J. Ind. Geophys. Union, 30(2) (2026), 89-101
https://doi.org/10.71122/JIGU.30(2)2026.0010

Seismic quiescence and spatio-temporal b-value variation in the Himalayan region for enhanced hazard analysis

Ashisan Dhodray and S. Lasitha*
Pondicherry University, Puducherry- 605014, India
*Corresponding author: lasitha_s@yahoo.com

ABSTRACT

This study presents an integrated spatial–temporal analysis of the Gutenberg–Richter b-value to evaluate the stress distribution and seismic potential along the Himalayan arc using earthquake catalogue spanning 1964–2025. The spatial distribution of b-values (0.5–1.2), exhibits marked heterogeneity, reflecting the complex tectonic architecture and variable stress conditions across the major thrust systems, including the Main Central Thrust (MCT), Main Boundary Thrust (MBT), and Main Frontal Thrust (MFT). Low b-values (<1.0) dominate along the MCT and MBT zones, denoting regions of elevated stress accumulation. In contrast, higher b-values (1.0–1.2) occur north of the MCT and along the MFT, representing relatively relaxed zones. A decreasing trend in b-value from west (0.8–1.0) to east (0.5–0.7), indicates increasing stress concentration in the eastern Himalaya.Temporal b-value variations reveals a cyclic pattern of seismic activity, with alternating phases of quiescence and activation. A recurring sequence of seismic quiescence, followed by a decline in b-value (Δb = 0.1–0.4), consistently precedes moderate-to-large earthquakes (Mb ≥ 6.0) signifying progressive stress build-up prior to rupture. Longer quiescent intervals (≥5 years) tend to precede major earthquakes (Mb ≥ 6.5), while shorter intervals (1–3 years) are associated with moderate events (Mb 5.7–6.1). The observed decline in b-value, following quiescent phases, may serve as a potential short-term precursor to large earthquakes offering valuable insights for seismic hazard assessment and forecasting in the Himalayan region. The increase in frequency of major earthquakes highlights a potential escalation of seismic energy release in the region.

Keywords: b-value, Spatial b-value variation, Temporal b-value variation, Seismic quiescence, Earthquake precursor, Himalayan region

INTRODUCTION

The seismicity of the Himalayan region is deeply influenced by the subduction of the Indian plate beneath the Eurasian plate and the gradual accumulation of stress along the active faults along the plate boundary. This accumulated stress is periodically released in the form of earthquakes. The devastating 2015 Gorkha earthquake, with a magnitude of 7.8 (Mw), stands as strong evidence of the seismic vulnerability of the region (Hayes and Briggs, 2017). The 2025 earthquake (M 7.1) in the Nepal-Tibet region, further highlights the persistent tectonic instability of this region.

While the convergence between the Indian and Eurasian plates is conventionally regarded as normal in the central Himalayan region, it becomes increasingly oblique towards the west relative to the structural trend and the Himalayan Frontal Thrust (HFT). The primary driver of substantial deformation within the Himalayan and Southern Tibet region is the oblique convergence (Styron et al., 2011; Murphy et al., 2014). Kundu et al. (2015) suggested the convergence velocity between India and Southern Tibet, exhibits a relatively consistent pattern, hovering at approximately 18 mm/yr along the arc. The GPS measurements showed a higher convergence rate of 18–20 ± 1 mm/yr in the eastern Himalayan region (Bilham et al., 1997; Avouac, 2003; Banerjee et al., 2008), decreasing westward to approximately 13.4 ± 5 mm/yr in western Nepal (Bettinelli et al., 2006).

The seismic hazard analysis can be approached in two ways: Deterministic Seismic Hazard Analysis (DSHA) and Probabilistic Seismic Hazard Analysis (PSHA). DSHA is a site-specific hazard analysis incorporating information about known active faults, their characteristics, and associated historical seismic events. However, PSHA takes a statistical approach to seismic hazard assessment considering a range of potential earthquake sources, magnitudes, and ground shaking intensities, providing a probability distribution of ground motion rather than a deterministic value. PSHA explicitly accounts for uncertainties associated with seismic hazard assessment, and it consider multiple seismic sources, including known faults, background seismicity, and seismicity from potential but unidentified sources. This allows for a holistic evaluation of seismic hazards, considering local and regional seismic activity.

In this study, we adopt a statistical framework to evaluate earthquake characteristics, with emphasis on the Gutenberg–Richter b-value. This approach allows us to investigate spatial and temporal variations in seismicity, analogous to how PSHA statistically models earthquake occurrence. The variation in the spatial and temporal b-value indicates the variation in the stress regime and accounts for the overall seismic hazard analysis of the study area. A lower b-value has been found to be associated with the high-stress region where the likelihood of a near-future major Earthquake, while a higher b-value seems to be associated with a lower stress regime. This study, therefore, aims to: (1) map the detailed spatio-temporal b-value variations across the central-eastern Himalayas using a comprehensive catalog from 1964-2022; (2) develop and apply a systematic, quantitative framework for identifying seismic cycles and associated quiescence phases; and (3) test the hypothesis that periods of seismic quiescence and low b-values are reliable indicators of heightened seismic hazard, using recent major