ANSO-MAS 2026: THE 2ND CONFERENCE ON ENVIRONMENTAL HAZARDS IN ASIA – BUILDING RESILIENCE TO FUTURE HAZARDS

ASSESSING THE DYNAMIC INFLUENCE OF THE KARJANTAU ACTIVE FAULT ZONE THROUGH HORIZONTAL DEFORMATION FIELD ANALYSIS

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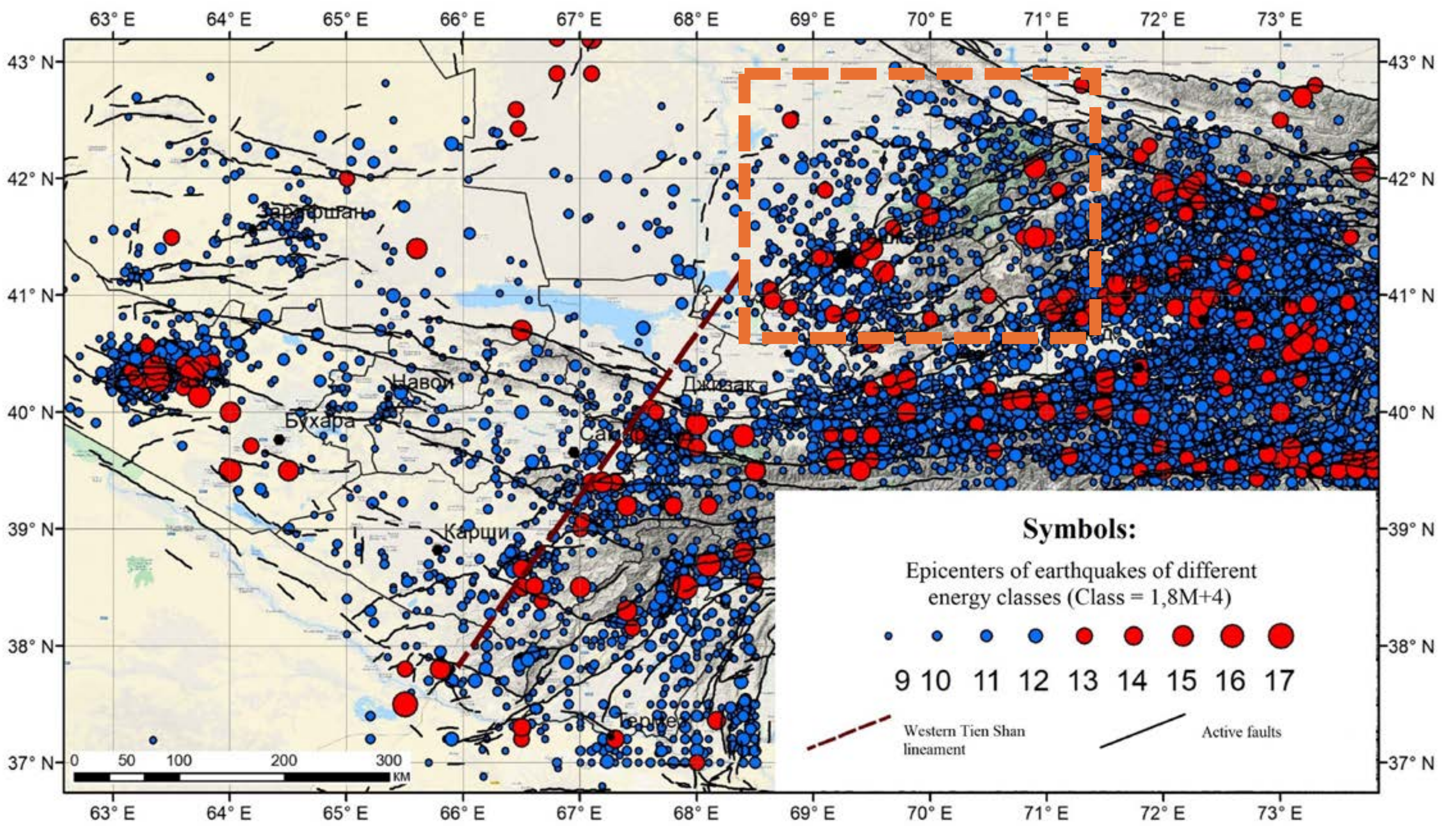
Research Background and Significance



