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GNSS-BASED VELOCITY FIELD OF THE TASHKENT REGION

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ABSTRACT--
The Tashkent region of Uzbekistan, located within the western Tien Shan, is one of the most seismically active areas of Central Asia. Monitoring crustal deformation is essential for assessing seismic hazard in this densely populated and industrially important area. In this study, we analyzed Global Navigation Satellite System (GNSS) observations from 2018–2024 at permanent and campaign stations across the region. Daily positions were processed using the GAMIT/GLOBK software package and aligned to the ITRF2014 reference frame. Eurasia-fixed velocities were then derived to isolate intra-plate deformation. To overcome the sparse distribution of GNSS sites, we applied the gpsgridder interpolation method implemented in Generic Mapping Tools (GMT), which produces a physically consistent two-dimensional velocity field. The results indicate a coherent northeastward motion of the Tashkent region relative to stable Eurasia, with velocities of approximately 4.9–5.6 mm/yr. Interpolated fields reveal subtle spatial gradients, with slightly higher velocities in the southern part of the region and localized anomalies near the Karzhantau and Kumbel faults. These zones coincide with clusters of seismicity during 2018–2024, confirming their role as primary strain accumulators. This study demonstrates the effectiveness of combining GNSS observations with advanced interpolation techniques to produce a continuous regional velocity field. The obtained results provide new insights into the active tectonics of the Tashkent region and represent an important contribution to seismic hazard assessment and geodynamic modeling in Uzbekistan.
KEYWORDS: *GNSS, Eurasia-fixed velocities, interpolation, Western Tien Shan, seismic hazard*-------------

1. INTRODUCTION

The territory of Uzbekistan lies within the western part of the Tien Shan mountain system, one of the largest intracontinental orogenic belts in Central Asia, which formed as a result of the ongoing collision between the Indian and Eurasian plates. This far-field deformation extends over thousands of kilometers, producing a complex mosaic of crustal blocks and active faults that accommodate convergence through strike-slip, thrust, and extensional structures [1]. In contrast to the Tibetan Plateau, deformation in the Pamir–Tien Shan region is concentrated within a relatively narrow zone, resulting in enhanced seismic activity and frequent strong earthquakes [2]. The southwestern Tien Shan and the Pamir act as distinct but interacting tectonic units. GPS measurements have demonstrated that both blocks undergo counterclockwise rotation relative to stable Eurasia and accommodate significant NNE–SSW shortening. The Pamir Frontal Thrust (PFT) and Talas–Fergana Fault (TFF) are recognized as major boundaries that localize deformation and control seismicity [2-4]. These large-scale processes directly affect the Tashkent region, situated at the junction of the Chatkal, Kurama, and Karzhantau ranges. Here, active faults such as the Karzhantau, Kumbel, and North Fergana faults have generated destructive earthquakes in the past, including the devastating 1966 Tashkent earthquake. Recent GNSS-based studies confirm that the Tashkent region is one of the most tectonically active areas in Uzbekistan. Observations from 2018 to 2023 reveal northeastward motions consistent with India–Eurasia convergence, with velocities ranging between 24.7 and 30.1 mm/yr and localized strain accumulation along the Karzhantau and Kumbel faults [5]. While GNSS networks provide high-precision point measurements of crustal velocities, the uneven distribution of sites across the region necessitates the use of geoinformation-based interpolation techniques to generate continuous velocity fields suitable for geodynamic analysis [6,7]. Building on these findings, this study aims to construct a continuous horizontal velocity field for the Tashkent region using GNSS observations spanning the period 2018–2024. By applying GIS-based interpolation methods, we seek to refine the spatial model of crustal deformation and provide new insights into the tectonic processes and seismic hazards in this densely populated and industrially significant area.

