Crustal structure of the Northern Caucasus from the continuous GNSS observations

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1. INTRODUCTION.

The Greater Caucasus is a zone of complex tectonics associated with the interaction of the two major tectonic plates, Arabian and Eurasian. The Greater Caucasus is symmetrically structured. The most outstanding pattern of the contemporary tectonic activity is revealed by the fold-thrust zone of the southern flank. The axial part of the Greater Caucasus in the neotectonic period demonstrates block motion with large-scale vertical and horizontal displacements and with the formation of linear tectonic depressions extending along the Main Caucasus Range. The north wing of the Greater Caucasus looks like flat monocline gradually dipping to the north. To the north it is limited by a linearly extended deep fault zone, which is mostly expressed along its northwest (Akhtyrsky) and southeast (Vladikavkaz) terminations.

The formation of this structure is primarily due to the stresses of subhorizontal compression oriented generally across strike. While the overall compression rate of the Greater Caucasus along the strike is resolved well enough (± 1 mm / year), the northern part of the Greater Caucasus is rather poorly studied.

That is way, since 2005 observations of the modern tectonic motion of the Northern Caucasus are carried out using the continuous GPS network. The Northern Caucasus regional network of the continuous GNSS stations consists of 13 stations and cover the territory of the Republics of Kabardino-Balkaria, Karachay-Cherkessia, North Ossetia-Alania, Dagestan, Stavropol and Krasnodar region of RF(Fig. 1).

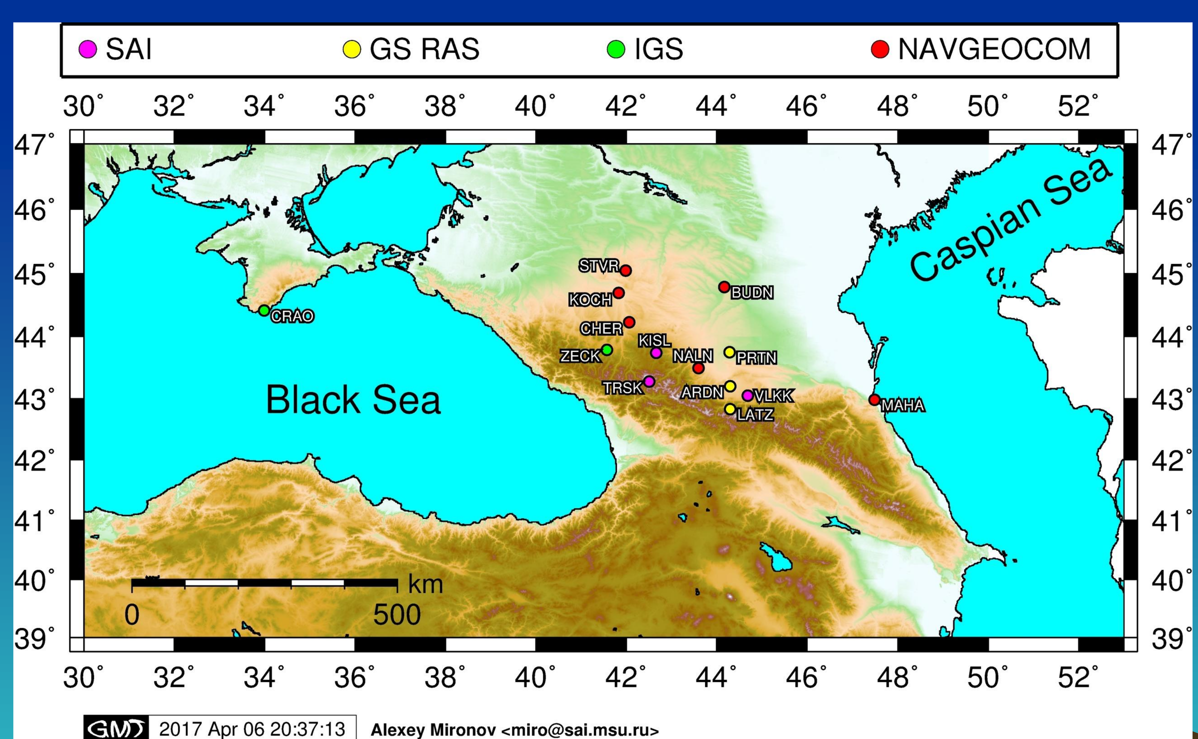

Fig. 1: The Northern Caucasian GNSS network.