In modern geodynamic research, space-based technologies, particularly GNSS observation results, are widely applied in international practice to assess active tectonic faults and modern crustal movements. Using GNSS technologies, we can record horizontal and vertical crustal movements with millimeter accuracy, determine the modern activity of active faults, and assess their seismic potential.

Eastern Uzbekistan, specifically the Karjantau tectonic fault zone, is considered one of the regions with high seismicity in Uzbekistan. Numerous strong earthquakes have been recorded in these zones from historical times to the present day. Therefore, the quantitative assessment of modern crustal movements in these areas is one of the most important tasks.

Understanding Active Faults

According to international scientific practice, active faults are faults that are currently moving or retain the potential to move under the influence of tectonic forces within the Earth's crust. The primary criterion for identifying an active fault is its geological age, specifically evidence of displacement during the Holocene Epoch (approximately the last 10,000–12,000 years). Some active faults may remain seismically quiet for thousands of years without producing earthquakes. Nevertheless, such faults may still be considered active. This is determined using paleoseismological methods.

The assessment of active faults is based on several factors:

1. Geological age (Holocene);
2. Occurrence of earthquakes;
3. Geomorphological evidence preserved in the relief;
4. Deformation rate.

In this study, we focused on the deformation rate, which was quantitatively estimated from GNSS observations to assess the current tectonic activity of the study area.

