deformation rates that effected to regional reference frames. We present an updated dense geodetic velocity field covering the Greek territory and the South Balkans. The velocity field derived using more than 220 continuously GNSS stations which are analyzed in a period of 16 years (2001-2016) using the GAMIT/GLOBK software suite. We identify 10 crustal blocks that appeared to move independently in Greek area applying the k-means clustering approach, Euler Pole estimation and statistical criteria. Clustering technique contributes only on a pattern identification of GNSS sites that follows similar horizontal velocity motion without using any apriori information or assumption.

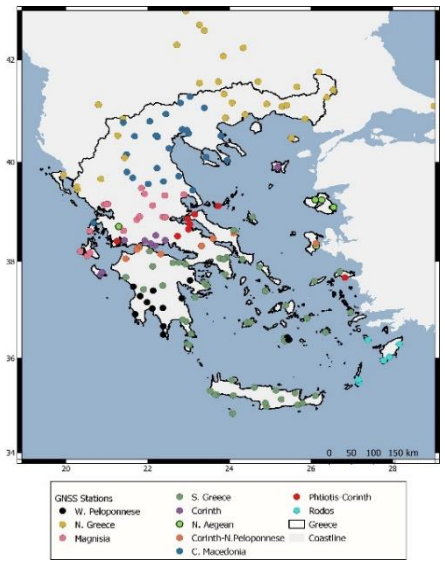

Fig. 1 – Cluster analysis using k-means algorithm for first block modeling identification.

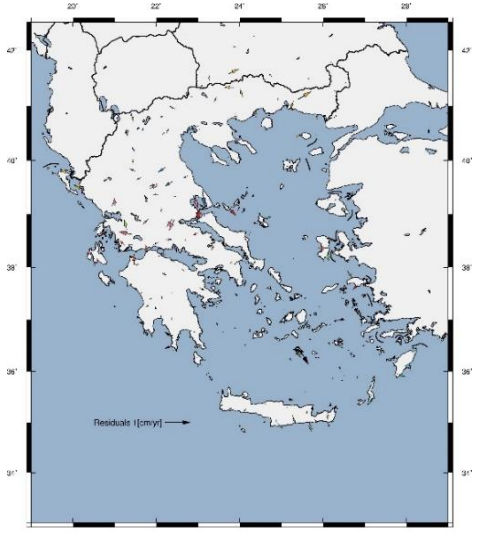

Fig. 2 – Residuals for mean cluster velocity per GNSS site.

The first step of our analysis was to identify patterns that could possibly represent microplates in the Hellenic area. For that reason, we use cluster analysis algorithms (i.e., k-means) that offers a robust tool for the grouping process, using as input parameters only the geodetic velocities. This approach offers various advantages in searching deformations patterns, in areas with strong geodynamic activity, without using any external information about the tectonic setting of the area.

Methodology

For each *n* crustal block, we determine the best-fit Euler pole vectors and then we calculate the predicted residuals relative to *n-1* other clusters. If the absolute value of the horizontal predicted residuals was smaller from the initial cluster, the GNSS station reassigned to another n-1 cluster. Statistical tests were applied in each Euler pole estimation of whether the goodness of the fit and the quality of the derived solution. Block boundaries obtained using Voronoi diagram methodology, providing polygons with the same kinematic behavior, without using any tectonics settings. To evaluate our results, we compare the residuals for the mean velocity of each block with four previous studies, takes into account the block boundaries of these studies and on the other hand the estimated velocities of the present work.

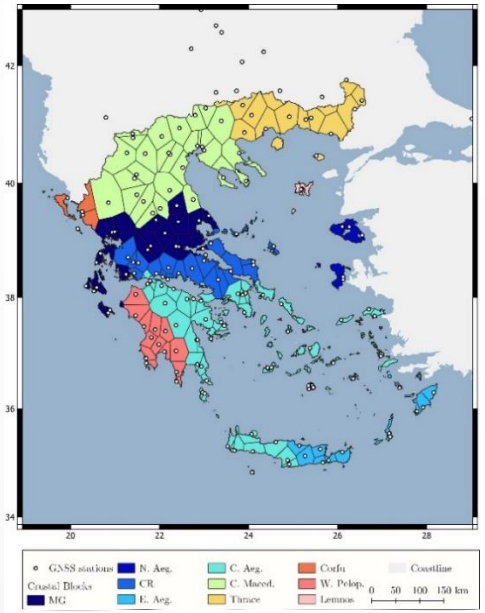

Fig. 3 - The geometrical block boundaries definition using cluster analysis and Euler pole.

Table 1 - Statistics for crustal block modelling, mean block velocity, residuals for the mean velocities.

Block	μV_n	μV_e	2D Residuals	Std	No. Sites
Magnisia (MG)	-10.5	-7.1	4.2	2.5	23
N. Aegean	-17.2	-20.8	3.2	1.5	5
Corinth	-18.4	-14.0	5.6	2.7	21
E. Aegean	-29.4	-14.7	3.3	1.3	13
C. Aegean	-26.9	-17.7	2.1	1.8	54
C. Macedonia	-7.2	-0.3	2.4	1.0	29
Thace	-2.4	0.0	2.5	1.5	16
Corfu	1.0	-2.8	2.8	1.6	4
W. Peloponnese	-27.8	-21.2	2.5	2.5	13
Lemnos	-13.1	-15.9	1.4	0.0	2
			3.0	1.6	180

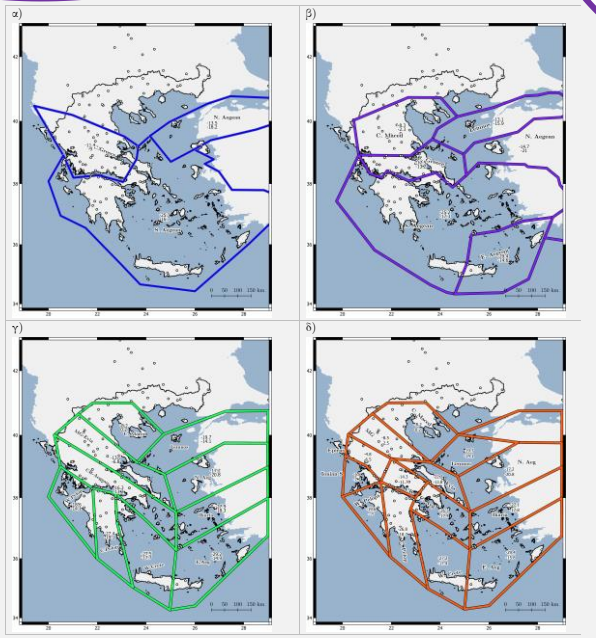

Fig. 4 – Previous studies micro-plates block boundaries

Studies	Residuals [mm/yr]	std	Num. of Sites	Num. of Blocks
Current study	3	±1.6	180	10
Reilinger et al. (2006)	3.4	±1.8	151	6
Floyd et al. (2010)	3.9	±2.1	158	14 (15)
Taymaz et al. (1991)	4.7	±2.3	155	10
Nyst and Thatcher (2004)	4.7	±2.8	138	3

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