2. GPS VELOCITIES ESTIMATION RELATIVE TO ITRF2008.

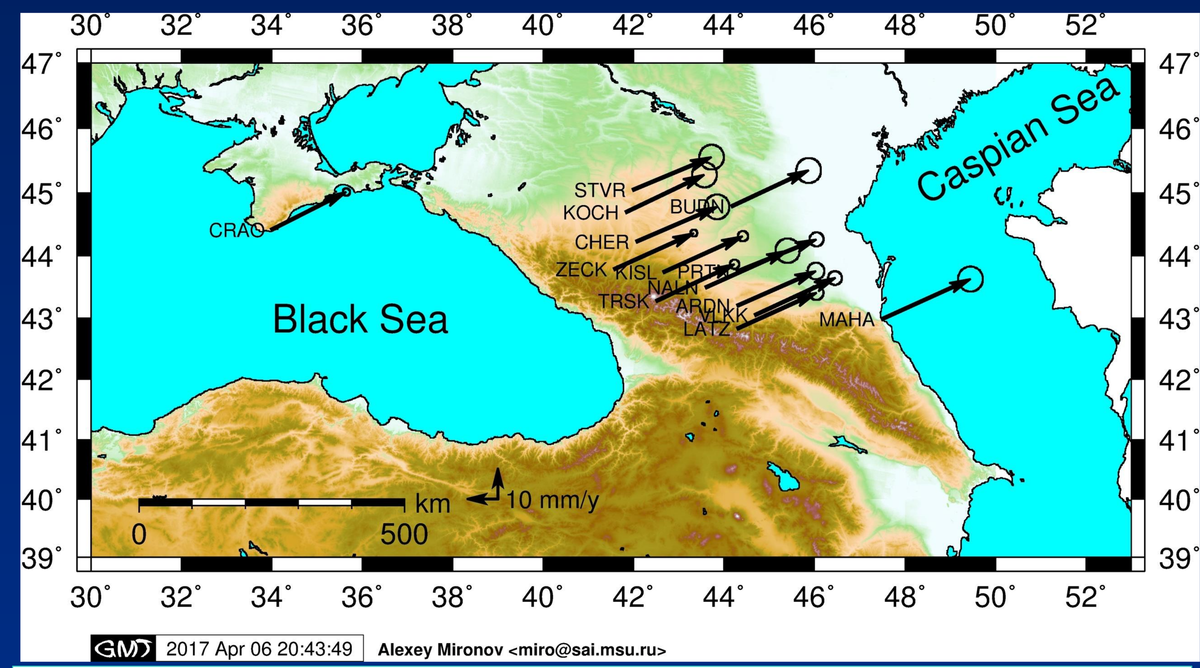

Fig. 2: Horizontal GPS velocities relative to ITRF2008

code	Ve (mm/yr)	Vn (mm/yr)	V (mm/yr)	azimuth (deg)
KISL	25.38±0.67	11.48±0.67	27.86±0.67	65.66
TRSK	25.04±0.61	11.77±0.61	27.67±0.61	64.82
VLKK	25.70±0.90	11.89±0.90	28.32±0.90	65.17
ARDN	25.21±1.10	11.08±1.10	27.54±1.10	66.27
LATZ	25.31±0.91	11.44±0.91	27.78±0.91	65.68
PRTN	25.51±0.92	10.28±0.92	27.50±0.92	68.05
BUDN	24.69±1.62	11.54±1.64	27.25±1.63	64.95
CHER	25.93±1.61	11.14±1.62	28.22±1.62	66.75
KOCH	25.21±1.62	12.03±1.64	27.93±1.63	64.49
MAHA	28.41±1.63	12.85±1.64	31.18±1.64	65.66
NALN	26.18±1.60	11.75±1.60	28.70±1.60	65.83
STVR	25.18±1.61	10.49±1.62	27.28±1.62	67.38
ZECK	25.56±0.45	11.53±0.45	28.04±0.45	65.72
CRAO	23.96±0.48	12.12±0.48	26.85±0.48	63.17

Tabl. 1: Horizontal GPS velocities and 1-σ uncertainties relative to ITRF2008.