Methodology: GNSS Data Processing

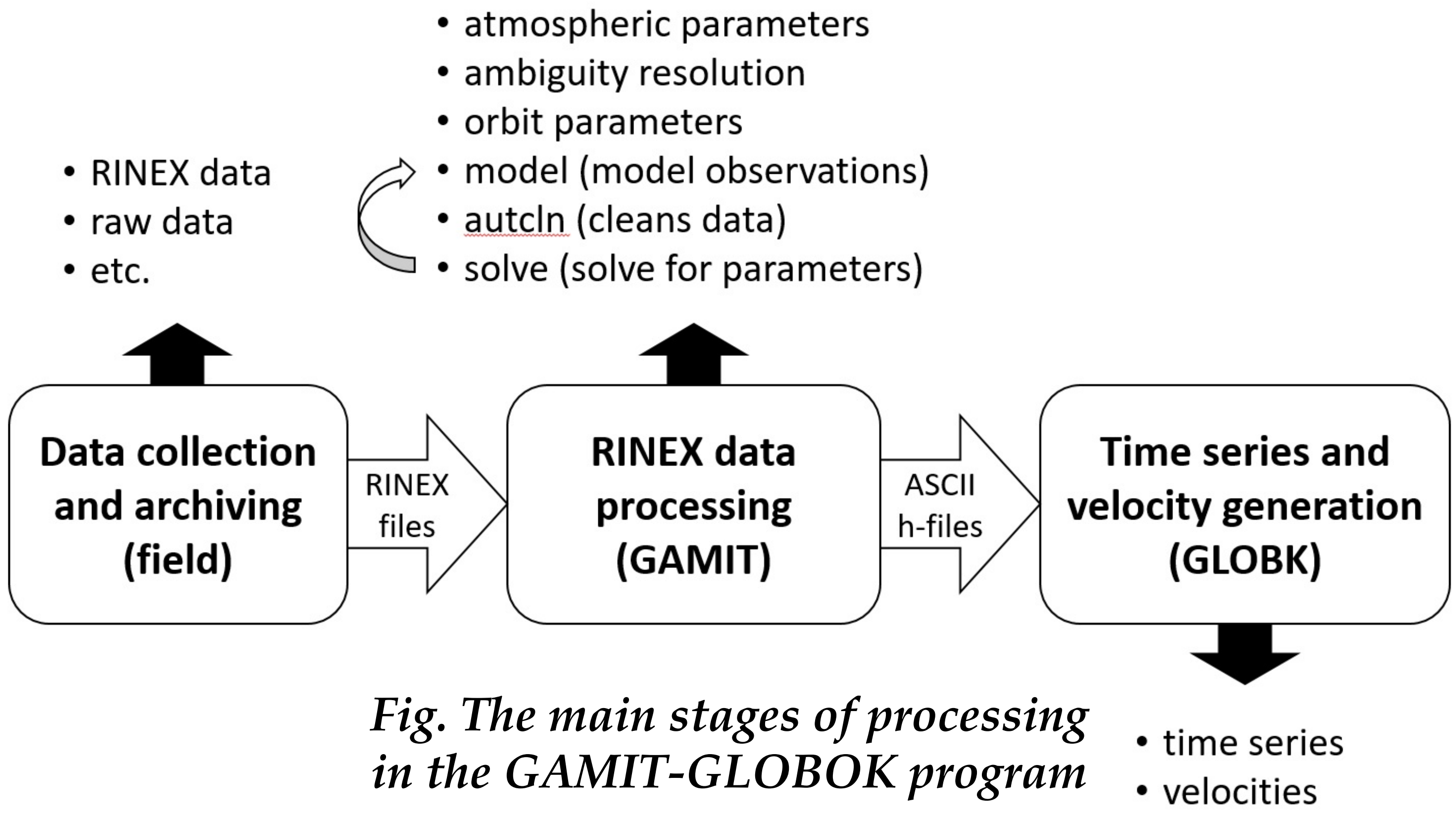