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MATERIALS AND METHOD

This study is based on GNSS observations collected from permanent and continuously operating stations in the Tashkent region between 2018 and 2024. The dataset includes sites from the national geodetic network maintained by the Agency for Cadaster of the Republic of Uzbekistan, as well as selected International GNSS Service (IGS) stations that provide reference frame stabilization. The network covers both tectonically active mountain ranges (Chatkal, Kurama, Karzhantau) and industrially developed lowlands (Angren–Almalyk) (Figure 1).

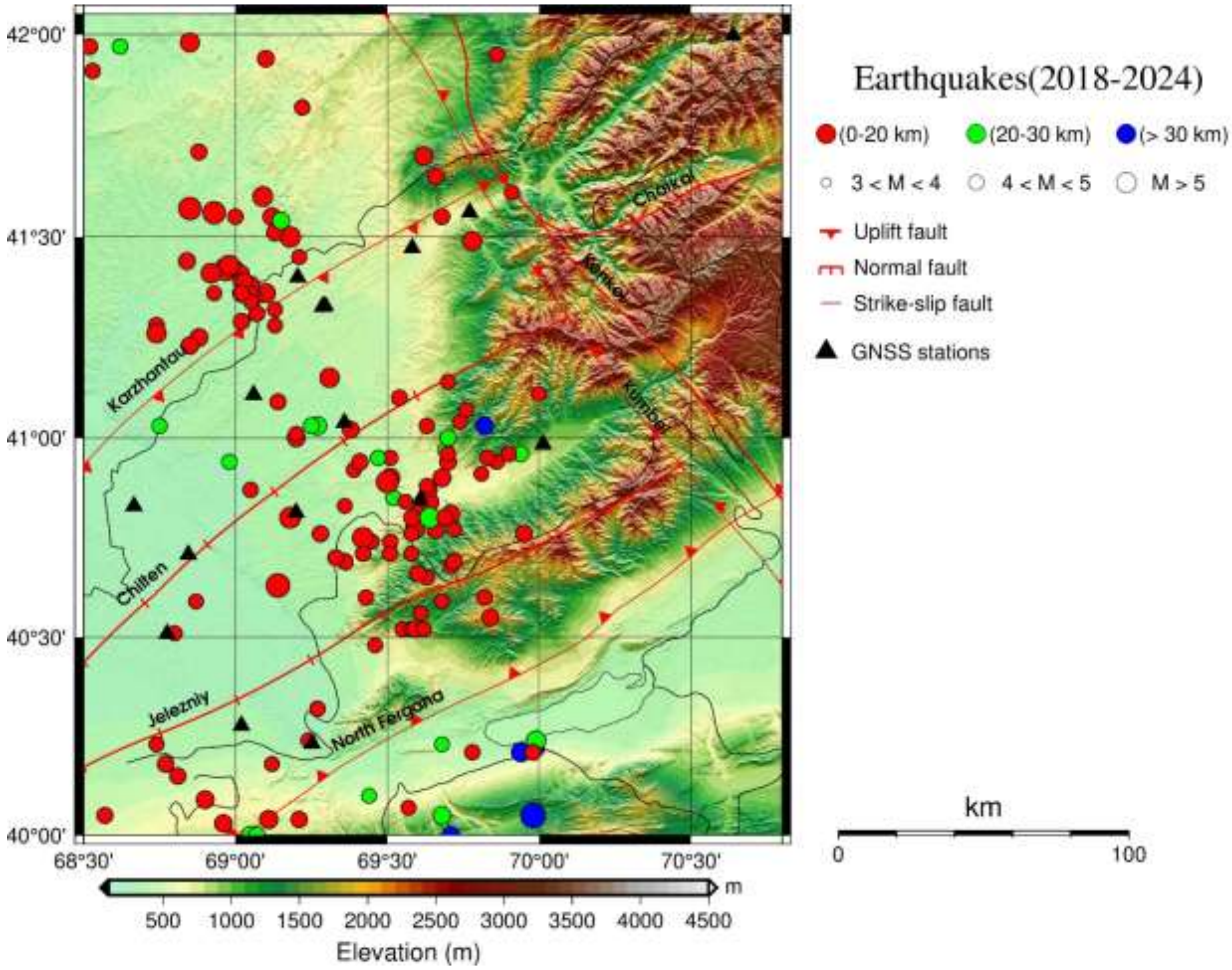

Figure 1. Tectonic framework of the Tashkent region, showing major faults, GNSS stations, and seismicity during 2018–2024.