3. GPS VELOCITIES RELATIVE TO FIXED EURASIA

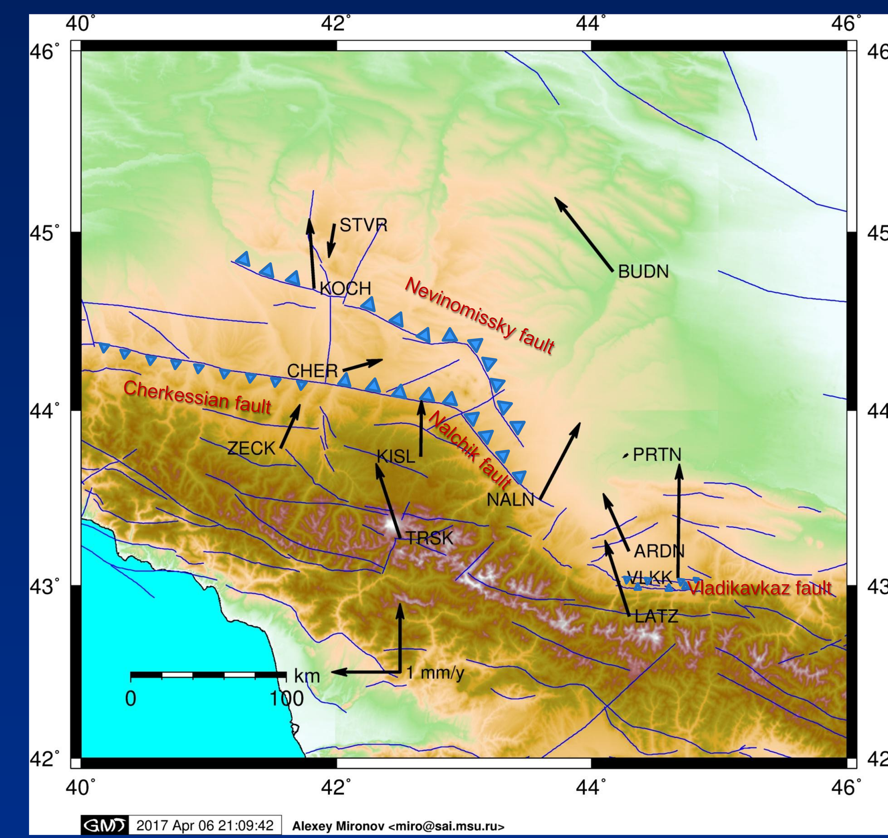

Fig. 3: Horizontal GPS velocities relative to fixed Eurasia

code	Ve (mm/yr)	Vn (mm/yr)	V (mm/yr)	azimuth (deg)
KISL	0.01±0.67	0.82±0.67	0.82±0.67	0.70
TRSK	-0.35±0.61	1.08±0.61	1.14±0.61	-17.96
VLKK	0.02±0.90	1.65±0.90	1.65±0.90	0.69
ARDN	-0.37±1.10	0.83±1.10	0.91±1.10	-24.03
LATZ	-0.35±0.91	1.10±0.91	1.15±0.91	-17.65
PRTN	-0.05±0.92	-0.04±0.92	0.06±0.92	-128.66
BUDN	-0.84±1.63	1.07±1.64	1.36±1.64	-38.13
CHER	0.57±1.61	0.16±1.62	0.59±1.62	74.32
KOCH	-0.07±1.63	1.01±1.64	1.01±1.64	-3.96
NALN	0.58±1.60	1.11±1.60	1.25±1.60	27.59
STVR	-0.08±1.61	-0.48±1.62	0.49±1.62	-170.54
ZECK	0.28±0.45	0.63±0.45	0.69±0.45	23.96

Tabl. 2: Horizontal GPS velocities and 1-σ uncertainties relative to fixed Eurasia.

4.GPS VELOCITY FIELD

The striking aspect of the velocity field of the Northern Caucasus derived from the NDCA stations is the rapid motion in the northeast direction with velocities of about 27-28 mm/year (Fig. 2, Tabl. 1).

The GPS velocities relative to fixed Eurasia confirm weak general compression of the Northern Caucasus at the rate of about 1-2 mm/year (Fig. 3, Tabl. 2). The result confirms that the source of deformation of the Northern Caucasus is the sub-meridional drift of the Arabian plate towards the adjacent boundary of the Eastern European part of the Eurasian lithospheric plate.