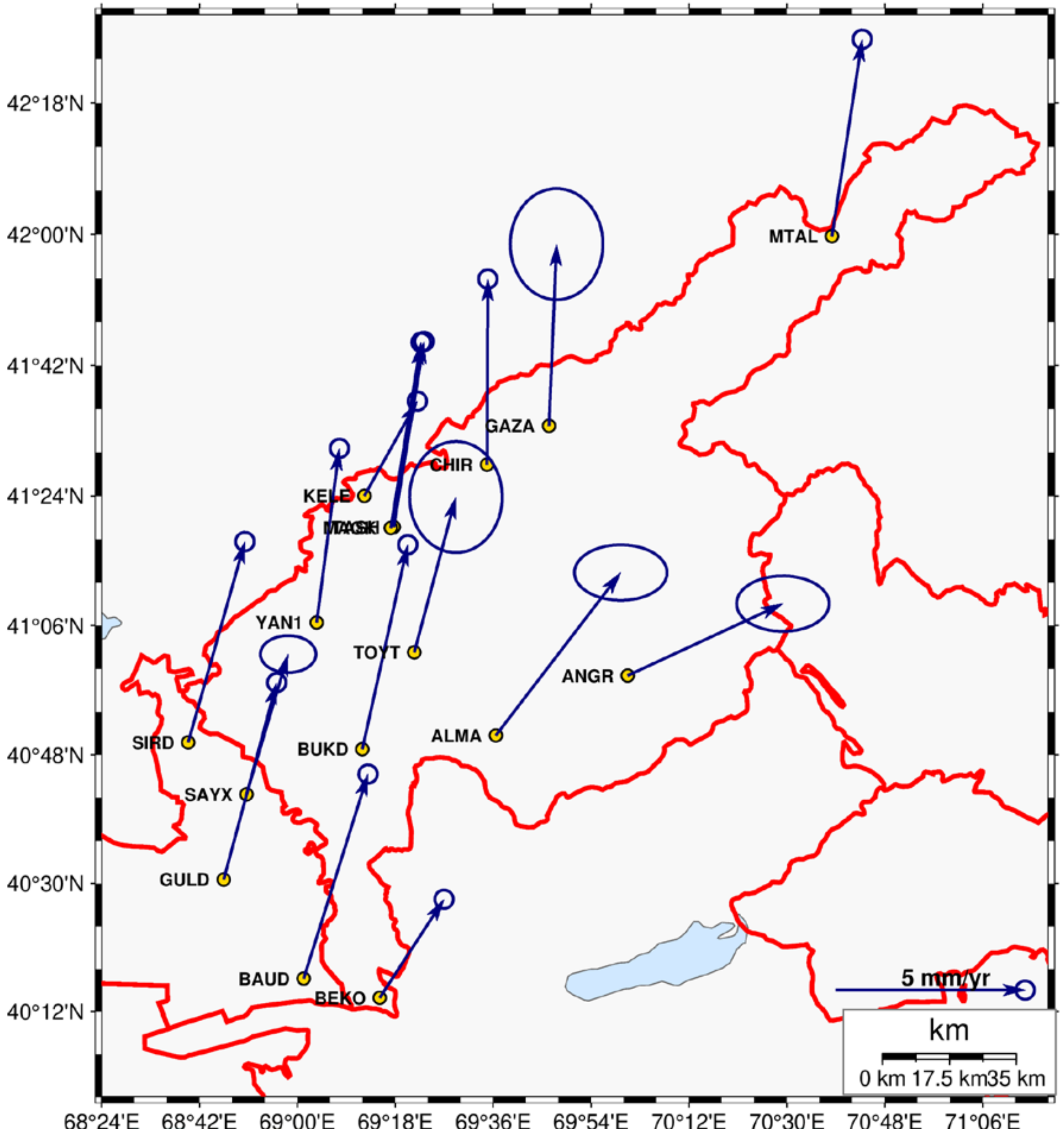
Fig. The main stages of processing in the GAMIT-GLOBOK program