Raw phase data were processed using the GAMIT/GLOBK software package (v10.7) [8]. Daily solutions were first computed for each station, estimating site coordinates, satellite orbits, Earth orientation parameters, and tropospheric delays. These daily solutions were then combined into a regional network solution, which was aligned to the ITRF2014 reference frame using a set of globally distributed IGS stations [9]. The final velocities were derived through the GLOBK Kalman filtering approach, yielding stable long-term site motions with associated uncertainties. To isolate the tectonic component of crustal motion, Eurasia-fixed velocities were calculated by removing the Euler pole rotation of the Eurasian plate [9]. This ensured that the resulting vectors reflect intra-plate deformation specific to the Tashkent region.

While GNSS measurements provide precise estimates of crustal motion at individual points, the sparse distribution of sites in the Tashkent region prevents direct visualization of a continuous velocity field. To address this, we applied spatial interpolation methods implemented in the Generic Mapping Tools (GMT) software package [7]. The gpsgridder module was employed, which interpolates two-dimensional vector fields by applying Green's function constraints from elastic plate theory [6]. Unlike classical interpolation methods (e.g., inverse distance weighting or kriging), gpsgridder ensures that the interpolated field is physically consistent with the mechanics of crustal deformation. The algorithm simultaneously fits the east–west and north–south velocity components on a

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regular grid while minimizing curvature and enforcing smoothness. Interpolation was performed with a grid spacing of 0.05° (~5 km), ensuring sufficient resolution to capture localized deformation patterns around major faults such as the Karzhantau and Kumbel structures. The resulting continuous velocity field was validated against independent station subsets to assess interpolation accuracy.

2. RESULTS AND DISCUSSION

The GNSS velocities obtained for the period 2018–2024 and expressed in the Eurasia-fixed reference frame show consistent northeastward motions across the Tashkent region (Figure 2).

