# Contemporary crustal deformation in Georgia (Caucasus)

# **Giorgi Khazaradze**<sup>1\*</sup>, Giorgi Sokhadze<sup>2</sup>, Galaktion Hahubia<sup>3</sup>, Manana Kachakhidze<sup>4</sup>,

<sup>1</sup> Grup RISKNAT, Institut Geomodels, University of Barcelona, Faculty of Earth Sciences, Department of Earth and Ocean Dynamics, Barcelona, Spain

<sup>2</sup> Geosciences and Technology Development Institute, Tbilisi, Georgia

<sup>3</sup> National Agency of Public Registry, Ministry of Justice of Georgia, Tbilisi, Georgia

<sup>4</sup> LEPL Institute "OPTIKA", Tbilisi, Georgia

\*Corresponding author: <a href="mailto:gkhazar@ub.edu">gkhazar@ub.edu</a>







# **Contemporary crustal deformation in Georgia (Caucasus)**

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Session: Active Tectonics and Geodynamics of Eastern Mediterranean (TS4.4)

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The republic of Georgia is located in the Caucasus, between the Black and Caspian seas from the west and the east, and Greater and Lesser Caucasus mountains from the north and the south. Tectonically, the region belongs to the Alpine-Himalayan collisional zone, formed during the late Cenozoic period as a result of a collision between the Arabian and Eurasian plates. The deformation zone due to this collision is broad and extends from Zagros mountains in southern Iran to the Greater Caucasus in the north. The GPS studies conducted during the last decade suggest a convergence rate of 18 mm/yr between the Arabia and Eurasia plates. Although majority of this convergence occurs in the southern part of the deformation zone, important part of this convergence takes place in Georgia, implying an elevated seismic risk in the region. This is corroborated by a presence of significant historical and instrumental earthquakes in the country.

As part of the project dealing with the detection of possible low frequency electromagnetic emissions proceeding earthquakes, in summer of 2016 we have installed a continuous GNSS station MTSK between Mtskheta and Tbilisi. The station consists of Leica GRX1200 GNSS receiver with an AS10 antenna. It is mounted on top of the building, anchored to the existing brick wall. In contrast, principal convergence between the Lesser and Greater Caucasus across the Tbilisi segment, occurs along the northern boundary of the Lesser Caucasus. To constrain the velocity gradient to the northern boundary of the lesser Caucasus, in 2019 an additional continuous GNSS station MKRN was installed in this deformation zone by the GTDI near the settlement of Mukhrani. It consists of Trimble 5700 receiver with a Zephyr Geodetic antenna.

The analysis of the data is performed using the Gamit/Globk software package from MIT and it is processed in conjunction with 26 continuous GNSS stations of the GEO-CORS network operated by National Agency of Public Registry of Georgia (*geocors.napr.gov.ge*). In addition, we analyze data form the stations located on Eurasia, Arabia and Africa plates. The main objective of the given work is to monitor millimeter level deformation of the crust due to the collision of Arabia and Eurasia tectonic plates and identify the regions of higher deformation and relate them to individual faults.

This work has been partially supported by Shota Rustaveli National Science Foundation of Georgia (grants DI/21/9-140/13 and FR17\_529) and PROMONTEC (CGL2017-84720-R AEI/FEDER, UE) project, financed by the Spanish MINEICO. We are grateful to the Andronikashvili Institute of Physics (*www.aiphysics.tsu.ge*) for letting us use their facility for the installation of the GNSS station.



# **Objectives**

Derive and update the 3D GPS velocity field of the Caucasus, with a special emphasis on Georgia, using GPS continuous data from 2011 to 2019.

➤ Identify areas with active deformation

Correlate the results with geological and anthropogenic processes

➤ Establish new CGPS stations







### The study area: Caucasus



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**Caucasus: seismicity** 



The focal mechanisms come from the SesimQuery of IRIS (<u>http://ds.iris.edu/SeismiQuery/sq-</u> <u>eventsmag.htm</u>) (blue) and the Turkish DDA catalog (magenta) (see Tuba Kadirioğlu et al., 2016).