We processed data from 16 continuous GNSS stations located in the Tashkent region and its surrounding areas for the 2020–2023 period. The data processing was performed in three stages using the GAMIT/GLOBK software package. In the first stage, daily GNSS observations were processed to estimate station coordinates, atmospheric zenith tropospheric delays, and satellite orbital parameters. In the second stage, the daily solutions were combined into loosely constrained regional solutions. In the third and final stage, a Kalman filter was applied to integrate all daily solutions and estimate the final station coordinates and velocities in the ITRF2014 reference frame.

As a result, two key outputs were obtained: 1. Time series of the points, and 2. A velocity table for the points.

These results provided the basis for the subsequent deformation and strain rate analyses.

Horizontal Velocity Results



The processing results show that the horizontal velocities in the study area are directed predominantly toward the northeast, with values ranging from 2.9 to 5.7 mm/year. The lowest velocities are observed in the northwestern part of the region, near the Tashkent station, whereas the highest velocities occur in the southeastern part, particularly around Angren and Almalyk.

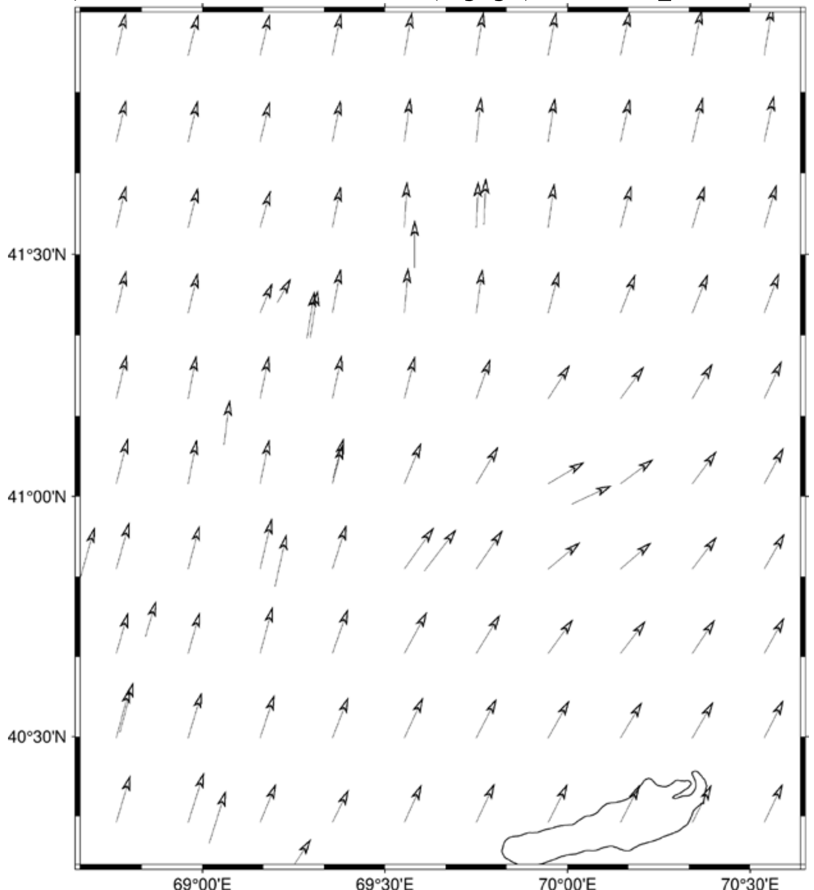
The gradual increase in horizontal velocity from northwest to southeast indicates a systematic regional deformation pattern. These spatial variations in velocity reflect differential crustal movement across the study area and delineate the zone of tectonic influence associated with the Karjantau Fault.

Strain Rate Calculation Methodology

Based on the horizontal velocity field, we constructed a map of the horizontal crustal deformation rate (strain rate). This process consisted of four main stages:

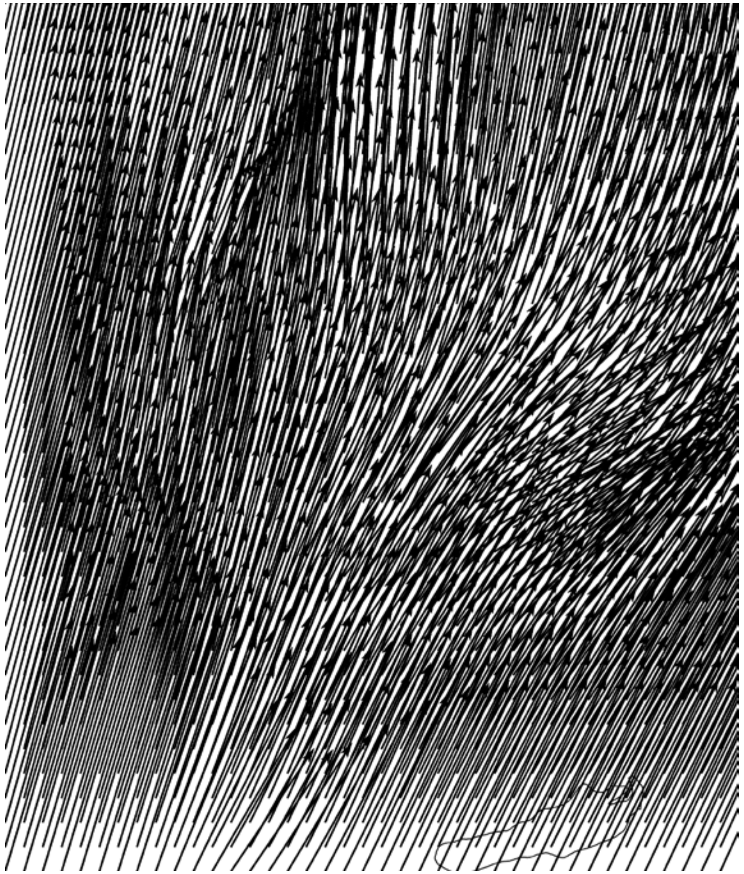
Stage 1: We interpolated the velocity fields based on geographic coordinates.