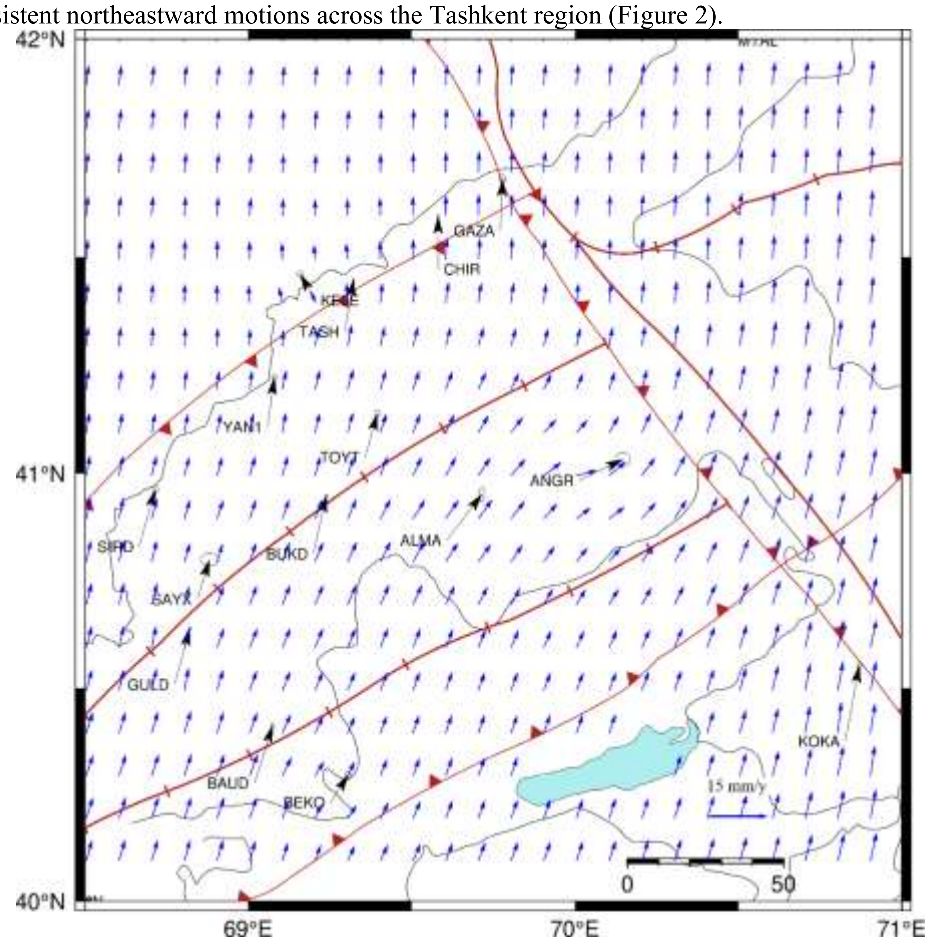

Figure 2. Interpolated GNSS velocity field for the Tashkent region (2018–2024). Black arrows show observed GNSS velocities with 95% confidence ellipses; blue arrows denote the interpolated field obtained with gpsgridder. Red lines represent major active faults.

Individual site velocities vary between ~4.9 and 5.6 mm/yr, with uncertainties typically below 0.1 mm/yr. This indicates that, relative to stable Eurasia, the entire study area is moving coherently to the northeast, reflecting the far-field effect of India–Eurasia convergence. Despite the overall uniform northeastward trend, interpolation of the GNSS velocities reveals subtle but significant spatial gradients. In the northern sector (stations MTAL, CHIR, KELE), velocities are slightly lower (~5.0 mm/yr) compared to the southern sites (BUKD, BEKO, BAUD), where magnitudes exceed 5.5 mm/yr. This gradient suggests that deformation increases from the stable foreland toward the tectonically active mountain ranges. Local anomalies are observed near the Karzhantau and Kumbel fault zones, where interpolated vectors show deviations from the regional NE trend. These velocity perturbations correspond to areas of high seismicity between 2018 and 2024, supporting the interpretation that these structures act as primary strain concentrators in the region. In particular, the Karzhantau fault, historically responsible for destructive earthquakes such as the 1966 Tashkent event, shows evidence of ongoing strain accumulation.

Overall, the interpolated Eurasia-fixed velocity field demonstrates that the Tashkent region accommodates deformation through a combination of distributed northeastward motion and localized strain concentration along major fault systems. This pattern is consistent with regional-scale geodetic models that describe the southwestern Tien Shan as a coherently moving block undergoing counterclockwise rotation and NNE–SSW shortening [1-2, 5].

3. CONCLUSIONS

GNSS observations from 2018–2024 expressed in the Eurasia-fixed reference frame show that the Tashkent region undergoes a coherent northeastward motion of ~5 mm/yr. Despite the overall uniform trend, the interpolated velocity field reveals localized gradients, with slightly higher rates in the southern sector compared to the north. The most pronounced deviations from the regional pattern are associated with the Karzhantau and Kumbel fault zones, where both GNSS velocities and recent seismicity indicate ongoing strain accumulation. These results confirm that deformation in the Tashkent region is accommodated not only by distributed crustal motion but also by localized strain concentration along major active faults.The integration of GNSS data with the gpsgridder interpolation method provides a reliable continuous velocity field and enhances our understanding of the active tectonics of the Tashkent region. This approach offers valuable input for seismic hazard assessment and geodynamic modeling in one of the most seismically vulnerable areas of Uzbekistan.

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