### **Previous geodetic studies**



Map showing GPS velocities relative to Eurasia with 95% confidence ellipses, where **red** vectors are from Reilinger et al., [2006] and Karakhanian et al. [2013] and **green** vectors are from Sokhadze et al., [2018].





### **Methods: analyzed CGPS Data**



• Magenta triangles denote Geo-CORS stations (Hahubia, 2012; http://geocors.napr.gov.ge)

- Yellow **diamonds** show stations installed by the authors.
- Grey lines depict tectonic faults (Gamkrelidze, et al., 2015)





### Newly established CGPS stations: MTSK and MKRN





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## Newly established CGPS stations: MTSK



On August 17ht of 2016, we have installed a new continuously operating GNSS station between Tbilisi and Mtskheta. It was installed in Mukhatgverdi (მუხათგვერდი), located 10 km to the north from Tbilisi. We were given permission from the Andronikashvili Institute of Physics (www.aiphysics.tsu.ge), that currently forms part of the Ivane Javakhishvili, Tbilsii State University (www.tsu.ge) to install the station on the territory of their laboratories, that have a 24 hour security.





# Newly established CGPS stations: MKRN



In 2019 a continuous GNSS station MKRN was installed by the Geosciences and Technology Development Institute, Tbilisi, Georgia with a financial support of the Shota Rustaveli National Science Foundation (grant FR17\_529) near the settlement of Mukhrani, some 30 km NW from Tbilisi. It consists of Trimble 5700 receiver with a Zephyr Geodetic antenna.





# Methods: data analysis

• GAMIT/GLOBK software from MIT

• Three-step approach

• All the steps are performed using several **C-shell** scripts specifically designed for the tasks at the UB





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### Methods: data analysis



A map of reference stations analyzed with the regional CGPS stations





### **Results: Caucasus Horizontal Velocities**



#### Legend expanded:

**UB**: Univ. of Barcelona CGPS station processing

Sokhdze: from Sokhadze et al., 2018.

Reilinger: from Reilinger et al., 2006.

**NGL**: Nevada Geodetic Lab Midas velocities (Blewitt et al., 2018).

**Green** arrow indicates convergence of Arabia vs. Eurasia based on NNR-MORVEL56 model (Argus et al., 2011),

#### Faults:

MCTF: Main Caucasus Thrust Fault LCTF: Lesser Caucasus Thrust Fault BKF: Borjomi-Kazbegi Fault





### **Results: Gerogia Horizontal Velocities**



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### **Results: Profile across Tbilisi**







### **Results: Strain Rates using SSPX**

#### **Dilatation Rates with Max and Min Strain Rate Axes**

**Maximum Shear Strain Rates** 





#### Vertical Rotation Rates (deg/yr)

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### Discussion



GPS velocities with respect to Eurasia with 1-sigma uncertainties plotted versus distance along the profile B-B'.



### **Future Plans**





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### Conclusions

- ➤ The Caucasus region is presently tectonically active and accommodating approximately 20% of the overall convergence of 25 mm/yr between Arabia and Eurasia tectonic plates.
- ➤ The velocity field is relatively homogenous, although some anomalous motions can be detected just north of Tbilisi, Georgia.
- Convergence between the Lesser and Greater Caucasus along the profile crossing Tbilisi, indicates a complex deformation pattern, where ~2 mm/yr extension occurs just north of the capital city, followed by 3-4 mm/yr compression in the narrow zone of ~60 km located between the Lesser Caucasus Thrust Fault in the south and Main Caucasus Thrust Fault in the north.
- Ongoing investigations promise to better characterize the source of observed strain, and accordingly, implications for seismic hazards and the tectonic evolution of the region.





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We are grateful to the Andronikashvili Institute of Physics (*www.aiphysics.tsu.ge*) for letting us use their facility for the installation of the GNSS station.

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