Stage 2: The two-dimensional deformation tensor was calculated, namely the eastern (εxx) and northern (εyy) components.

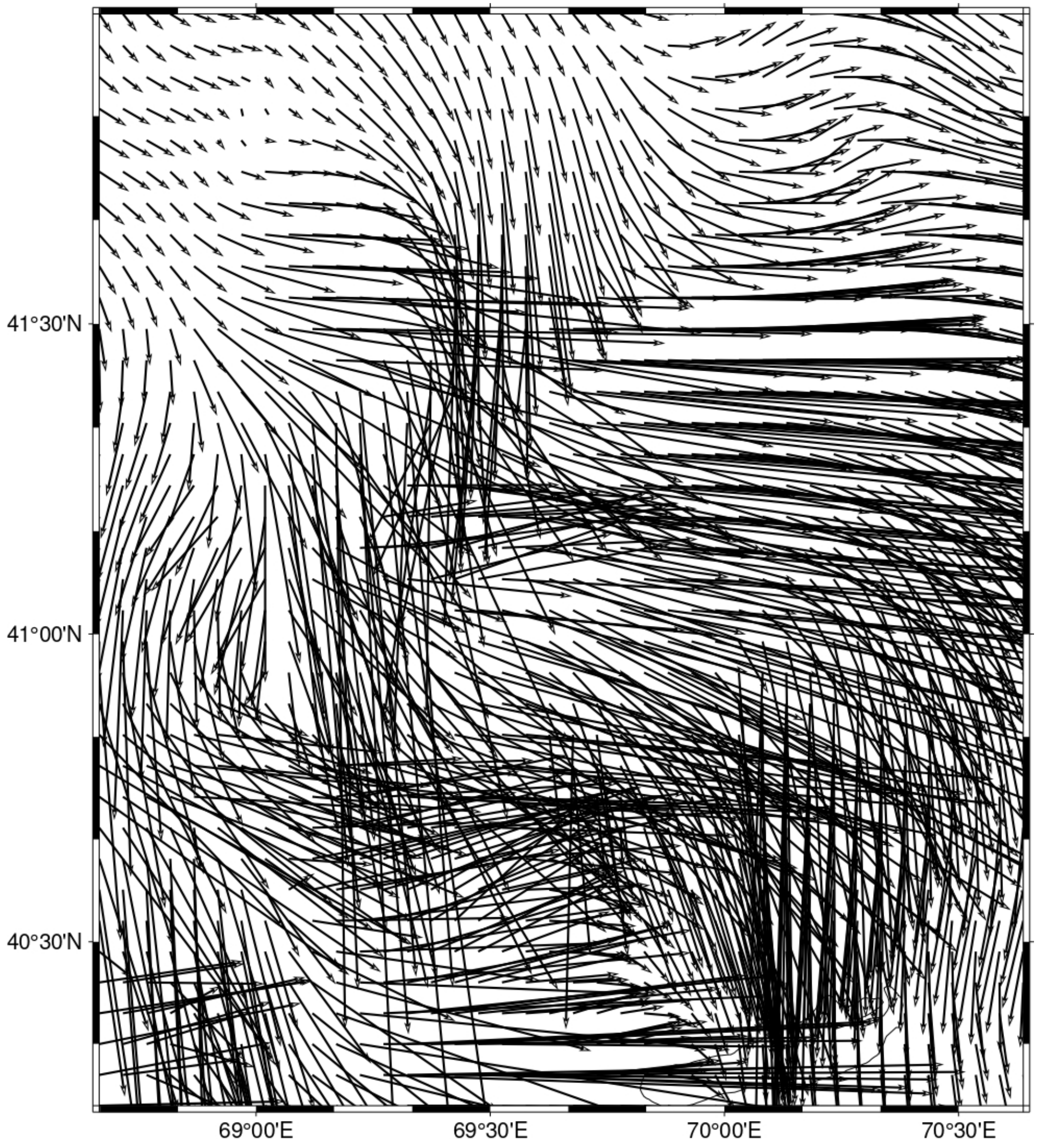


$$\varepsilon_{xx} = \frac{\partial v_e}{\partial x}$$

$$\varepsilon_{yy} = \frac{\partial v_n}{\partial y}$$



Strain Rate Calculation Methodology



Stage 3: We converted the values into physical units, i.e., nanostrain/year.