Regional geodynamics is caused by the complex fault system in the region. The stations KOCH and CHER, located on opposite sides of the Nevinnomysky fault (flexure), demonstrate a left reverse fault along it. In this zone, there are continually weak earthquakes (the last one was in 2010). The stations NALN and CHER may also be situated in another relatively homogeneous tectonic block, separated from the previous one by the Cherkessian fault. The similar vector and displacement values for the three Ossetian stations LATZ, VLKK and ARDN can be explained by the passive state of the Vladikavkaz fault zone, one of the largest disjunctive structures in the North Caucasus .

5. STRAIN RATE TENSOR.

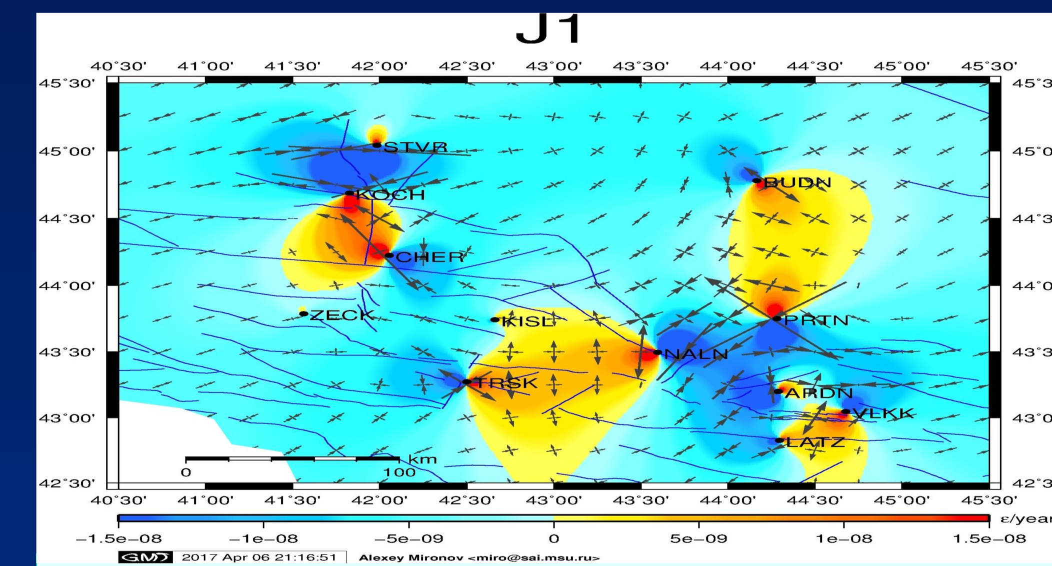

Fig. 4: First invariant (I_1) and the major axes of the horizontal strain rate tensor.

Weak deviation of observed velocities from the pattern corresponding to homogeneous compression can also be revealed. A few deformation subregions may be traced from the strain tensor pattern: compression in the north-west part and south-east part of the region; expansion in in the central mountainous part of the region. Compression-extension major axes of all the subregions are aligned across the Main Caucasus Ridge. Slight variations in the major axes orientation in the central part of the region implies some line of shear strains.

6. CONCLUSION.

The horizontal motion at the boundary of the Northern Caucasus with respect to the Eurasian plate causes the higher seismic and tectonic activity of this transition zone. This result confirms that the source of deformation of the Northern Caucasus is the sub-meridional drift of the Arabian plate towards the adjacent boundary of the Eastern European part of the Eurasian lithospheric plate. The concept of such convergence implies that the Caucasian segment of the Alpine-Himalayan mobile belt is under compression, the layers of sedimentary and volcanic rocks are folded, the basement blocks are subject to shifts in various directions, and the upper crust layers are ruptured by reverse faults and thrusts.

Distribution of the first invariant of the strain tensor intensity calculated from the displacements velocities shows spatial alternation of the compression and extension up to $1.5x10^{-8}$ along the faults system of the Greater Caucasus. As for the foothills, extension is only visible to the north of PRTN. This may testify that a significant number of the Caucasus mountain system faults are active and more detailed surveying together with appropriate modelling can clarify the motion along each active fault.

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