$$\varepsilon_{xx}^{\text{nstrain}} = \left(\frac{\partial v_e}{\partial x}\right) \times 8.984 \qquad \varepsilon_{yy}^{\text{nstrain}} = \left(\frac{\partial v_n}{\partial y}\right) \times 8.984$$

Stage 4: We calculated the key indicator – dilatation, which is the volumetric strain rate of the field.

$$\Delta = \varepsilon_{xx} + \varepsilon_{yy}$$

Here, a positive value signifies extension, while a negative value signifies contraction.

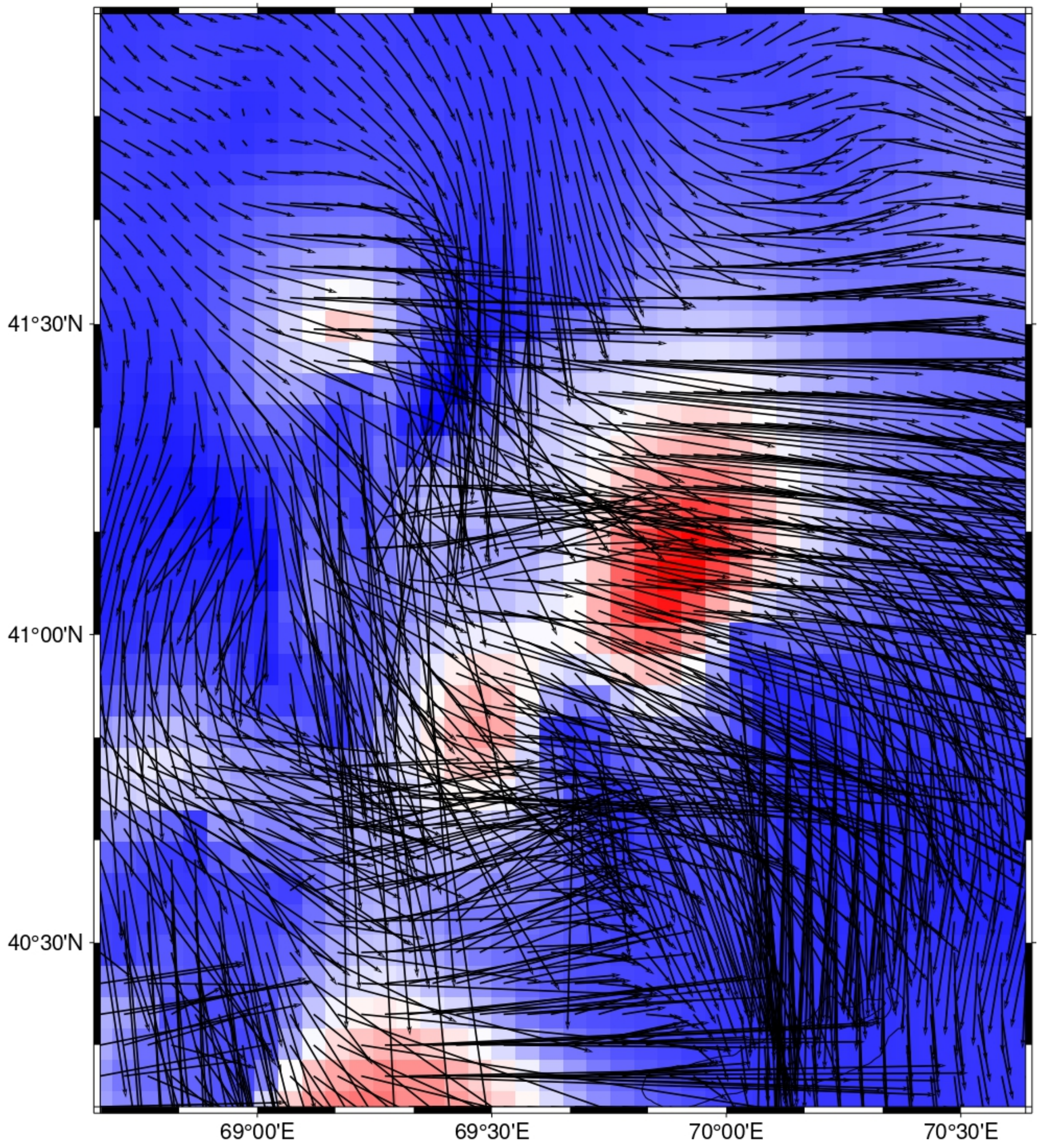
Deformation Map of the Karjantau Fault Zone

The constructed strain rate map clearly confirms that the current geodynamic state of the Earth's crust in the Karjantau fault zone is active. The non-uniform distribution of dilatation values in the deformation field indicates that tectonic stresses are not homogeneous in these areas.

The red color on the map represents positive dilatation, indicating that extensional processes are dominant in the Earth's crust. This condition is observed particularly in blocks located farther from the faults. In extension zones, there is a high probability of new faults emerging or existing ones becoming active.

The negative dilatation, depicted in blue, signifies that compressional processes are dominant in the Earth's crust. These zones are mainly located near the faults, indicating that the blocks are exerting pressure on one another. It is precisely in these compression zones that stress accumulation is high, which may lead to an increased risk of future earthquakes.

The study showed that the deformation gradient is sharply high in areas close to the faults. This condition corresponds with the sharp changes in slip rates observed through GNSS stations.



Comparison with International Studies

Firstly, a study conducted by Sagiya et al. (2000) along the Japanese island arc showed that zones with deformation rates of 20 nanostrain/year or higher in major active fault areas are associated with high seismic hazard. In our study area, the deformation rate along the eastern part of the Karjantau fault reached approximately 14.7 nanostrain/year. In addition, the Karjantau fault exhibits a sharp transition between a zone of positive dilatation (+14.7 nanostrain/year) and adjacent zones of negative dilatation (−10 to −20 nanostrain/year). This combination of relatively high deformation and contrasting deformation patterns indicates active tectonic stress accumulation and suggests that the Karjantau fault has a significant potential for future seismic activity, similar to other high seismic hazard regions.

Secondly, on a Central Asian scale, GNSS studies by Zubovich et al. (2010) demonstrated that the Tien Shan is moving northeastward as a result of the convergence between the Indian and Eurasian plates. Our results are consistent with this regional tectonic pattern, with horizontal velocities also directed toward the northeast, ranging from 2.9 to 5.7 mm/year.

Conclusions

In conclusion:

1. The deformation field in the Karjantau fault zone is non-uniformly distributed, featuring areas with high gradients.
2. Positive dilatation (extension) is mainly observed in blocks distant from the fault, while negative dilatation (compression) is observed near the fault.
3. The zones of maximum deformation serve as sources of tectonic energy accumulation.
4. These results provide a crucial scientific basis for assessing the seismic hazard of the region and analyzing geodynamic processes.

Our future plans include increasing the density of GNSS stations in the Eastern Uzbekistan region and conducting a more accurate quantitative assessment of the stress-strain state of the faults.

Thank you for your attention!